Declaration
Navigability of the Gila River Between the Arizona-New Mexico Stateline and the Confluence with the Colorado River

Submitted To:

Salt River Project
PO Box 52025
Phoenix, Arizona 85072-2025

Submitted by:

Robert A. Mussetter, PhD, PE
TETRA TECH
3801 Automation Way, Suite 100
Fort Collins, CO 80525

January 8, 2014

Table of Contents

List of Figures

1 Introduction and Summary of Opinions

At the request of the Salt River Project Agricultural Improvement and Power District and Salt River Valley Water Users' Association (collectively, SRP), I have made an independent assessment of the navigability of the Gila River between the Arizona-New Mexico Stateline and the confluence with the Colorado River to aid in determining ownership of the bed and banks of the river under the equal-footing doctrine. This assessment included review of the expert report (Schumm, 2004) and testimony of Dr. Stanley Schumm regarding this matter, and independent review of additional relevant information, including various technical documents that will be cited below, the Arizona Division One Court of Appeals opinion that vacated and remanded for further proceedings the Arizona Navigable Streams Adjudication Commission (ANSAC) 2005 decision on navigability of the Lower Salt River and the U.S. Supreme Court's ruling in the PPL Montana case. My review also included a low-elevation overflight of the Gila River from its confluence with the Salt River to about seven miles northwest of the Town of Gila Bend (~24 river miles downstream from Gillespie Dam) to gain first-hand knowledge of the present-day condition of the river and the surrounding landscape.

1.1 Qualifications

I am a registered Professional Engineer in ten states, including Arizona, with over 30 years of experience in analyzing the behavior of natural and manmade stream channels. I have a Ph.D. in Hydraulic Engineering from Colorado State University with emphasis on river mechanics, and I am currently a Program Manager and Discipline Lead for Hydraulic Engineering in the Surface Water Group of Tetra Tech, Inc. In 1989, I founded Mussetter Engineering, Inc. (MEI), and in 1994, Dr. Schumm joined me as part owner of MEI. From 1986 until his death in 2011, I collaborated with Dr. Schumm on a wide variety of projects related to stream channel processes. I was President and Principal Engineer of MEI during the time Dr. Schumm prepared his report and provided testimony to the ANSAC regarding this matter, and I was generally familiar with the work he performed in preparing the report and testimony. This familiarity was gained, in part, through discussions with Dr. Schumm about the information that he had obtained and the opinions that he was forming from that information. Over the course of my career, I have also performed significant technical work in Arizona, and particularly, the greater-Phoenix area, related to stream channel processes through which I have gained first-hand knowledge of the climatic, hydrologic and geomorphic conditions in the Gila River and many of its tributaries.

1.2 Opinions

Based on my review of Dr. Schumm's report and background material, independent review of other background material, my knowledge of the climatic, hydrologic and geomorphic conditions in the Gila River valley, and my knowledge of processes in arid stream channels, I agree with the opinions that were expressed by Dr. Schumm in his report and testimony, and offer the following clarifications and additional opinions for ANSAC's consideration in this matter:

1. From the mid-1800s until the early-1900s, portions of the reach of the Gila River through Arizona had a single-thread channel that was lined with thick stands of woody riparian vegetation.

2. Large floods that occurred during the period between 1895 and 1906 scoured away much of this vegetation, caused extensive bank erosion and channel widening, and converted the Gila River to a wide, braided planform[1] that persists to the present time.
3. Under present hydrologic conditions, and those that existed in the early-1900s when Arizona became a state (February 14, 1912), extensive reaches of the Gila River were dry or carried little flow except during periods of flooding.
4. The braided planform and generally low to non-existent flows would have made it highly impractical (or impossible in many places) to navigate the river with watercraft during the general timeframe of Arizona's statehood.
5. Descriptions of the river in the mid- to late-1800s indicate that it may have been possible to float a small boat in some reaches during some periods of time. However, reconstructed annual flow records extending back to the 1600s indicate that the mid- to late-1800s corresponded to an extended period of unusually low flows, and therefore, the absence of major floods. As a result, the character of the river during this period was not typical of the longer-term, wide, braided character that was and continues to be controlled by large floods. Based on the above, it is my opinion that the Gila River was not navigable or *susceptible to navigation in its ordinary and natural condition*[2].
6. Furthermore, it is my opinion that segmentation of the Gila River is not necessary because no significant segment of the river was navigable in its ordinary and natural condition.

---

[1] Planform refers the horizontal alignment of the channel (e.g., a meandering stream has a sinuous planform alignment.)

[2] Arizona Revised Statutes (A.R.S.) section 37-1101(5) (2003) defines navigability as follows:

> "Navigable" or "navigable watercourse" means a watercourse that was in existence on February 14, 1912, and at that time was used or was susceptible to being used, in its ordinary and natural condition, as a highway for commerce, over which trade and travel were or could have been conducted in the customary modes of trade and travel on water.

In vacating and remanding for further proceedings, ANSAC's 2005 decision that the Lower Salt River was not navigable at the date of Arizona's Statehood (Case No CA-CV 07-0704), the Arizona Division I Court of Appeals concluded that *… ANSAC was required to determine what the River would have looked like on February 14, 1912, in its ordinary (i.e., usual, absent major flooding or drought) and natural (i.e., without man-made dams, canals, or other diversions) condition.*

2 Basis for Opinions

2.1 General Character of Dryland Rivers

River channels take on a variety of configurations that range from relatively narrow, single-thread cross sectional shapes with meandering planform to wide, braided cross sections with a relatively straight, down-valley alignment (Schumm, 1981; **Figure 1**)[3]. In general, the configuration results from the interplay between stream power and the resistance of the boundary materials to erosion (Graf, 2002). The configuration is also affected by the magnitude of the upstream sediment supply in relation to the local sediment transport capacity. Meandering configurations are most common in rivers with low stream power and high bank resistance resulting from erosion-resistant (i.e., cohesive) bank material and thick riparian vegetation. Braided configurations are common in rivers with high stream power, low boundary resistance and a high sediment load, particularly when a significant percentage of the load is carried as bed load[4].

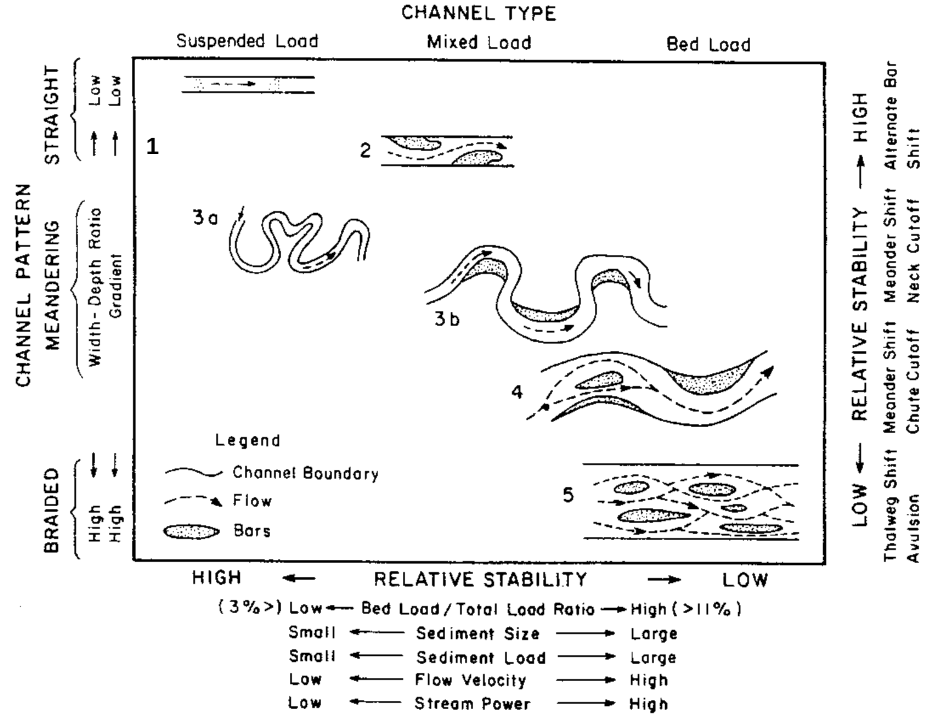

Figure 1. Channel classification based on pattern and type of sediment load, showing types of channels, their relative stability, and some associated variables (after Schumm, 1981).

---

[3] Meandering streams have a sinuous horizontal alignment consisting of a sequence of channel bends that are separated by relatively short, straight channel segments (often referred to as crossings). Meandering streams typically have only a single channel. Braided streams are streams that consist of an interlacing network of branching and reuniting shallow channels separated from each other by islands or channel bars.

[4] Bed load is that part of the total sediment load that moves by rolling, sliding or saltating along the streambed, in contrast to the suspended load that is carried in the water column above the channel bed.

Graf (1983) argued that dryland river channels are not equilibrium forms. The morphology of the channel at any point in time is inherited from the last significant, flood-driven alteration, and this controls the channel form during the subsequent recovery period (Graf, 2002). Following the channel-altering flood event, the river channel returns to its pre-disturbance condition (i.e., it recovers) relatively slowly compared to the rate of adjustment during the flood through sedimentation in low energy areas and re-establishment of riparian vegetation on the surfaces that were disturbed by the flood. As a result, it is not possible to define a dominant discharge, because the larger, more infrequent flows are more geomorphically effective than the frequently occurring flows (Graf, 2002; Baker, 1977). During floods, the flows are so powerful that they can rapidly and significantly alter the channel and adjacent overbanks. The amount of alteration depends on many factors, including the magnitude and duration of the flows, the inflowing sediment load, the characteristics of the bed and bank material and riparian vegetation, and the degree to which the channel has recovered from the last major event. During the recovery periods of low- to moderate sustained flows, the channel form tends toward a single-thread, sinuous configuration within the overall wider cross section created by the disturbance flows.

The channel behavior described in the previous paragraph has been documented in a wide variety of settings. As noted in Dr. Schumm's expert report, for example, the Cimmaron River in southwestern Kansas was transformed from a narrow sinuous, 50-foot wide channel to a 1,200-foot wide, braided channel by a series of floods during the 1930s (Schumm and Lichty, 1963). Another notable example includes the Rio Salado, a tributary of the Rio Grande near San Acacia, New Mexico, where the channel width ranged from 12 feet to 49 feet in 1882, but widened to 330 feet to 550 feet by 1918 (Bryan, 1927). The Smoky Hill River originally *…had alternating sandy stretches and grassy stretches with series of pools* (sic). *Later the former were widened and the latter were sanded up…..* (Smith, 1940). The Republican River was greatly affected by the flood of 1935: *Formerly a narrow stream with a practically perennial flow of clear water and with well-wooded banks, the Republican now has a broad, shallow sandy channel with intermittent flow. The trees were practically all washed out and destroyed, much valuable farmland…was sanded over, and the channel has been filled up by several feet.* (Smith, 1940)

An additional example is the Red River floodplain near Burkburnett, Texas, that was the object of intensive study to resolve a boundary dispute between Oklahoma and Texas (Glenn, 1925; Sellards, 1923). The Red River was never a narrow, meandering stream in historic times; a survey in 1874 showed the river to be about 4,000 feet wide. The channel, however, has undergone some important changes. For example, comparison of a map prepared in 1920 (Sellards, 1923) with aerial photographs taken in 1953 showed enlargement of the floodplain; 5.5 mi^2 of floodplain were added over a 10-mile reach of the river. In 1937, the river averaged three-quarters of a mile wide, close to the average for the 1874 survey. In 1953, the average width had decreased to half a mile. In 1957, the river averaged two-thirds of one mile wide, indicating significant widening between 1953 and 1957, during which period three large floods occurred in the reach.

In summary, dryland streams in the arid southwestern U.S. experience cycles of low- to moderate flows punctuated by large, infrequent, monsoon-driven flood events. During the low to moderate flow periods they tend toward a single-thread, meandering planform, and during the infrequent, large floods, they can rapidly transform into a wide, braided, multi-channel planform in which the flow depths are highly irregular, both spatially and temporally. Both conditions are *natural and ordinary* conditions of the river. Particularly during the floods and the subsequent recovery periods following the floods, the multiple, individual channels in the braided planform tend to be very shallow and unstable.

2.2 Historical Character of the Gila River

The recorded history of the Gila River documents cyclical changes that are very consistent with those described above. In a detailed study of the impacts of phreatophytes on the Gila River in the Safford Valley, Burkham (1972 and 1981) concluded that the historical character of the Gila River channel can be grouped into three time periods: 1846-1904, 1905-1917 and 1918-1970. From 1846-1904, the channel was relatively narrow, and it meandered through a floodplain covered with willow, cottonwood, and mesquite (**Figure 2**). Only moderate changes occurred in the channel width and sinuosity during this period. The maximum width was about 150 feet in 1875 and about 300 feet in 1903. In response to a series of large floods in the early-1900s that completely destroyed the meander pattern and floodplain vegetation, the average width of the river had increased to about 2,000 feet by 1917. The river then narrowed and developed a more sinuous planform with a densely vegetated floodplain between 1918 and 1970; by 1964, the maximum width had decreased to only about 200 feet.

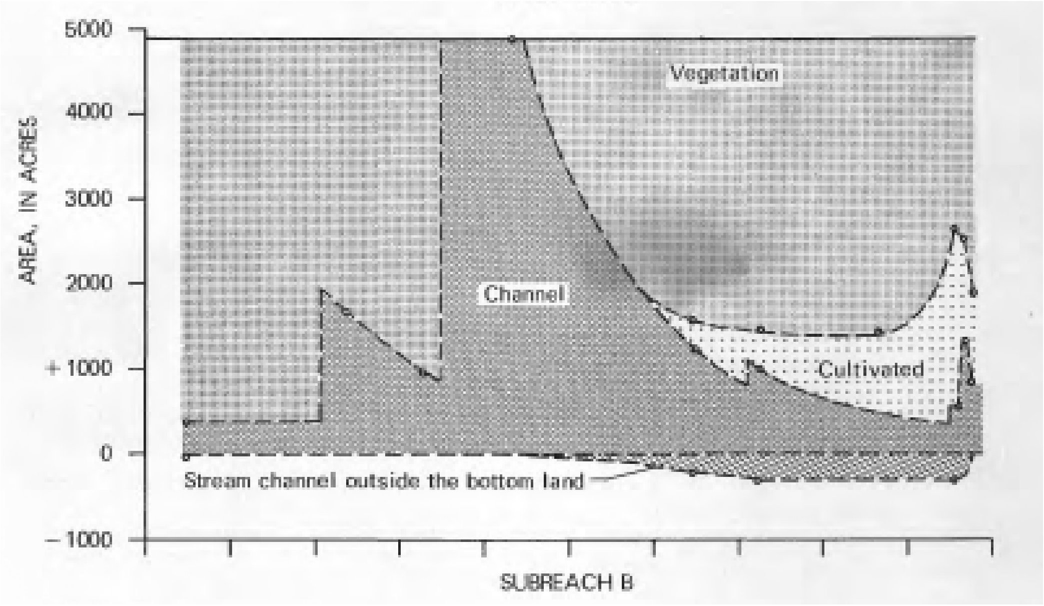

Figure 2. Historical changes in channel area of upper Gila River (San Simon to Pima) (from Burkham, 1972).

Huckleberry (1993) showed similar changes in the middle Gila River (**Figure 3**). In the late-1800s, the channel width averaged about 60 m (~200 feet), increasing to about 300 m (~1,000 feet) by about 1925 as a result of the large floods in the early-1900s, and then decreased back to about 40 m (~130 feet) by the 1940s. In response to large floods that occurred in the 1980s, the width increased to about 70 m (~230 feet) by the early-1990s.

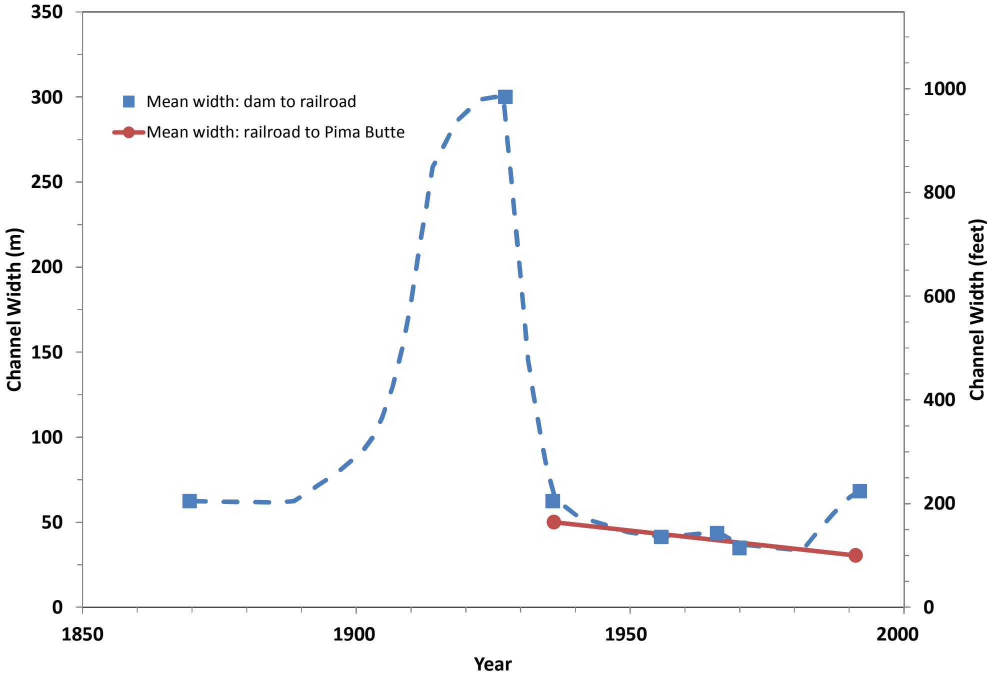

Figure 3. Changes in channel width for the middle Gila River (modified from Huckleberry, 1993).

2.2.1 Gila River at and after the Date of Statehood

From at least the date of Arizona's Statehood to the late-1980s, the Gila River has been characterized by inherent instability and frequent and destructive channel migration (Chin, 1988; Graf, 1981). For example, the channel shifted 0.5 miles near Buckeye during a flood in 1941 (Chin, 1988). According to Graf et al. (1994, p. 32), the lower Gila River …*typified braided streams, variable in channel configuration and dimensions…* In 1917, the river was an *interrupted stream,* that is, one that has local reaches of flow while most of the river was dry (Ross, 1923, p. 36). Ross (1923, p. 76) also noted that:

> *Gila River below Salt River is a winding stream subject to considerable changes of volume… Between the principal terraces is the flood plain which is in most places from one mile to several miles wide. Incised into the floodplain are channels 1 foot to 10 feet or more deep and a few feet to the* (sic) *mile wide. The position, size, and number of channels change with every flood.*

According to Huckleberry (1996, p. 16):

> *The Gila River is a classic example of a dryland river that seldom seeks an equilibrium form. Unlike rivers in humid regions that have more stable channels that are adjusted for more continuous streamflow with less variance in discharge, the dryland rivers are inherently more unstable and more prone to changes in channel configuration. In such unstable fluvial systems, channel configuration depends much upon the history of previous flood events. Periods of high flood frequency are likely to correlate to periods of increased channel instability.*

From these and other historical descriptions that have been presented to the ANSAC, it is clear that the Gila River was not navigable at the date of Arizona's Statehood.

2.2.2 Historical Gila River Prior to the Date of Statehood

Various descriptions of the pre-statehood Gila River generally agree that the river had a primarily single-thread channel that was bordered by willows and cottonwoods in the mid- to late-1800s (Graf et al., 1994; Darton, 1933; Ross, 1923). Water has been diverted from the Gila River for irrigation since long before European man came to the area. *In this region* [i.e., the upper Gila River near the towns of Thatcher, Central, Pima, and Fort Thomas in the Safford Valley] *are many remains of dwellings and pottery of aborigines who used the water of the Gila River for irrigation many centuries before the coming of the white man* (Darton, 1933, p. 210).

Calvin (1946) [as reported by Burkham (1972, p. G4)] noted that Coronado crossed the Gila River near the present town of Geronimo in 1540, and described it as …*a deep and reedy stream.* Burkham (1972) also noted that Emory (1848, p. 67) …*described the Gila River near Bonita Creek as having a cross section of "about 70 feet by 4 feet" on October 27, 1846*, and Johnston (in Emory, 1848, p. 588) reported that: …*the grass along the edge of the water on the river grows in a thin stripe very luxuriantly; there is usually a thicket of willows, about 10 yards deep, along the borders of the stream; then in the bottom, which is subject to overflow, cottonwoods grow of two and three feet diameter; this strip is usually 200 or 300 yards wide.*

Burkham (1972, p. G5) also cited a number of similar descriptions of the upper Gila River in the mid-1800s, and concluded that …*before 1875 the Gila River probably was less than 150 feet wide and 10 feet deep at bankfull stage. The river meandered through a flood plain covered with willow, cottonwood, and mesquite.*

Huckleberry (1996, p. 7-8) provided the following description of the middle Gila River:

> *Historical descriptions of the Gila River extend back to 1697 when Padre Kino and Captain Juan Manje described a channel with large cottonwoods supporting irrigation agriculture at the Pima Villages…Subsequent European visitors passing through the area also described a stable, narrow and relatively deep channel with dense riparian galleries (Huckleberry, 1993b; Rea, 1983). Before Anglo settlement in the 1860's, the middle Gila River would periodically run dry near the Pima Villages during May and June (Rea, 1983). The early cadastral surveys… also characterize the middle Gila as having a single, narrow channel up until 1891*.

2.2.3 Historical Perspective on Role of Large Floods and Drought on Navigability

The Arizona Division 1 Court of Appeals found that *ordinary* conditions of the river means the absence of *major flooding or drought* and *natural* conditions means the absence of *man-made dams, canals and other diversions*[1]. By the date of Arizona's Statehood in 1912, the character of the Gila River had been affected by human activities for many centuries; thus, given the legal standard in the Arizona Court of Appeals Opinion, it is reasonable to question whether the river was in its *ordinary and natural* condition, and if not, whether it would have been sufficiently different under *ordinary and natural conditions* to make it susceptible to navigation.

While it is reasonable to exclude the limited periods when the river is actually experiencing major flooding or drought when considering navigability, the effects of these periods on the long-term character of the river cannot be discounted. The wide, braided planform that is created by major flooding persists for a significant period and influences the form of the river throughout the ensuing low- to moderate flow periods. Extended droughts can also have a long-term impact on the character of the river, especially when followed by a major flood, because they tend to diminish the amount of riparian vegetation, making the river even more susceptible to widening and braiding during flooding.

Meko et al. (1995) reconstructed the annual flows in the Gila River in the vicinity of Safford using tree ring data. His results show that the mid- to late-1800s, when many of the above descriptions of a single-thread, meandering character were made, corresponded to an extended period of low flows (**Figure 4**). As is true for most dryland rivers, there is strong correlation between the annual flood peak and the annual runoff in the Gila River (**Figure 5**); thus, the low-flow period in the mid-1800s also very likely corresponded to with an absence of major flooding. Despite the effects of irrigation diversions, dams, exotic vegetation, and channelization on *the hydraulics and hydrology of the channel* (Huckleberry, 1996, p. 2), channel changes on the Gila River are driven primarily by large floods (Huckleberry, 1996; Burkham, 1972), consistent with the above discussion of dryland channels. *Beginning in the 1890's, streamflow on the middle Gila River was greatly reduced due to Anglo irrigation diversion, but the river was still susceptible to large flood flows. Beginning in 1905, a series of large floods struck the middle Gila River coinciding with a radical transformation in channel planform and geometry…*[**Figure 6**]*. Similar to the upper Gila River (Burkham, 1972), the middle Gila River contained a wide, braided channel between 1905 and 1920 correlating to a period of high large flood frequency with the largest floods occurring in 1905, 1914, and 1916.* (Huckleberry, 1996, p. 7-8). Pre- and post-1905 General Land Office surveys show that the Gila River widened significantly and shifted position in T1N, R1W between 1867 and 1915 (**Figure 7**), and in T1N, R2W between 1883-1907 (**Figure 8**), and these are typical of the river throughout this area.

The Meko et al. (1995) analysis clearly shows that, while some of the floods in the early-1900s were unusually large, the Gila River experienced large annual flow volumes, and thus, large floods prior to the dry period in the mid- to late-1800s. These floods would have caused the river to become wide and braided, similar to the character during the early-1900s and the ensuing drier period. Ross (1923, p. 17) states that [t]*he Gila is the only tributary of Colorado River in the region except Williams River that contains water in considerable portions of the bed at all seasons. Even the Gila, however, is a through-flowing stream only after heavy rains.*

Based on the above information, it is my opinion that the Gila River would not have been suitable for navigation on a consistent and reliable basis under *ordinary and natural conditions*.

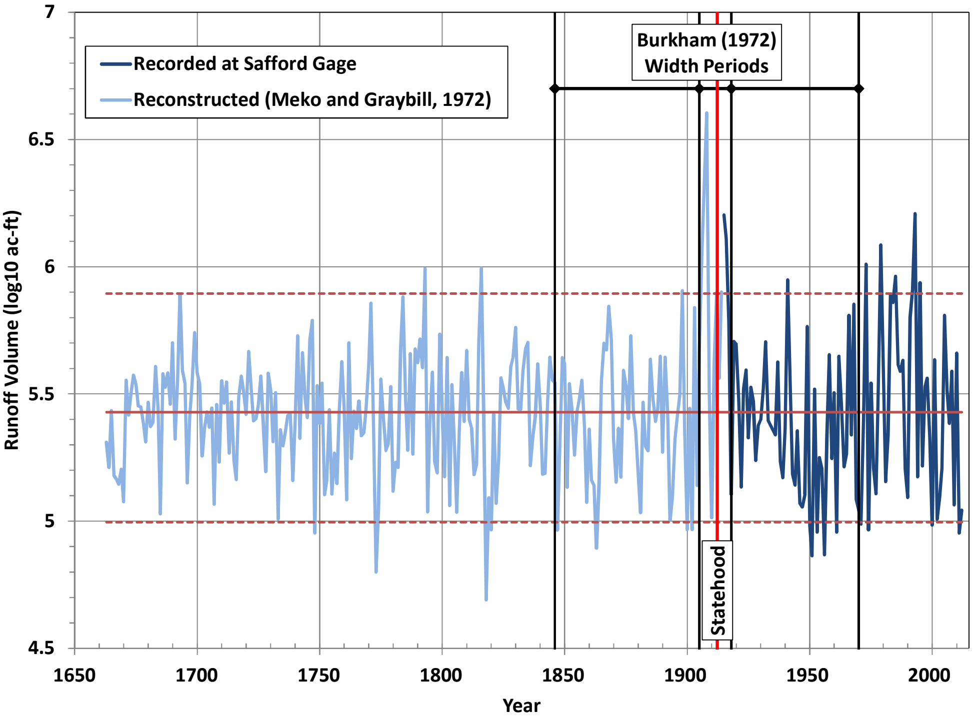

Figure 4. Time-series plot of Gila River annual discharge (1663-1914 from reconstruction of Meko et al., 1995; 1915-2012 from recorded flows at USGS Gage No. 09448500, Gila River at Head of Safford Valley. Also shown are the periods of different typical channel widths identified by Burkham, 1972). Solid horizontal line is median, dashed lines are 10th and 90th percentiles (i.e., 10 percent of the values fall above and below these lines, respectively).

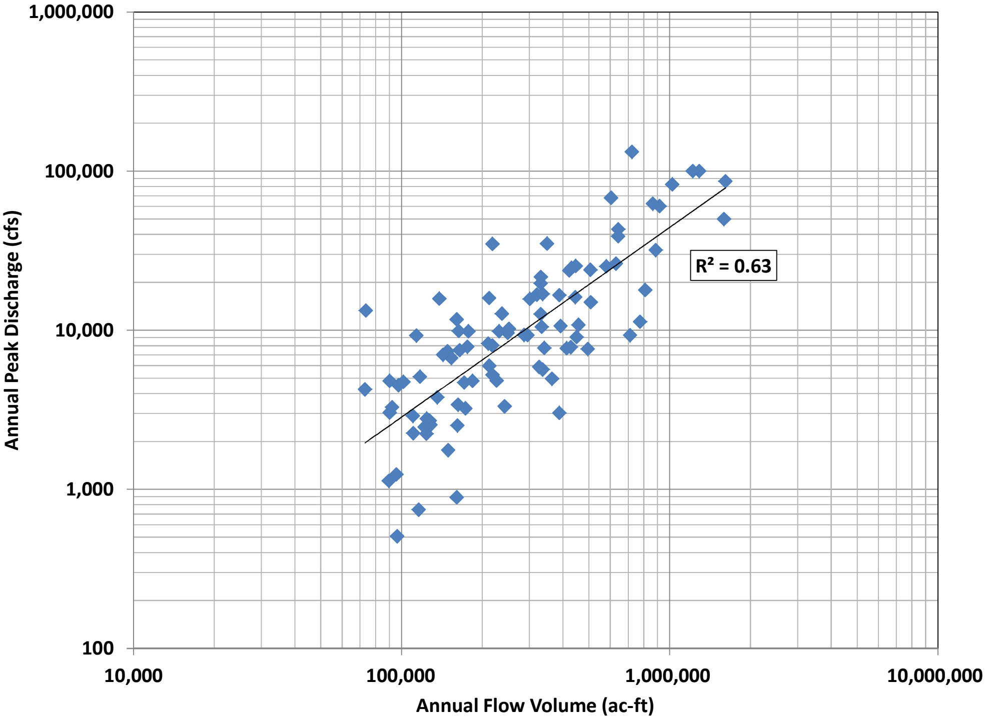

Figure 5. Annual peak discharge and corresponding annual flow volume for the period of record from 1915 through 2012 at the Gila River at Head of Safford Valley gage (USGS Gage No. 09448500).

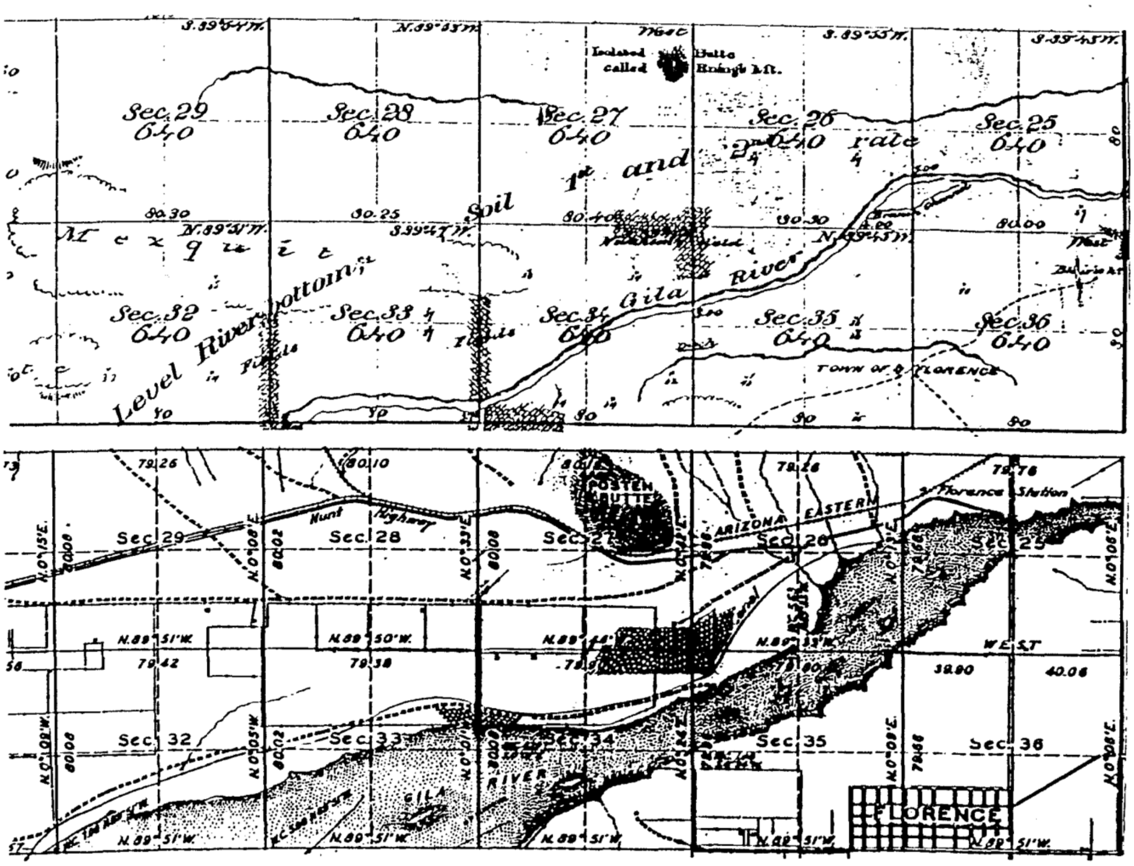

Figure 6. General Land Office plats of township T4S, R9E surveyed in 1869 (above) and 1928 (below) showing the change in the width of the Gila River channel (Figure D from Huckleberry, 1996).

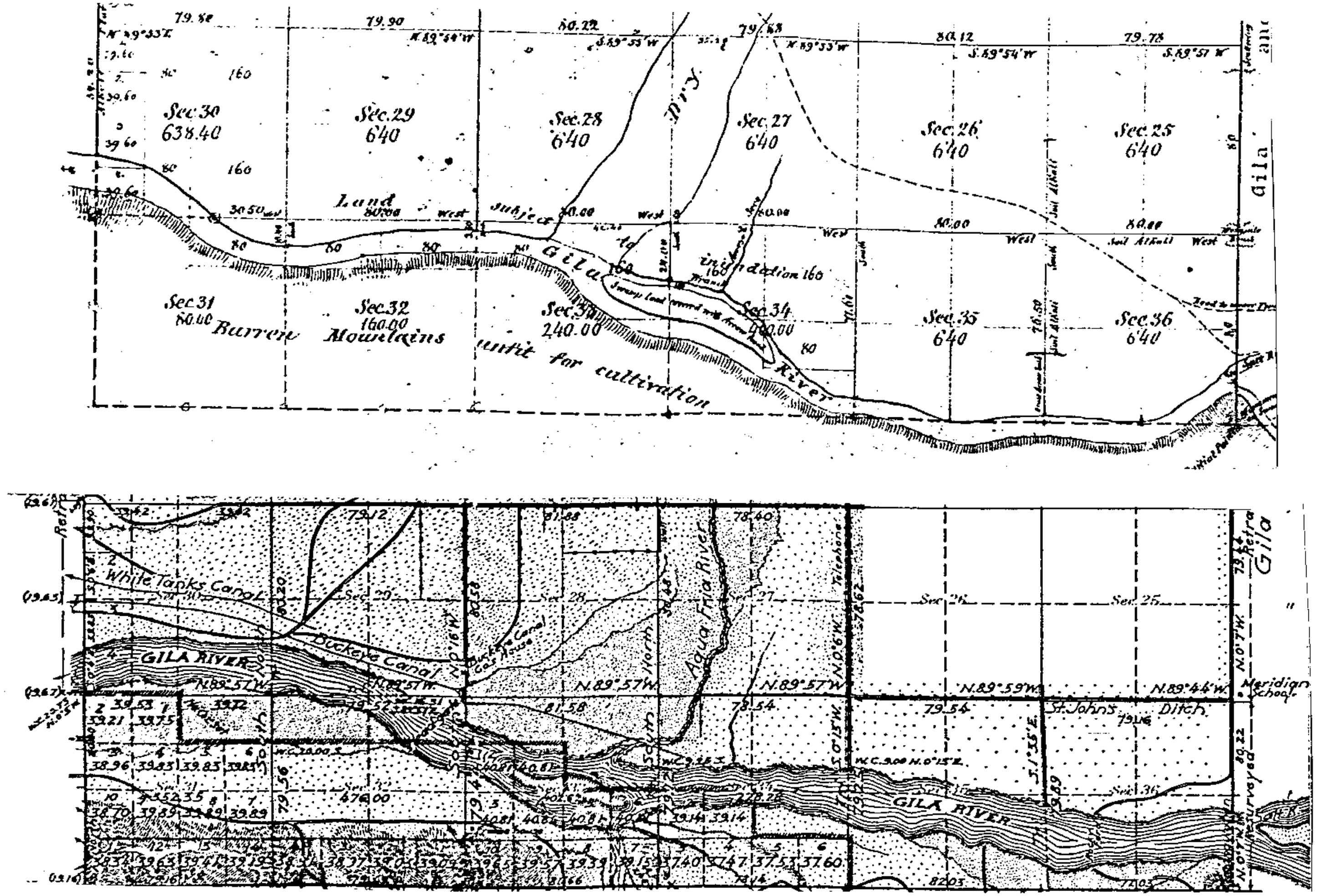

Figure 7. General Land Office plats of township T1N, R1W, downstream from the Salt River confluence surveyed in 1867 (above) and 1915 (below) showing the change in the width of the Gila River channel.

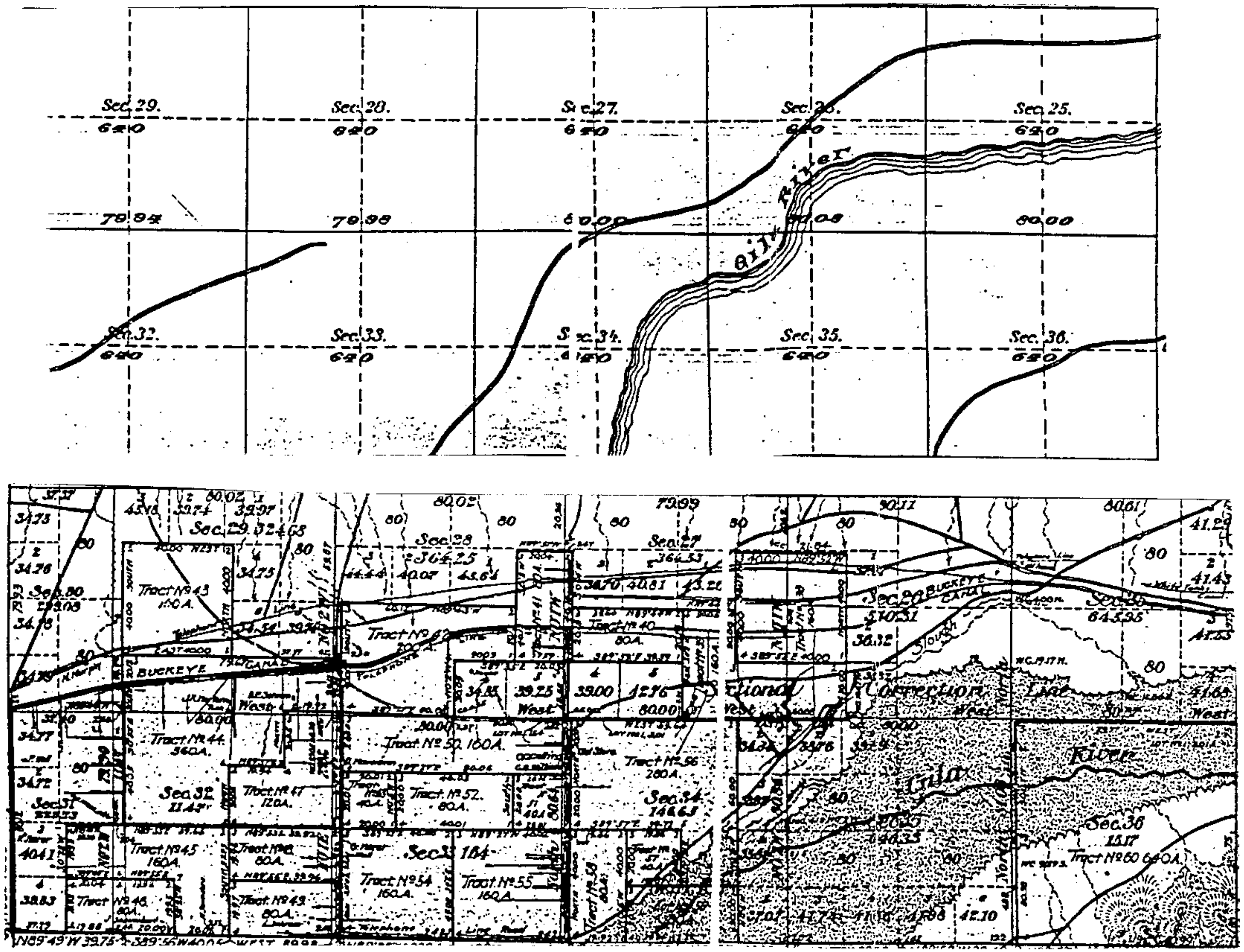

Figure 8. General Land Office plats of township T1N, R2W, surveyed in 1883 (above) and 1907 (below) showing the change in the width of the Gila River channel.

3 References

Baker, V.R., 1977. Stream Channel Response to Floods, with Examples from Central Texas. Geologist Society of America Bulletin, v. 86, pp. 1057-1071.

Bryan, K., 1927. Channel erosion of the Rio Salado, Socorro County, New Mexico. U.S. Geological Survey Bull. 77, pp. 1-11.

Burkham, D.E., 1972. Channel changes of the Gila River in Safford Valley, Arizona. U.S. Geological Survey Prof. Paper 655-G, 24 p.

Burkham, D.E., 1981. Uncertainties resulting from changes in river form. Jour. Hydraulics Div., Amer. Soc. Civil Engrs, v. 107, pp. 593-610.

Calvin, R., 1946. *River of the Sun Stories of the Storied Gila*. Albuquerque, New Mexico Univ. Press. 153 p.

Chin, A., 1988. The Buckeye crossing. In Graf, W.L., (ed), *The Salt and Gila Rivers in Central Arizona*, pp. 145-158.

Darton, N.H., 1933. Guidebook of the western United States. U.S. Geol. Survey Bull. 845, 304 p.

Emory, W.H., 1848, Notes of a military reconnaissance, from Fort Leavenworth, in Missouri, to San Diego, in California, including part of the Arkansas, Del Norte, and Gila Rivers: U.S. 30th Cong., 1st sess. Ex. Doc. 41, 614 p.

Graf, W.L., 1981. Channel instability in a braided sand-bed river. Water Resources Research, v. 17, pp. 1087-1094.

Graf, W.L., 1983. Flood-related Channel Change in an Arid-region River. Earth Surface Process and Landforms, v. 8, pp. 125-139.

Graf, W.L., 2002. *Fluvial Processes in Dryland Rivers*. The Blackburn Press, Section 5.4, pp. 196-218.

Graf, W.L. et al., 1994. Geomorphic assessment of the lower Gila River, west central Arizona. Unpublished report for U.S. Army Corps of Engineers, Los Angeles District, 142 p.

Glenn, L.C., 1925. Geology and groundwater resources of Meade County, Kansas. Kansas Geological Survey Bull. 45, 152 p.

Huckleberry, G.A., 1993. Late-Holocene stream dynamics on the middle Gila River, Pinal County, Arizona. Unpublished dissertation, Univ. of Arizona, 135 p.

Huckleberry, G.A., 1994. Contrasting channel response to floods on the Middle Gila River, Arizona. Geology, v. 22, pp. 1083-1086.

Huckleberry, G.A., 1996. Historical geomorphology of the Gila River. Arizona Geological Survey, Open-File Report 96-14, 20 p.

Meko, D. and Graybill, D.A., 1995. Tree-ring Reconstruction of Upper Gila River Discharge, Water Resources Bulletin, v. 31, no.4, pp. 605-616.

Rea, A.M., 1983. *Once a River*. Univ. Arizona Press, Tucson, 285 p.

Ross, C.P. 1923. The lower Gila region, Arizona. U.S. Geol. Survey Water-Supply Paper 498, 237 p.

Schumm, S.A., 1981. Evolution and response of the fluvial system: Sedimentologic implications, Soc. Economic Paleontologists and Mineralogists Spec. Pub. 31, pp. 19-29.

Schumm, S.A., 2004. Geomorphic Character of the Lower Gila River. Prepared for the Salt River Project, June, 20 p.

Schumm, S.A. and Lichty, R.W., 1963. Channel widening and flood-plain construction along Cimarron River in southwestern Kansas. U.S. Geol. Survey Prof. Paper 352-D, pp. 71-88.

Sellards, E.H., 1923. Geologic and soil studies on the alluvial lands of the Red River valley. Texas Univ. Bull. 2327, pp. 27-87.

Smith, H.T.U., 1940. Notes on historic changes in stream courses of western Kansas, with a plea for additional data. Kansas Acad. Sci. Trans., v. 43, pp. 299-300.