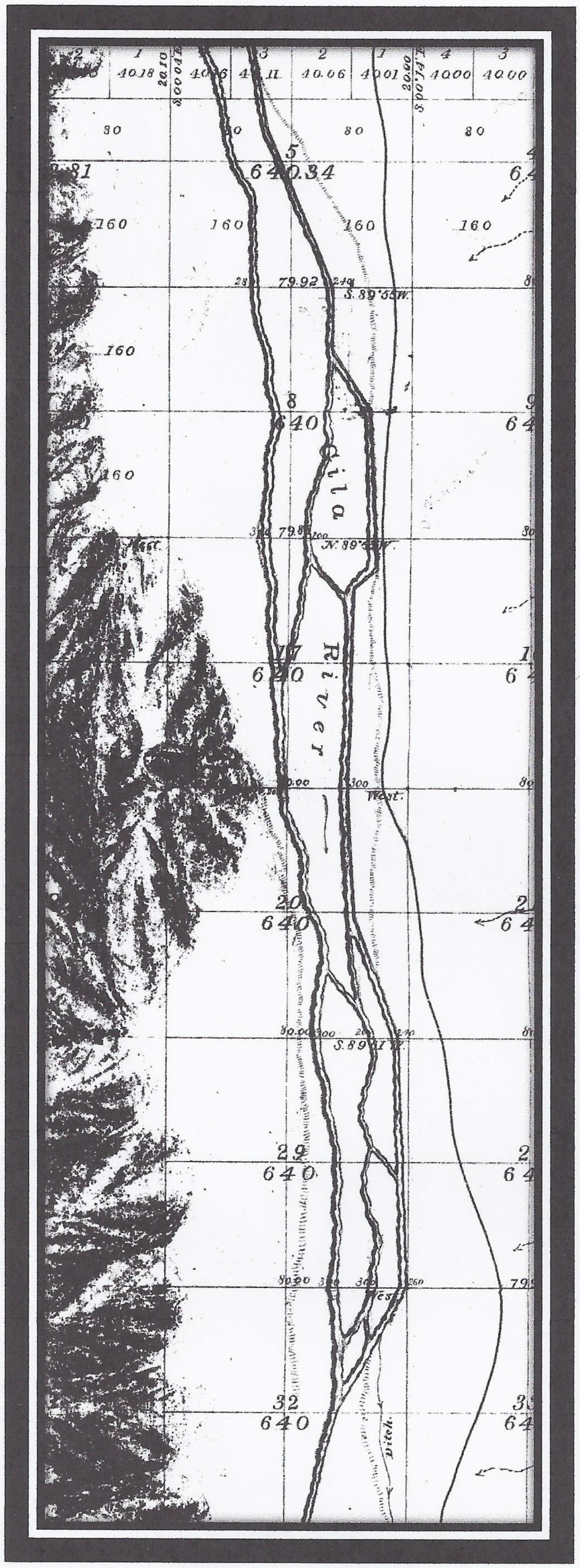

Report on the Navigability of the Gila River

Prepared for
The Gila River Indian Community

By

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EXECUTIVE SUMMARY

The Gila River in Arizona can be divided into six segments which are:

1. Duncan Valley
2. Box Canyon
3. Safford Valley
4. Kearney
5. Middle Gila
6. Lower Gila

The Gila River Indian Reservation lies in the Middle Gila segment.

As development began with the Ho-hu-kam, continued with the Pimas, and expanded with Anglo-American settlements, all three groups traded with others.

If the Gila River had been navigable, it would have been navigated for about 2,000 years. No evidence of commercial navigation exists.

The period approaching Statehood took the non-navigable and partially braided Gila River and made it worse. Numerous large floods occurred in 1890 through 1906 that scoured and widened the river channel. The resulting river channels were braided. These braided channels existed at Statehood because of natural phenomena.

In 1930, Utah Special Master Warren rendered a detailed decision concerning the navigability of four Southwestern rivers as of 1896. Based on far more data concerning actual historic navigation than is available on the Gila River, the Utah Special Master concluded that a mean depth of three feet was necessary for commercial navigation in 1896. As bigger and better boats occur for navigation, you would expect the depth required for navigation to increase or stay the same. Navigability requires at least a three foot depth in 1912.

To navigate a braided river takes extreme amounts of flow. We have topographic surveys for the Middle Gila River dating from 1914. The data contained on these maps and contemporaneous references to the soils of the riverbed allow a determination of the actual water depths for different flows and locations. Table “Executive Survey” shows the flows and resulting depths for mean, median, and low flows. The three foot requirement is not met.

We also have the flow/depth records for the gage at Kelvin as of statehood. The depths are greater than one foot and less than two feet for base, median, and mean flows. There were natural obstacles including numerous beaver dams and marshes on the Gila River and the extreme and rapid increases in flows during floods all would have been and impediment to navigation.

Summary			
	Below Kelvin	Above Confluence	Units
Mean Flow	755	637	CFS
Depth	0.70	0.98	Feet
Velocity	1.35	1.13	Ft/Sec
Median Flow	345	193	CFS
Depth	0.55	0.74	Feet
Velocity	1.01	0.77	Ft/Sec
Low Flow	175	23*	CFS
Depth	0.44	0.24	Feet
Velocity	0.77	0.33	Ft/Sec

*Flow is questionable (See Text)

The Gila River was not navigable in its “ordinary and natural” condition as of February 14, 1912.

I. INTRODUCTION

This report was prepared on behalf of the Gila River Indian Community ("Community"). The Gila River Indian Community is a Federally Recognized Indian Tribe and occupies the Gila River Indian Reservation ("Reservation"). This report is being prepared at the Community's request for presentation to the Arizona Navigable Stream Adjudication Commission ("ANSAC") for its use in determining the navigability of the main stem of the Gila River.

A. GILA RIVER

The Gila River and its tributaries drain water from roughly forty percent (40%) of the land in the State of Arizona. The Gila River's watershed is an area of 66,020 square miles.[1] The Gila River is the major watercourse in central and southern Arizona with its headwaters in the mountains of western New Mexico. The Gila River runs in a general westerly direction and drains into the Colorado River north of Yuma. The Salt River, Agua Fria, and Santa Cruz Rivers are three major tributaries of the Gila River that empty into the Gila River on or near the Reservation.

[1] ANSAC 2006 pg 7.

The Reservation is located in Central Arizona at the confluence of the Salt and Gila Rivers. The Reservation runs easterly from that confluence point, primarily along the Gila River (see location map I-1).

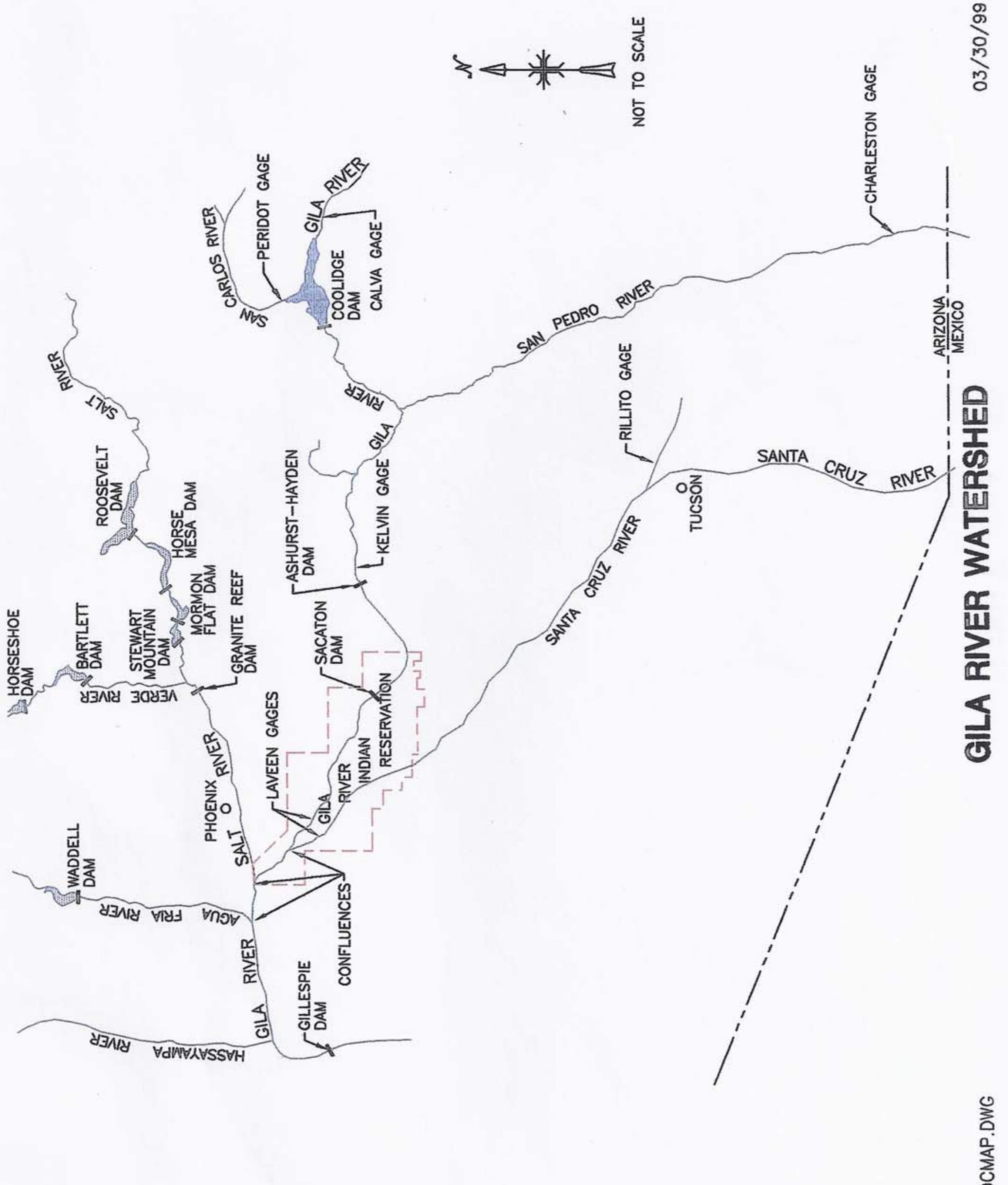
In addition to these major watercourses, there are several lesser washes and watercourses on the Reservation. The Vekol and Santa Rosa Washes with watershed areas to the south of the Reservation merge with the Santa Cruz River on the west end of the Reservation. The McClellan Wash enters the Reservation in the southeastern corner and meets the Gila River north of Sacaton. A variety of unnamed washes and drainage courses also carry stormwater from the Reservation's mountains to the larger watercourses.

Rea provides a very good description of the Gila River:

> The Gila River was once a well-defined stream meandering across a Lower Sonoran Desert floodplain with here and there marshes, legumes, and oxbows. Its gallery forest of native cottonwoods and willows formed a green ribbon that travelers could trace for hundreds of miles through the desert. Other living streams – the San Pedro, Santa Cruz, Salt, Aqua Fria – added their own waters to the Gila. Villages of agricultural Indians, early historic, as well as pre-historic dotted the fertile floodplains. These streams with their woods, legumes, and grasslands, all abounding in birds and other forms of wildlife are a thing of the past. The rivers are dead.[2]

The Gila River Indian Reservation was created by an Act of Congress in 1859. Subsequent expansions to the Reservation through Executive

[2] Rea pg 7.



LOCATION MAP

Figure I-1

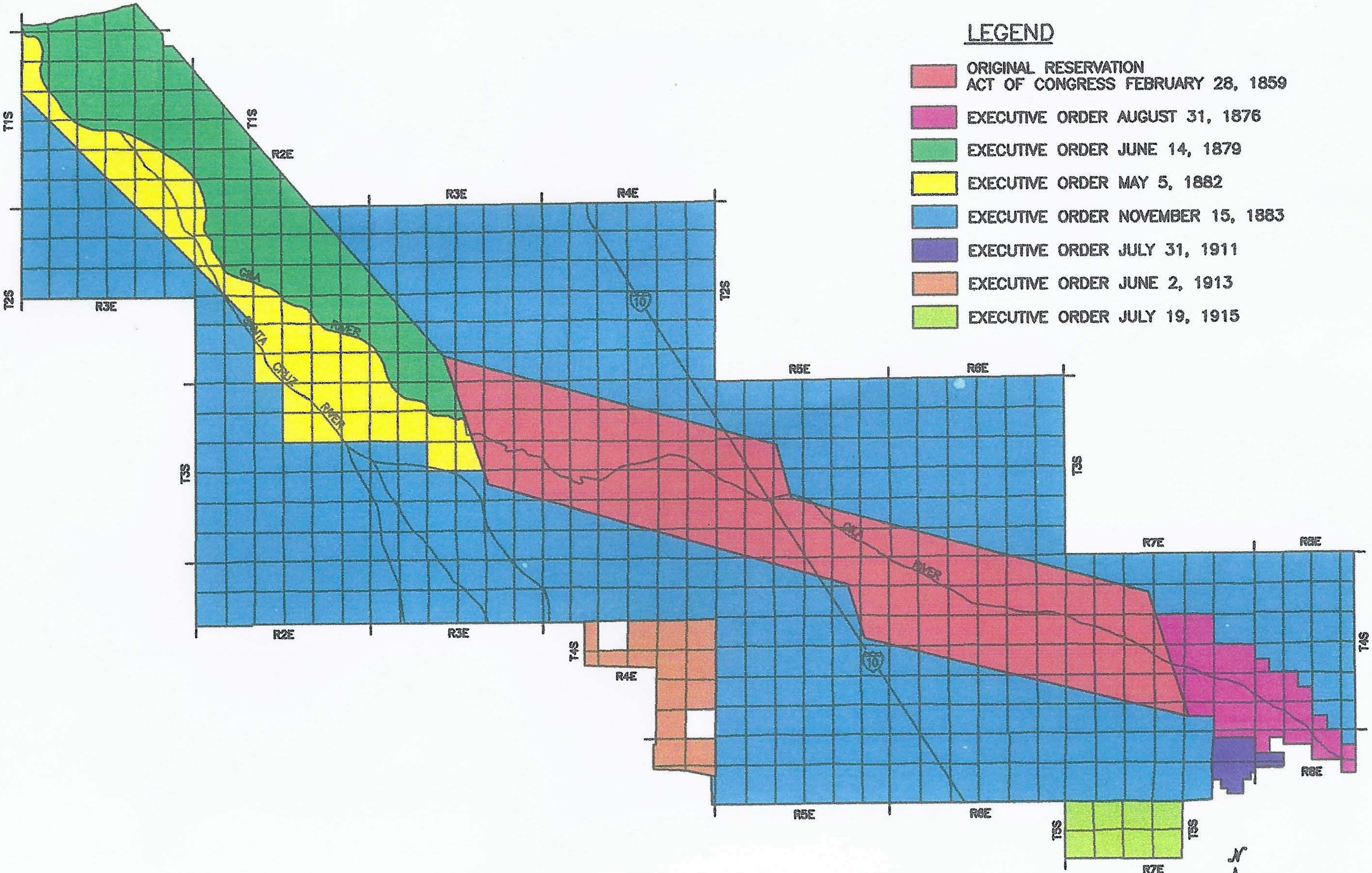
Orders in 1876, 1879, 1882, and 1883 brought the Reservation to a size approximating the current boundaries. Minor changes were made in the boundaries of the Reservation during the period 1911 through 1915. These changes left the Reservation with its current boundaries (see Figure I-2).

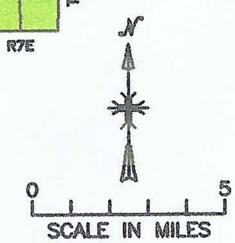
The Gila River Pima-Maricopa Indian Community was formally organized on May 14, 1936, pursuant to the Indian Reorganization Act of June 18, 1934 (48 Stat. 984) as amended by the Act of June 15, 1935 (49 Stat. 378). An amended Constitution and Bylaws of the Community was approved on March 17, 1960 and the name was changed to the Gila River Indian Community. The Community is governed by the Gila River Indian Community Council.

B. LEGAL CRITERIA

Several court cases are of importance in determining the navigability of the Gila River. The three primary cases are *State v. Arizona Navigable Stream Adjudication Commission*[3] ("Arizona Appellate Decision"), *PPL Montana, LLC v. Montana*[4] ("Montana Decision"), and the *United States v. Utah*[5] ("Utah Decision"). These Decisions lay out certain key concepts that will be addressed in the chapters following.

[3] 224 Ariz. 230.
[4] 132 S.Ct. 1215.
[5] 284 U.S. 64.





ORIGINAL GILA RIVER INDIAN RESERVATION AND SUBSEQUENT ADDITIONS

09/15/97

Figure I-2

The Arizona Appellate Decision provides a definition for “ordinary” and a definition for “natural”. The concept of “ordinary” primarily relates to the hydrology of the river. This topic of “ordinary” will be addressed in chapter II which deals with the hydrology of the Gila River. “Natural” has more to do with the channel itself. What is the channel in its natural condition? This topic of “natural” is addressed in chapter III.

The fundamental navigability test is a factual inquiry as to whether or not trade did occur through the use of rivers. The concept of historic navigation is addressed in chapter IV.

The Utah Decision addressed the concept of susceptibility of navigation which, in essence, suggested that just because navigation didn’t occur, does not inherently mean that the river was not navigable, if there was no reason to navigate the river. The concept of whether navigation was needed also is addressed in chapter IV.

Related to this susceptibility of navigation concept is an analysis of what the Gila River would have been like in its “ordinary and natural” condition. This susceptibility of navigation concept is addressed in chapter V.

C. SEGMENTATION

The Montana Decision provides guidance relating to how the river is to be segmented. I have not devoted an entire chapter to this because I have not seen that this is particularly important for the Gila River. However, the Gila River does have, based on the basic geomorphology of the reach, certain very clear and distinct reaches that probably should be considered separately.

Beginning at the Arizona-New Mexico state line, there is a farming segment of the Gila River that is called the Duncan Valley. Actually, the Valley in toto is the Duncan-Virden Valley with Duncan being the Arizona portion and Virden being the New Mexico portion. The Duncan-Virden Valley is one geologic configuration divided into two political halves. The second segment of the Gila River is downstream from the Duncan Valley. This segment of the Gila River is a long narrow canyon that picks up substantial flow from the San Francisco River and traverses a canyon that is known as the Box Canyon. I call this segment the Box Canyon Segment. The third segment of the Gila River is a wide alluvial basin roughly centered on the City of Safford. This valley, which reaches from the end of the Box Canyon down to the current Coolidge Dam, is normally referred to as the Safford Valley Segment. A portion of the San Carlos Apache Reservation lies on the west end of the Safford Valley Segment. Also, the San Carlos Reservoir, which was impounded behind Coolidge Dam, is on the west end of the Safford Valley Segment. The fourth segment of the Gila River is from Coolidge Dam down to an irrigation diversion structure named Ashurst-

Hayden Dam. This segment of the river is primarily a canyon that also receives water from the San Pedro River. This segment will be referred to as the Kearny Segment. The water of the Gila River exits the Kearny Segment near a USGS gaging station called Kelvin where it enters a broad valley, (the fifth segment,) that is generally referred to as the Middle Gila Segment. The gage at Kelvin and the Ashurst-Hayden Diversion Dam are located very close to one another. Hydrologists generally use Kelvin data as a measure of the flow at Ashurst-Hayden. The Middle Gila segment flows primarily through the Reservation down to its confluence of the Salt River. Finally, there is the sixth segment of the Gila River from the Salt-Gila confluence down to the Gila-Colorado River confluence. This segment is normally called the Lower Gila. Therefore, I believe the segments to be considered are:

1. Duncan Valley
2. Box Canyon
3. Safford Valley
4. Kearny
5. Middle Gila
6. Lower Gila

The primary emphasis of this report will be the Middle Gila River Segment, which is the segment that the Reservation is in.

II. HYDROLOGY

In order to determine whether a river is susceptible of navigation, there are many factors that need to be considered, but two factors tend to overshadow the other factors. One factor is the amount of water in the river channel and the second factor is the shape and size of the river channel. This chapter deals with how much water would have been in the Gila River channel under "ordinary and natural" conditions as of the time of Statehood.[1] It also discusses flood events that occurred on the Gila River prior to Statehood.

The Arizona Appellate Decision addressed the words "ordinary" and "natural" separately. "Ordinary" is defined as "occurring in the regular course of events; normal; usual".[2] The Arizona Appellate Court also defines "ordinary" as "customary"[3]. The primary thrust of the definitions and the further explanation by the Appellate Court indicate that navigability is not prevented by unusual droughts, nor does boating in usually high river flows prove navigability. Normal, or "usual," means that most of the time, a percentage of the time far greater than 50%, but somewhat less than

[1] 224 Ariz. 230 pg 24.
[2] 224 Ariz. 230 pg 24.
[3] 224 Ariz. 230 pg 24.

100%, you would expect to have the conditions indicated. In hydrology, this would represent a range of values. The low end of the range would probably be what is called the base flow because the base flow is dependable and you would usually expect to see at least that much water on any but the driest of days. Baseflow is best shown by the flows, other than in direct response to rainfall or snowmelt, during the summer, usually in June.

The high end flows that can be considered part of the navigable range would be primarily affected by the velocity. There is no question during high flows or flood flows that there is plenty of depth and plenty of width. The acceptable velocity of water is primarily dependent on two things, safety and ability to transport upstream.

The second term that the Arizona Appellate Court defined is "natural". In the case of river flows, natural flows are what the flows would have been if humanity had not been in the region.[4] In hydrology, this is called "virgin flow".

A. VIRGIN FLOW

There are several sources of information that can be used to determine the virgin flow of a river in Arizona. The first, and by far, the most

[4] 224 Ariz. 230.

detailed analysis is the so-called “White Book” published by the U. S. Bureau of Reclamation[5]. The second source is the USGS report for annual runoff[6]. The third source is the groundwater basin mappings developed by Freethey and Anderson, also referred to as HA-664. The fourth source used was the pre-development report prepared for the Gila River Indian Reservation by the United States Geological Survey[7]. Finally, the early historic data coupled with early observations does provide some additional quantification of flows at certain specific places on the Gila River.

1. White Book

The numerous reasons why I prefer the “White Book” (the nickname for a Bureau of Reclamation Report) analysis were presented in testimony concerning the San Pedro River before ANSAC in August 2013[8] and apply equally to the Gila River. The White Book provides mean annual flow data for the Salt River at Granite Reef and for the Gila River at Kelvin.

The White Book provides a detailed explanation for its data and how it arrived at the virgin flows. This enables me to make considerable flow determinations at additional locations using the data in the White Book. These determinations are attached in Appendix A. In making this analysis, I

[5]U. S. Bureau of Reclamation.
[6]Krug, et. al.
[7]Thomsen and Eychaner.
[8]Gookin slide 26-27.

wished to find the mean daily flow, the median daily flow, and the low flow for the Gila River at Kelvin. The Gila River at Kelvin is the river's entrance to the Middle Gila River segment. I also computed the same three flows for the Gila River before and after its confluence with the Salt River.

The approach was to use historic data from gages that are draining relatively undisturbed areas. On the Gila River at Kelvin, I used the Gila River at Redrock with substitutions for the Gila River near Blue Creek when the Redrock gage was not active, the San Francisco River at Clifton and the San Carlos River at Peridot. In each case, I added the flows and I compared the total of those flows to the historic flow shown by the White Book at Kelvin. Obviously, they will not match; they are different locations and have different drainage areas. However, given that I knew what the mean average historic flow was at Kelvin, and in each case, the three gages contained the most productive areas of the watershed, the results were very close and better than I expected. I then took the historic data and proportionately adjusted the daily flows to match the historic White Book value. The adjustment required was less than 10 percent. This provided me with the beginning estimate of historic mean, median, and low flow at the White Book station of Kelvin.

There is one additional change to be made to calculate virgin flow, that is net depletion.

The net depletion (human caused) amounts I added back in to all three flows, mean, median and low flow. The reason I added back depletion to all three flows is that, before dams, farmers would divert what they can divert, whenever they can divert. Farmers would do this in an attempt to store the water in their soil horizon so that during periods of inadequate water supply, the water stored in the root zone of their crops might tide the crop over until an additional supply of water became available. Thus, for mean and median flows, it clearly made sense to add back the depletion.

When it comes to the low flow, the assumption that a water accounting approach[9] (i.e. the White Book) is the approach to use is probably wrong. Low flow or base flow is dependent on local geology. The accounting approach does work where an historic measured low flow exists. Then the additional flow will be on the surface. At an unmeasured or dry location, the accounting approach will probably overstate the flow.

As a result, the computed mean, median and low flows for the Gila River at Kelvin are shown in Figure II-1.

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[9] The accounting approach, which is used in the White Book, is the approach of taking the historic flow and then adding and subtracting the changes in the River that are due to human influences.

Figure II-1

Summary of Flows (All Data in CFS)

Description		Source	Data	Gookin
Kelvin				
	Mean	(1)	755	755
		(4)	610	-
	Median	(1)	345	345
	Low	(1)	175	175
Sacaton		(5)	95	95
Above Confluence Gila				
	Mean	(1)	637	637
	Median	(1)	193	193
	Low	(1)	23	23*
Below Confluence				
	Mean	(1)	2504	2504
	Median	(1)	774	774
	Low	(1)	109	74
		(2)	88	
		(3)	100	
		(4)	74	
		(6)	69	

* Value Computed is thought high

Source:
1. Bureau of Reclamation
2. Hodges
3. Freethey and Anderson as computed by Gookin
4. Thomsen
5. Southworth
6. USGS 1901

To get the flow above and below the Salt-Gila Confluence, I needed to add the flows to the major gaged tributaries between Kelvin and the Salt-Gila Confluence.[10] These were adjusted for the flow condition in a similar manner to Kelvin. This leaves the additional ungaged area which has human depletions, change of vegetation, and a new variable ungaged inflow. These were allocated according to physical parameters as shown in Appendix A.

The new category of natural surface inflow was applied to the mean flow but not the median or low flow. Ungaged inflows have a different characteristic. Inflows in central Arizona are almost totally from surface runoff and come down dry ephemeral washes in time periods that are measured in minutes. Although it is possible that some inflows might occur at a time when the river flow is below the median (the lower 50 percent), it is highly unlikely. Because the water is coming from storms, the river is almost certainly flowing at more than at its median level.

2. USGS Annual Runoff

The second source, the USGS annual runoff report, suffers from extremely weak documentation of what was done and how it is to be interpreted. This runoff report is known as the Krug Report. By taking the

[10]The White Book provides information for the Salt River at Granite Reef and the Santa Cruz at Rillito.

data presented in the USGS annual runoff report and comparing the numeric values, particularly the drainage areas, with the values published by the USGS in the Water Supply Papers, I was able to construct the average flows based on the Krug report. These flows are not shown in Figure II-1 due to Krug's failure to provide flows or data at the critical locations of Kelvin and the Salt-Gila Confluence.

The Krug report's data are not always reasonable. For example, according to the Krug report, the Gila River at its mouth near Yuma has an average discharge historically of 800 cfs. This equates to 0.19 inches of runoff for the entire Gila watershed. Krug then adjusts that runoff downwards so that the virgin runoff is only 0.04 inches per acre or 21 percent of the historic runoff. Mathematically, this computes that the total runoff at Yuma goes from 800 cfs historic mean annual runoff down to 171 cfs in virgin conditions. You would expect the numerous dams, groundwater pumping, and diversions to have the reverse impact. The virgin mean average flow should have been higher than the historic mean average flow, not 1/4th of the historic mean average flow.

There are other ways in which the annual runoff data do not make sense. For example, in Hydrologic Cataloging Unit 15070101, the analysis is shown as being based on the flows of the Centennial Wash.[11] However, the Centennial Wash in reality flows into Hydrologic Cataloging Unit 15070104 where Krug did not consider the wash.

The Hydrologic Cataloging Unit 1507014 is determined to have a net gain of zero cfs. The next Hydrologic Cataloging Unit downstream is the Gila River heading to its mouth near Yuma which also has a net gain of zero cfs. This means that, in both watersheds, the losses in each reach also just happened to exactly match the new runoff generated by rain. A very, very unlikely scenario.

A scan of Krug's runoffs to the rivers shows that he believes that there is no such thing as a losing reach for any river in the entire United States. Krug is wrong.

3. Freethey and Anderson

The Freethey and Anderson plates are a source for the base flow in some unusual locations. Unfortunately, the Freethey and Anderson plates do not show what the flow is at the confluence. The Freethey and Anderson map shows the flow discharged at the City of Buckeye, a distance of over 17 miles in a straight line downstream from the confluence. This is a big difference due to the Aqua Fria River entering the Gila River in that 17 mile

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[11] Krug pg 321.

reach. While the Aqua Fria River is ephemeral, it has a significant underflow that would emerge in this 17 mile reach. According to very early measurements by the U.S.G.S., the Gila River was gaining about 9.9 cfs per mile near the Salt River-Gila River confluence.[12]

Freethey and Anderson's pie charts do not reflect hydrologic reality. The pie charts show no discharge to base flow in the Salt and Gila reaches immediately above the Salt-Gila confluence. This is wrong. It has been recognized since at least the Pima occupation that baseflow occurs shortly upstream of the Salt-Gila confluence on both rivers. There was even a lake fed by baseflow on the west end of the Reservation.[13] Also, we know that the Maricopas moved to the confluence area due to its firm water supply coming from groundwater. When the Pimas had water supply problems in the 1870s, many Pimas moved to the Gila Crossing area because of the stable baseflow arising from the groundwater.

Freethey and Anderson warn in their document not to use it for this level of detail. Freethey and Anderson explain that their three plates are "a conceptual model" that only shows the "magnitude" of the values.[14]

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[12]Newell pg 79.
[13]Southworth pg 122.
[14]Freethey and Anderson Plate 1.

Using the Freethey and Anderson plates to compute the baseflow at most stations is extremely tedious and prone to mistakes. For the above reasons I did not bother computing the baseflow at the one point of interest shown on the plates, Kelvin.

4. Thomsen and Eychaner

Thomsen and Eychaner of the USGS created a report concerning pre-development conditions for the Gila River Indian Reservation. In that process, Thomsen and Eychaner determined that the virgin flow at Kelvin was 500,000 ac-ft per year.[15]

Thomsen and Eychaner in the Gila Report also estimated the base flow at the Salt-Gila Confluence. Thomsen's and Eychaner's accounting includes the inflows from the Salt and the Gila.[16] Based on these data, the low flow below the confluence as computed by Thomsen and Eychaner is 73.9 cfs under pre-development conditions.

5. Contemporary Sources

There are two locations, one near Sacaton on the Gila River Indian Reservation, and the other, near the confluence of the Salt and Gila Rivers, where very early historic materials were used by hydrologists at the time to estimate virgin flows.

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[15]Thomsen and Eychaner pg 16.
[16]Thomsen and Eychaner.

a. Sacaton

In the very early planning stages of Coolidge Dam, a report was written by Southworth of the Indian Irrigation Service. This report involved extensive plane table surveys through the Gila River Indian Reservation up into the Safford Valley. These surveys provided detailed inventories of irrigated lands, canals, their sizes and shapes. In Southworth's report, based on seepage studies performed previously, he calculated the flow that would be available at Sacaton on the Gila River Indian Reservation if there were no upstream diversions. Southworth's calculations came to 95 cfs.[17] Based on the discussion on the next page of the Southworth report, this value appears to be best described as being between a median and a low daily flow.

b. Confluence

Two different sources have estimated the base flow below the Confluence of the Salt and Gila. The USGS in 1899 did a set of seepage and diversion measurements to determine the losses and gains as the river moved downstream. That study computed that the flow at Buckeye Canal, which is 3-½ miles downstream of the Confluence, was 103.3 cfs.[18]

[17] Southworth pg 242.
[18] Newell pg 383.

Subtracting the 9.9 cfs gain per mile from the same source, this equals 68.7 cfs[19] at the Confluence.

A second set of studies by hydrographer Paul Hodges of the Irrigation Division of the Office of Indian Affairs broke the actual flow at the Confluence into base flow and the surface runoff that had occurred. This analysis showed that the base flow was at a minimum in August rather than June with 88.1 cfs.[20]

Figure II-1 shows all the values along with what I adopted.

6. Conclusions

Based on the Figure II-1, I conclude the virgin flows at Kelvin to be:

Mean	755 cfs
Median	345 cfs
Low	175 cfs

The flow at Sacaton is 95 cfs. This flow is somewhere between low flow and median flow. I suspect it is a little high for low flow but I wish to err in favor of navigability. For the Gila River above the Salt-Gila confluence, I conclude the virgin flows to be:

Mean	637 cfs
Median	193 cfs

[19] 103.3 cfs – [9.9 cfs/mile x 3.5 miles] = 68.7 cfs
[20] Hodges pg 4.

Low	23 cfs

The low flow is not considered reliable as already discussed.

The flows for the Gila River below the Salt-Gila Confluence are as follows:

Mean	2,397 cfs
Median	774 cfs
Low	109 cfs

The low flow after the confluence is based on Thomsen and Eychaner. It falls between the two contemporary flow estimates and is based on a more detailed analysis than the two contemporary sources or Freethey and Anderson. My computation, based on the White Book for the low flow, was, as already explained, expected to be incorrect.

B. FLOODS

1. Historic

Floods have a major impact on channel geometry. There are two groupings of major floods that occurred in 1890-91 and 1905-06.[21] There were also major floods in 1915-1916. These floods were the floods that turned the Gila River from being a primarily single channel river into a primarily braided stream. This statement is true in the Upper Gila, the

[21] See also Fuller 2003 pg VII-3.

Middle Gila, and the Lower Gila. These floods had a tremendous impact on the channel shape and, as will be discussed in chapter III, caused the Gila River to become braided in many areas.

The first major flood grouping was during the period of February 1890 through February 1891. During this 13 month period, there were 4 major floods. There were floods in each of the two Februarys; there was one flood in August 1890 and another flood in October 1890.

The first flood was in February 1890. The Salt River rose 17 feet in 15 hours.[22] In the Lower Gila River, the peak flow was estimated to be about 140,000 cfs.[23]Also, the Walnut Grove Dam on the Hassayampa River burst in a nearly instantaneous total failure.

We do not know the extent to which the Walnut Grove Dam failure caused channel changes downstream. Walnut Grove Dam's break caused substantial flows. Therefore, channel shapes from February 1890 to February 1891 should be considered unnatural. The Gila River channel may have been reshaped into a natural configuration by the floods that followed. However, given the availability of information on historic navigation (Chapter IV) and channel characteristics (Chapter III) before the dam failure, it is safer to limit our examination to pre-dam failure.

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[22]Flood Control District of Maricopa County no page.
[23]Graf pg 1089.

There were two more moderate floods. The final flood in February 1891 was a dramatic finale – a 65,000 cfs flood[24] came down the San Pedro River at about the same time 150,000 cfs[25] was flowing down the Verde River. When the two floods met along with lesser floods along the way, an estimated 300,000 cfs[26] was flowing below the Salt-Gila confluence. As a result "… the channels of both the Salt and Gila Rivers were changed in many places."[27] There were moderate floods in 1895 through 1898.[28]

In January 1905 through December 1906, there was another period of multiple and major floods. For several months, the snow pack had been building until a rapid snowmelt[29] occurred causing the flow below the Salt River/Gila River confluence to reach 115,000 cfs.[30] In November 1905 and August 1906 there were more floods. In November 1906, a large snow pack developed followed by a large warm rain on December 1-4.[31] The runoff may[32] have been 200,000 cfs.

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[24]Pope et. al. pg 263.
[25]Pope et. al. pg 741.
[26]Graf pg 1089.
[27]Russell pg 62 based on talking stick records.
[28] Durrenberger and Ingram pg 8-9.
[29] Durrenberger and Ingram pg 9-16.
[30]Graf pg 1089.
[31]Durrenberger and Ingram pg 11.
[32]The Graf table shows 200,000 cfs in a spot that would be consistent with 1906. However, it appears to be mislabeled to be 1895. The amount is consistent

The 1915-16 flood is significant because it would have also reworked the channels. Since we are interested in the natural conditions as of statehood we need to consider channel data that occurs between 1906 and 1915. The natural channel as of 1912 was created by the tremenous erosive and depositional power of the 1905/6 floods. The channels would have remained in that configuration until the 1915/1916 events. After that we do not know if the natural channel was reflective of the conditions as of 1912 or not.

2. Impact on Navigation

One of the aspects of floods in this area is that they are very rapid, very violent, come without warning, and carry a tremendous amount of debris with them. In short, floods are dangerous to watercraft. In 1905, the USGS stated:

> At times the wave of sand traveling along the bed of the stream are so large, the current is so swift, and the stream to (so?) shallow, that the water is broken into a uniform succession of waves two feet high and over... At every flood, the channel shifts. The valley at its narrowest is a half mile wide and the waters may occupy any part or all of it. (WSP No. 175, p. 164).[33]

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with other flows in the Gila system specifically 190,000 cfs at Kelvin (USGS website) and the Verde River below Tangle Creek 65,000 cfs (Pope pg 743).

[33]Fuller 2003 pg IV-12.

As the USGS observed concerning the Gila and Salt River:

> These floods are of the most destructive and violent character; the rate at which the water rises and increased in amount is astonishingly rapid, … . For instance, in an ordinary flood, the Salt River, the principal tributary of the Gila, has risen in about three hours from 500 second-feet to 30,000 second-feet, falling again almost as rapidly, so that they average for the day or for two or three days would not be more than 10,000 or perhaps 5,000 second-feet. From this it will be recognized that the onsite of such a flood is terrific. **Coming without warning, it catches up logs and bowlders [sic] in the bed, undermines the banks, and tearing out trees and cutting sand-bars is loaded with this mass of sand, gravel, and driftwood – most formidable weapons for destruction... . [emphasis added] .**[34]

The USGS in the next year stated:

> These streams fluctuate greatly, being at times subject to sudden floods, … when they often sweep up bridges, dams, and canal head works,[35]

The USGS went on to state "The floods of the Gila are usually short and violent,"[36]

In the Sixteenth Annual Report, the USGS stated:

> …but these floods occur at such irregular intervals and come with such violence...[37]

The Special Master in the Utah Decision, in his analysis of the navigability of the rivers, considered the issue of "variations in flow and

[34]Fuller 2003 pg IV-42 citing the Eleventh Annual Report of the USGS pg 58-59.
[35]Fuller 2003 pg IV-42.
[36]Fuller 2003 pg IV-44.
[37]Fuller 2003 pg IV-46.

rapidity of variations."[38] The Utah Special Master concluded that flow variations in the rivers he was considering were not sufficient to preclude navigability. However, the floods that the Utah Special Master considered[39] had slower rises and slower falls due in part to the large areas that they drain.

The Utah Special Master concluded, based primarily on the fact that people had successfully navigated the rivers, that the change in the velocities and stage of the river did not effectively deter navigation and that floods were not an obstacle to successful navigation. This cannot be said of the Gila or Salt Rivers. The changes are more dramatic, and have a greater potential for destruction of boats

C. Dry Spots

Although the Gila River was perennial, it was at some times dry or very low. The earliest recorded observation of the river being dry was in 1775.[40]In 1854, the Gila River was dry in mid-February.[41] Frank Russell stated:

> About every fifth year in primitive times the Gila River failed in midwinter, the flow diminishing day by day until at length the

[38]Warren pg 169.
[39]Warren pg 170.
[40]Fuller 2003 pg IV-1.
[41]Fuller 2003 pg IV-3.

last drop that could not gain shelter beneath the sands was licked up by the ever thirsty sun.[42]

[42]Russell pg 66.

III. GEOMORPHOLOGY

The Arizona Appellate Court made a major factual mistake in their opinion when they suggest that there is a single "natural state" that can be used for any period of time that humans are not present.[1] Rivers change, with or without humans. What the river was before and during the Hohokam occupation is different than what the river was in the 1800s. Neither of these is the same thing as what it would have been in 1912 in its natural state.

For nature to remain constant, the rainfall would have to be replicated exactly the same every year. There would have to be no movement of the Earth's crust. The sun could have no flares. Ocean currents and temperatures must be constant. Vegetative patterns could not change. Insect infestations would either have to be continuous or not at all. The list of natural factors that constantly vary that would have to be locked into some kind of permanent stasis goes on and on and on.

The Arizona Appellate Court stated ANSAC must consider whether the river would have been navigable in its "ordinary and natural" condition on February 14, 1912.[2] This statement is contrary to the Court's suggestion that an earlier period of time can be used.

[1] 224 Ariz. 230 pg 28-29.
[2] 224 Ariz. 230 pg 29.

The reason that no single condition can be used is simply that a river is variable. In Arizona, that statement becomes an even greater truism than for most areas. Variability occurs both in the flow, and in the shapes of the channel, both of which vary over the length of the river and over time. Schumm pointed out that:

> ...Rivers change naturally through time as a result of climate and hydrologic change; … there can be considerable variability of channel morphology along any one river as a result of geologic and geomorphic controls.[3]

Of particular importance to the question of navigability is the question of river braiding. While it is possible to navigate a braided river, it takes far more river flow than any of the experts or records suggest for the Gila River. The reason is explained by Osterkamp:

> [D]ownstream changes in discharge for these [braided] streams are accommodated totally by adjustments in channel width, not by changes in mean channel depth or water velocity... In other words, increases in discharge for braided streams do not result in increased channel depth, and because all flow (at normal discharge rates) remains in proximity to the wetted perimeter, velocities also remain nearly constant in the downstream direction.[4]

In simpler English, as more water comes in, the river leaves the low flow channel and the river spreads and spreads. This continues until the overall

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[3]Schumm pg 4.
[4]Osterkamp pg 193.

channel that is hundreds or thousands of feet wide is totally covered. Only after that point can the depth of the river begin to significantly increase.

The Gila River was extensively braided in the Safford, the Middle Gila, and the Lower Gila reaches by 1912.[5] The Gila River was also braided in smaller reaches in the mid 1800s.

The pro-navigability parties suggest that human impacts caused the braided conditions of the Gila River at Statehood. Human causes are not substantiated by geomorphologists or general geomorphic theory and historic evidence.

A. GEOMORPHOLOGIST CONCLUSIONS

Schumm pointed out in his last major work that "The Gila River in Arizona provides a good example of channel adjustment to floods." Schumm goes on to state:

> The average width of the channel of the Gila River increased during 1905 – 17 to about 2000 feet (*c.* 610 m). Mainly as a result of large winter floods that carried relatively small sediment loads. The meander pattern of the stream and the vegetation in the flood plain were destroyed completely by the floods.[6]

Osterkamp points out that "… the most significant effect on channel morphology appears to be the timing of flood events."[7] Osterkamp also draws

[5] Fuller 2005 slides 16-18.
[6] Schumm pg 129.
[7] Osterkamp pg 191.

a schematic that shows four floods that hit different types of streams and their recovery. Osterkamp then describes the figure as follows:

> A moderate flood (Fig 4, Flood 1) widens all four channels. … Widening is substantial in the sandy, perennial stream channels because the poorly cohesive banks are readily eroded.[8]

Further, Huckleberry states that:

> Channel changes on the Gila River are driven primarily by changes in the frequency of large floods (Burkham, 1972, Huckleberry, 1993b).[9]

Huckleberry does acknowledge other factors contributed, but the primary cause was the floods.

One thing that Huckleberry does point out is that it is not just the peak flow that creates the channel change. "... [A]s recent floods attest, it is not the peak discharge that is as critical in channel transformations as the duration of those floods."[10]

According to Huckleberry, the Middle Gila was primarily affected by the large flood in 1891.[11] The 1905 flood coincided "...with a radical transformation in channel planform[12] and geometry...".[13]

The Lower Gila River acted differently. In that case, based upon cadastral surveys, we know that "Between 1868 and 1929 the channel was

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[8]Osterkamp pg 197.
[9]Fuller 2003 pg VII-1.
[10]Fuller 2003 pg VII-5.
[11]Fuller 2003 pg VII-4, 5.
[12]As seen from above
[13]Fuller 2003 pg VII-5.

braided and the 1905 flood had no particular geomorphic significance."[14] Huckleberry does believe that "[d]ramatic changes appear to have occurred during two large floods in 1890 and 1891."[15]

B. GEOMORPHIC PRINCIPLES

The motive force that causes channel change is stream flow. The stream flow carries the sediments that will be deposited or removed at a specific location. It takes huge amounts of energy to scour a river that is roughly 500 miles long so as to widen the river by hundreds of feet and an unknown depth and moving all of that dirt down to the Colorado River or the ocean. This energy comes from water movement. When water moves, the amount of energy a drop of water has increases as the square of the velocity. That is, if the river velocity doubles, the energy available to move the sediment quadruples. During a flood, the water in a river moves faster than at low or median flow. Plus, during a flood, there are more water drops pushing the sediment downstream.

Floods create the prime motive power. The Gila River and its tributaries have generally entrenched and widened. These changes were observed immediately after big floods. When the braiding occurred was a function of when the floods occurred. If the floods that lead to the braiding had occurred

[14] Fuller 2003 pg VII-6.
[15] Fuller 2003 pg VII-6-7.

in 1913 or later, then the Gila River would have remained in its early 1800s state of being primarily a well-defined single channel. I say primarily because even in that period major braided reaches existed.

What causes the variability? The biggest natural cause of channel change is floods, particularly huge floods. Other factors may exacerbate or diminish the impacts of floods. There are literally dozens of other factors. In the context of this hearing, the natural factors do not matter. They all contribute to the "natural condition".

The human influences potentially do matter in this hearing. Five types of human influences have been discussed during the navigability hearings to date. These are overgrazing, irrigation diversions, storage dams, mining, and beaver trapping.

1. Overgrazing

Overgrazing did occur in Arizona. Overgrazing technically started in the 1880s, but nature, by coincidence, compensated by raining more than normal and causing abnormally large expanses of grass. Contemporaneous records show that the grass was destroyed by the cattle after the floods of February 1890 through February 1891.

> The most severe drought, and the one that affected the largest part of the region, began in the summer of 1891 and ended in 1904. In combination with overstocking of the range, the early-

> twentieth-century drought caused the death of half of the cattle in the region between 1891 and 1896.[16]

The reason overgrazing could matter is that the overgrazing kills the root structure holding the soil together. This makes it easier for water drops to move the sediment to washes and eventually rivers. If overgrazing was the problem, you would expect the flood waters to have a large sediment load. The 1905 flood had very low sediment loads, which is inconsistent with overgrazing.[17]

> Grazing apparently did not have a significant influence on the major floods during 1905-17 and, therefore, probably had no effect on the widening of the stream channel. … Since about 1905, the number of cattle in the area has been small compared to the number in 1890. The parts of the Gila River drainage that were overstocked in 1890 were in the valleys below the shaded mountain forests and below the area that produced most of the floodwater; … .[18]

2. Irrigation

Irrigation is the second possible cause of the braiding. However, the diversion dams before 1912 were not the concrete structures you see today. The diversion dams were made of rocks, brush, and other items including garbage. Most importantly these diversion structures washed out as floods began. Thus, the low flows were diverted but the major floods were not affected.

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[16] Webb et. al. pg 11.
[17] Burkham 1972 pg G-8.
[18] Burkham 1972 pg G-8.

3. Storage Dams

Major dams are a different story. Roosevelt Dam had a huge impact on Salt River floods. Due to that fact, the Lower Gila River was affected by storage dams starting in 1910. The second dam of interest was the Walnut Grove Dam which impounded a very small portion of the Hassayampa watershed. Specifically, Walnut Grove Dam impounded the headwaters of the Hassayampa River. Therefore Walnut Grove Dam's impact was generally small. In 1890, Walnut Grove Dam overtopped and rapidly collapsed. Accounts claim Walnut Grove Dam released a 100 foot wall of water into the Hassayampa River. While the wall of water would have attenuated greatly, the wall of water probably had a significant artificial influence on the Gila channel below the mouth of the Hassayampa River. As a result, the Gila River channel below the Hassayampa was in its "natural" state up to 1890 but probably no later. Similarly the channel of the Gila above the Hassayampa but below the Salt stopped being "natural" in 1910. Nothing much happened hydrologically in the two years before Statehood. The Gila River between the Salt and Hassayampa Rivers retained its natural channel until past Statehood. The Gila channel above the Salt was in its natural condition past 1912.

4. Mining

There was mining in Arizona. The consumptive use of water by mines is very significant today because of environmental requirements to prevent the discharge of the polluted waters back into the rivers. No such requirements existed at or before Statehood. Most of the water diverted would have returned to the rivers unconsumed (albeit polluted).

5. Beaver Trapping

The last human influence is beaver trapping. Beaver trapping was extensive in the early 1800s. As a result, the beaver dams that existed prior to the trapping would have failed due to a lack of maintenance. The impact of the loss of the beaver dams was twofold.

The first impact is that if the dams had been present during the large floods of 1890 to 1905, the beaver dams would have failed. This failure would have increased the flow volume (although probably not the peak) of the flood waters. The additional water released by the beaver dam failures would have increased the erosion and braiding of the floods. Given the large amounts of water involved in the floods, I doubt the beaver dam failures would have been significant.

The second impact would have been significant to navigability, but not to erosion. As discussed in chapter V, beaver dams would have forced considerable amounts of portage in the natural state. It is a legal matter as to whether adding 5 days[19] of portages to a commercial trip is relevant if it is

[19]A round number picked for an example only. Depending on the reach involved and the number of beaver dams in that reach, the number of portages would

divided into 50 separate small trips or one long trip. Either way, does however, have the same adverse impact on physical navigation.

C. PRE-HISTORIC CHANNEL CHANGES

On the San Pedro, there were several cases where Michael Waters had, based on his field work and dating techniques, determined that entrenchments occur and they have occurred both in history and pre-historically. John Ravesloot and Waters performed similar field work on the Gila River Indian Reservation to see what the geomorphic history of the Middle Gila channel would tell us. The story is considerably different from that of the San Pedro in details but is consistent in that major changes occurred shortly before Statehood. Figure III-1 shows an expanded cross section of the Gila River in the middle reach. Figures III-2 and III-3 show the timeline of what happened. The Gila River had been aggrading due to “braided stream deposition”[20] for 7,000 years. A significant sediment change occurred 4,500 years ago. There were two episodes where the Gila River widened. The first widening was about 800 years ago and occurred during a wet climatic episode that was “a period of intense high-magnitude flooding”[21]. Waters indicates that the second set of changes in the late 19th century “...are

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probably have been larger unless a very short reach of the Gila River was navigated.

[20]Figure III-2.

[21]Waters pg 336.

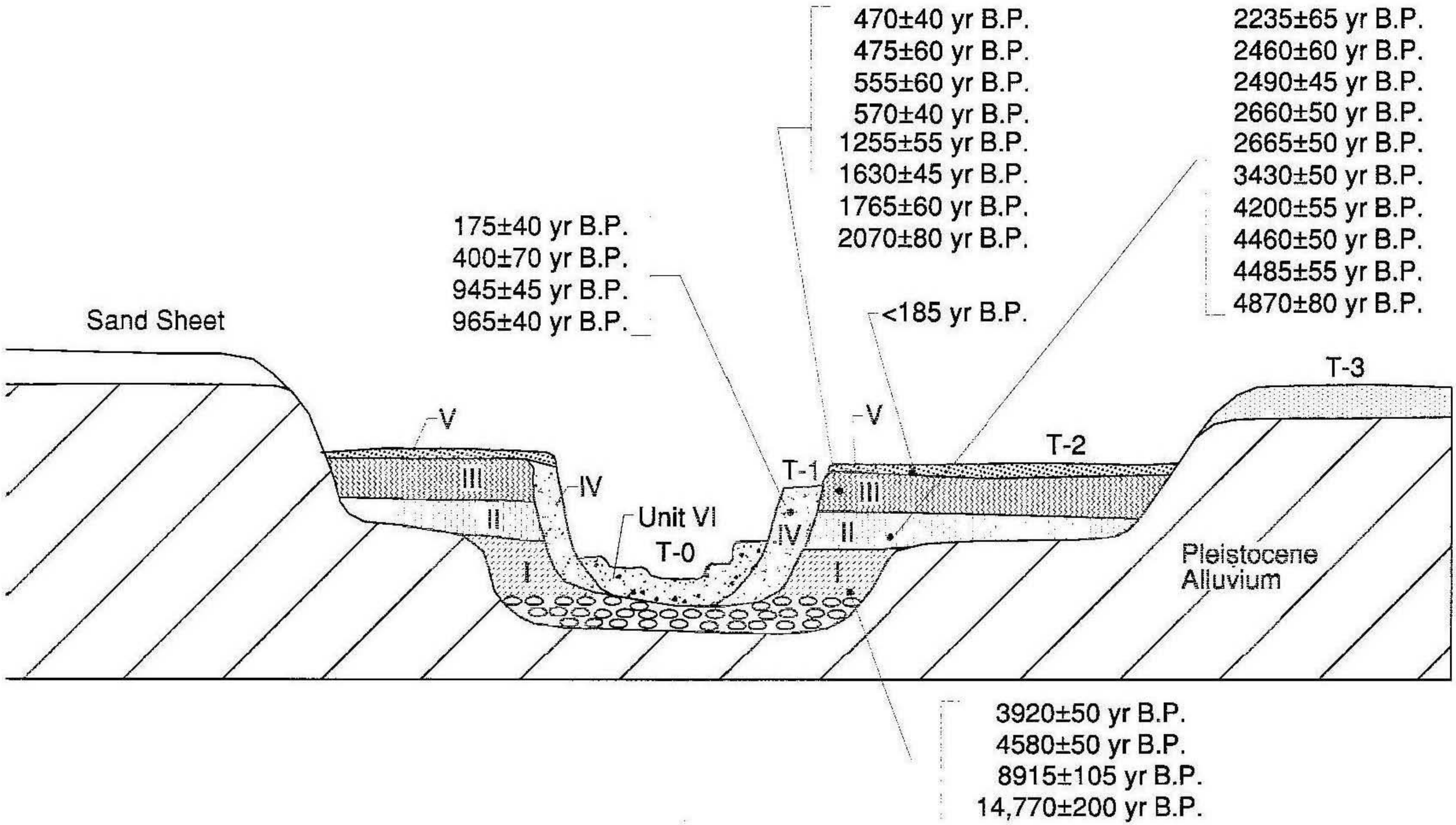


Figure 3. Generalized diagram of the late Quaternary alluvial units of the middle Gila River. Also shown are the radiocarbon dates in uncalibrated 14C years B.P. from these units.

Figure III-1

Source: Waters and Ravesloot pg 289

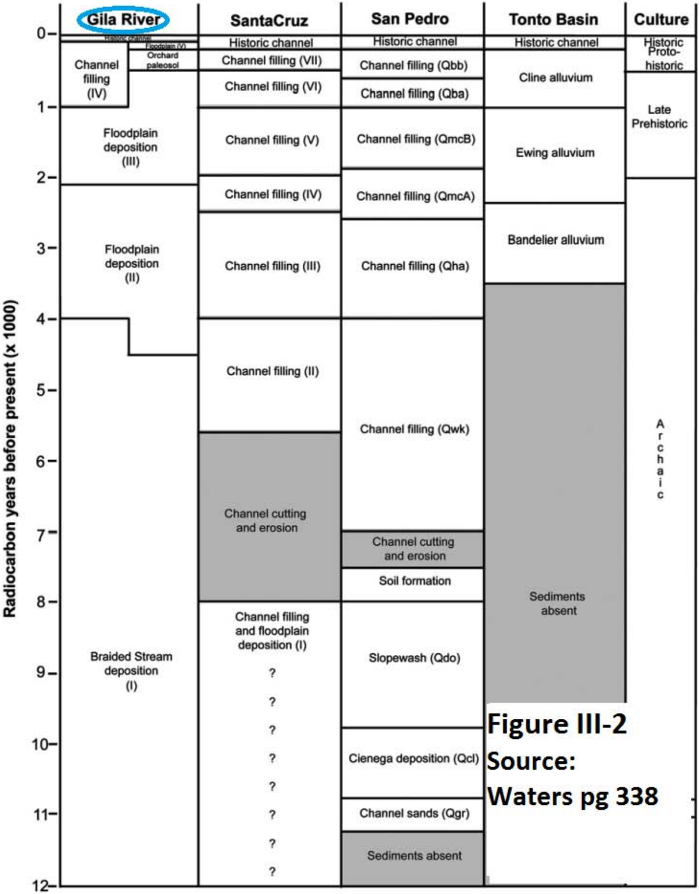
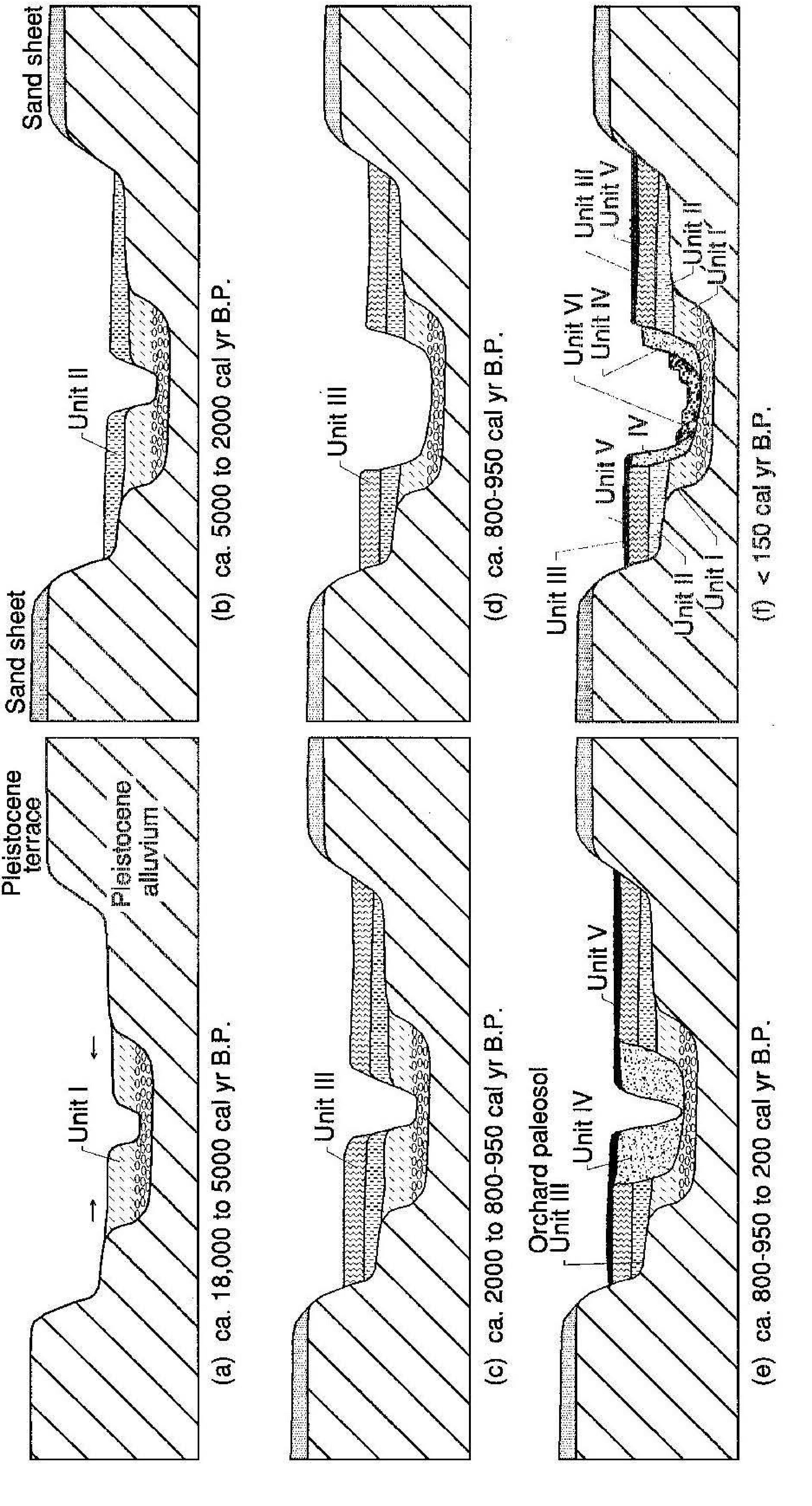


Figure III-2
Source: Waters pg 338



Series of diagrams outlining the sequential landscape history of the middle Gila River from 18,000 cal B.P. to present.

Source: Waters and Ravesloot pg 290

Figure III-3

attributed to the large floods that occurred in the late 1800s..."[22] Simply put, natural floods had caused the river to be braided at least once before and nature's floods that occurred around 1900 caused the river to be braided again. Figure III-4 shows photos of the Gila River before and after Statehood.

As can be seen, the Gila River was extremely wide. Of particular importance is Figure III-4F. There is a long line of wagons in part of the river (see arrow). This helps to visualize the magnitude of the channel width. This picture was during a high flow, five times the average at Kelvin.

D. PRE-FLOOD BRAIDING

Braiding did not occur just with the floods around 1900. We know that some braiding existed on the Gila River prior to the floods. This information comes from early government land survey maps. Attached are figures in this report that are early cadastral surveys that show the clear existence of braids. These surveys are dated before there was any significant irrigation by non-Indians, before many cattle were grazing, before the major dams were built, and before mining was extensive.

The above braiding along with other locations occurred in the Lower Gila segment. These plats are shown in Figure III-5. The Middle Gila segment also had braided reaches as shown in Figure III-6.

[22] Waters pg 336.

Figure III-4A - Photo taken near Ft. Thomas in 1885

Safford Segment Source: Burkam pg G-6.

Figure III-4B Photo taken near Geronimo looking downstream in 1910

Safford Segment Source: Burkam pg G10.

Figure III-4C Photo taken near Calva in 1932

Safford Segment Source: Culler and others Frontispiece.

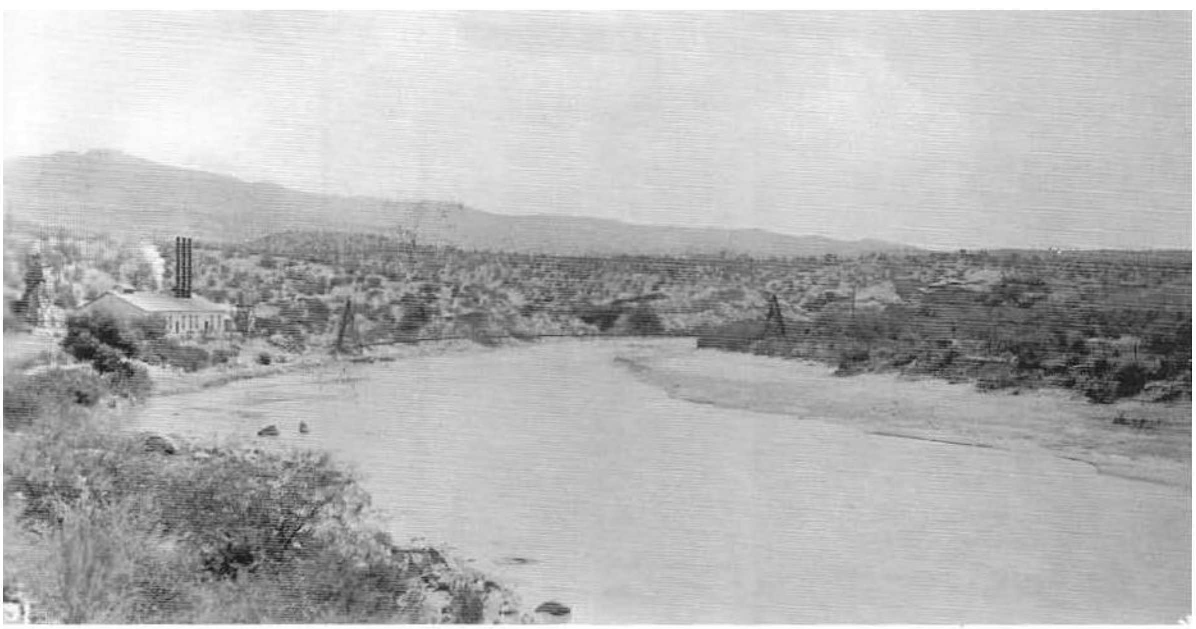


Figure III-4D Photo taken near Kelvin looking upstream on Sept. 2,1915.

Flow @ Kelvin 200 cfs

Middle Gila Segment Source: Webb et.al. pg 208

Figure III-4E   Photo taken near Kelvin in 1908

Middle Gila Segment   Source: Webb et.al. pg 209

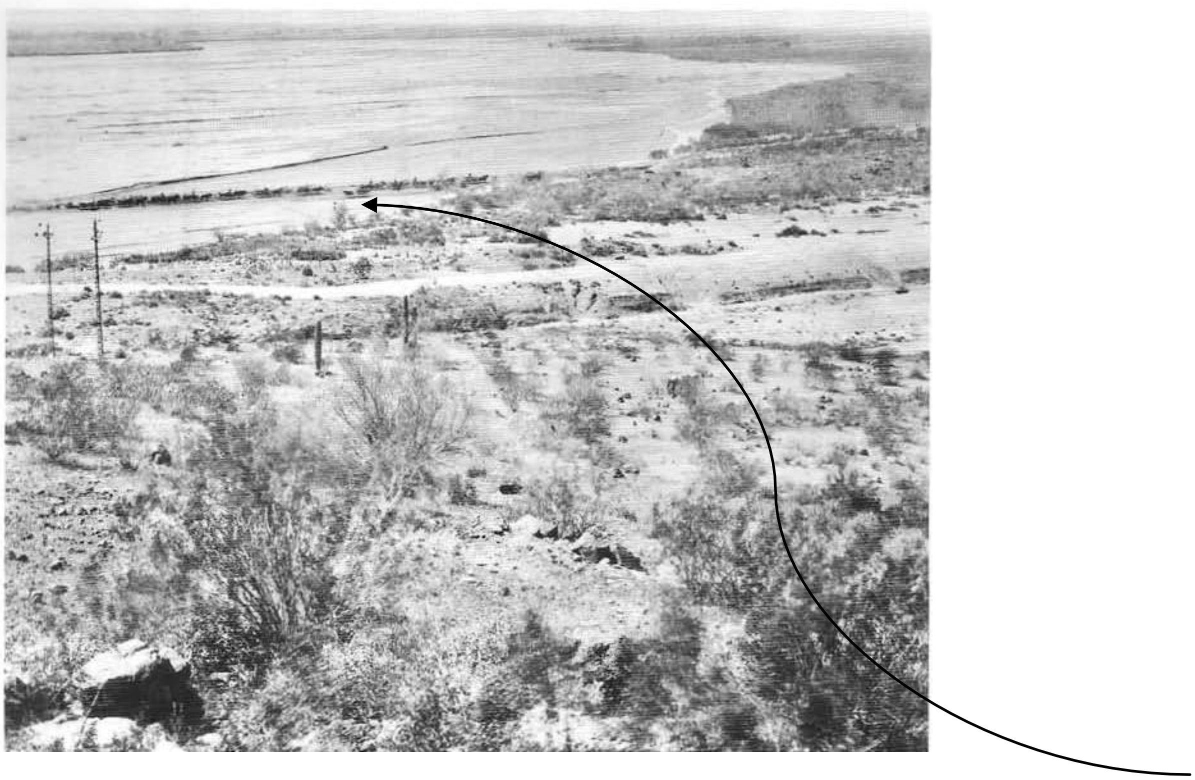


Figure III-4F   Photo taken near Sacaton on March 17,1915. Notice Line of Wagons for Scale. Flow @ Kelvin was 3180 cfs

Middle Gila Segment   Source: Rea 1983 pg 342

Township No. 1 North, Range No. 1 West, Gila and Salt River Meridian.

2624

Recd. ... in U.S. Land Office Prescott, Arizona December 2nd 1870.

OFFICIALLY FILED 12-2-1870

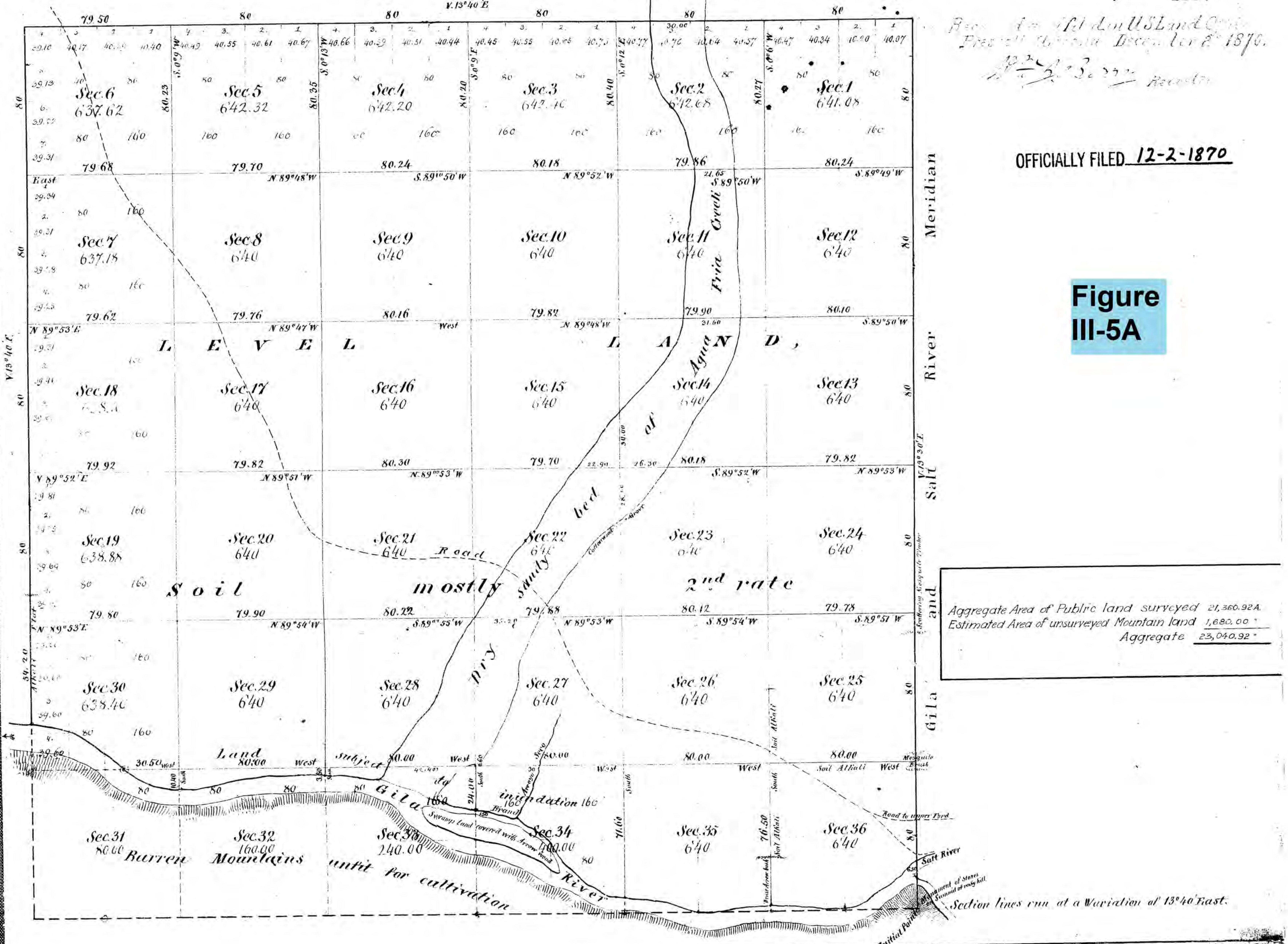


Figure III-5A

Aggregate Area of Public land surveyed 21,360.92 A.
Estimated Area of unsurveyed Mountain land 1,680.00 "
Aggregate 23,040.92 "

Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
East boundary of Township	Wm. H. Pierce	December 15th 1866		1867
Rest of Township Lines	G. P. Ingalls	February 29th 1868	10 Ms. 53 Chs. 70 Lks.	1868
Section lines	" "	" " "	54 " 56 " 65 "	June 22nd 1868

The above Map of Township No. 1 North, Range No. 1 West of Gila and Salt River Meridian, is strictly conformable to the field notes of the Surveys thereof on file in this Office, which have been examined and approved.
Surveyor General's Office,
San Francisco, California,
December 31st 1868.

Sherman Day
Surv. Gen. Calª. and Ariz.

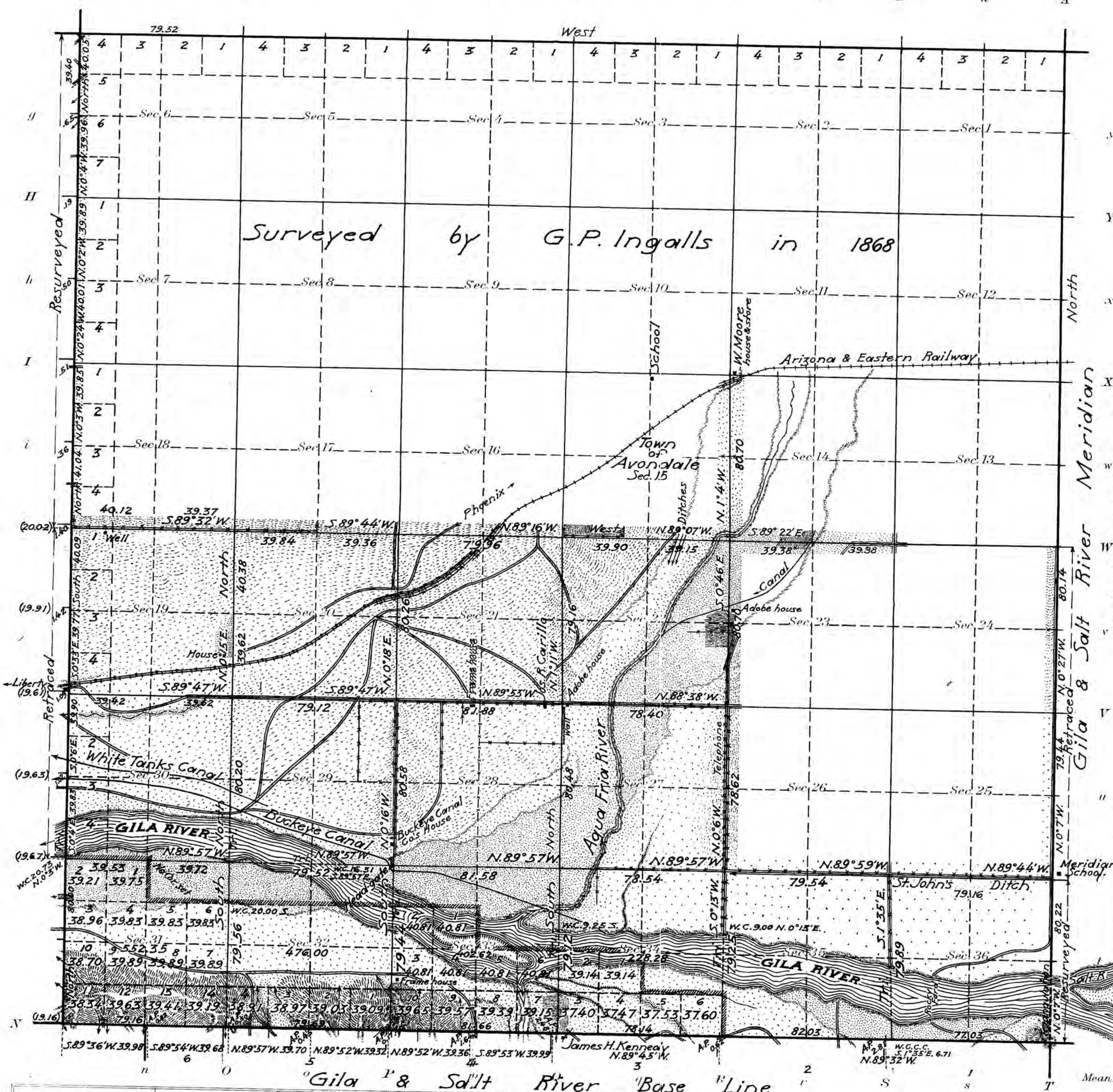
Surveys and Resurveys in
Township No. 1 North Range No. 1 West, Gila and Salt River Meridian, Arizona

Accepted August 27, 1918.

2623

OFFICIALLY FILED 11-4-1918

Figure III-5B



The resurvey of all those parts or portions of the sections previously returned as surveyed, represented on this plat, was made for the purpose of restoring, as near as may be possible, to their original positions, all lost or obliterated corners necessary to define the boundaries of the sections and ¼ sections in accordance with the original survey of the township approved Dec. 31, 1868.

The boundaries of the sections are therefore to be considered as unchanged from those fixed by the original survey, the plat of which survey therefore remains in full force and effect and still governs the disposal of the lands.

Areas in Acres	
Public Land	1659.25
Indian Reservation	
Indian Allotments	
Mineral Claims	
Water Surface	
Total Area	1659.25

Latitude 33°22'33"N.
Longitude 112°18'24"W.

Scale 40 Chains to an inch

Mean Magnetic Declination 14°15'E.

Surveys Designated	By Whom Surveyed	Group No.	Group Date	Amount of Surveys (Mls. chs. lks.)	When Surveyed: Begun	When Surveyed: Completed
G & S.R. Mer.-Ret.	Sidney E. Blout, U.S.S.	40	Dec. 16, 1914.	E. of 24 & 25	Mar. 11,	1915.
" .-Resur.	"	"	"	E. of 36	" . 19,	" .
W. Bdy. Ret.	"	"	"	W. of 19 & 30	" . 9 to 13,	" .
Subdivisions-Sur.	"	"	"	S¾ 31-32, S¾ 32-	Mar 9, 1915.	
				33, S½ 33-34.		
" -Resur.	"	"	"	14/15, W½ 14-23, bdrs.		
				19-22, 27-30, 35 &	to	
				36, N¼ 31-32, N. ¼		
				32-33, & N½ 33-34.	Apr. 9, 1915.	

The above map of surveys & resurveys in Township No. 1 North Range No. 1 West of the Gila & Salt River Meridian Arizona is strictly conformable to the field notes of the survey thereof on file in this office, which have been examined and approved.

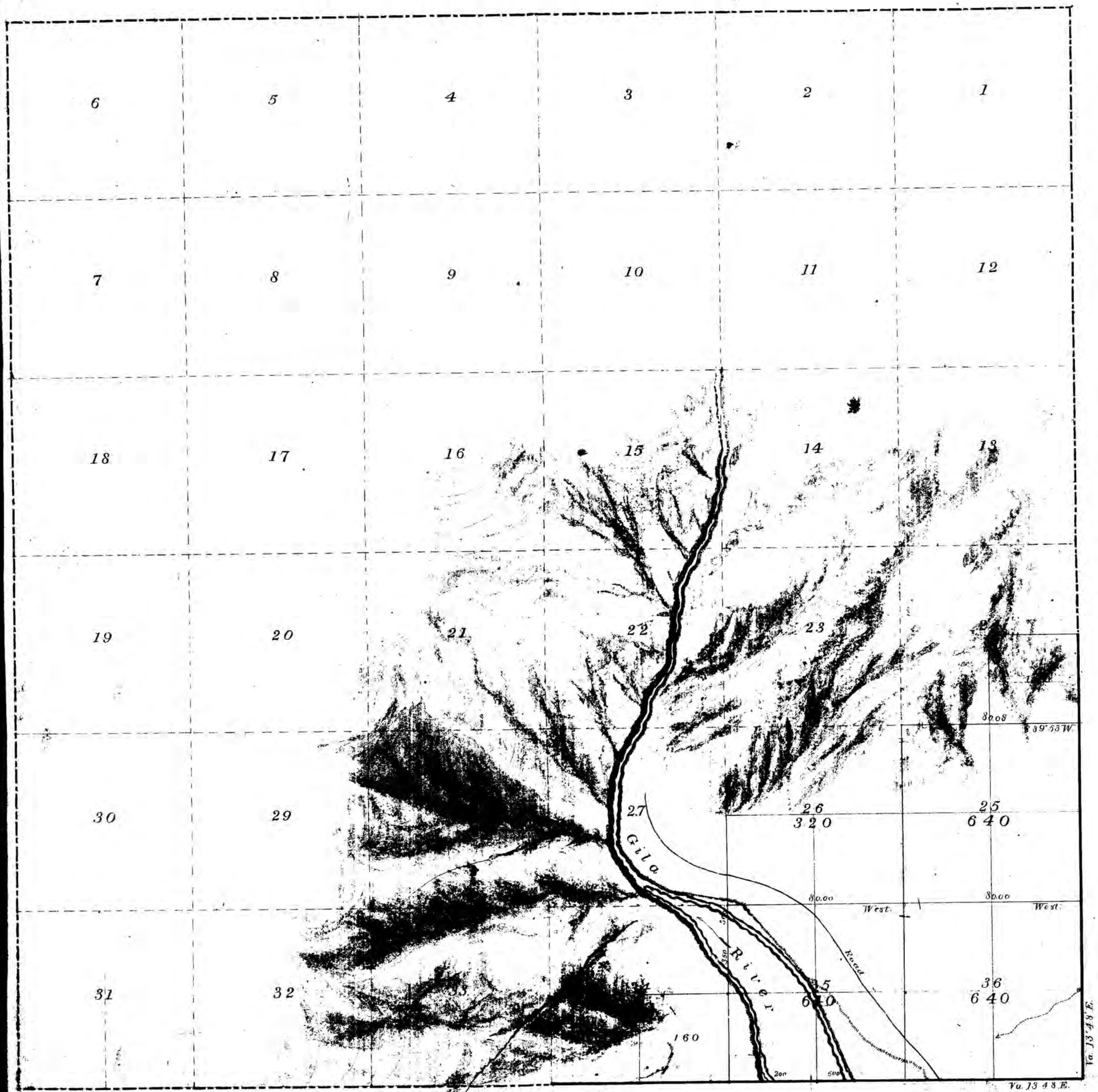
U.S. Surveyor General's Office.
Phoenix, Ariz., Sept. 19, 1917.

Frank D. Frost
Surveyor General.

TOWNSHIP No. 2 SOUTH RANGE No. 5 WEST
GILA AND SALT RIVER MERIDIAN

OFFICIALLY FILED

Fig III-5C



Subdivision lines run at a Variation of 13°48' East.

Aggregate area of Public Lands surveyed 2,560.00 acres
Estimated " " " " unsurveyed 20,440.00
Total 23,000.00

Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Survey	When Surveyed
Township lines	S. W. Foreman	March 16, 1871	5 ms. 40 chs. 01 lk	April 6, 1871
Subdivisions	do.	do.	6 " 40 " 8 "	" 27 "

The above Map of Township No. 2 South of Range No. 5 West of the Gila and Salt River Meridian is strictly conformable to the field notes of the surveys thereof on file in this Office, which have been examined and approved.

Surveyor General's Office
Tucson, Arizona May 18, 1871

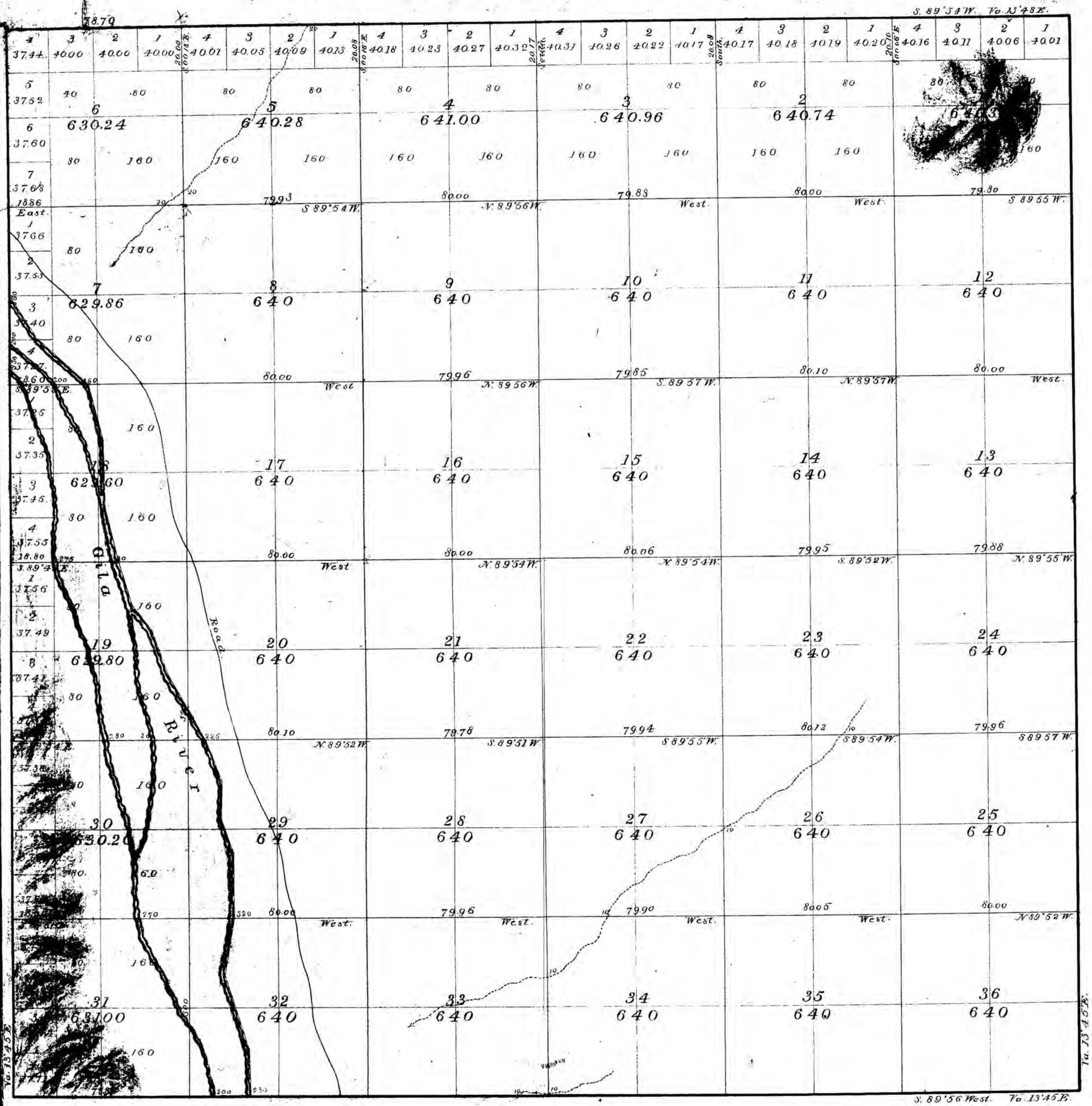
John Wasson
Sur. Gen!

TOWNSHIP No. 3 SOUTH RANGE No. 4 WEST

GILA AND SALT RIVER MERIDIAN

OFFICIALLY FILED 6-23-1871

Fig. III-5D



Aggregate area of Public Lands Surveyed 22,984.02 ac

Subdivision lines run at a Variation of 13°45'E.

Surveys Designated	By Whom Surveyed	Date of Contract	[illegible]	When Surveyed
Township lines	S. W. Foreman	March 16, 1871	23 ms. 77 [illegible]	April 4-5, 1871
Subdivisions	do.	do.	59 " 73 " 46 "	" 17-25. "

The above Map of Township No. 3 South of Range No. 4 West of the Gila and Salt River Meridian is strictly conformable to the field notes of the survey thereof on file in this Office, which have been examined and approved.

Surveyor General's Office
Tucson, Arizona, May 18, 1871.

John Wasson
Sur. Gen.

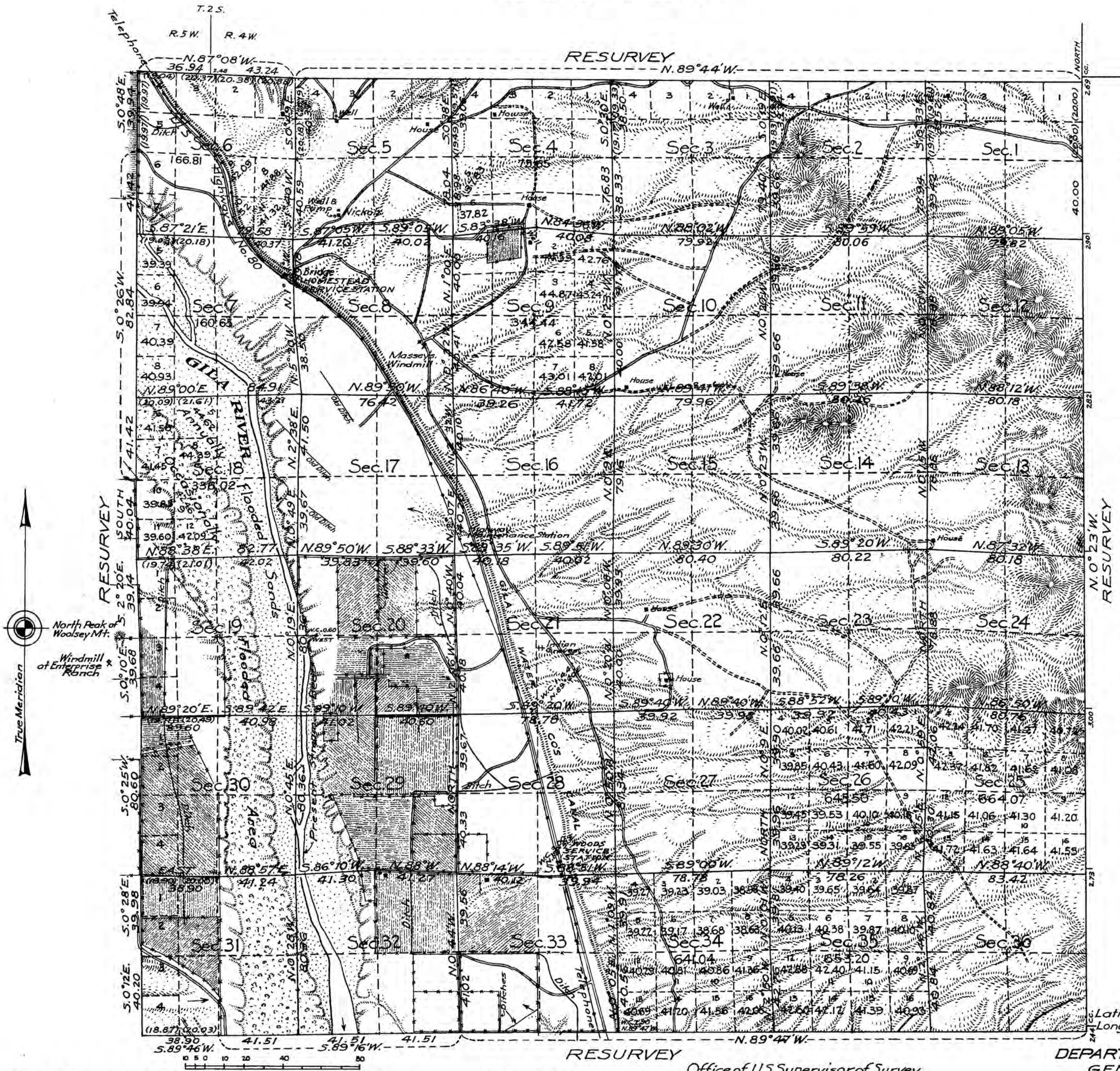
TOWNSHIP Nº 3 SOUTH, RANGE Nº 4 WEST, GILA AND SALT RIVER MERIDIAN, ARIZONA.

DEPENDENT RESURVEY

3749

OFFICIALLY FILED 9-5-1933

Fig. III-5E



This plat of the resurvey of T. 3 S., R. 4 W., G. & S. R. Base & Meridian, Arizona, delineates a retracement and reestablishment of the lines of the original survey as shown upon the plat approved May 18 1871, in their true original position according to the best available evidence of the position of the original corners; all differences between the measurements shown on the original plat and those derived in the retracement have been distributed proportionally between accepted corners in accordance with surveying rules; reference will be made to the original plat for the showing of all the areas except the vacant land in those sections where the area of one or more of the subdivisions, computed on the basis of the measurement of the resurvey is beyond the limits of excess or deficiency of the original area as defined by Chapter 8, Par. 661 of the 1930 Manual of Surveying Instructions, in which cases the section is considered as the unit and all of the vacant land therein subdivided, with amended designations and areas as shown hereon, and such amended designations and areas will hereafter govern the disposal of said vacant land.

Resurvey authorized by letter 1401517 "E" dated January 19, 1931.

Mean Magnetic Declination 14°37' E. Scale: 40 Chains to an Inch Area resurveyed 23,091.94 Acres

LINES DESIGNATED	BY WHOM SURVEYED	GROUP Nº	GROUP DATE	MILEAGE MLS.	MILEAGE CHS.	WHEN SURVEYED BEGUN	WHEN SURVEYED COMPLETED
Exterior	Karl L. Siebecker	164	July 15, 1930 &	24	8.87	Nov. 28, 1930.	Apr. 28, 1931.
Subdivisional	Benj. J. Kinsey		Feb. 16, 1931.	60	11.32	Apr. 7, 1931.	. . 29, . .

Office of U.S. Supervisor of Survey
Denver, Colorado, June 14, 1932.
The above plat of Township No. 3 South, Range No. 4 West, Gila and Salt River Meridian, Arizona, is strictly conformable to the field notes of the survey thereof which have been examined and approved.

[signature]
U.S. Supervisor of Surveys

DEPARTMENT OF THE INTERIOR
GENERAL LAND OFFICE
Washington, D.C., November 10, 1932
The survey represented by this plat having been correctly executed in accordance with the requirements of law and the regulations of this office, is hereby accepted.

[signature]
Acting Assistant Commissioner

JXB

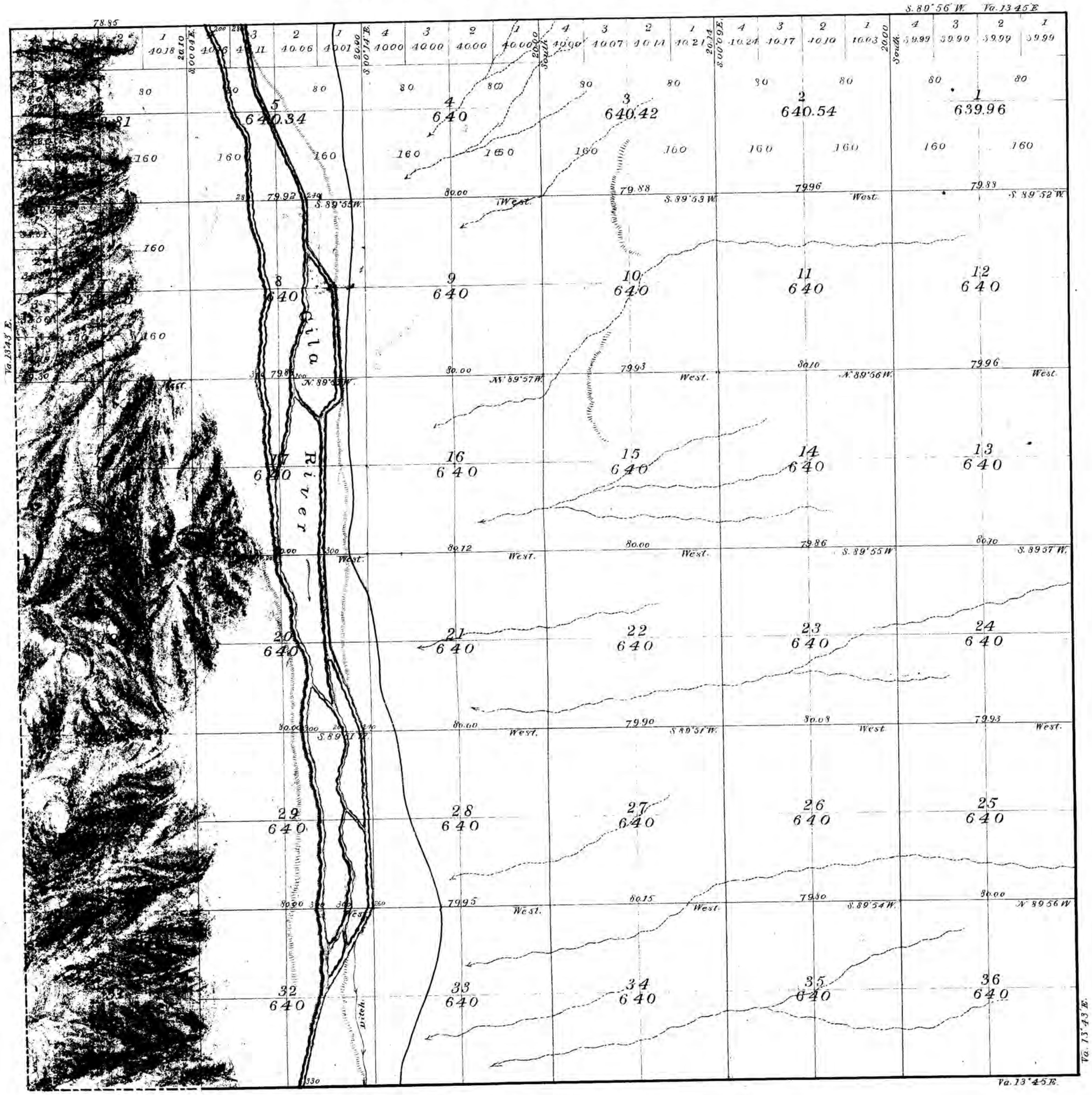
TOWNSHIP Nº 4 SOUTH RANGE Nº 4 WEST

3771

GILA AND SALT RIVER MERIDIAN

· OFFICIALLY FILED 6-23-1871

Fig III-5F



Aggregate area of Public Lands surveyed 20.628.27 Acres
Estimated " " " " unsurveyed 2380.00 "
Total 23,008.27 "

Subdivision lines run at a Variation of 13° 43' East.

Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	Date of Surveys
Township lines	S. W. Foreman	March 16, 1871	18 m. 78 chs 85 lks	April 1-3, 1871
Subdivisions.	do.	do.	56 " 78 " 17 "	" 7-15, "

The above Map of Township No 4 South of Range No 4 West of the Gila and Salt River Meridian is strictly conformable to the field notes of the survey thereof on file in this Office, which have been examined and approved

Surveyor General's Office
Tucson, Arizona May 18, 1871

John Wasson
Surv. Genl.

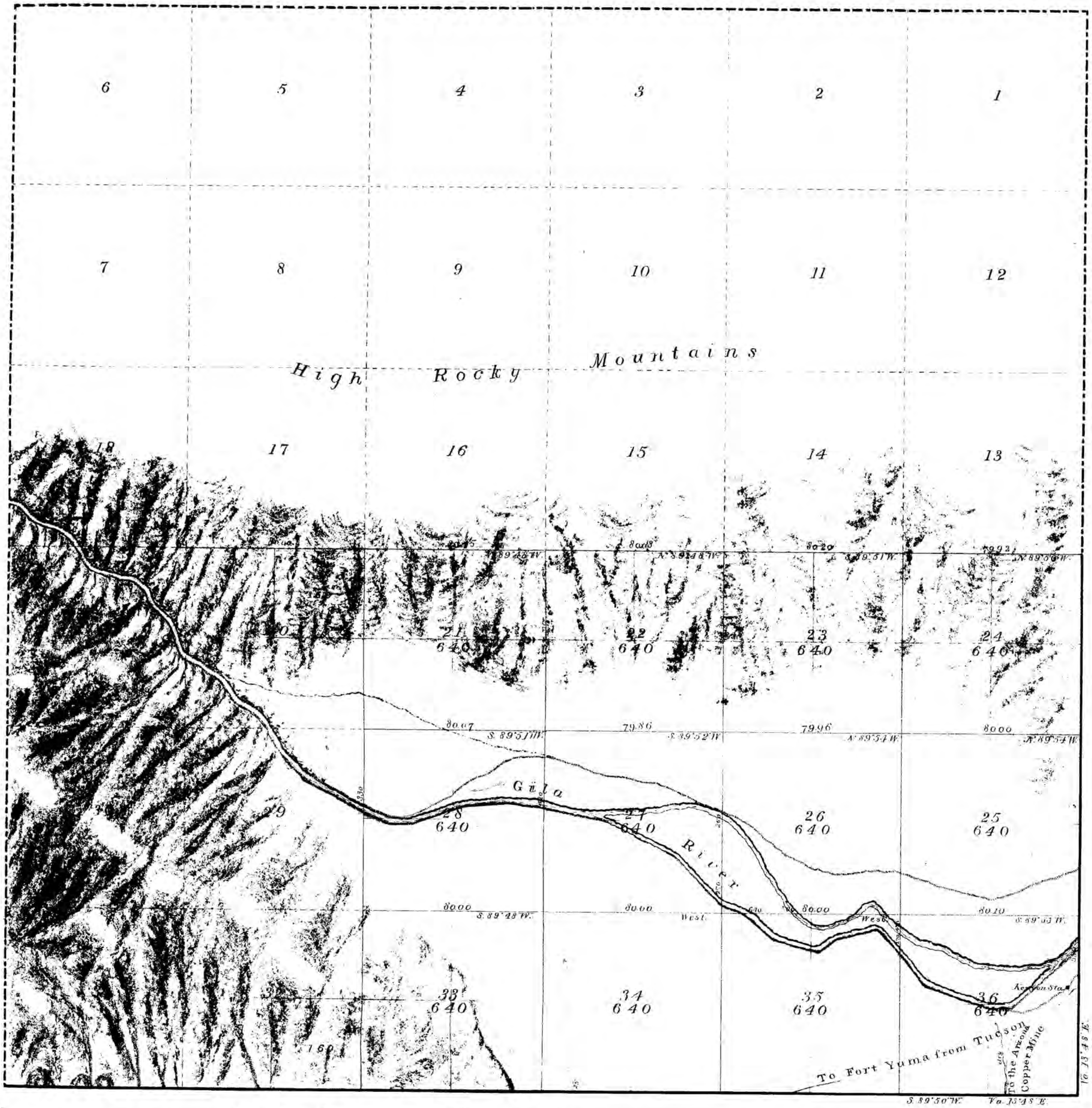
7

TOWNSHIP No. 4 SOUTH RANGE No. 7 WEST

GILA AND SALT RIVER MERIDIAN

OFFICIALLY FILED 6-23-1871

Fig III-5G



Subdivision lines run at a Variation of 13°48' East.

Aggregate area of Public Lands surveyed 8,000.00 Acres
Estimated " " " " unsurveyed 15,000.00 "
Total 23,000.00 "

Surveys Designated	By Whom Surveyed	Date of Contract	Amount of Surveys	When Surveyed
Township lines	S. W. Foreman	Feb. 13, 1871	8 miles 78 chs. 96 lk	March 2-3 1871
Subdivisions	do.	do.	25 " 0 " 64 "	" 18-30 "

The above Map of Township No. 4 South of Range No. 7 West of the Gila and Salt River Meridian is strictly conformable to the field notes of the survey thereof on file in this Office, which have been examined and approved

Surveyor Generals Office
Tucson, Arizona, May 1, 1871

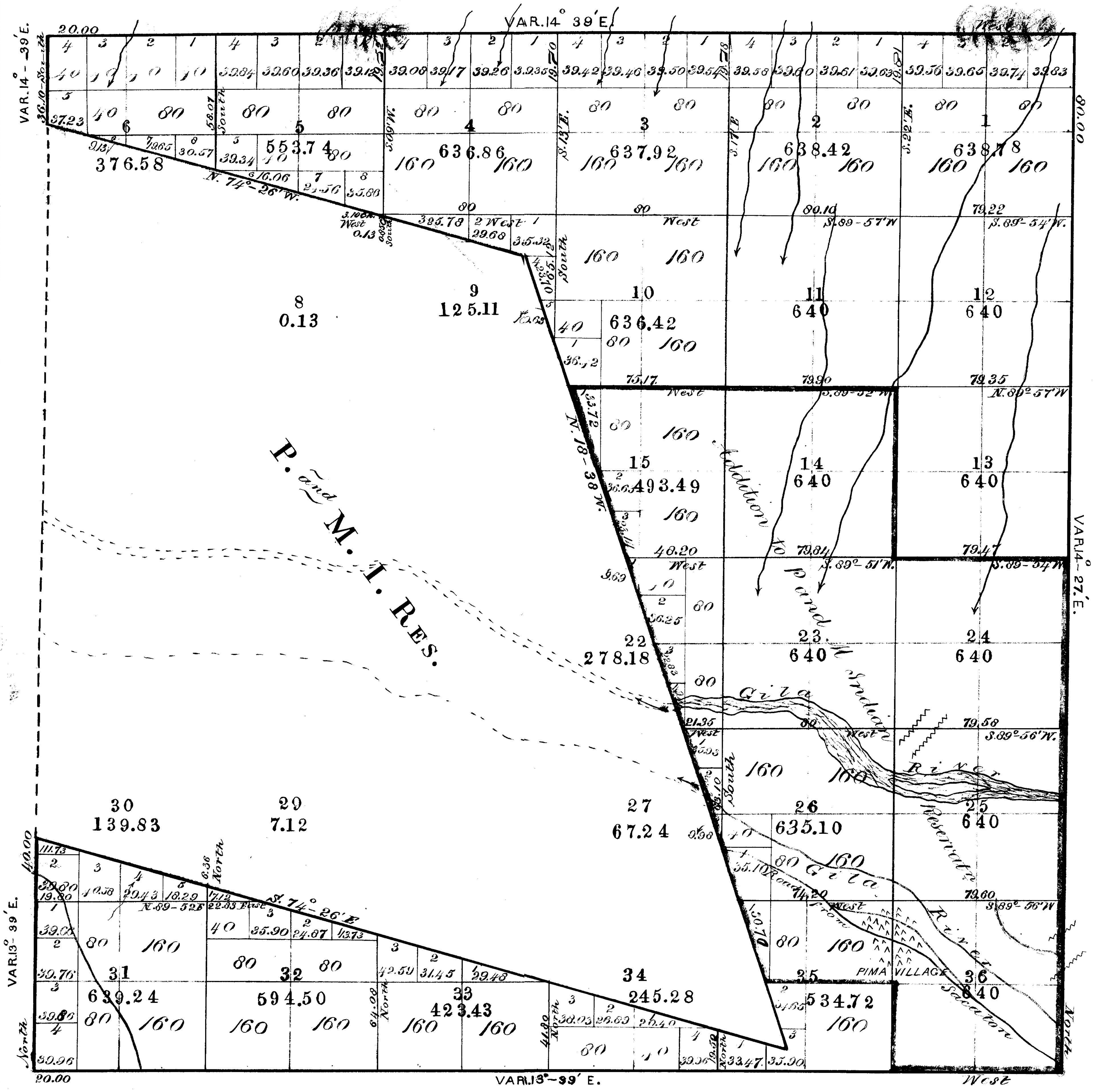
John Wasson
Sur. Genl.

TOWNSHIP No. 4 SOUTH RANGE No. 7 EAST GILA AND SALT RIVER MERIDIAN.

1543

OFFICIALLY FILED 9-16-1876

Fig. III-6A



Addition to Pima and Maricopa Indian Resevn delineated in red as established by Executive order of date August 31st 1876.

Subdivision lines run at a variation of 14° 27' East.

Surveys Designated.	By Whom Surveyed.	Date of Contract.	Amount of Surveys. Ms. Chs. Lks.	When Surveyed
Township Lines	Theo. F. White	Decr 6th 1875	12 - 36 - 10	Jany. 22d Feb. 1st 1876
Subdivisions.	Theo. F. White	Decr 6th 1875	31 - 79 - 42	Feby. 2 - 5th 1876
	Total number of Acres			13422.09

The above Map of Township No. 4 South of Range No. 7 East Gila and Salt River Meridian, Arizona, is strictly conformable to the field notes of the survey thereof on file in this office, which have been examined and approved.

Surveyor General's Office, Tucson, Arizona, Sept. 15. 1876.

J. Wasson

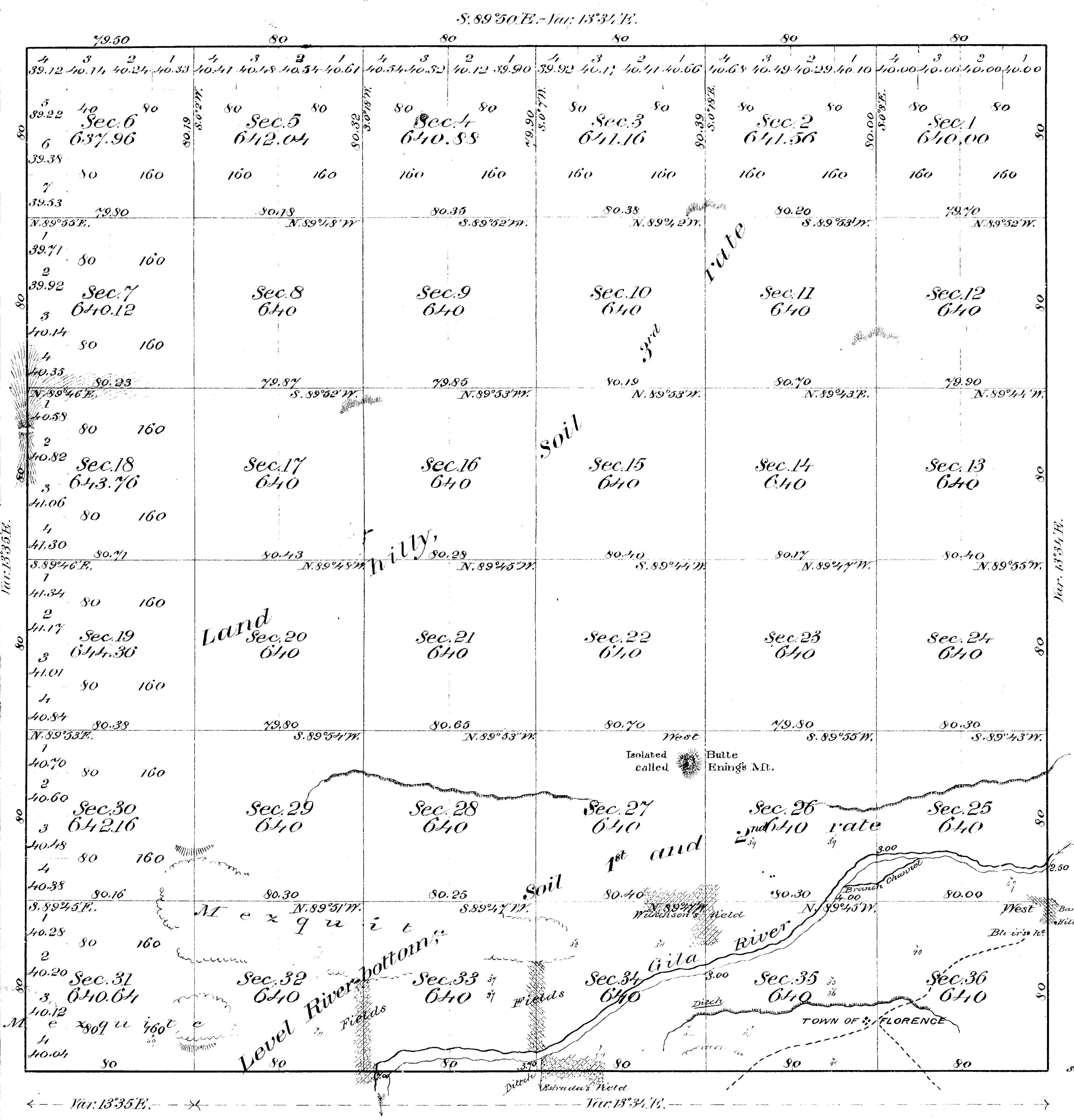
Sur. Gen.

Township No. 4 South, Range No. 9 East, Gila and Salt River Meridian.

1551

OFFICIALLY FILED 12-2-1870

Fig III-6B



Aggregate Area of Public land 23,054.64 Acres

Section lines run with a Variation of 13°34'E.

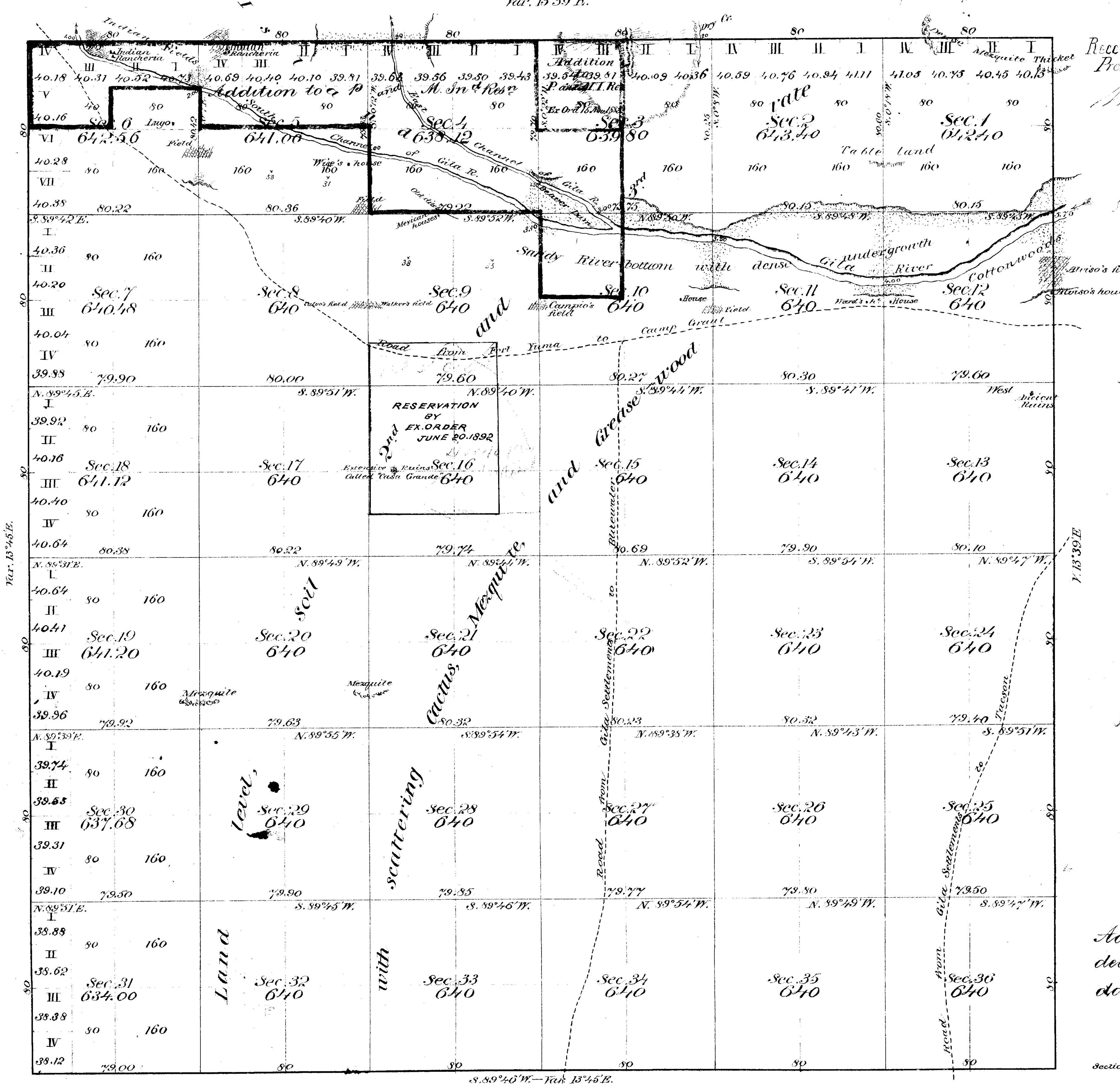
Surveys Designated	By whom surveyed	Date of Contract	Amount of surveys	When surveyed
Township lines	Ralph W. Norris	Feb. 25th 1869	23 mls. 79 chs. 50 lks.	1869
Section "	"	"	60 " 07 " 58 "	May 22nd 1869

The above Map of Township No. 4 South, Range No. 9 East, Gila and Salt River Meridian, is strictly conformable to the field notes of the survey thereof on file in this Office which have been examined and approved.

U. S. Surveyor General's Office
San Francisco, California
October 5th 1869

Sherman Day
U. S. Survr. Genl. Cala. and Arizona

Township Nº 5 South, Range Nº 8 East, Gila and Salt River Meridian. 1638



Received at Local U.S. Land Office Prescott Arizona December 2nd 1870

OFFICIALLY FILED 12-2-1870

Fig III-6C

Aggregate Area of Public Land 23041.76 Acres.

Addition to Pima and Maricopa Indian Reservation delineated in red as established by Executive Order of date August 31st 1876.

Sur. Gen.

Section lines run with a Variation of 13°45'E.

The above Map of Township Nº 5 South, Range Nº 8 East, Gila and Salt River Meridian, is strictly conformable to the field notes of the survey thereof on file in this Office, which have been examined and approved.

U.S. Surveyor General's Office
San Francisco, California
October 5th 1869

Sherman Day
U.S. Surv. Gen. Cal. and Ariz.

Surveys designated	By whom surveyed	Date of Contract	Amount of surveys	When surveyed
Township lines	Ralph W. Norris	Special Insts. October 1st 1869	23 mls. 79 chs. 00 lks.	1869
Section "	"	" " "	59 " 79 " 49 "	August 7th 1869

As mentioned at the beginning of this chapter, the assumption that a well defined single channel is the preferred natural state is incorrect. In reality, as geomorphic studies and field trenching have established in the Middle Gila, there was very mild period from about 1450 to the early 1800s that permitted the establishment of a single channel that normally overflowed on to floodplains to replenish its soils[23] in a manner similar, albeit smaller, to the Nile River's historic annual replenishing floods. As Figure III-2 shows, if one state is to be interpreted as being the "natural" condition, then based on durations, the majority vote of the years is for a braided stream deposition.

If the decision of what is the "natural" condition is based on the most typical condition, then the Army Corps of Engineers states:

> Often considered the most common channel type in dry regions (Tooth 2000), compound channels are characterized by a single, low-flow meandering channel insert into a wider braided channel network.[24]

If the decision is based on what was the "natural" condition as of 1912, then what actually existed on the Gila River in 1912, above the Hassayampa River, was the "natural" condition.

---

[23] Waters and Ravesloot pg 293.

[24] Lichvar and McColley pg 8.

IV. NAVIGABLE IN FACT

The primary facts normally used by the Courts to determine navigability is whether or not the river has actually been navigated for commercial purposes historically. If the river has been successfully navigated under the correct legal conditions, then it is navigable in fact and it is legally navigable. If the river has not been successfully navigated, generally speaking, the river is not navigable. The Utah Decision expanded on an exception to that rule--that is if it can be demonstrated that there was no need to navigate the river then the lack of historic navigation does not prove or disprove navigability. This rule simplifies to: was there a reason to conduct trade and would that trade have been facilitated by a water route.

There seems to be little disagreement that there is no history of commercial navigation on the Gila River. As Hjalmarson stated in his 2001 confidential notes:

> My limited research on the history of navigability of the Gila River suggests it was not used on a regular basis for any kind of water transportation of bulk commodities such as furs or covered wagons or people. There are a few historic accounts that suggest the river was used for navigation such as for the transport furs [sic]-there was trapping along the river. The navigability is mentioned in the *Treaty of Guadalupe Hidalgo* and this is presented later in these notes. **Clearly, no**

accounts that the river was developed for navigation were found [emphasis added].[1]

A. THE HOKOKAM

Virtually anybody who has lived in Arizona for an extended period has heard of the Hohokam. In fact, the Hohokam culture is why the City of Phoenix is named after the mythical Phoenix bird. Our current culture is a reborn culture where a previous civilization used to be. The Hohokam culture extended over a large area of southern and central Arizona and was a long-lived hydraulic (based on irrigation) civilization. ANSAC has written a detailed analysis of the evidence concerning the Hohokam.[2] Most importantly, ANSAC found that no evidence was presented that the Hohokam traveled by water.[3]

There are two additional points to consider. First, did the Hohokam engage in trade with surrounding civilizations that could have followed rivers? For example, according to the Arizona Museum of Natural History, the Hohokam traded for glycymeris, clam shells from the Gulf of Baja.[4] If the Gila River had been navigable, you would have expected the Hohokam would have traveled down the Gila River to the Colorado River, then followed the Colorado, which we know to have been navigable, to the Gulf

[1] Hjalmarson 2001 pg <1.
[2] ANSAC 2006 pg 23-29.
[3] ANSAC 2006 pg 27.
[4] Gregonis and Reinhard pg 8.

of California region. The Hohokam, for example, had a route that did just that (Figure IV-1). It followed the Gila but they walked.[5]

A second piece of evidence regarding navigability of the Gila comes from the University of Arizona in discussing the pottery of the Hohokam:

> A common Hohokam design painted on pottery depicts a walking figure with a hiking staff, carrying a bundle on his back. This figure is often referred to as the "burden basket carrier" and may be a trader. Since earliest times, the Hohokam were active traders. They received goods from western New Mexico, most of Arizona, and the coasts of California and Mexico, as well as from the more advanced cultures of west-central Mexico.[6]

The concept that the traders were recorded on the pottery but boats were not is an additional indication of the Hohokam reliance on trade by walking.

The Hohokam irrigation development was substantial, which leads to the question; did the Hohokam ruin the river in their time so as to preclude navigation? It is almost certain that there would have been times during the period of the Hohokam development that the irrigation would have negated the ability of traders to use the water for navigation down the Lower Gila. However, the Hohokam period lasted between 1,000 to 1,700 years. The Hohokam canal system did not occur overnight. It was not like we build irrigation projects today where we get a loan from the federal government and ten years later the project is fully built. These Hohokam canals were

[5] Pry and Andersen pg 7.
[6] Gregonis and Reinhard no page.

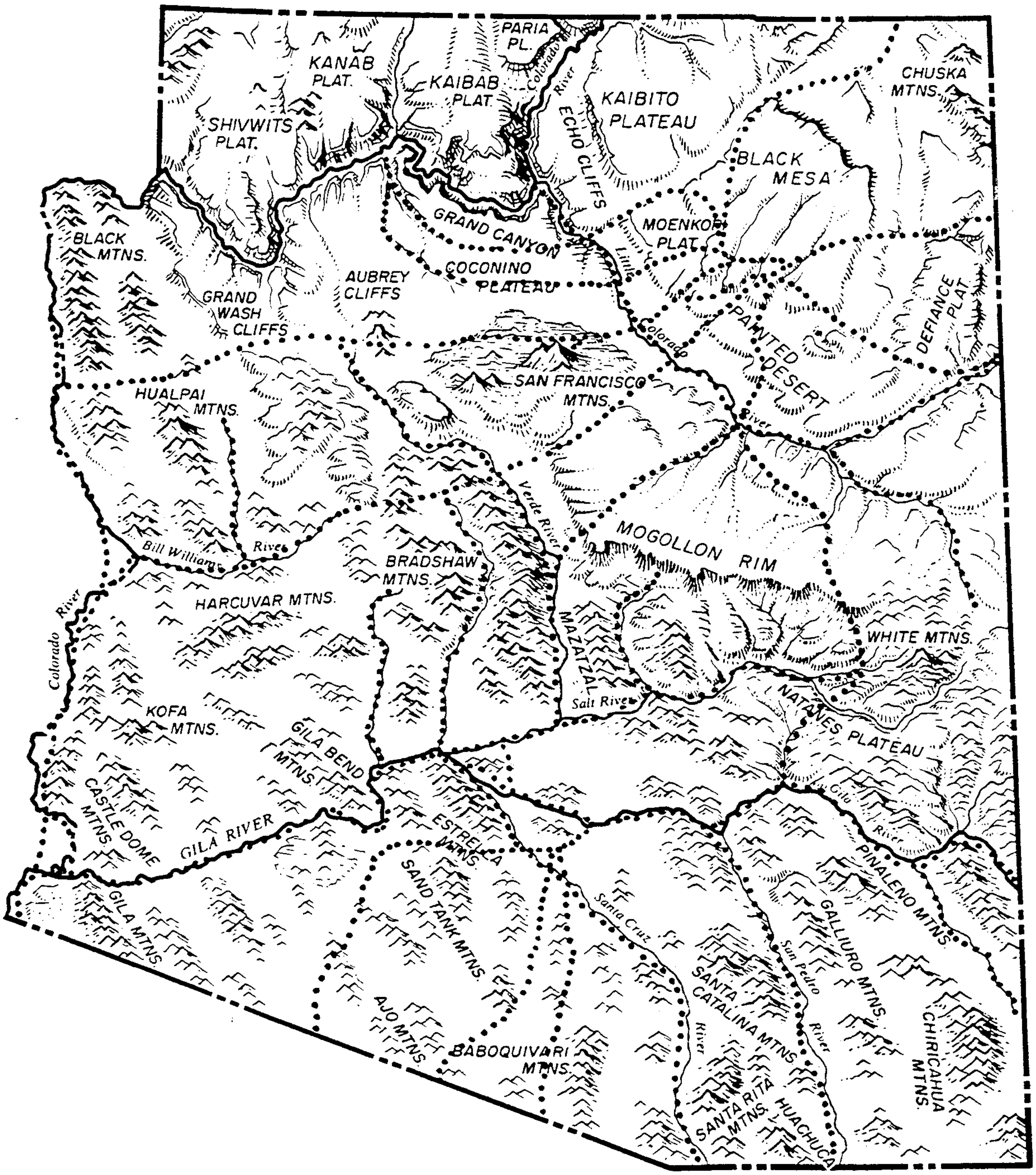


Figure 1. Prehistoric and Early Historic Trails in Arizona.

From Pat H. Stein, *Historic Trails in Arizona from Coronado to 1940* (Phoenix: Arizona State Historic Preservation Office, 1994), 4.

Source: Pry and Andersen

Figure IV-1

dug by hand and started from scratch. There would have been lengthy periods where the rivers would have been virtually unaffected by diversions due to the small amount those diversions would have been. If the Hohokam could have navigated they would have, but they did not, the Hohokam chose to walk.

B. PIMA-MARICOPA CONFEDERATION

No one is certain when the Pimas entered the middle Gila Valley. The Pimas believe they were descendants of the original Hohokam who survived whatever disaster collapsed the Hohokam civilization in the mid 1400s. Certainly much of the Pima culture mirrored the Hohokam culture. We know however that by 1699, the Pimas were established in the region.[7]

In 1900, Frank Russell, a member of the Harvard Faculty of Arts and Sciences, went to the Gila River Indian Reservation and lived with the Pimas and Maricopas for one year. After this, Russell wrote a limited description of their history and of major importance for this issue, an extensive discussion of their technology. Russell based his analysis upon interviews conducted with numerous elders of the Reservation. In addition, the Pimas had “talking sticks”. These were long poles with carvings that recorded historic events and served as an aid to refresh the memories of the readers of the talking stick.

[7] ANSAC 2006 pg 31.

In his book, Russell devotes almost 100 pages to the types of technology that the Pima-Maricopas had developed. He described their food supply, their agricultural equipment, their weapons, their cooking supplies, how they made various items from rope to tobacco pouches, pottery, basketry, and even how they would decorate themselves. There is also a specific section on trade. Russell discusses the various measurements used in trade and who traded with whom.

Only one mention of a raft occurs in the Russell book and the book does not mention any boats or canoes. To confirm that no mention is made of water craft, in addition to reviewing the index and table of contents, skimming the entire section on technology and carefully reading the section on trade, I downloaded an electronic copy of the book from Google Books, OCRd the text, and ran a search for the words “boat”, “canoe”, and “raft”, and only one occurrence appeared.

The raft that was mentioned (in the Russell book) was recorded on the Pima talking sticks. In 1873 to 1874,

> The Pimas went on a campaign against the Salt River Apaches soon after a heavy rain. When they reached the Salt river it was too high to be safely forded, so they built a raft and tried to take their saddles and blankets across on it. The raft sank and they lost all their effects.[8]

[8] Russell pg 55.

There were several features that are apparent in this discussion. First, it was not on the Gila River. Second, it was a military operation not commerce. Third, the Salt River was apparently at, or near a flood stage, and hence, not in the ordinary condition. Fourth, the Pimas were only using the raft as a ferry, not for navigation up and down the stream. Finally, the crossing failed.[9]

The Pimas could have benefitted from water travel for trading purposes because they traded upstream and downstream from the middle Gila and the Salt River before the water supply failed due to upstream diversions. Trade did not occur all the time with every party nearby. The Pimas, like all cultures, varied in their lifestyle, habits, and trade patterns throughout their history. When early Jesuit Missionary, Father Eusebio Kino, visited the Pimas in 1699, he said that "All its inhabitants are fisherman, and have many nets and other tackles which they fish all the year, sustaining themselves with the abundant fish and with their maize, beans, and calabashes".[10] No irrigation facilities were mentioned in any of Father Kino's travels in the late 1690s. Father Kino does mention a canal that had been built upstream from what is now the Casa Grande National

[9]The word rafters did appear numerous times in the text but it was always in reference to how the ceilings and roofs were constructed.
[10]Rea pg 17.

Monument.[11] Dobyns explains that the probable initial means of irrigation for the Pimas was to plant crops near ponds and marshes. "The Gila River Pimas had only to sow seed in the sub-irrigated fields, pull or hoe weeds, and harvest the crops on these naturally irrigated fields."[12] In this case, the Pimas were replacing marsh land consumptive use with crop consumptive use which would have had very little impact on the water supply. Yet, at that time, the Pimas were engaged in trade upstream and downstream.[13] But there is no evidence of any boats used in trade.

Pimas did not trade with the Yumans or the Mojaves for quite a period of time until the middle of the 19th century, due to an ongoing war between the Pima-Maricopa Confederation and the Lower Colorado Tribes. But after the war ended, trade did resume and again and there is no mention of any kind of water craft being used by the Pimas.

Russell does address the issue of how the Pimas transported heavy loads. "In the Golden Age of Pimeria all burdens were born by the women, either on their heads with the aid of the head ring or upon their backs with the unique contrivance which they call kiaha... ."[14] The use of the kiaha is demonstrated in Figure IV-2 of this report. The Pima women's loads that

[11] Dobyns pg 3-5.
[12] Dobyns pg 3-1.
[13] Dobyns pg 2-10 – 2-14.
[14] Russell pg 140.

a LOADING THE KIÂHÂ

b RISING WITH THE LOAD

c THE LOAD IN POSITION

d REMOVING THE LOAD

Source: Russell plate 34

WOMAN WITH KIÂHÂ

Fig IV-2

they carried were around 100 pounds and to aid them in getting on their feet, the women used what was called a “helping stick”.[15]

This leads to the question as to whether the river was in its natural state during the periods of Pima occupation before significant American development in the region. In the beginning, the Pimas appeared to only practice farming of flooded areas. Later the Pimas irrigated and dried up the river at the Little Gila (now part of the Casa Blanca Canal) by diverting all the low flow. However, at the end of the Little Gila, which was a canal, the Pimas returned the unused water back to the mainstem of the Gila. Thus, the depletion of the river would have been the net consumptive use of the crops grown.

Prior to World War II, consumptive use for irrigated crops was significantly lower than it was after World War II. In the 1950s and 1960s, there was an agricultural phenomenon called the “green revolution.” As a result of genetic selection, mechanized equipment which allowed crops to be grown more densely, fertilizers, insecticides and other reasons, the yield of crops increased considerably. As the yield increased, so did the water use. Back in prehistoric times, the consumptive use for crops was also low. Reducing this impact even further is the fact that in the 1800s, the current Gila River Indian Reservation had dense thick thickets of mesquite

[15] Russell pg 141.

bosques. The Pimas, due to custom, would rotate their farm fields with mesquite. This increased the fertility of the soil due to the nitrogen-fixing abilities of the mesquite plant.

The mesquite is a fairly unusual desert plant. Mesquite can grow in the desert and be a xerophyte (plant that grows in arid climates, i.e. desert dweller) or mesquite can be a phreatophyte (also called riparian vegetation or plant that grows with its roots in saturated soil). The mesquite trees that grew on the Gila River Indian Reservation were primarily phreatophytic mesquite. In the xerophyte configuration, mesquite shows up as small bushes that are widely distributed with extensive root structures reaching out to capture whatever moisture is available. When mesquite is near a water supply, they can put a root down 50 feet (and more) to get to the groundwater table and suck the water up. In the phreatophytic configuration, mesquite turns into a fairly large tree.

The phreatophytic mesquite was very important to the Pimas, providing about half their food. Mesquite wood was used for many purposes. Mesquite provided grazing for cattle. Mesquite provided tools, medicines, cosmetics, etc.

If the mesquite is provided access to water, it consumes more water than most of the crops would have consumed that were being farmed. The consumptive use for a mesquite bosque is 2.86 acre-feet per acre.[16] The crops grown would have used between a maximum of 3.40 acre-feet per acre for irrigation pasture and 1.26 acre-feet per acre for winter grains[17]. The Pimas primarily grew corn, wheat, barley, and vegetables, all of which are low consumptive use crops[18] requiring less water than the mesquite trees.[19] Therefore, the net impact on river flows by the Pimas would have been minimal. Yet, the Pimas did not trade by water.

C. ANGLO-AMERICAN IMPACT

This section deals with the activities of pre-development conditions along the Gila River during the early 1800s.

The Arizona Appellate Decision indicates that the river must be considered in its "ordinary and natural" condition. As chapter II indicates, by 1912 the river flow had been artificially depleted. Chapter III shows that by 1912, the Gila River channel had naturally changed to its condition of extensive braiding above the Gila/Hassayampa Confluence. The Salt River and the Lower Gila River above the Hassayampa River were only impacted by Roosevelt Dam from 1910 to 1912. This three-year period was a quiet one that would not have affected these river reaches.

---

[16]U. S. Bureau of Reclamation pg App B 79 based on mesquite at 75% density.
[17]U. S. Bureau of Reclamation pg App B 49 based on Pinal County crops.
[18]Corn consumptive use is 2.19 ac-ft/acre; grains are between 1.26 to 1.83 ac-ft/acre; vegetables are 1.89 ac-ft/acre.
[19]Russell pg 90-91.

1. Failure of Navigation

The flow of the rivers was reduced. When did the period that did not have a significant impact on river flows end? It is hard to put a specific year on what was a continuous process. While the process of irrigation development was continuous, we do have significant breaks in attempts to navigate the Gila River in any fashion. The first significant break in attempts to navigate the Gila River occurred between 1850 and 1881. The 1881 effort to navigate consisted of the boaters pushing the boat down the River.[20] One other effort to navigate recorded the party planning to leave, but no mention that the party actually left or that the party completed the trip.[21] After 1881, another long gap exists in attempts to navigate the Gila until 1895. By that point, only headwaters retained most of their low flows.

2. Early Activities Removed Barriers

There were earlier impacts along the Gila River due to non-farming related activities. The major activity was beaver trapping. If beaver trapping had not occurred, then it would have been much harder to navigate the river. The first recorded trappers, the Pattie party, came in 1825 and numerous other parties occurred after that.

[20] Fuller 2003 pg IV-7.
[21] Fuller 2003 pg IV-7.

It is unlikely that the beaver population was as dense along the Gila as it was on the San Pedro. The San Pedro River, was given the name the Beaver River, by Pattie. This indicates to me that the concentration of beaver along the San Pedro River was exceptional. Given the length of the Gila River versus the length of the San Pedro River, there would have probably been even more beaver dams on the Gila River than there were on the San Pedro River but the density of the beaver dams was probably less.

Beaver dams would provide a significant obstacle to commerce up and down the Gila River. While traversing each individual dam would not constitute a major barrier, hundreds or even thousands of them cumulatively would make commercial trade impracticable. The U.S. Supreme Court made the point that "Even if portage were to take travelers only one day, … it demonstrates the need to bypass the river segment, all because that part of the river is non-navigable."[22] My logic of considering hundreds of small trips as making the river non-navigable is well explained by the Special Master in the Utah Decision, in which he was evaluating the problem of sand bars. The Special Master states:

> The test must be, in my opinion, the extent to which those difficulties prevent persons from using the River by boats to attain the end or purpose which they seek, or, in other words,

[22] 132 S. Ct. 1215 pg 18.

> how far the bars prove an impediment to the practicable use of the Rivers in the commerce for which they are used or capable of being used.[23]

I believe that 100s of portages would "… prove an impediment to the practicable use of the River."

Other than the one event of the Pattie party using a canoe due to flood conditions, there is no evidence that the beaver trappers used water transport until they got to the Colorado River where river transport does get mentioned. This is significant because it shows the chronicler did consider building water transport worth recording but did not record water transport on the Gila.

Beginning in 1846, military operations commenced in the region due to the Mexican War. The routes that the three military expeditions took are of significant importance (see Figure IV-3). Specifically, the military ignored the water route from the area between the confluence of the Santa Cruz Wash and the Gila River, past the Gila River's junction with Salt River down to approximately Painted Rock Dam (which did not exist at that time but is given for locational reference only). Instead of the water route, the military chose to march directly from the Gila-Salt confluence across the desert to the approximate location of Painted Rock Dam that exists today.

[23] Warren pg 91-92.

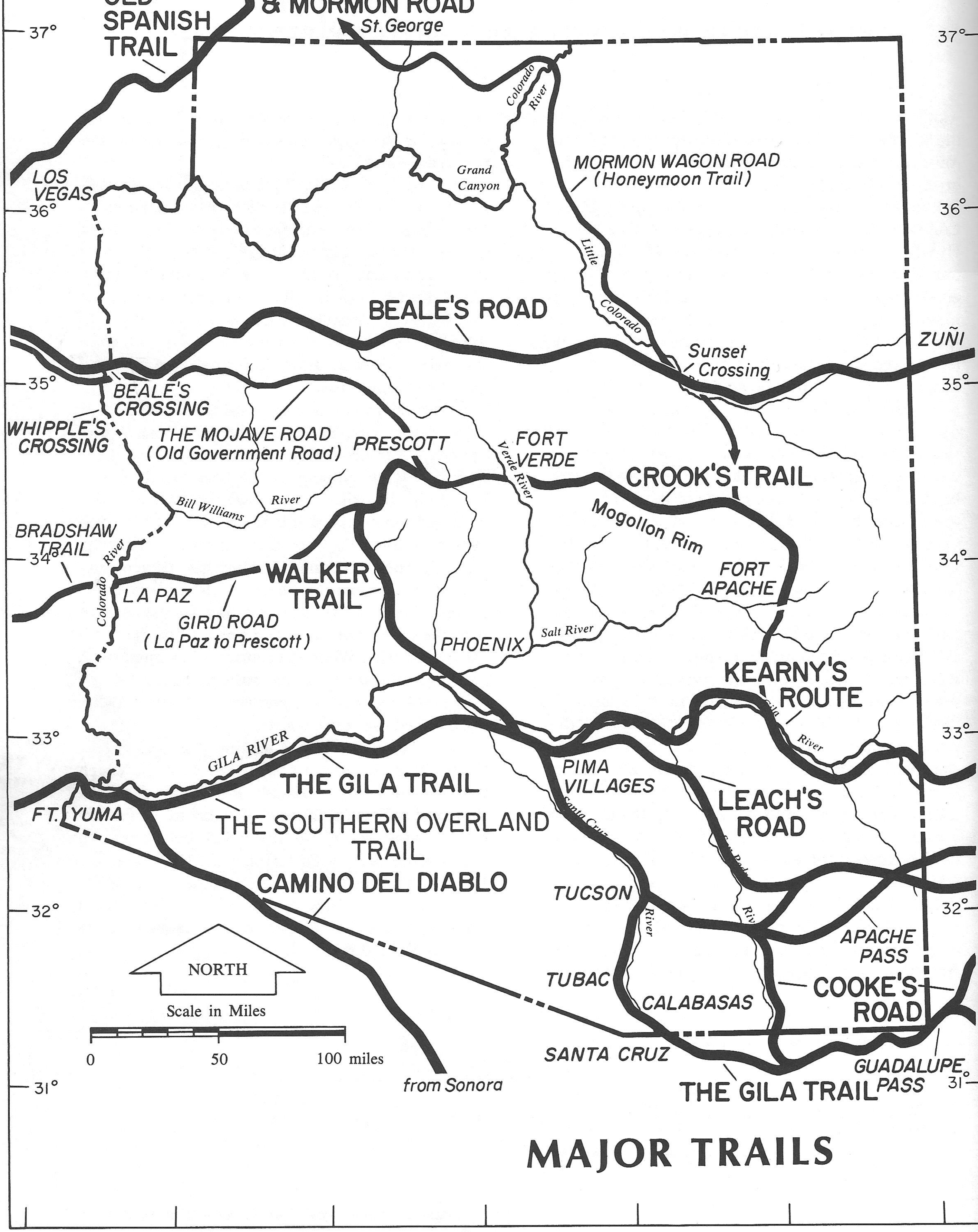


Figure IV-3

Source: Walker and Bufkin Map 40

If people heading west could have used water-bound vehicles, it was far easier and safer to transport by river craft through the Gila Bend area. It was further to travel on the river, but the cut across required marching up and over the Estrella Mountains and the Sand Tank Mountains with no water supply available. There was one instance mentioned by Captain Cook of trying to use a raft constructed from two wagon beds. This raft was unsuccessful.[24] The officer assigned to the effort reported to his Commander that boating on the Gila was not to be recommended to Washington.[25] Further, "[i]t demonstrated that it was not practical for navigation." [26]

In 1849, the gold rush began. Subsequent explorers also used the Gila Bend cut off (see Figure IV-3)-and did not attempt to boat down the Gila River. There is the one unsigned letter saying that 49ers built boats to "lighten the load" and made it down the Gila. Thus, we have an unknown source saying that unknown people built unknown boats at unknown times of the year for personal, i.e. non-commercial, purposes. This goal of "lightening the load" is very reminiscent of the U. S. Supreme Court's Montana Decision when it said "Mere use by initial explorers or trappers,

[24] Fuller 2003 pg IV-2.
[25] Corle pg 154.
[26] Corle pg 154.

who may have dragged their boats in or alongside the river despite its nonnavigability … is not itself enough."[27]

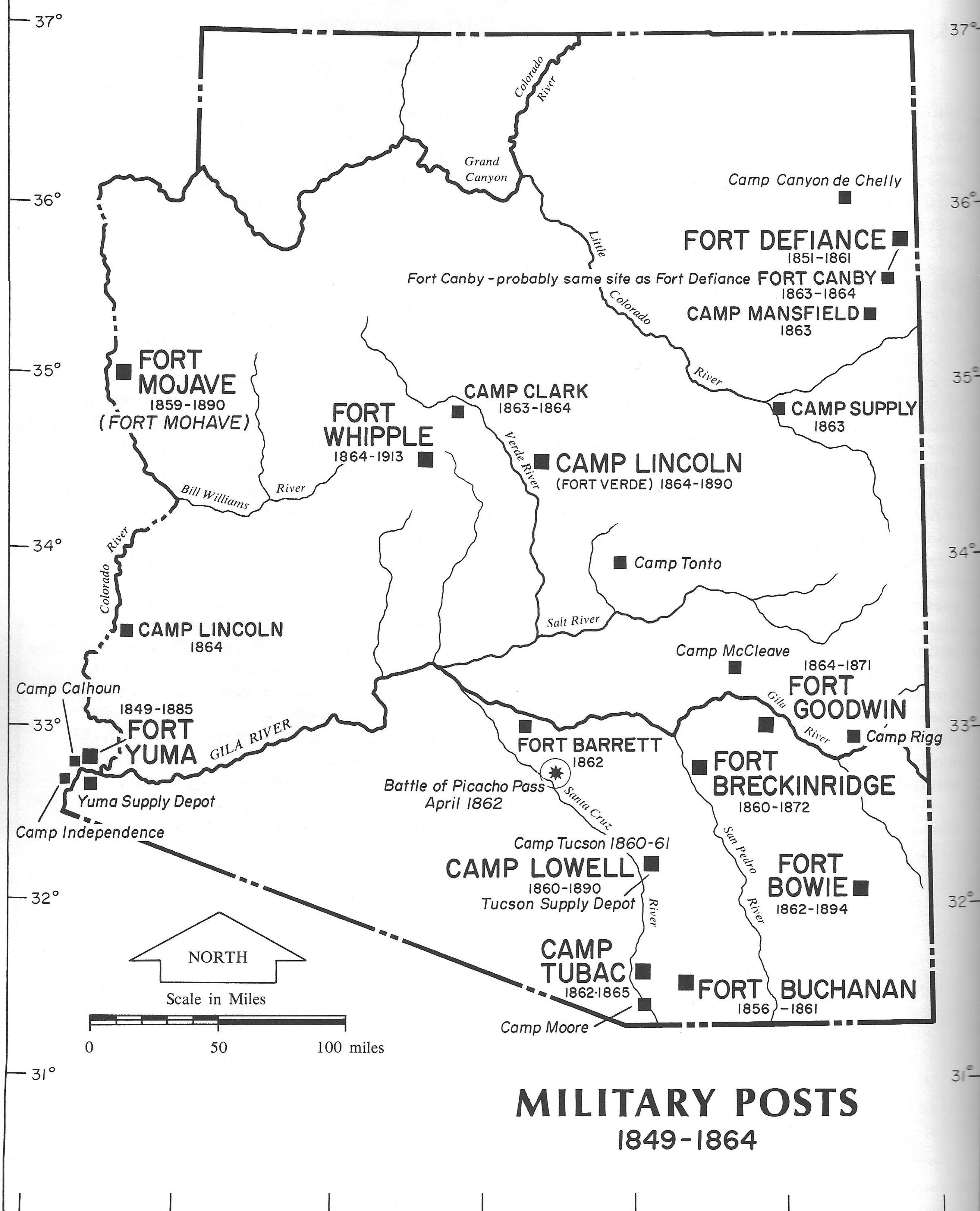
There were good reasons for using the rivers if they had been navigable. As shown on Figure IV-4, there were numerous locations where forts were located that required supplies. Although references are easily found to ships that came down the Pacific Coast, around the Baja of California, and up the Colorado River to supply military posts on the Colorado River, there are no records indicating that the forts in the Gila Watershed were supplied by river deliveries.[28] Shipping was available to the Colorado River since 1882.[29]Figure IV-5 shows the numerous ports on the Colorado River and the absence of ports on the rest of the rivers in Arizona. Despite the ease of heading east along a navigable river, the Army found that:

> ... [t]ravel inland from the [Colorado] river still required a difficult and time-consuming journey by horse or stagecoach, one made worse by the poor condition of the few existing roads.[30]

One other factor that proves the need for transportation along the Gila River is how the territory expanded once the railroads arrived.

> The arrival of the railroad truly opened southern Arizona. Intensive farming and ranching, and substantial new city and town

[27]132 S.Ct. 1215 pg 21-22.
[28]Walker and Bufkin Map 39.
[29]Pry and Andersen pg 14.
[30]Pry and Andersen pg 14.



Source: Walker and Bufkin Map 26

Figure IV-4A

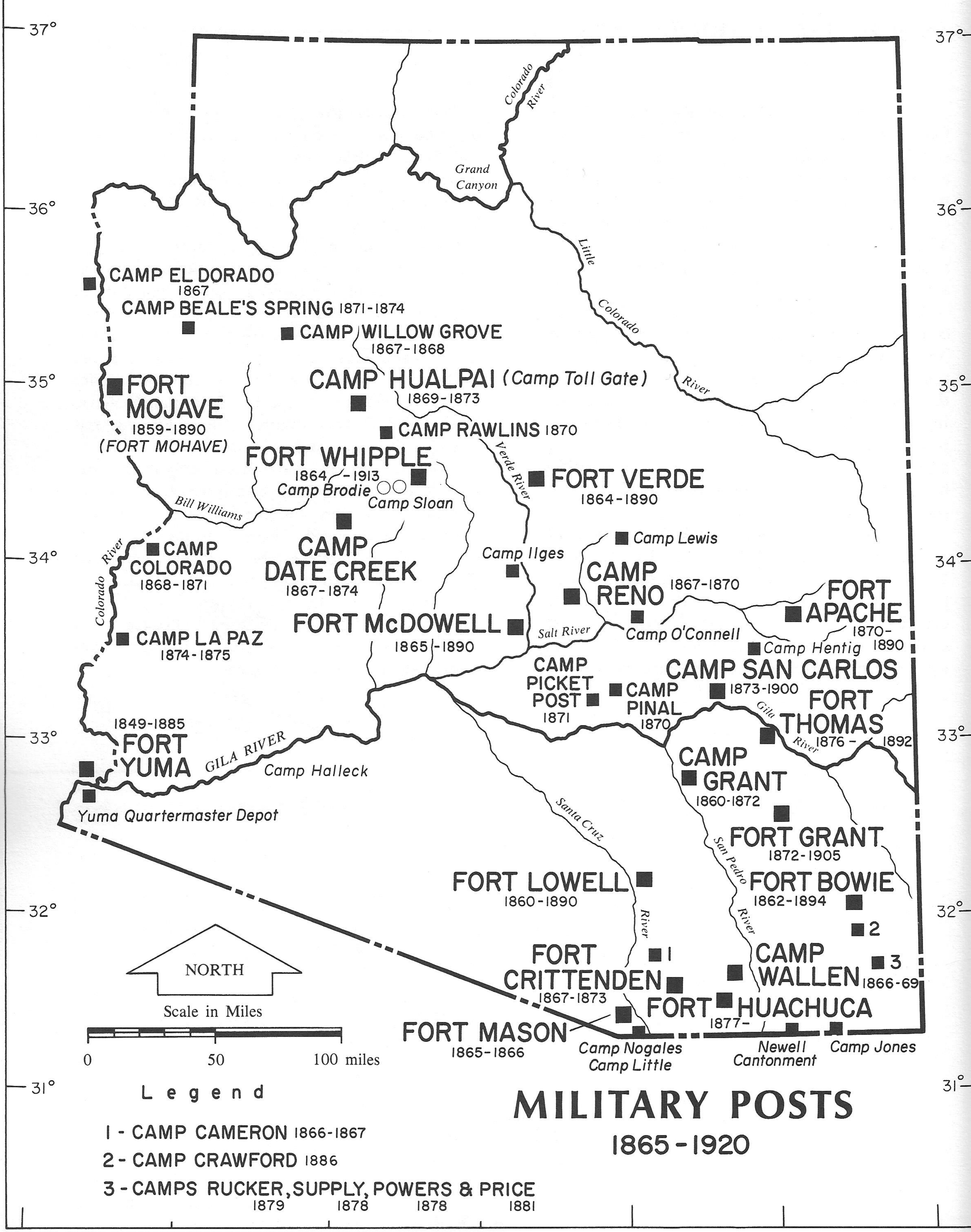
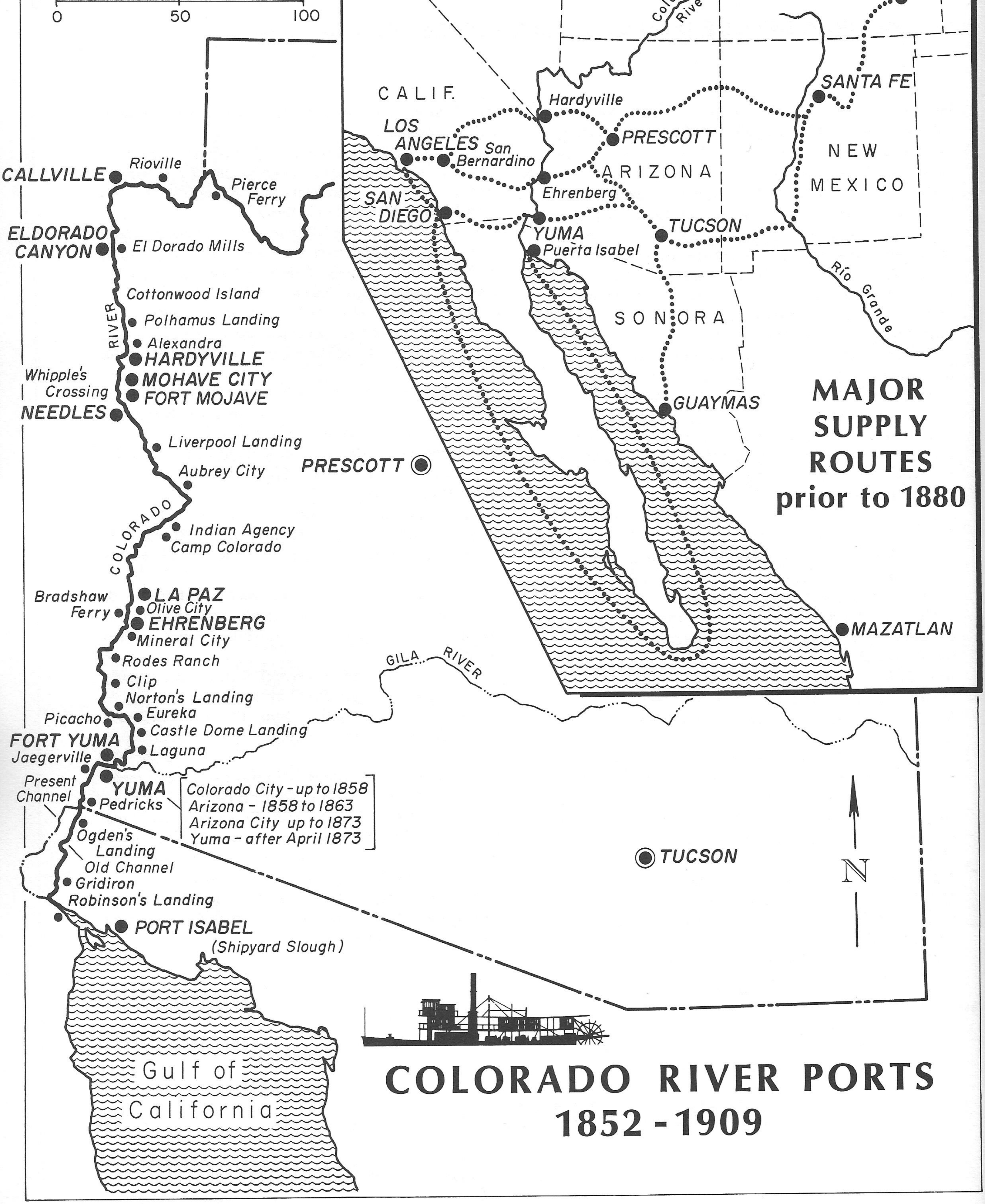


Figure IV-4B

Source: Walker and Bufkin Map 37



Source: Walker and Bufkin Map 39

Figure IV-5

> development date to the completion of the railroad. It provided a way to ship out agricultural and mining products, and to bring in imported foodstuffs and finished products which formerly had been subject to hideously expensive and always uncertain overland freighting.[31]

One of the interesting aspects was that the railroad did not connect with Phoenix (Figure IV-6). Since the railroad paralleled much of the Gila River, it would have been an easy thing to get off the train at some point on the Gila River, hop on a commercial boat and go to Phoenix IF the Gila and Salt Rivers were navigable. Instead, the railroad passengers got off at the closest stop (to Phoenix), which was Maricopa, and rode a stagecoach for 35 miles north to Phoenix.[32]

The railroad, by providing what the Gila River never did, sustainable commercial transport "laid the groundwork for the development of Arizona's modern economy."[33]

Irrespective of the legal aspect, if the beaver dams had been present, the failed efforts to navigate earlier would have been even less successful if they had tried it to navigate the river with hundreds of dams in their way.

[31] Berry and Marmaduke pg 235-236.
[32] Pry and Andersen pg 20.
[33] Pry and Andersen pg 20.

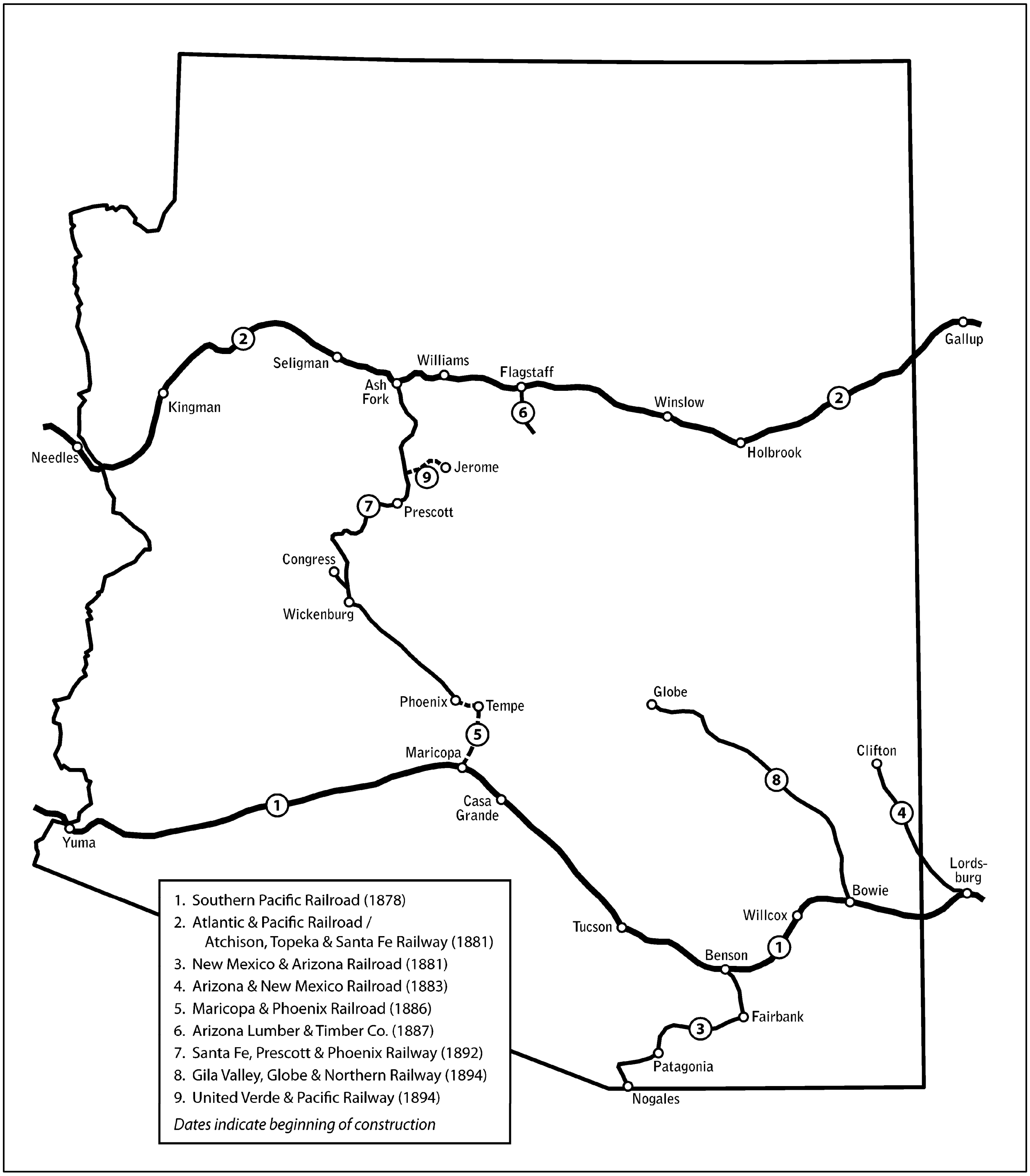


Figure 3. Early Arizona Railroads, 1894.

With the exception of the two transcontinental railroads, the Southern Pacific and the Santa Fe, most of the early railroads in Arizona were built to serve the Territory's mining regions. Based on data from Donald B. Robertson, *Encyclopedia of Western Railroad History; The Desert States: Arizona, Nevada, New Mexico, Utah* (Caldwell, Idaho: Caxton Printers, 1986).

Figure IV-6

Source: Pry and Anderson

V. SUSCEPTIBILITY OF NAVIGATION

As discussed in chapter IV, the Gila River was not navigated despite an historic need to do so. This appears to meet the test required by the Utah Decision for the river to be declared non-navigable. This chapter answers the question of why the Middle Gila River was not navigated. This chapter examines three specific elements of that navigation question.

Part A examines the question of what does it take for a river to be navigable. What criteria must the river meet?

Part B determines the depths of flow for the Middle Gila River. Depth is a major issue in river navigation.

Part C shows the measured depths of flow for various flows at early gage sites on the Gila River

Part C outlines additional obstacles to navigation. These obstacles could restrict navigation even if the overall depth is sufficient.

A. CRITERIA

The question arises as to what is required for a commercial boat to travel on a river.

1. Utah Decision

The Utah Decision is the primary decision that expanded and developed the concept of susceptibility of navigation. Reviewing how the

Utah Special Master came to his conclusions as to what was navigable is very instructive. What the Utah Special Master did was review a great number of historic navigations that actually occurred on the four rivers that he considered. Based on those boats that had been used, both before and somewhat after Utah Statehood (1896), the Utah Special Master concluded it took a “mean depth” of 3 feet for commercial activity as of 1896.

For those reaches where navigation did not occur, the Utah Special Master first determined that there was a reason other than river characteristics that caused the lack of navigation; specifically there was no reason to navigate the reach. There were no population centers or mines or other activities that could have benefitted from trade. It was pretty much wilderness. The Utah Special Master then applied the three foot depth to those river reaches and said if the three foot criteria were met, it may be navigable. The Utah Special Master also went on to consider whether or not there were rapids or other obstructions[1] that created “an impediment to the practicable use of the Rivers … “. [2]

The Utah Special Master used the river as it was in order to determine if it was navigable. The Utah Special Master did not use data from periods long after Utah's statehood. The period of consideration for

[1]Based on considerable evidence, the Utah Special Master concluded sand bars did not qualify as an obstacle.
[2]Warren pg 91-92.

navigation and the various boats that went over the rivers extended from the mid 1800s to the late 1920s. Hence, the Utah Special Master's conclusions of depth requirement is just as relevant to the Gila River watershed as they were to the watersheds the Utah Special Master considered. Based on the evidence presented above, I think three foot of mean depth is an accurate requirement.

This leaves the question of what did the Utah Special Master mean by mean depth. Does the Utah Special Master mean the maximum depth that occurred during mean flow or did the Utah Special Master want the depth across the channel to average three feet (what the hydrologists call the hydraulic depth). The context makes it clear that the Utah Special Master was not talking about the depth at mean average flow. The Utah Special Master very carefully used historic data to determine at what flow rates there would be a three foot or greater mean depth in the river. The Utah Special Master then totaled all of the flow rates that provided three feet or more of mean depth and decided whether it was for a sufficient period to allow commercial activity. This means the Utah Special Master is using the mean average cross-section depth, not the maximum depth.

2. Pinkerton

In 1914, a report was prepared by Pinkerton about canoeing. In that report, Pinkerton indicates that it takes 19 inches of water for a freight canoe to float.[3] Plus, the United States Army Corp of Engineers has indicated that you cannot effectively navigate a river if you are dragging bottom and in fact, due to the hydraulics of boating, you should limit your draft to 75 percent of river depth. These two sources together suggest that for a commercial canoe, the river should have a depth of at least 25 inches.

3. Washington State Criteria

The State of Washington has examined the concept of navigability and created various laws for it. Statutorily, the State of Washington has determined that if the average depth on the river is greater than 3.5 feet deep, and 45 feet wide, then the river is probably navigable. The State of Washington believes two feet is the minimum depth to have any real chance of navigation and the range 2 to 3.5 feet is a “maybe”.[4]

4. Army Corps of Engineers Criteria

Finally, the Army Corp of Engineers is the agency directed by the United States Congress to maintain navigability. As documented at Slide 104 of my testimony in the San Pedro, the following depths were legislated by Congress as depths the Army Corp of Engineers was to maintain:

YEAR	DEPTH (FEET)	RIVER REACH
1866	4	Upper Mississippi

[3]Pinkerton, near the end of chapter 2.
[4]Magirl and Olsen pg 2.

1878	4.5	Upper Mississippi
1896	9	Lower Mississippi
1907	6	Upper Mississippi
1907	6	Lower Missouri
1910	9	Ohio

5. Summary

Three feet was what was necessary for navigation in the Southwest in 1896. Depths required for river navigation have generally increased over time. I doubt that over a period of 16 years[5], the increase in required depth for navigation has been significant. I believe three feet is a valid depth to use as a standard for navigability as of Statehood.

B. COMPUTED DEPTHS OF MIDDLE GILA

To compute the depth of water I need information concerning four things.

1. Flow (Q)
2. Longitudinal slope of the channel (S)
3. Channel shape
    a. Cross-sectional area (A)
    b. Wetted perimeter (P)

[5] 1912-1896 = 16

4. Roughness factor (n)

The flows (designated Q) were determined in chapter II. Longitudinal slope and channel shape are discussed in part 1 Survey below. Roughness factor is discussed in part 2 soils which follows part 1 survey.

These are the variables necessary to solve the Manning's Equation for depth. Manning's Equation is the most important equation in surface water hydrology. It has been used successfully for over 100 years throughout the world.

1. Survey

The Gila River Indian Community and Reservation had a long history of water shortages that had occurred due to upstream diversions. Due to the history of cooperation between the U.S. Military and the Pima-Maricopas, the U.S. Military felt an obligation to help restore the water supplies to the Pimas. Numerous efforts began and ended in attempts to do this. One of the activities taken in attempting to gather information to allow for the eventual construction of Coolidge Dam was a survey of the Gila River.

This survey was a plane table survey. On a plane table survey, the surveyor has a tripod with a special drawing surface (called the table) attached to the top. An instrument called an Alidade is used to view a pole held by the rodperson. This instrument allows the instrument person to plot on the table (drawing surface) distances, bearings and elevations. This allowed mapping of large areas before aerial photography, both as to topography, human, and geographic features. I have seen the original sheets for this survey and they bear distinctive marks from the plane table where the special screws used by a plane table had been tightened to hold the paper in place.

This survey was physically done very shortly after Statehood and represents an excellent topographic map of what the Middle Gila River was like, in its natural condition, as of Statehood. Using the data contained on these plane table surveys, it is tedious, but easy to reconstruct a channel cross-section in the river. I did this for 2 cross-sections.

This survey which had five foot contours allowed me to mathematically determine the cross-sectional area (A) and the wetted perimeter (P) for all possible depths. The survey also allowed me to compute the longitudinal slope (S). The only remaining variable is roughness (n).

2. Soils

As I have indicated earlier, the floods around 1900 changed the characteristic of the river and the soils in the river. The period most relevant to the date of Statehood is the period after the 1890, 1891, 1905, and 1906 floods, but before the 1916 flood. The closer in time to 1912 the better.

According to the 1927 soils study, Lower Gila River bottoms had what was called “Gila Fine Sandy Loam”. In addition, there is “River Wash”, which “...includes beds of stone, gravel, loose sand, and heavier textured materials that occupy the lower parts of the floodplains and channels of the larger streams.”[6] In the Middle Gila segment, there is a soil survey from 1920. The river bed was covered with river wash. In this area, river wash is “...a mixture of course, medium, and fine sands, together with some finer sediments.”[7] These unfortunately are after the 1916 flood.

Fuller compiled a large number of references from G.L.O. survey plats, U.S.G.S. reports, and other sources.[8] By running word scans of Fuller’s chapter IV, I found dozens of references to the Gila riverbed being sand. Two times I found mention of a mixture of sand and silt; twice there was mention of gravel; there was one mention of boulders and one mention of bowlders [sic]. I found no references of clay or loam in the riverbed. Overwhelmingly, the riverbed was sand. This was true before the floods, after the floods, and in the critical period 1907-1915.

The variable for roughness of the channel (n) reflects numerous factors. These are generally soil, vegetation and obstacles. An ordinary flow channel usually has no vegetation. In fact, one of the primary determinants

[6] Harper and Youngs pg 20 and 31.
[7] Eckmann et. al. pg 29.
[8] Fuller 2003 chapter 4.

of the limits of the “ordinary high water mark” is the area swept clean of vegetation. Obstacles are addressed separately in their own section below. This leaves us to discuss a sandy channel bed.

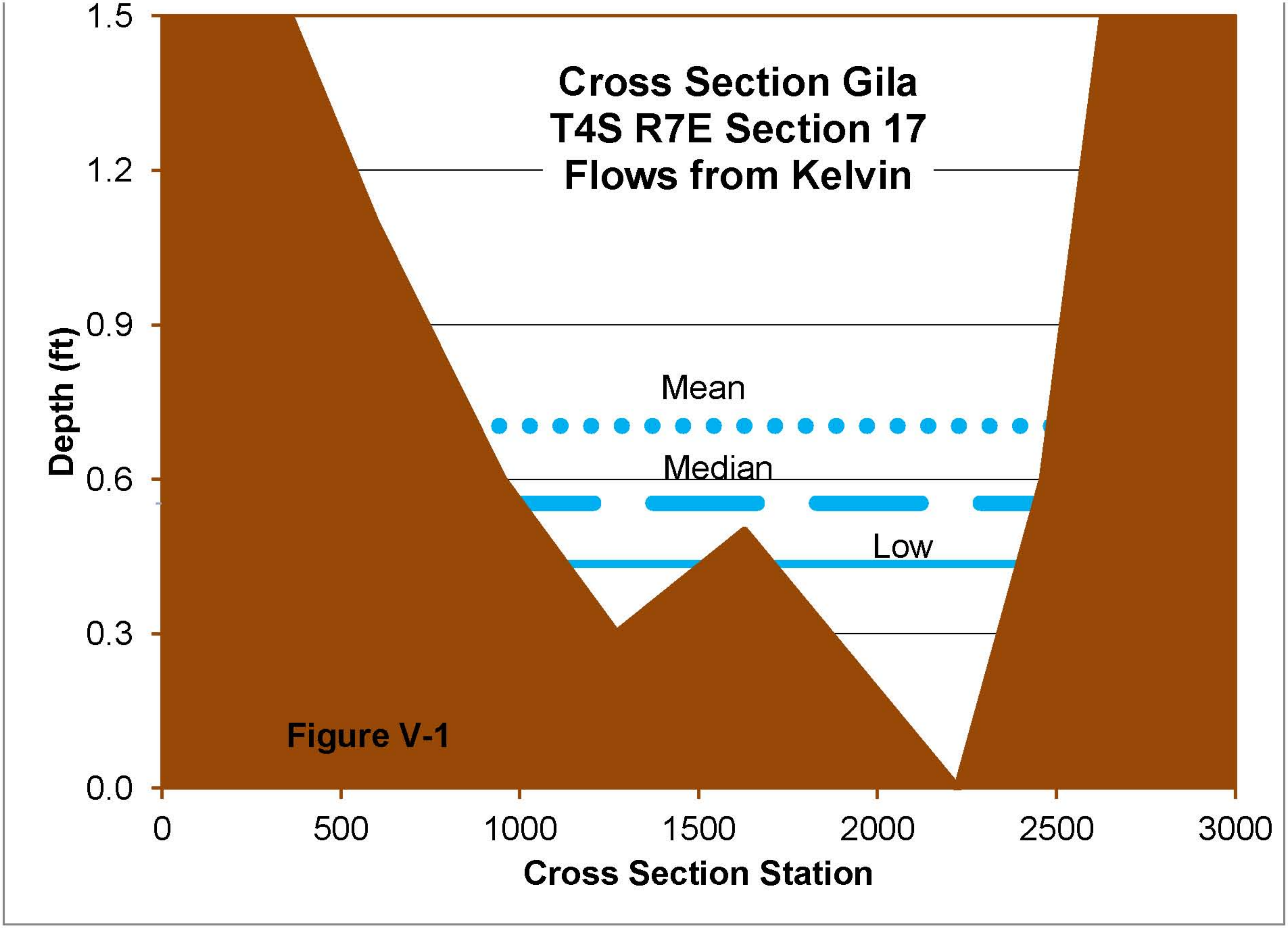
The proper “n” value for a sandy bottom varies on the flow. Because sand is so moveable, it can take varying shapes which affect the Manning's “n” values greatly. This is very significant during floods. If you are considering “ordinary flow” then the “n” value is 0.020.[9]

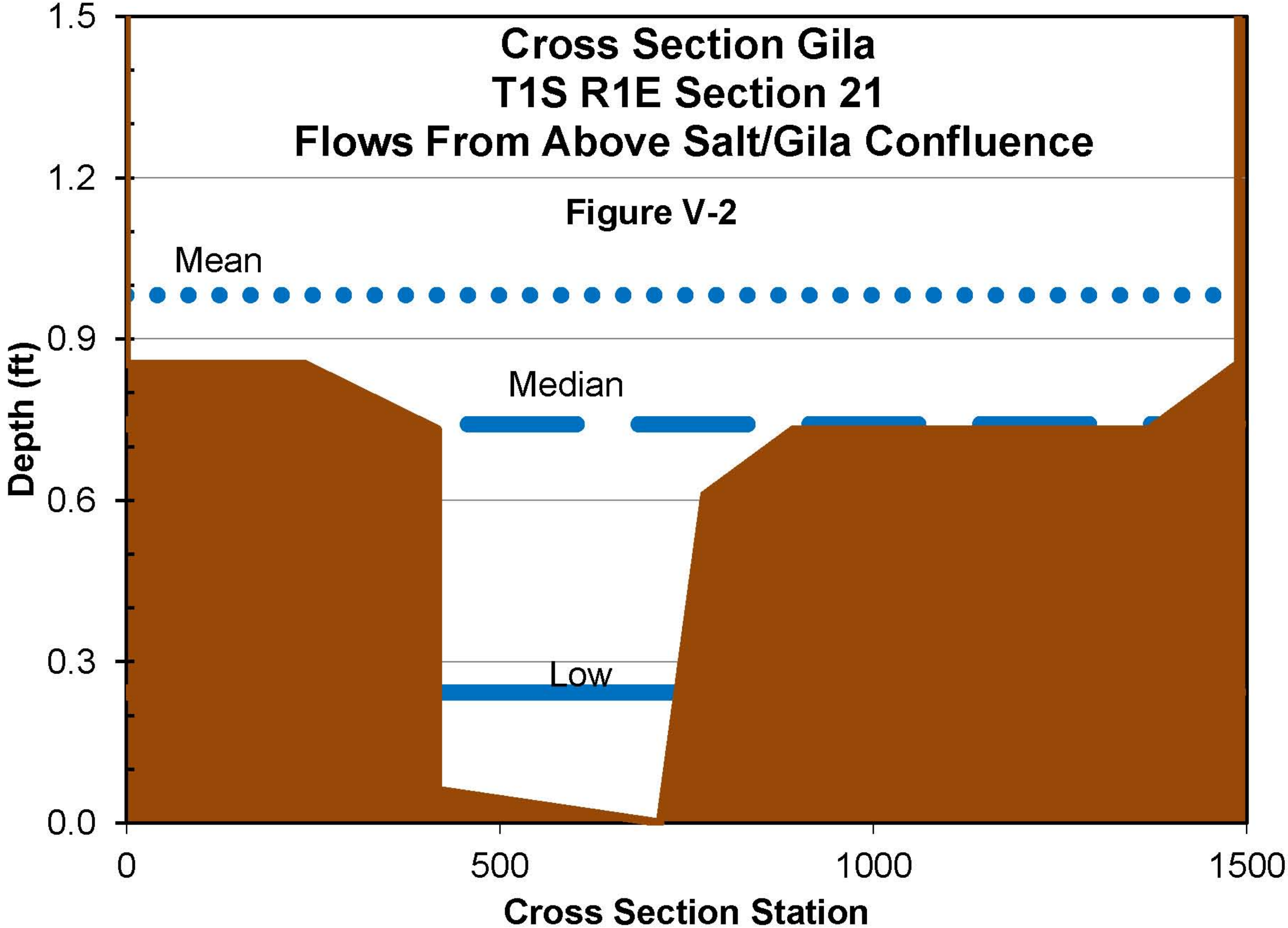
Using the Manning's Equation, I computed the water elevation that would have occurred at various flows.[10] These cross sections are presented as Figures V-1 and V-2. Figure V-3 shows the resulting depths, widths, and velocities that would have been available for boats as of the time of Statehood.

For both cross-sections, the flow was well below the three foot level needed for navigation. In fact, even the mean average flow only produced a one foot depth (technically 0.98 feet) at one of the two cross-sections. The median and low flows were significantly lower than one foot in both locations.

The Utah Decision used mean depth as its criteria. In a braided channel, the mean depth does not give a useable number once the low

[9]Simons, Li & Associates pg 4.10.
[10]I solved the equation using the Section Factor technique.


Cross Section Gila
T4S R7E Section 17
Flows from Kelvin
Mean
Median
Low
Figure V-1
Depth (ft)
0.0
0.3
0.6
0.9
1.2
1.5
0
500
1000
1500
2000
2500
3000
Cross Section Station


Cross Section Gila
T1S R1E Section 21
Flows From Above Salt/Gila Confluence
Figure V-2
Mean
Median
Low
Depth (ft)
1.5
1.2
0.9
0.6
0.3
0.0
0
500
1000
1500
Cross Section Station

Summary			
	Below Kelvin	Above Confluence	Units
Mean Flow	755	637	CFS
Depth	0.70	0.98	Feet
Velocity	1.35	1.13	Ft/Sec
Median Flow	345	193	CFS
Depth	0.55	0.74	Feet
Velocity	1.01	0.77	Ft/Sec
Low Flow	175	23*	CFS
Depth	0.44	0.24	Feet
Velocity	0.77	0.33	Ft/Sec

*Flow is questionable (See Text)

Figure V-3

flow channel overflows. Overflow creates a thin sheet of water over the far far wider riverbed. When overflow begins, the mean depth mathematically decreases with more flow. Knowing that the maximum depth is a more useable number, I solved for the maximum depth. If the river did not have a maximum depth of three feet, then it could not have a mean depth of three feet and I sidestep this mathematical anomaly. The maximum depths are so much less than three feet that the problem of mean depth vs. maximum depth is not relevant. The Middle Gila segment is clearly not navigable.

C. MEASURED DEPTH

There is one stream gage on the Middle Gila River that has been in operation since early in the 1900s. Measurements at Kelvin began in January 1911. A very important part of any stream gaging station is having hydrographers go out into the field and repeatedly survey the river. The measurements enable the USGS to create stage-discharge curves. Stage-discharge curves are used to enable the flow to be determined by simply measuring the elevation (based on an arbitrary datum) and using a mathematically derived curve. When the survey is made, measurements are made of the width of the water along with several measurements of the water depth at various points and the water velocity. These records are kept by the USGS and with considerable effort (due to post 9/11 Federal Security Regulations) are available from the USGS. The Community has managed to acquire these records which are presented in Appendix A. This is a very valuable resource. With these measurements, we do not have to argue about channel shape, Manning's “n”, river slopes, widths, soils or whatever. We know, within the physical ability to measure, what the depth of the water was for various flows.

Fortunately, it does not matter whether the flow is depleted or not for this analysis. When a given flow rate occurs, we know what the depth was at or near the time of Statehood. All that is left is the question of how often the flow occurs.

I plotted the measurements from the gage data from its beginning until January 1916. In January 1916, there was a large flood on the Gila River. There are two reasons why I stopped before the January 1916 flood. First, we are not concerned about depths during floods. We are worried about flows that are “Ordinary and Natural”. Second, a major flood often creates major changes in the channel configuration. We are interested in what the "ordinary and natural "flow depths would have been in 1912, at the time of Statehood. I then plotted these points on a special type of graph paper called log-log paper. If you look at each of the axes, you will see the major divisions increase in the number of digits (i.e. 1, 10, 100, etc.). I used a statistical technique called regression analysis to fit a power curve to each of the two datasets. The power curve is a type of equation that plots a straight line on the log-log paper. This is how stage-discharge curves are normally plotted.

The graph is show as Figure V-4. Two items need to be explained. First, there is a square red point labeled "Outlier Ignored". In regression analysis the mathematics rely on the square of the distance between each point and the line. If a point is well outside the apparent normal spread of values, which this point is, that distance when squared distorts the answer. When this happens the point is called an outlier and is usually ignored. I did also run the analysis with the outlier included and the impact was to rotate the line clockwise around the point where the line crosses one foot. This means that for the depths we are concerned about the depth shown without the outlier included is deeper than when the outlier is included. The line I have shown represents a better interpretation of the data for pro-navigability advocates.

The second item are the red X's. These are the computed depths for the (beginning in the lower left and moving to the upper right) base flow (1.1 foot), median flow (1.4 feet), and mean average flow (1.7 feet). The depths are also shown in red boxes directly above the point.

To reasonably guarantee the required flow depths, a safety margin should be added. The reason relates to the variance of measured depths that routinely occur either due to measurement error or shifting sands. For

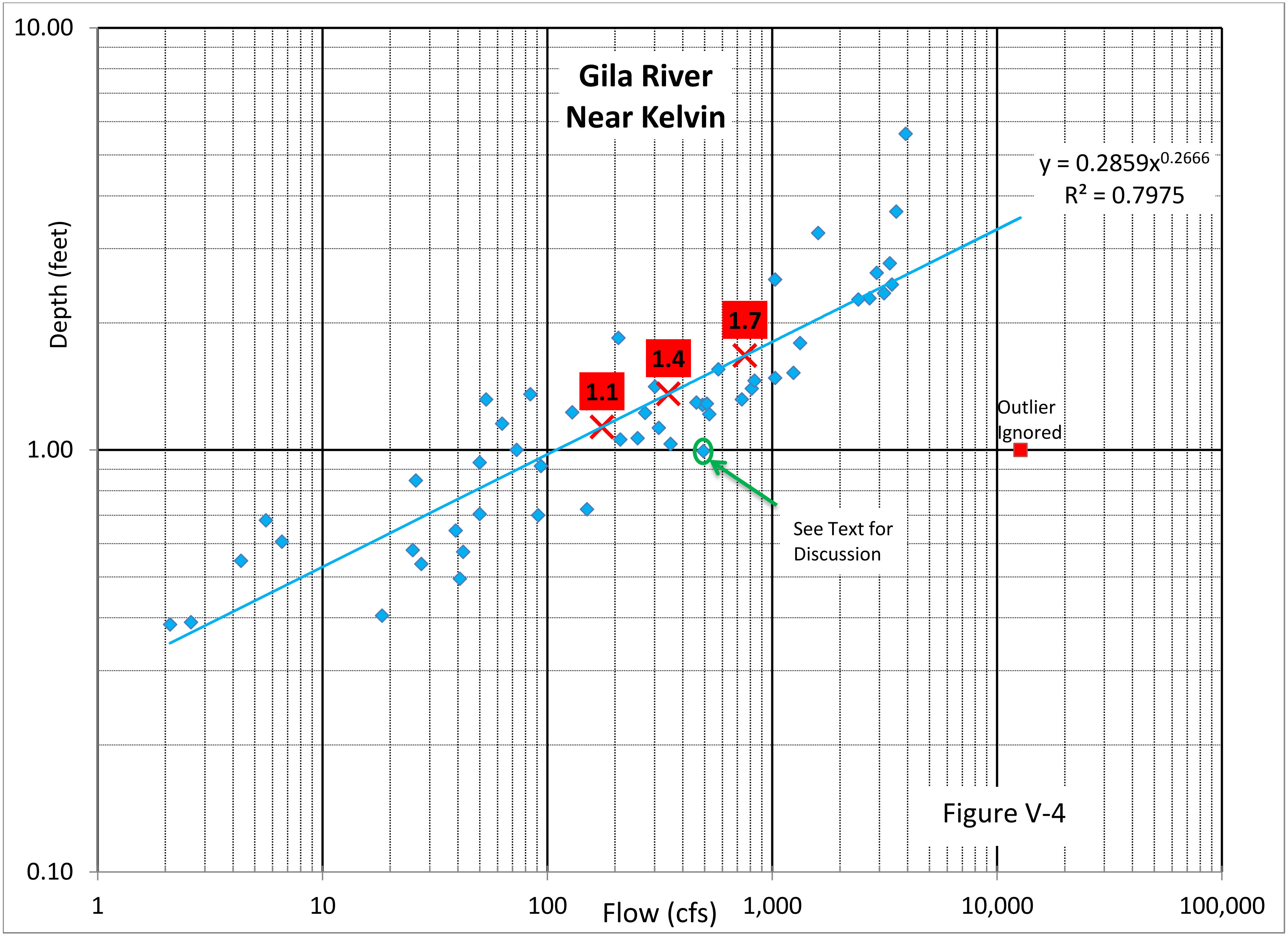

Gila River
Near Kelvin
y = 0.2859x^0.2666
R² = 0.7975
1.1
1.4
1.7
Outlier
Ignored
See Text for
Discussion
Depth (feet)
Flow (cfs)
10.00
1.00
0.10
1
10
100
1,000
10,000
100,000

Figure V-4

example, the median flow is 1.4 feet deep. Yet there is a higher flow (circled in green and labeled "See Text For Discussion") that did not quite provide one foot in depth. If reasonable certainty was to be the standard the median flow depth is less than one foot.

Gage locations are generally in places where the underground flow is pushed to the surface. Although the Kelvin gage is often considered to be the beginning of the Middle Gila River, it is physically located in a narrow canyon with shallow bedrock. This represents a very favorable spot for navigation along the Gila River. This is the reason why the depths at Kelvin are deeper than my computed depths below Kelvin. Specifically, the widths at the Kelvin gaging site are significantly narrower than they are on the flats that constitute the vast majority of the Middle Gila River.

As Figure V-4 demonstrates, if the near Statehood measurements of the river section at Kelvin are used, then it is obvious the Gila River was not navigable for commercial purposes under the criteria for navigability set forth above.

D. OBSTACLES

The use of the Manning's Equation as described above did not consider obstacles. Obstacles can, and often do, exist in the natural state.

> Many streams that may not be boatable due to boulders, vegetation, frequent waterfalls, or significant natural hazards

> may have average annual flow rates or flood peaks that, … indicate that boating could occur.[11]

Obstacles that must be considered are beaver dams, riffles, marshes and braiding.

1. Beaver Dams

Beaver dams have been discussed earlier. Given the characteristics of canoes at or before Statehood, the only way to cross a beaver dam was by portage. Current day small water craft are built differently from those in 1912. In 1912, small water craft were built of wood. Now they are made of stronger materials such as fiberglass. Fiberglass is much stronger than wood. To demonstrate this, I went to materials manufacturer's websites and found that fiberglass' strength is 30,000 psi.[12] The 1912 Sears catalog shows canoes as being made out of cedar. Cedar's strength varies on how the load is applied to the grain. If the load is parallel to the grain, cedar can handle 1990 psi to 6310 psi depending on what type of cedar. If the load is perpendicular to the grain, which is the most likely scenario, cedar can handle from 240 psi to 920 psi.[13] As can be seen, fiberglass is far stronger than wood.

[11] Stantec Consulting Inc. pg 15.
[12] American Acrylic Corporation no page number.
[13] Green et al. pg 4-11, 4-12.

The canoe had considerable advantages to trappers. First, canoes lightened the load. Second, trapper Pattie pointed out that:

> [a] canoe is a great advantage, where the beavers are wild; as the trapper can thus set his traps along the shore without leaving his scent upon the ground around it.[14]

The fact that the trappers did not use canoes for cargo and/or the hunting advantage tells us the river was not navigable in the early 1800s.

2. Riffles

The second obstacle is riffles. A riffle is described as follows:

> The riffle is a bed feature that may have gravel or larger rock particles. The water depth is relatively shallow, and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, which removes fine sediments and provides oxygen to the stream. Riffles enter and exit meanders and control the streambed elevation. Pools are located on the outside bends of meanders between riffles. The pool has a flat surface (with little or no slope) and is much deeper than the stream's average depth. At low flows, pools are depositional features and riffles are scour features.[15]

Riffles are prevalent on most streams.

> Natural channels characteristically exhibit alternating pools or deep reaches and riffles or shallow reaches, regardless of the type of pattern.[16]

The Gila River "... is a pool - and - riffle type. "[17]

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[14] Pattie pg 136.
[15] North Carolina Stream Restoration Institute pg 10.
[16] Leopold and Wolman pg 39.
[17] Burkham 1972 pg G3.

The issue of riffles affects navigability in two ways. First, sometimes riffles are minor obstacles but other times, riffles can be rapids. Second, riffles affect the depth of water.

In the Utah Decision, the Utah Special Master found that a riffle per se was not enough to stop navigation. Rapids, however, were enough to stop navigation. This distinction was primarily based on the experiences of people who had navigated the river. The distinction between riffles and rapids were based on a wave heights, head losses, and slopes.[18]

The second effect of riffles is that riffles change the slopes of a river. Rivers descend in a kind of stair-step manner. There are shallow short steep reaches followed by relatively flat deeper pools of water followed by another shallow short steep reach followed by etc. A steeper slope changes the depth. On the Middle Gila River, we have one location that has been studied for riffles. This location is near Kelvin which is the stream gage that measures the flow as it enters the Middle Gila segment.[19] In the Kelvin study, there were two reaches that were riffles. The average slope over the study area was 0.0027. The lesser of the two riffles has a slope of 0.004 or only 48% steeper. Given the mathematics of the Manning's Equation and assuming the width is constant; this translates to a decrease in depth of

[18]Warren pg 82-83.
[19]Beaulieu et. al. pgs 55-65.

only 12.5%. The other riffle has a slope of 0.0109 or four times the mean average slope (400%). In the Manning's Equation, there are several exponents involved. Due to these exponents, increasing the slope by 400% only causes the depth to decrease by 50%, again assuming all the variance occurs in the depth.

The assumption that width would not change is usually wrong. In actuality, with a steeper slope, the width would normally get smaller and the depth shallower according to the river geography. However, the riffles do have a significant impact on depths.

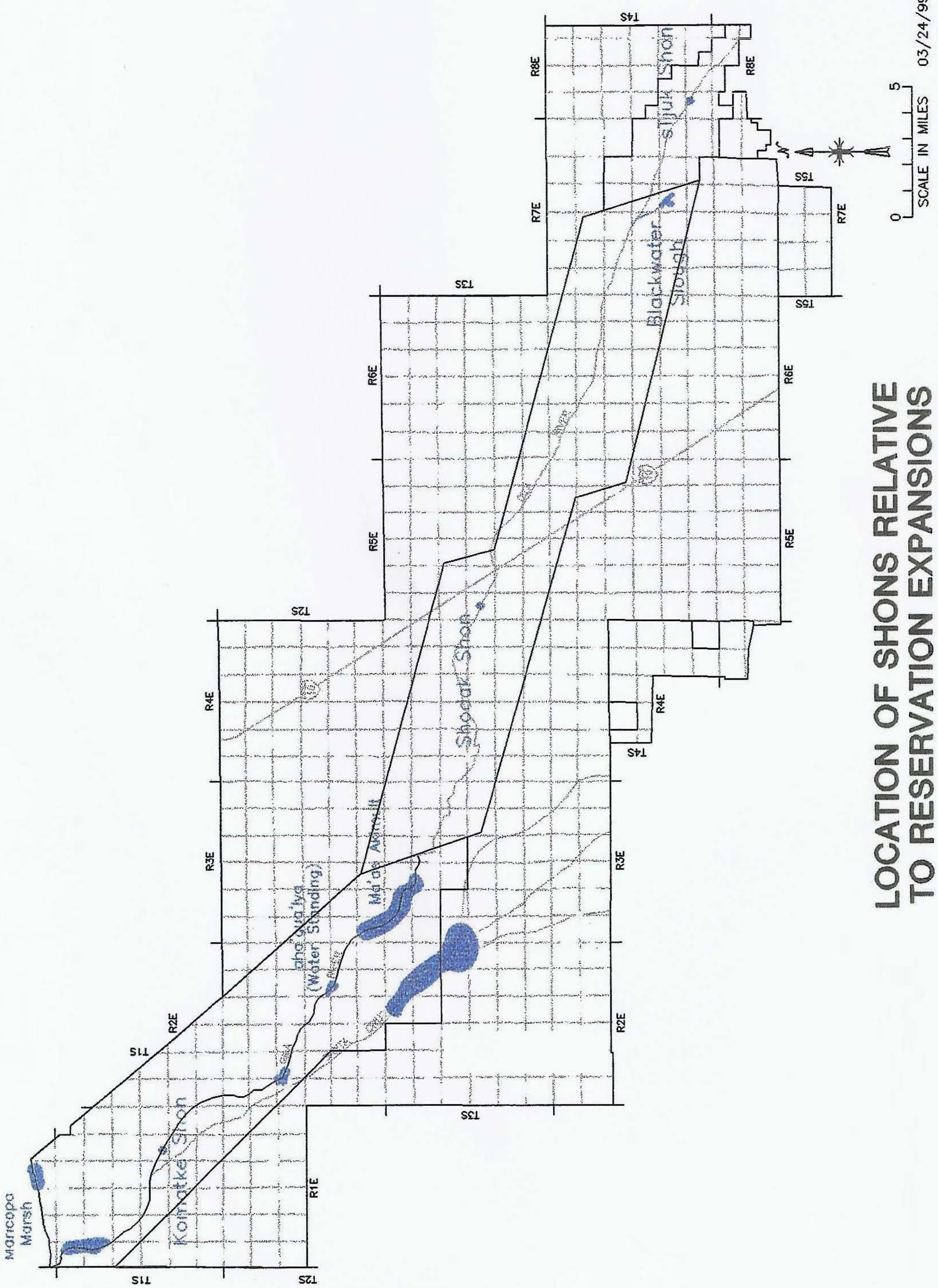
3. Marshes

The third obstacle is marshes. Marshes are also called swamps or cienegas. We know from travelers that

> There is also little doubt that the channel consisted of braided, weaving strands through sandy islands in the center. Several marshy areas, possibly sustaining alkali sacaton, were present, including near present-day Sacaton, at the Santa Cruz-Gila confluence and near the mouth of the Salt River.[20]

Many of these swamps coincided with sh-shon. Shon is a Pima word meaning spring or seep. Repeating the first sound makes it plural. Figure V-5 shows the locations of the sh-shon on the Reservation. These features were not new but had existed in prehistoric times.

[20] Webb et al pg 337.



LOCATION OF SHONS RELATIVE TO RESERVATION EXPANSIONS

Fig. V-5

> Along the formerly great Gila River (the now dry bed of which stretches across the Sonoran Desert of western Arizona) there were extensive marshes, swamps, and flood plains with cattail (Typha domingensis), bulrush (Scirpus olneyi), giant reed (Arundo donax), common reed (Phragmites communis), arrowweed (Pluchea sericea), and many trees. The dense vegetation of these well-developed riparian communities often stood 10 to 15 feet high and supported a tremendous quantity of wildlife [Lowe 1964:30].[21]

The U.S.G.S. in its modeling of the predevelopment condition of the Gila River Indian Reservation found that in 1870 the western 1/3 of the Reservation had "large marshy areas"[22] due to groundwater coming to the surface. As late as 1915, the area still contained swamps.[23]

4. Braiding

As discussed in the Geomorphology chapter, some reaches of the Gila River were braided in the early 1870s. After the major floods of 1890-91 and 1905-06, many portions of the Gila River were braided.

The early braiding on the Lower Gila River is shown on surveys in 1870-71. There was also very early braiding on the Middle Gila River. Because the very first non-Indian diversions occurred on the Salt River in 1869 and the first non-Indian diversions on the Gila River occurred in the 1860s, the amount of developed acreage to affect streamflow would have been trivial. The lands on the Gila River Indian Reservation were being

[21] Fuller 2003 pg III-20.
[22] Thomsen and Eychaner pg 38.
[23] Southworth pg 122.

farmed but had their farmed consumptive uses offset by the consumptive use of the mesquite that the farms replaced. This braiding was clearly in natural conditions.

A braided channel is very wide. It has an almost totally flat bottom with two vertical banks. In that bottom, there will be one or more very shallow depressions that the low flows occupy. If more flow occurs, the river overflows the shallow depression and the water spreads out side to side. Because there are no side restrictions until the river occupies the entirety of the very wide channel, the depths increase very little. Then the depth begins to increase as the rectangular channel begins to fill.

Once the braiding was established from the 1890-1906 floods, there was no way for the river to recover before 1912. On the Upper Gila, Huckleberry points out that "It took 50 years for the flood plain to return to conditions resembling those before 1905, …".[24]

Osterkamp, along with others point out how slow recovery is:

> Most natural alluvial stream channels do not have nearly constant discharge, but show variations of at least several orders of magnitude. A channel that is widened by the excessive shear stresses of an erosive flood, therefore, is not adjusted to the conditions of mean discharge following the flood. Generally, **the channel requires an extended period** of normal flow conditions and shear stresses before accretion and deposition of fine sediment are sufficient to affect channel narrowing and an essentially adjusted geometry. If the

[24]Fuller 2003 pg VII-3.

> sediment available for fluvial transport is principally of sand sizes, the rate of narrowing may be slow owing to a lack of fine cohesive material to form a stable channel section [emphasis added].[25]

As Schumm also points out:

> Wohl (2000b, p. 167) states...: A flood may cause dramatic changes along some reaches of a channel and have relatively little effect on other reaches. Similarly, a flood that occurs once every hundred years may create erosional and depositional forms that are completely reworked within 10 years along one channel, but that persists for decades along a neighboring channel.[26]

It takes several decades in the arid regions for a river to undo the damage created by a flood, and restore it to a single channel, well-defined river. This is particularly true in areas like Central and Southern Arizona.

> Arid and semiarid streams tend to be more susceptible to rapid changes in channel geometry (Graf, 1988) and require a greater amount of time to re-establish their original geometry following a disturbance (Wolman and Gerson, 1979).[27]

Osterkamp reiterated 16 years after his 1980 article

> In arid regions and smaller watersheds, flow variability is higher and extreme events can cause channel changes that persist for decades or centuries (Baker 1977).[28]

Due to the extensive braiding, the Middle and Lower Gila segments along with the Safford segment were not navigable as of Statehood.

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[25] Osterkamp et. al. pg 14
[26] Schumm pg 127.
[27] Fuller 2003 pg V-8, V-9.
[28] Friedman et. al. pg 2168. Osterkamp was part of the et. al.

Appendix

A

Possible Gages to use for distribution of Virigin Flows	[====USGS WRIR 98-4225====] Mean CFS	Median CFS	Lowest 15 CFS	[=========Math===========] Mean 1,000's AF	Median 1,000's AF	Lowest 15 1,000's AF	[===White Book===] Virgin 1,000's AF	Historic 1,000's AF	Depletion 1,000's AF
SALT RIVER TO GRANITE REEF									
Tonto Creek @ Roosevelt	163.0	24.0	0.0	118.1	17.4	0.0	108.4	107.9	
Salt River @ Roosevelt	921.0	341.0	78.0	667.2	247.0	56.5	710.3	706.5	
Verde River above Horseshoe Dam*	591.0	240.0	76.0	428.2	173.9	55.1	544.3	522.4	
Sum of Hist vs White Book @ Granite Reef	1,675.0	605.0	154.0	1,213.5	438.3	111.6	1,423.8	1,331.8	92.0
Adjust Historic Math to Historic White (Multiply by 1.0975)				1,331.8	481.0	122.4			
Add White Book Depletion as constant				1,423.8	573.0	214.4			
Convert Granite Reef to CFS	1,965.3	791.0	296.0						
GILA RIVER TO KELVIN									
Gila at Red Rock/Blue Creek	367.0	120.0	11.0	265.9	86.9	8.0	157.3	155.0	
San Fransico @ Clifton	227.0	78.0	11.0	164.5	56.5	8.0	168.8	161.4	
San Carlos @ Peridot	63.0	10.0	0.0	45.6	7.2	0.0	51.4	50.5	
Sum of Hist vs White Book @ Kelvin	657.0	208.0	22.0	476.0	150.7	15.9	546.8	434.9	111.9
Adjust Historic Math to Historic White (Multiply by 0.9137)				434.9	137.7	14.6			
Add White Book Depletion as constant				546.8	249.6	126.5			
Convert Kelvin to CFS	754.7	344.5	174.6						
Losses on Gila to Confluence				(85)	(110)	(110)			
Gila above Confluence				461.78	139.90	16.78			
Convert Above Confluence to CFS	637.4	193.1	23.2						
Losses on Salt to Confluence				(149)	(152)	(152)			
Salt above Confluence				1,274.96	420.72	62.13			
Convert Above Confluence to CFS	1,759.9	580.7	85.8						
Below Confluence				1,736.74	560.62	78.91			
Convert Below Confluence to CFS	2,397.3	773.8	108.9						

* White Book Values are for below Bartlett

Reach	Upstream Virgin Flow	Drainage Area	%	Virgin Inflow	Length	"A Number"	% of Total	Pro-rated Losses	Total
Gila	546,800	18,011							
Santa Cruz	44,200	3,503							
Salt	1,423,800	12,900							
Agua Fria	129,500	1,460							
Middle Gila	546,800	3,575	26.0%	24,665	75	41,010,000	24.6%	109,679	85,014
Lower Salt	1,423,800	505	3.7%	3,484	40	56,952,000	34.1%	152,314	148,830
Lower Santa Cruz	44,200	5,078	37.0%	35,035	15	663,000	0.4%	1,773	(33,262)
Lower Agua Fria	129,500	553	4.0%	3,815	30	3,885,000	2.3%	10,390	6,575
Lower Gila	2,144,300	4,015	29.3%	27,701	30	64,329,000	38.6%	172,044	144,343
Total		13,726				166,839,000		446,200	

	Add to Mean	Median	Low
Middle Gila & Lower Santa Cruz	(85,014)	(109,679)	(109,679)
Lower Salt	(148,830)	(152,314)	(152,314)

"A Number" is the product of the Length by the Flow. It is used to provide a way to divide the riparian losses
Due to the normally dry reach of the Santa Cruz in Virgin Times the active reach is limited to 15 miles

Gila River Cross Section generally along the Middle of Section 21 T1S R1E

n=	0.02		WSL=	65.128	ft	V=	1.125	fps
Q=	637	Mean Flow	SFc=	254.5				
Slope =	0.0011		SFg=	297.2				

Measurement in mm	Convert to Feet	Channel Depth	Elevation	Height	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0	0	0.0	70.00	5.85								
0.0	0.0	0.0	65.00	0.85	0.0	0.128	0.128	5.00	3%	0.0	0.0	0.982
4.0	238.1	0.0	65.00	0.85	238.1	0.128	0.128	0.00	100%	30.5	238.1	0.982
7.0	416.7	2.0	64.88	0.73	178.6	0.250	0.250	0.12	100%	33.7	178.6	0.982
7.0	416.7	13.0	64.21	0.06	0.0	0.921	0.921	0.67	100%	0.0	0.0	0.982
12.0	714.3	14.0	64.15	0.00	297.6	0.982	0.982	0.06	100%	283.1	297.6	0.982
13.0	773.8	4.0	64.76	0.61	59.5	0.372	0.982	0.61	100%	40.3	59.5	0.982
15.0	892.9	2.0	64.88	0.73	119.0	0.250	0.372	0.12	100%	37.0	119.0	0.982
23.0	1369.0	2.0	64.88	0.73	476.2	0.250	0.250	0.00	100%	119.0	476.2	0.982
25.0	1488.1	0.0	65.00	0.85	119.0	0.128	0.250	0.12	100%	22.5	119.0	0.982
25	1488.1	0.0	70.00	5.85	0.0	0.000	0.128	5.00	3%	0.0	0.0	0.982
			64.15		1488.1		0.982			566.1	1488.1	

Gila River Cross Section generally along the Middle of Section 21 T1S R1E

n=	0.02			WSL=	64.888	ft		V=	0.766	fps		
Q=	193		Median	SFc=	77.1							
Slope =	0.00114			SFg=	77.1							

Measurement in mm	Convert to Feet	Channel Depth	Elevation	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0	0	0.0	70.00								
0.0	0.0	0.0	65.00	0.0	0.000	0.000	5.00	0%	0.0	0.0	0.741
4.0	238.1	0.0	65.00	238.1	0.000	0.000	0.00	100%	0.0	238.1	0.741
7.0	416.7	2.0	64.88	178.6	0.010	0.010	0.12	100%	0.9	178.6	0.741
7.0	416.7	13.0	64.21	0.0	0.680	0.680	0.67	100%	0.0	0.0	0.741
12.0	714.3	14.0	64.15	297.6	0.741	0.741	0.06	100%	211.6	297.6	0.741
13.0	773.8	4.0	64.76	59.5	0.132	0.741	0.61	100%	26.0	59.5	0.741
15.0	892.9	2.0	64.88	119.0	0.010	0.132	0.12	100%	8.4	119.0	0.741
23.0	1369.0	2.0	64.88	476.2	0.010	0.010	0.00	100%	4.6	476.2	0.741
25.0	1488.1	0.0	65.00	119.0	0.000	0.010	0.12	100%	0.6	119.0	0.741
25	1488.1	0.0	70.00	0.0	0.000	0.000	5.00	0%	0.0	0.0	0.741
				1488.1		0.741			251.9	1488.1	

Gila River Cross Section generally along the Middle of Section 21 T1S R1E

n=	0.02			WSL=		64.389	ft	V=		0.327	fps	
Q=	23	Low Flow		SFc=		9.2						
Slope =	0.001135			SFg=		9.2						

Measurement in mm	Convert to Feet	Channel Depth	Elevation	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0	0	0.0	70.00								
0.0	0.0	0.0	65.00	0.0	0.000	0.000	5.00	0%	0.0	0.0	0.243
4.0	238.1	0.0	65.00	238.1	0.000	0.000	0.00	100%	0.0	238.1	0.243
7.0	416.7	2.0	64.88	178.6	0.000	0.000	0.12	100%	0.0	178.6	0.243
7.0	416.7	13.0	64.21	0.0	0.182	0.182	0.67	100%	0.0	0.0	0.243
12.0	714.3	14.0	64.15	297.6	0.243	0.243	0.06	100%	63.1	297.6	0.243
13.0	773.8	4.0	64.76	59.5	0.000	0.243	0.61	100%	7.2	59.5	0.243
15.0	892.9	2.0	64.88	119.0	0.000	0.000	0.12	100%	0.0	119.0	0.243
23.0	1369.0	2.0	64.88	476.2	0.000	0.000	0.00	100%	0.0	476.2	0.243
25.0	1488.1	0.0	65.00	119.0	0.000	0.000	0.12	100%	0.0	119.0	0.243
25	1488.1	0.0	70.00	0.0	0.000	0.000	5.00	0%	0.0	0.0	0.243
				1488.1		0.243			70.4	1488.1	

Gila River Cross Section generally along Section 17 T4S R7E

n=	0.02			WSL=	2.604	ft		V=	1.348	fps
Q=	755			SFc=	278.0					
Slope =	0.00134			SFg=	278.0					

Measurement in mm	Convert to Feet	Elevation	Height	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0.0	0.0	5.0	3.1		0.000						0.704
0.0	0.0	4.0	2.1	0.0	0.000	0.000	1.0	0%	0.0	0.0	0.704
1.5	595.5	3.0	1.1	595.5	0.000	0.000	1.0	0%	0.0	0.0	0.704
2.4	952.8	2.5	0.6	357.3	0.104	0.104	0.5	21%	3.8	74.0	0.704
3.2	1270.4	2.2	0.3	317.6	0.404	0.404	0.3	100%	80.5	317.6	0.704
4.1	1627.7	2.4	0.5	357.3	0.204	0.404	0.2	100%	108.5	357.3	0.704
5.6	2223.2	1.9	0.0	595.5	0.704	0.704	0.5	100%	270.1	595.5	0.704
6.2	2461.4	2.5	0.6	238.2	0.104	0.704	0.6	100%	96.1	238.2	0.704
7.0	2778.9	4.2	2.3	317.6	0.000	0.104	1.7	6%	1.0	19.4	0.704
7.0	2778.9	5.0	3.1	0.0	0.000	0.000	0.8	0%	0.0	0.0	0.704
				2778.9		0.704			560.1	1602.0	

Gila River Cross Section generally along Section 17 T4S R7E

n=	0.02	WSL=	2.454 ft	V=	1.010 fps
Q=	345	SFc=	127.0		
Slope =	0.00134	SFg=	127.0		

Measurement in mm	Convert to Feet	Elevation	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0.0	0.0	5.0		0.000						
0.0	0.0	4.0	0.0	0.000	0.000	1.0	0%	0.0	0.0	0.554
1.5	595.5	3.0	595.5	0.000	0.000	1.0	0%	0.0	0.0	0.554
2.4	952.8	2.5	357.3	0.000	0.000	0.5	0%	0.0	0.0	0.554
3.2	1270.4	2.2	317.6	0.254	0.254	0.3	100%	40.3	317.6	0.554
4.1	1627.7	2.4	357.3	0.054	0.254	0.2	100%	54.8	357.3	0.554
5.6	2223.2	1.9	595.5	0.554	0.554	0.5	100%	180.7	595.5	0.554
6.2	2461.4	2.5	238.2	0.000	0.554	0.6	100%	65.9	238.2	0.554
7.0	2778.9	4.2	317.6	0.000	0.000	1.7	0%	0.0	0.0	0.554
7.0	2778.9	5.0	0.0	0.000	0.000	0.8	0%	0.0	0.0	0.554
			2778.9		0.554			341.8	1508.6	

Gila River Cross Section generally along Section 17 T4S R7E

n=	0.02		WSL=	2.336	ft		V=	0.770	fps
Q=	175		SFc=	64.4					
Slope =	0.0013		SFg=	64.4					

Measurement in mm	Convert to Feet	Elevation	Width	Depth @ Point	Max Depth for Reach	Elevation difference	Percent Wetted	Area	Perimeter	WSL Graphic
0.0	0.0	5.0		0.000						0.436
0.0	0.0	4.0	0.0	0.000	0.000	1.0	0%	0.0	0.0	0.436
1.5	595.5	3.0	595.5	0.000	0.000	1.0	0%	0.0	0.0	0.436
2.4	952.8	2.5	357.3	0.000	0.000	0.5	0%	0.0	0.0	0.436
3.2	1270.4	2.2	317.6	0.136	0.136	0.3	100%	21.5	317.6	0.436
4.1	1627.7	2.4	357.3	0.000	0.136	0.2	100%	24.2	357.3	0.436
5.6	2223.2	1.9	595.5	0.436	0.436	0.5	100%	129.7	595.5	0.436
6.2	2461.4	2.5	238.2	0.000	0.436	0.6	100%	51.9	238.2	0.436
7.0	2778.9	4.2	317.6	0.000	0.000	1.7	0%	0.0	0.0	0.436
7.0	2778.9	5.0	0.0	0.000	0.000	0.8	0%	0.0	0.0	0.436
			2778.9		0.436			227.4	1508.6	

Gage Measurements for Gila River at Kelvin

date	meas#	width_ft	area_ft2	depth_ft	vel_ft/s	gage h_ft	q_cfs	rating	notes
1/27/1911	1	151.00	193.00	1.28	2.54	4.60	490.00		
2/17/1911	2	112.00	145.00	1.29	3.17	4.50	460.00		
3/22/1911	3	134.00	208.00	1.55	2.77	4.90	576.00		
4/25/1911	4	43.00	43.00	1.00	1.70	4.00	73.00		
5/24/1911	5	6.60	4.00	0.61	1.65	3.70	6.60		
7/26/1911	6	1,200.00	1,200.00	1.00	10.60	10.00	12,700.00		
7/27/1911	7	191.00	701.00	3.67	5.08	7.10	3,560.00		
9/12/1911	8	30.00	28.00	0.93	1.78	4.00	50.00		
10/5/1911	9	154.00	228.00	1.48	4.52	5.78	1,030.00		
10/5/1911	9a	90.00	228.00	2.53	4.52	5.79	1,030.00		
10/6/1911	10	98.00	320.00	3.27	5.00	6.20	1,600.00		
10/30/1911	11	100.00	561.00	5.61	6.99	7.18	3,920.00		
11/24/1911	12	86.00	91.00	1.06	2.32	4.71	211.00		
12/20/1911	13	76.00	93.00	1.22	2.92	4.79	272.00		
1/10/192	14	76.00	81.00	1.07	3.12	4.76	252.00		
2/28/1912	15	182.00	326.00	1.79	4.08	5.60	1,330.00		
6/6/1912	16	13.00	11.00	0.85	2.36	3.86	26.00		
8/17/1912	17	57.00	105.00	1.84	1.97	4.14	207.00		
9/20/1912	18	44.00	31.00	0.70	1.61	3.48	50.00		
10/11/1912	19	112.00	81.00	0.72	1.85	3.90	150.00		
11/18/1912	20	31.00	42.00	1.35	2.00	3.55	84.00		
12/10/1912	21	59.00	76.00	1.29	1.97	3.81	150.00		
3/12/1913	22	171.00	239.00	1.40	3.36	4.30	811.00		
4/15/1913	23	151.00	156.00	1.03	2.26	4.30	353.00		
5/21/1913	24	41.00	26.40	0.64	1.45	3.34	39.10		
6/3/1913	25	42.00	17.00	0.40	1.06	3.10	18.40		
6/17/1913	26	10.50	4.10	0.39	0.63	2.93	2.60		
7/14/1913	27	33.00	19.10	0.58	1.32	3.15	25.20		
7/30/1913	28	80.00	56.00	0.70	1.62	3.57	91.00		
8/29/1913	29	26.00	30.00	1.15	2.10	3.50	62.90		
9/22/1913	30	56.00	32.10	0.57	1.31	3.48	42.20		
10/31/1913	31	61.00	30.20	0.50	1.35	3.40	40.80		

11/25/1913	32	13.90	18.30	1.32	2.92	4.56	53.40
1/5/1914	33	90.00	101.50	1.13	3.04	4.29	313.00
1/29/1914	34	74.00	104.50	1.41	2.87	4.22	301.00
3/23/1914	35	70.00	64.10	0.92	1.46	3.64	93.60
4/24/1914	36	41.00	22.00	0.54	1.25	3.28	27.50
5/25/1914	37	9.50	6.47	0.68	0.87	3.00	5.60
6/14/1914	1	5.00	2.73	0.55	1.59	0.59	4.34
6/20/1914	2	3.50	1.35	0.39	1.55	0.56	2.10
7/10/1914	3	144.00	175.00	1.22	3.00	1.86	525.00
7/30/1914	4	214.40	504.00	2.35	6.24	3.10	3,143.00
7/31/1914	5	214.20	527.96	2.46	6.45	3.30	3,405.60
8/7/1914	6	210.00	480.25	2.29	5.64	2.91	2,708.20
8/8/1914	7	197.00	299.95	1.52	4.13	2.47	1,242.60
9/9/1914	8	205.00	270.00	1.32	2.72	1.95	732.50
9/27/1914	9	51.00	62.60	1.23	2.06	1.25	129.00
10/7/1914	10	185.00	512.00	2.77	6.50	3.70	3,333.00
10/8/1914	11	184.00	418.00	2.27	5.78	3.40	2,415.00
10/31/1914	12	129.00	166.00	1.29	3.09	2.02	512.00
11/19/1914	13	170.00	248.00	1.46	3.36	2.34	834.00
12/12/1914	14	154.00	153.00	0.99	3.22	1.90	494.00
1/7/1915	15	185.00	486.00	2.63	6.00	3.82	2,915.00
1/27/1915	16	183.00	239.00	1.31	4.00	3.06	954.00
1/27/1915	17	183.00	242.00	1.32	4.06	3.06	982.00
2/6/1915	18	221.00	676.00	3.06	5.45	4.90	3,692.00
3/2/1915	19	221.00	552.00	2.50	6.52	4.25	3,623.00
3/2/1915	20	221.00	550.00	2.49	6.56	4.25	3,615.00
4/3/1915	21	235.00	760.00	3.23	7.79	4.80	5,918.00
4/3/1915	22	235.00	777.00	3.31	7.26	4.80	5,641.00
4/4/1915	23	232.00	728.00	3.14	7.03	4.65	5,120.00
4/4/1915	24	232.00	731.00	3.15	6.96	4.65	5,072.00
4/30/1915	25	239.00	421.00	1.76	4.92	3.53	2,066.00
5/8/1915	26	232.00	353.00	1.52	4.63	3.32	1,637.00
5/8/1915	27	232.00	346.00	1.49	4.60	3.35	1,595.00
5/9/1915	28	230.00	345.00	1.50	4.42	3.28	1,526.00

5/9/1915	29	230.00	323.00	1.40	4.42	3.25	1,427.00
5/13/1915	30	230.00	298.00	1.30	3.88	3.05	1,155.00
5/14/1915	31	230.00	262.00	1.14	4.00	3.12	1,043.00
5/14/1915	32	230.00	261.00	1.13	4.20	3.12	1,098.00
5/27/1915	33	138.00	163.00	1.18	2.86	2.71	466.00
5/27/1915	34	138.00	152.00	1.10	3.32	2.71	507.00
5/28/1915	35	135.00	165.00	1.22	3.31	2.77	547.00
5/28/1915	36	135.00	167.00	1.24	3.02	2.77	505.00
6/15/1915	37	117.00	98.30	0.84	1.98	2.28	231.00
7/2/1915	38	93.00	44.20	0.48	1.56	1.86	69.00
8/4/1915	39	152.00	266.00	1.75	3.46	2.70	922.00
8/4/1915	40	152.00	266.00	1.75	3.58	2.70	949.00
8/5/1915	41	153.00	246.00	1.61	4.15	2.75	1,019.00
9/1/1915	42	115.00	109.00	0.95	2.12	2.05	233.00
9/1/1915	43	127.00	116.10	0.91	1.88	2.04	218.00
9/2/1915	44	117.00	109.00	0.93	2.06	2.04	224.00
9/2/1915	45	118.00	114.00	0.97	1.89	2.03	216.00
9/30/1915	46	145.00	146.30	1.01	2.93	2.28	430.00
10/5/1915	47	62.00	75.00	1.21	2.47	2.02	185.00
10/12/1915	48	39.00	42.60	1.09	2.28	1.83	96.70
10/29/1915	49	36.00	39.50	1.10	1.72	1.80	68.00
10/29/1915	50	36.00	38.50	1.07	1.87	1.80	72.00
11/27/1915	51	59.00	59.00	1.00	2.02	1.89	119.00
11/27/1915	52	59.00	57.00	0.97	2.04	1.89	116.00
1/12/1916	53	157.00	202.00	1.29	4.01	2.60	810.00
1/12/1916	54	157.00	202.00	1.29	4.61	2.65	932.00
8/27/1929	383	128.00	127.00	0.99	3.42	3.01	434.00
9/17/1929	384	37.00	50.40	1.36	2.06	2.50	104.00
9/24/1929	385	216.00	721.00	3.34	5.53	4.90	3,990.00
10/8/1929	387	37.00	66.40	1.79	2.53	2.69	168.00
11/5/1929	388	43.00	49.00	1.14	2.27	2.67	111.00
12/10/1929	389	33.00	43.10	1.31	1.89	2.56	81.20
1/6/1930	390	21.50	26.50	1.23	1.44	2.38	38.30
2/4/1930	391	26.50	23.80	0.90	1.88	2.77	44.70

2/25/1930	392	56.00	90.40	1.61	2.87	3.11	259.00	
3/18/1930	393	223.00	645.00	2.89	4.87	4.57	3,140.00	
3/29/1930	394	94.00	78.80	0.84	2.14	2.79	169.00	
4/18/1930	395	142.00	143.00	1.01	2.98	3.43	426.00	
4/28/1930	396	139.00	166.00	1.19	3.43	3.38	570.00	
5/19/1930	397	130.00	151.00	1.16	2.62	3.34	395.00	
6/9/1930	398	157.00	191.00	1.22	3.49	3.46	667.00	
7/1/1930	399	157.00	240.00	1.53	2.62	3.49	629.00	
7/15/1930	400	165.00	187.00	1.13	3.19	3.21	597.00	
7/22/1930	401	145.00	192.00	1.32	4.28	3.30	822.00	
8/9/1930	402	190.00	608.00	3.20	2.80	4.14	1,700.00	
8/10/1930	403	173.00	323.00	1.87	2.42	3.37	783.00	
8/10/1930	404	145.00	234.00	1.61	3.04	3.28	711.00	
8/11/1930	405	144.00	225.00	1.56	2.70	3.17	608.00	
8/11/1930	406	144.00	217.00	1.51	2.54	3.13	551.00	
8/11/1930	407	189.00	518.00	2.74	4.33	4.17	2,243.00	
8/12/1930	408	182.00	313.00	1.72	3.03	3.51	949.00	
8/13/1930	409	134.00	155.00	1.16	2.32	2.91	359.00	
8/14/1930	410	133.00	134.00	1.01	1.98	2.76	266.00	
8/20/1930	411	134.00	244.00	1.82	2.63	3.38	641.00	
9/2/1930	412	136.00	234.00	1.72	3.92	3.43	918.00	
9/22/1930	413	140.00	198.00	1.41	3.09	3.38	612.00	
10/13/1930	414	73.00	69.90	0.96	2.37	2.86	166.00	
11/3/1930	415	68.00	74.50	1.10	1.99	2.77	148.00	
11/24/1930	416	57.00	43.00	0.75	1.49	2.51	64.20	
12/13/1930	417	76.00	36.70	0.48	1.69	2.62	62.00	
12/22/1930	418	46.00	39.00	0.85	2.40	2.64	93.80	
1/5/1931	419	43.00	55.40	1.29	2.04	2.65	113.00	
1/26/1931	420	54.00	59.20	1.10	2.37	2.63	140.00	
1/20/1982	109	52.00	78.00	1.50	2.08	3.94	62.00	G
2/17/1982	110	53.00	115.00	2.17	2.03	4.33	233.00	F
3/24/1982	111				0.00	5.68	531.00	F
4/22/1982	112				0.00	5.64	578.00	G
5/18/1982	113	68.00	132.00	1.94	2.51	4.80	331.00	G

6/10/1982	113A				0.00	5.68			
6/16/1982	114				0.00	5.75	619.00	G	
8/10/1982	115	76.00	264.00	3.47	3.25	6.18	858.00	G	
9/1/1982	116	76.00	216.00	2.84	2.94	5.71	635.00	G	
9/12/1982	117	143.00	667.00	4.66	4.80	9.36	3,200.00	F	
9/17/1982	117A				0.00	5.30			
9/22/1982	118	68.00	136.00	2.00	2.04	4.60	277.00	G	
10/22/1982	119	34.50	41.80	1.21	0.77	2.72	32.30	F	
10/28/1982	106	53.00	39.70	0.75	1.56	3.14	16.80	F	
11/3/1982	120	29.50	31.70	1.07	0.80	2.59	25.20	G	
11/18/1982	107	37.00	31.60	0.85	1.20	2.80	37.80	G	
12/3/1982	121	51.00	55.80	1.09	2.08	3.58	116.00	F	
12/10/1982	108	66.50	106.00	1.59	2.16	4.30	229.00	G	
1/4/1983	122	27.00	37.30	1.38	2.04	3.27	76.20	F	
2/2/1983	123	87.00	147.00	1.69	2.08	4.90	306.00	F	
2/25/1983	124	43.50	98.00	2.25	1.54	4.04	151.00	F	
3/21/1983	125				0.00	7.17	1,500.00	F	
3/30/1983	126				0.00	5.30	446.00	F	
5/4/1983	127				0.00	5.36	449.00	F	
6/1/1983	128	75.00	183.00	2.44	2.93	5.65	537.00	G	
7/6/1983	129	76.00	227.00	2.99	3.44	6.04	782.00	F	
8/2/1983	130	72.00	236.00	3.28	3.36	6.14	798.00	G	
9/2/1983	131	73.00	240.00	3.29	3.63	6.29	871.00	G	
10/2/1983	131A				0.00		100,000.00		
10/5/1983	132	170.00	974.00	5.73	3.28	10.23	3,430.00	G	
10/21/1983	133	120.00	374.00	3.12	4.22	7.20	1,580.00	G	
11/2/1983	134	85.00	337.00	3.96	2.38	5.72	802.00	G	
12/1/1983	135	75.00	215.00	2.87	3.04	5.42	666.00	F	CLEAR
12/16/1983	136	121.00	452.00	3.74	4.44	7.67	2,020.00	G	
1/3/1984	137	185.00	534.00	2.89	4.49	8.10	2,430.00	G	CLEAR
1/18/1984	138	78.00	271.00	3.47	3.74	6.27	1,020.00	F	
2/1/1984	139	82.00	246.00	3.00	3.20	5.60	800.00	G	
3/2/1984	140	75.00	198.00	2.64	2.92	5.25	578.00	G	
4/3/1984	141	72.50	224.00	3.09	3.00	5.51	674.00	G	

5/2/1984	142	73.50	191.00	2.60	2.65	5.14	506.00	F	
6/1/1984	143	75.00	249.00	3.32	3.05	5.82	760.00	G	
7/3/1984	144	76.00	303.00	3.99	3.52	6.33	1,070.00	G	
8/7/1984	145	78.00	281.00	3.60	3.46	6.16	974.00	F	
9/5/1984	146	64.00	243.00	3.80	3.45	5.78	840.00	G	
10/2/1984	147	59.00	60.80	1.03	1.96	3.56	119.00	G	CLEAR
10/24/1984	148	32.00	49.00	1.53	2.20	3.65	107.00	G	CLEAR
11/1/1984	149	35.60	41.00	1.15	2.07	3.56	85.00	G	CLEAR
12/4/1984	150				0.00	3.71	113.00	G	CLEAR
12/20/1984	151	63.00	115.00	1.83	2.22	4.32	255.00	G	CLEAR
1/3/1985	152	115.00	346.00	3.01	4.49	7.20	1,560.00	G	CLEAR
1/31/1985	153	149.00	627.00	4.21	5.42	9.25	3,430.00	G	CLEAR
2/28/1985	154	150.00	642.00	4.28	5.20	8.82	3,350.00	G	CLEAR
4/2/1985	155	130.00	336.00	2.58	3.51	6.14	1,180.00	G	CLEAR
5/2/1985	156	120.00	316.00	2.63	3.96	6.09	1,250.00	F	
6/4/1985	157	68.00	270.00	3.97	3.10	5.70	836.00	G	
7/2/1985	158				0.00	6.14	1,220.00	G	
8/2/1985	159	115.00	341.00	2.97	3.89	6.35	1,330.00	F	CLEAR
8/26/1985	160	70.00	296.00	4.23	3.67	6.06	1,090.00	F	CLEAR
9/30/1985	161	67.00	238.00	3.55	2.75	5.47	655.00	F	CLEAR
11/5/1985	162	46.00	32.00	0.70	1.80	2.77	58.50	G	CLEAR
12/5/1985	163	79.00	118.00	1.49	2.02	3.93	239.00	F	
1/3/1986	164	44.00	69.60	1.58	2.28	3.58	159.00	F	
2/4/1986	165	46.00	74.00	1.61	2.30	3.68	170.00	F	
3/3/1986	166	66.00	233.00	3.53	2.62	5.13	638.00	F	
3/19/1986	167	130.00	442.00	3.40	4.45	7.53	2,130.00	F	
4/4/1986	168	74.00	250.00	3.38	3.15	5.49	812.00	G	
5/1/1986	169	68.00	225.00	3.31	2.80	5.15	629.00	G	CLEAR
6/5/1986	170	77.00	258.00	3.35	3.35	5.82	865.00	G	
7/1/1986	171	75.00	337.00	4.49	3.80	6.46	1,280.00	G	
8/1/1986	172	73.00	327.00	4.48	3.40	6.33	1,110.00	F	
9/2/1986	173	115.00	300.00	2.61	3.86	6.24	1,160.00	G	CLEAR
10/6/1986	174	61.00	99.50	1.63	1.35	3.39	134.00	G	
10/24/1986	175	54.00	79.60	1.47	0.69	2.75	54.80	F	

11/25/1986	176	80.00	107.00	1.34	1.44	3.54	154.00	G	
12/9/1986	177				0.00	4.52	372.00	G	CLEAR
1/8/1987	178	61.00	63.50	1.04	1.29	3.05	82.10	F	
1/22/1987	179	63.00	88.00	1.40	1.68	3.46	148.00	G	CLEAR
2/4/1987	180	70.00	135.00	1.93	1.70	3.90	229.00	F	
2/18/1987	181	73.00	194.00	2.66	1.95	4.42	378.00	G	CLEAR
3/3/1987	182				0.00	4.71	435.00	G	CLEAR
3/24/1987	183	77.00	305.00	3.96	3.41	5.79	1,040.00	G	CLEAR
4/9/1987	184	70.00	246.00	3.51	3.05	5.30	751.00	G	
4/21/1987	185	70.00	231.00	3.30	2.52	4.94	582.00	G	
5/6/1987	186	70.00	241.00	3.44	3.00	5.24	724.00	G	
5/20/1987	187	76.00	288.00	3.79	3.10	5.71	982.00	G	
6/2/1987	188	75.00	291.00	3.88	3.02	5.66	879.00	F	CLEAR
6/23/1987	189	83.00	356.00	4.29	3.60	6.11	1,280.00	F	CLEAR
7/8/1987	190	80.00	336.00	4.20	4.08	6.35	1,360.00	F	CLEAR
8/5/1987	191	80.00	342.00	4.28	3.92	6.35	1,340.00	F	
8/31/1987	192	80.00	327.00	4.09	3.61	6.08	1,180.00	G	
9/9/1987	193	72.00	292.00	4.06	2.99	5.68	871.00	G	
10/6/1987	194	67.00	107.00	1.60	1.02	3.30	109.00	G	CLEAR
11/6/1987	195	57.00	25.90	0.45	1.51	2.72	39.20	G	CLEAR
12/1/1987	196	65.00	53.40	0.82	1.51	3.11	80.40	G	
12/21/1987	197				0.00	3.62	164.00	G	
1/21/1988	198	80.50	168.00	2.09	2.29	4.52	385.00	G	CLEAR
2/3/1988	199	86.50	101.00	1.17	1.18	3.33	119.00	G	
2/16/1988	200	72.00	128.00	1.78	1.80	3.94	230.00	G	
3/1/1988	201	72.00	237.00	3.29	2.43	4.98	576.00	G	CLEAR
3/15/1988	202	77.00	312.00	4.05	3.69	6.00	1,150.00	G	CLEAR
3/29/1988	203	69.00	300.00	4.35	3.37	5.85	1,010.00	F	CLEAR
4/26/1988	204	62.00	102.00	1.65	1.33	3.38	136.00	F	CLEAR
5/11/1988	205	70.00	209.00	2.99	2.73	4.83	572.00	F	CLEAR
5/24/1988	206	72.00	299.00	4.15	3.56	5.98	1,060.00	F	CLEAR
6/7/1988	207	76.00	320.00	4.21	3.40	5.99	1,090.00	G	LGT DEBRIS
6/23/1988	208	84.00	343.00	4.08	3.76	6.29	1,290.00	G	CLEAR
7/14/1988	209	121.00	372.00	3.07	3.74	6.44	1,390.00	G	CLEAR

7/26/1988	210	75.00	426.00	5.68	4.18	6.92	1,780.00	G	CLEAR
8/9/1988	211	88.00	343.00	3.90	3.76	6.25	1,290.00	G	CLEAR
8/22/1988	212	82.00	355.00	4.33	4.08	6.45	1,450.00	G	CLEAR
9/8/1988	213	78.00	296.00	3.79	3.38	5.76	1,000.00	G	CLEAR
9/20/1988	214	70.00	175.00	2.50	1.73	4.22	303.00	G	CLEAR
10/31/1988	215	57.00	55.70	0.98	0.66		36.60	F	
12/1/1988	216	66.00	107.00	1.62	1.68		180.00	G	CLEAR
2/10/1989	217	60.00	98.90	1.65	1.63		161.00	G	CLEAR
3/25/1989	218	66.00	259.00	3.92	2.95	5.42	765.00	G	CLEAR
5/18/1989	219	66.00	257.00	3.89	3.12		803.00	G	CLEAR
6/23/1989	220	79.00	312.00	3.95	3.65		1,140.00	G	
8/23/1989	221	82.00	322.00	3.93	3.39		1,090.00	G	CLEAR
9/26/1989	222	31.50	33.90	1.08	1.52		51.60	G	CLEAR
11/9/1989	223	21.00	17.10	0.81	0.58		9.96	G	CLEAR
1/30/1990	224	39.00	32.00	0.82	0.62		19.70	F	CLEAR
2/22/1990	225	67.00	74.40	1.11	1.53		133.00	G	CLEAR
2/23/1990	226	41.00	61.10	1.49	1.87		114.00	G	CLEAR
4/23/1990	227	65.00	110.00	1.69	1.97		217.00	G	CLEAR
5/30/1990	228	55.00	124.00	2.25	1.67		207.00		
6/8/1990	229	17.80	13.00	0.73	0.92		12.00	F	CLEAR
7/12/1990	230	23.00	16.40	0.71	1.62		26.70	G	CLEAR
7/26/1990	231	61.00	26.00	0.43	2.41		62.60	G	CLEAR
8/27/1990	232	34.50	26.00	0.75	0.77		19.50	F	CLEAR
9/28/1990	233	14.00	5.18	0.37	1.67		8.66	F	CLEAR
10/4/1990	234	19.50	7.82	0.40	1.59		12.40	F	CLEAR
11/30/1990	235	15.50	7.52	0.49	1.38		10.40	F	LGT DEBRIS
12/21/1990	236	61.50	80.90	1.32	4.02	4.01	325.00	F	CLEAR
1/10/1991	237	48.50	47.90	0.99	2.36		113.00	G	CLEAR
1/30/1991	238	36.00	38.10	1.06	1.11		42.20	F	CLEAR
3/6/1991	239	104.00	125.00	1.20	2.31		289.00	F	CLEAR
4/29/1991	240	91.00	139.00	1.53	2.38		302.00	G	CLEAR
5/14/1991	241	83.20	226.00	2.72	0.00		472.00	F	CLEAR
6/7/1991	242	83.00	252.00	3.04	0.00		672.00	F	CLEAR
8/15/1991	243	77.00	313.00	4.06	3.45	6.40	1,080.00	G	CLEAR

9/3/1991	244	72.00	309.00	4.29	3.33	6.29	1,030.00	G	CLEAR
9/16/1991	245	69.00	221.00	3.20	2.14	5.08	473.00	F	CLEAR
10/16/1991	246				0.00		147.00	G	CLEAR
11/5/1991	247	21.00	14.70	0.70	1.17	2.34	17.20	F	LGT DEBRIS
12/3/1991	248	66.00	100.00	1.52	1.36	3.74	136.00	G	CLEAR
1/14/1992	249				0.00		358.00	F	
1/30/1992	250				0.00		104.00	G	CLEAR
2/13/1992	251				0.00		464.00		CLEAR
2/14/1992	252				0.00	8.82	3,640.00	F	SUBMERGED
2/21/1992	253	81.00	141.00	1.74	1.19	4.25	177.00	F	CLEAR
3/6/1992	254				0.00	7.39	1,860.00	G	SUBMERGED
3/10/1992	255				0.00	8.52	3,160.00	G	SUBMERGED
3/31/1992	256	86.00	399.00	4.64	3.51	6.72	1,400.00	G	CLEAR
5/1/1992	257				0.00	5.92	966.00	G	
5/22/1992	258				0.00	6.45	1,170.00	G	CLEAR
6/22/1992	259				0.00	6.55	1,370.00	G	CLEAR
7/30/1992	260				0.00		1,180.00	G	CLEAR
8/28/1992	261				0.00		1,340.00	F	CLEAR
9/9/1992	262				0.00		474.00	G	CLEAR
9/16/1992	263				0.00		239.00	G	CLEAR
9/30/1992	264				0.00		159.00	G	
11/1/1992	265	44.00	51.60	1.17	0.83		42.90	E	CLEAR
11/20/1992	266	45.00	46.00	1.02	0.83		38.00	G	CLEAR
12/11/1992	267				0.00	3.55	188.00	G	
12/23/1992	268				0.00		82.10	G	
1/8/1993	269				0.00	14.76	10,500.00	F	
1/9/1993	270				0.00	26.26	31,500.00	F	
1/12/1993	271				0.00	19.42	15,400.00	P	
1/27/1993	272				0.00	16.60	11,100.00	F	
2/27/1993	273				0.00	15.08	10,400.00	F	
3/31/1993	274				0.00	10.57	4,960.00	G	
4/11/1993	275				0.00	10.26	4,750.00	G	
5/1/1993	276	122.00	231.00	1.89	1.19	3.21	286.00		
5/28/1993	277		404.00		2.60	5.07	1,050.00	G	

6/29/1993	278				0.00	5.68	1,330.00	F	CLEAR
7/28/1993	279		447.00		0.00	5.71	1,320.00	G	CLEAR
8/29/1993	280				0.00	4.81	467.00	F	CLEAR
9/16/1993	281				0.00	4.07	340.00	F	
11/1/1993	282	77.00	93.20	1.21	0.71		66.40	P	CLEAR
12/1/1993	283	57.00	45.80	0.80	2.14	2.40	97.80	F	
12/28/1993	284				0.00	3.85	349.00	G	
1/13/1994	285	100.00	167.00	1.67	1.76	3.66	294.00	F	
2/28/1994	286				0.00	4.72	654.00	F	CLEAR
3/29/1994	287				0.00	4.59	677.00	P	CLEAR
4/28/1994	288	221.00	296.00	1.34	2.76	4.84	824.00	P	CLEAR
5/25/1994	289				0.00	5.10	962.00	P	CLEAR
6/1/1994	290				0.00	4.66	703.00	P	CLEAR
6/29/1994	291				0.00	6.00	1,300.00	P	CLEAR
7/28/1994	292				0.00	6.03	1,220.00	P	SUBMERGED
8/30/1994	293				0.00	5.50	1,050.00	P	CLEAR
9/28/1994	294	77.00	78.60	1.02	1.58	2.30	123.00	P	CLEAR
10/27/1994	295	50.00	39.60	0.79	0.94		37.20	F	CLEAR
11/29/1994	296	52.00	44.60	0.86	1.18	1.70	52.50	F	CLEAR
12/6/1994	297	53.00	141.00	2.66	2.54	4.02	358.00	F	CLEAR
1/12/1995	298	55.00	206.00	3.75	1.67	3.53	343.00	F	CLEAR
1/31/1995	299	38.00	52.10	1.37	3.15	3.02	164.00	F	CLEAR
3/2/1995	300	158.00	341.00	2.16	2.25		775.00	F	CLEAR
3/23/1995	301				0.00	5.19	965.00	G	CLEAR
5/8/1995	302				0.00	4.85	854.00	F	CLEAR
5/30/1995	303				0.00	4.84	802.00	F	CLEAR
6/30/1995	304	164.00	388.00	2.37	3.14	5.70	1,220.00	G	CLEAR
7/25/1995	305				0.00	5.71	1,220.00	G	CLEAR
8/23/1995	306				0.00	5.05	885.00	F	CLEAR
9/29/1995	307	98.00	142.00	1.45	2.62	3.59	372.00	G	CLEAR
10/31/1995	308	79.00	46.80	0.59	1.14		53.20	G	CLEAR
11/21/1995	309	58.00	67.60	1.17	0.49	1.61	32.80	F	CLEAR
11/29/1995	310	20.50	17.90	0.87	2.08	1.72	36.20	G	CLEAR
1/4/1996	311	93.00	161.00	1.73	1.29	2.91	207.00	G	CLEAR

1/29/1996	312				0.00	3.16	234.00	F	CLEAR
2/29/1996	313				0.00	4.35	637.00	F	CLEAR
3/26/1996	314				0.00	5.20	1,010.00	F	CLEAR
4/30/1996	315				0.00	4.99	932.00	F	CLEAR
5/1/1996	316				0.00	4.99	964.00	F	CLEAR
5/8/1996	317				0.00	5.14	959.00	F	CLEAR
5/31/1996	318				0.00	5.02	915.00	F	CLEAR
6/19/1996	319				0.00	5.60	1,200.00	F	CLEAR
7/31/1996	320				0.00	5.40	1,050.00	F	CLEAR
8/27/1996	321				0.00	5.32	1,070.00	F	CLEAR
9/12/1996	322	112.00	154.00	1.38	3.25	3.78	500.00	G	CLEAR
9/19/1996	323	84.00	156.00	1.86	1.41	3.07	220.00	G	CLEAR
10/1/1996	324	111.00	127.00	1.14	1.91	2.99	243.00	G	CLEAR
10/30/1996	325	60.00	48.90	0.82	1.05	1.88	51.50	G	CLEAR
11/20/1996	326	63.50	64.20	1.01	0.37	1.48	23.80	F	CLEAR
12/4/1996	327	87.00	167.00	1.92	2.16	3.57	361.00	F	CLEAR
12/12/1996	328	84.50	164.00	1.94	1.88	3.41	308.00	F	CLEAR
12/23/1996	329	87.00	109.00	1.25	2.35	3.25	256.00	F	CLEAR
1/8/1997	330	68.00	125.00	1.84	1.12	2.61	140.00	G	MOD DEBRIS
1/22/1997	331	69.00	123.00	1.78	0.70	2.27	86.00	F	CLEAR
2/3/1997	332	113.00	127.00	1.12	2.32	3.20	295.00	G	CLEAR
2/28/1997	333	106.00	130.00	1.23	2.22	3.42	288.00	F	CLEAR
3/11/1997	334	71.00	199.00	2.80	2.68	4.09	538.00	F	CLEAR
3/26/1997	335				0.00	4.80	774.00	G	CLEAR
4/4/1997	336				0.00	4.34	669.00	F	
4/11/1997	337				0.00	3.90	467.00	F	CLEAR
4/22/1997	338				0.00	4.00	524.00	P	CLEAR
5/16/1997	339				0.00	4.22	595.00	F	CLEAR
6/2/1997	340				0.00	4.10	585.00	F	CLEAR
6/18/1997	341				0.00	4.30	661.00	F	CLEAR
7/15/1997	342				0.00	4.98	857.00	F	CLEAR
7/29/1997	343				0.00	4.79	807.00	F	CLEAR
8/18/1997	344				0.00	4.20	642.00	P	CLEAR
8/29/1997	345	85.00	137.00	1.61	1.28	2.78	175.00	G	CLEAR

10/1/1997	346	67.00	139.00	2.07	1.05	2.57	146.00	P	CLEAR
11/4/1997	347	66.00	27.30	0.41	0.54	1.35	14.80	F	CLEAR
11/28/1997	348	17.00	7.00	0.41	1.81	1.32	12.70	F	CLEAR
12/8/1997	349	71.00	72.10	1.02	2.32	2.75	167.00	F	CLEAR
12/30/1997	350	82.00	141.00	1.72	1.82	3.18	257.00	G	CLEAR
1/29/1998	351	75.00	93.00	1.24	1.10	2.39	103.00	F	
3/5/1998	352	87.00	113.00	1.30	2.09	3.19	236.00	F	CLEAR
3/31/1998	353				0.00	4.68	726.00	F	CLEAR
4/13/1998	354	82.50	204.00	2.47	2.60	3.97	534.00	F	CLEAR
5/1/1998	355	91.00	180.00	1.98	2.92	4.24	526.00	F	CLEAR
5/28/1998	356				0.00	4.52	773.00	F	CLEAR
6/17/1998	357				0.00	4.54	727.00	F	CLEAR
7/13/1998	358				0.00	4.69	746.00	F	
8/11/1998	359				0.00	5.15	1,030.00	F	CLEAR
9/29/1998	360	83.00	152.00	1.83	1.82	3.38	278.00	G	CLEAR
10/6/1998	361	82.00	150.00	1.83	1.75		262.00	F	CLEAR
10/30/1998	362	51.00	26.80	0.53	1.09		28.40	F	CLEAR
12/4/1998	363	91.00	140.00	1.54	2.52		353.00	F	CLEAR
12/30/1998	364	103.00	176.00	1.71	2.08		366.00	F	
1/8/1999	365	79.00	95.10	1.20	0.82	2.60	79.00	F	CLEAR
2/9/1999	366	69.00	119.00	1.72	1.42		169.00	F	SUBMERGED
2/17/1999	367	84.00	117.00	1.39	1.51		187.00	F	CLEAR
3/31/1999	368	85.00	146.00	1.72	2.02		294.00	F	
4/21/1999	369	80.00	109.00	1.36	1.46		159.00	F	
5/27/1999	370	83.00	155.00	1.87	2.41		374.00	F	
6/2/1999	371	55.00	36.30	0.66	1.26		45.30	P	
6/3/1999	372	59.00	61.70	1.05	0.48		29.30	F	CLEAR
6/17/1999	373	29.50	14.40	0.49	0.24		3.45	P	CLEAR
6/17/1999	374	29.50	15.10	0.51	0.23		3.54	P	
6/29/1999	375	3.50	1.07	0.31	0.67	1.29	0.77	P	
6/29/1999	375A	3.50	1.08	0.31	0.62	1.29	0.67	P	CLEAR
7/14/1999	376	75.00	69.60	0.93	0.64		44.50	F	
7/26/1999	377	82.00	135.00	1.65	1.58		226.00	P	
9/3/1999	378	68.00	174.00	2.56	1.82		316.00	F	CLEAR

10/13/1999	379	76.00	104.00	1.37	1.05		109.00	F	CLEAR
11/2/1999	380	48.00	25.80	0.54	0.36	1.58	9.36	P	CLEAR
12/2/1999	381	53.00	33.00	0.62	0.36	1.80	11.90	P	CLEAR
12/28/1999	382	82.00	101.00	1.23	1.44	2.72	146.00	P	CLEAR
1/3/2000	383	73.00	89.80	1.23	1.19	2.58	107.00	P	CLEAR
1/28/2000	384	81.00	98.70	1.22	1.44	2.77	142.00	F	CLEAR
2/28/2000	385	81.50	98.90	1.21	1.78		176.00	F	CLEAR
3/29/2000	386	93.50	133.00	1.42	2.54		338.00	F	SUBMERGED
4/28/2000	387	81.00	162.00	2.00	1.98		320.00	P	CLEAR
5/22/2000	388	87.00	94.20	1.08	1.43		134.00	P	CLEAR
6/9/2000	389	9.50	2.06	0.22	0.89		1.82	P	CLEAR
6/15/2000	390	8.00	1.61	0.20	0.45		0.73	P	CLEAR
6/21/2000	391	76.00	74.40	0.98	1.09		81.00	P	CLEAR
6/27/2000	392	10.00	3.05	0.31	1.04		3.17	P	CLEAR
7/26/2000	393	3.00	0.41	0.14	0.49		0.20	P	CLEAR
8/2/2000	394	3.30	0.37	0.11	0.57		0.21	P	CLEAR
9/6/2000	395	66.00	80.60	1.22	0.40		32.30	P	CLEAR
10/9/2000	396	1.00	0.28	0.28	1.04		0.28	P	
12/1/2000	397	82.00			0.00		27.00	F	
12/15/2000	398	65.00	251.00	3.86	1.31		329.00	F	
1/26/2001	399	75.00	64.00	0.85	0.00		34.20	P	
2/16/2001	400	80.00	187.00	2.34	2.57		481.00	P	CLEAR
2/23/2001	401	44.00	55.50	1.26	2.09		117.00	F	CLEAR
2/27/2001	402	45.00	99.00	2.20	1.61		160.00	F	CLEAR
3/27/2001	403	72.00	275.00	3.82	2.70		750.00	F	LGT DEBRIS
4/30/2001	404	87.00	114.00	1.31	3.55		404.00	F	CLEAR
6/26/2001	405	68.00	264.00	3.88	2.69		711.00	F	CLEAR
8/6/2001	406	66.00	199.00	3.02	2.32		462.00	F	CLEAR
8/31/2001	407	65.00	181.00	2.78	2.23		404.00	G	CLEAR
10/16/2001	408	63.00	122.00	1.94	1.84		224.00	F	CLEAR
10/26/2001	409	62.00	110.00	1.77	1.92		211.00	F	CLEAR
11/5/2001	410	30.00	18.90	0.63	0.62		11.80	F	CLEAR
12/10/2001	411	62.00	130.00	2.10	2.02		263.00	F	CLEAR
1/3/2002	412	61.00	112.00	1.84	1.25		140.00	F	CLEAR

2/7/2002	413	60.00	83.50	1.39	1.25	104.00	F	CLEAR
3/6/2002	414	63.00	134.00	2.13	1.99	267.00	P	CLEAR
3/20/2002	415	62.00	127.00	2.05	2.03	258.00	F	CLEAR
4/3/2002	416	62.00	69.10	1.11	0.79	54.50	G	CLEAR
5/1/2002	417	11.00	5.78	0.53	1.46	8.44	F	LGT DEBRIS
5/23/2002	418	9.00	3.05	0.34	0.24	0.74	F	CLEAR
7/9/2002	419				0.00	0.02	P	CLEAR
8/7/2002	420	62.00	71.60	1.15	1.15	82.50	F	CLEAR
9/4/2002	421	4.90	1.08	0.22	0.11	0.12	P	CLEAR
9/18/2002	422	29.00	50.60	1.74	1.58	80.20	F	CLEAR
10/3/2002	423	58.00	99.20	1.71	1.03	102.00	F	CLEAR
11/1/2002	424	19.00	8.64	0.45	0.45	3.91	F	CLEAR
11/14/2002	425	7.00	2.64	0.38	0.32	0.85	P	MOD DEBRIS
11/27/2002	426	7.00	2.61	0.37	0.45	1.18	P	MOD DEBRIS
12/31/2002	427	66.00	60.00	0.91	1.03	61.80	F	CLEAR
1/29/2003	428	67.00	55.70	0.83	1.02	56.80	F	
3/3/2003	429	111.00	169.00	1.52	2.25	380.00	F	CLEAR
3/27/2003	430	87.00	170.00	1.95	2.28	387.00	F	CLEAR
5/1/2003	431	59.00	85.30	1.45	1.35	115.00	F	CLEAR
5/19/2003	432	58.00	70.00	1.21	1.08	75.50	F	CLEAR
5/29/2003	433	21.00	13.20	0.63	1.74	23.00	F	CLEAR
7/1/2003	434	3.90	0.84	0.22	0.21	0.18	P	LGT DEBRIS
8/1/2003	435	29.00	35.20	1.21	2.13	75.00	P	CLEAR
9/5/2003	436	3.80	0.80	0.21	0.55	0.44	P	CLEAR
9/26/2003	437				0.00	0.05	P	
11/6/2003	438				0.00	0.01	P	CLEAR
12/8/2003	439	11.00	2.95	0.27	0.07	0.20	P	CLEAR
12/16/2003	440	65.00	68.40	1.05	1.23	83.80	F	CLEAR
2/10/2004	441	66.00	86.80	1.32	1.54	134.00	F	CLEAR
2/27/2004	442	66.00	86.80	1.32	1.51	131.00	F	CLEAR
3/6/2004	443	52.00	216.00	4.15	3.37	964.00	P	CLEAR
3/12/2004	444	55.00	135.00	2.45	1.91	258.00	F	CLEAR
3/22/2004	445	55.00	139.00	2.53	2.15	299.00	P	CLEAR
4/1/2004	446	57.00	146.00	2.56	2.15	299.00	G	CLEAR

4/27/2004	447	56.00	153.00	2.73	2.27		347.00	F	CLEAR
6/3/2004	448	10.20	7.82	0.77	1.27		9.92	P	CLEAR
6/30/2004	449				0.00		0.32	P	CLEAR
8/11/2004	450	33.00	48.60	1.47	1.31		63.80	F	CLEAR
8/24/2004	451	54.00	104.00	1.93	1.79		186.00	F	CLEAR
9/30/2004	452	12.40	4.94	0.40	1.56		7.69	F	CLEAR
10/25/2004	453	6.70	1.80	0.27	0.46		0.83	P	HVY DEBRIS
11/17/2004	454				0.00	2.59	0.32	P	HVY DEBRIS
12/14/2004	455	63	72.7	1.15	1.53	3.02	111.00	F	CLEAR
1/10/2005	456	24	30.6	1.28	2.44	2.92	74.70	F	CLEAR
2/8/2005	457	26.5	47	1.77	3.26	3.70	153.00	P	CLEAR
2/23/2005	458	55	165	3.00	2.39	5.10	395.00	P	CLEAR
3/25/2005	459	56	156	2.79	2.48	5.05	387.00	F	CLEAR
5/5/2005	460	61	179	2.93	2.59	5.30	463.00	F	CLEAR
5/25/2005	461	77	204	2.65	2.95	5.64	602.00	F	CLEAR
6/23/2005	462	83	179	2.16	3.96	5.68	709.00	G	CLEAR
9/27/2005	463	46	144	3.13	1.82	4.87	262.00	F	CLEAR
11/3/2005	464	43.5	37.3	0.86	0.65	3.53	24.10	F	CLEAR
12/1/2005	465	23	15.5	0.67	0.76	3.26	11.80	F	
12/6/2005	466	59	157	2.66	2.26	5.10	355.00	G	CLEAR
1/9/2006	467	46	76.5	1.66	1.41	4.15	108.00	F	CLEAR

Appendix B
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SUMMARY

Mr. Gookin has been involved in river movement studies, demographics, power and energy contracts and studies, various phases of engineering design and surveying, economic analyses and hydrologic fields, such as groundwater, surface water and flood control. Mr. Gookin is co-author of the computerized "Call System" adopted by the United States District Court to administer diversions on the Gila River mainstem. Mr. Gookin has also been a lecturer to the Arizona State Bar on "Subflow" in Arizona.

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West High School - Phoenix, Arizona
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Arizona State University - Tempe, Arizona
B.S. in Engineering - With Distinction

SEMINARS AND OTHER STUDIES

2010 HEC-RAS
2009 Editor - AIH/AHS Conference Proceedings
2009 Co-chair and Presenter – AIH/AHS Annual Conference
2007 Presenter – AIH Annual Conference
2006 Resolving Conflicts of Survey Evidence Seminar
2006 Incoming AIH Vice-President for Institutional Development
2006 AIH Conference
2006 Urban Watershed Mgmt. Seminar
2005 Single-Family Plan Rev. Workshop
2004 Presenter – AIH Annual Conference
2004 Arizona Boundary Law Conference
2004 Pipe Design, Installation, Inspection Seminar
2003 ADS Training Seminar
2003 Land Survey Seminar - COS
2003 Instructor on Subflow Arizona Water Law Conference
1997 Understanding & Protecting Your Water Rights in Arizona Seminar
1994 Cybernet
1987 HEC-1
1985 Engineering Management
1983 Hydrology & Hydraulics
1979 Survey Boundary Control
1977 Modeling of Rivers
1977 Civil Engineering Review Course
1976 Hydraulics and Hydrology Seminar
1976 Fundamentals of Engineering Rev.
1975 Surveyor's Review Course

REGISTRATIONS

CA	27892	Civil Engineer
AZ	12255	Civil Engineer
AZ	15864	Land Surveyor
NV	8169	Civil Engineer
NV	1242	State Water Right Surveyor
A.I.H.	949	Hydrologist

PROFESSIONAL HONORS

NSPE Young Engineer of the Year, Papago Chapter, 1979
Order of the Engineer
Tau Beta Pi Honorary Engineering Fraternity
Who's Who in the West
Who's Who in America
Who's Who in the World
Who's Who in Finance and Industry
Who's Who of Emerging Leaders in America
Who's Who in Science and Technology
Who's Who in American Colleges & Univ.
Outstanding Engineering Project - ASPE

PROFESSIONAL AFFILIATIONS

Member of:
AZ Board of Technical Registration
Engineering Enforcement Committee,
Land Surveying Enforcement Committee,
Past President - Papago Chapter NSPE
American Society of Civil Engineers
Arizona Department of Water Resources
Subflow Delineation Committee
American Institute of Hydrology (AIH)
National Vice President, 2007-8
National Treasurer, 2009 - present
Arizona Hydrological Society (AHS)

PUBLISHED ARTICLES

"Annual Virgin Flows of Central Arizona" (2009)
"Stockpond Seepage in Southern Arizona" (2007)
"Subflow The Child of the Stream" (2007)
"Pumping and Globe Equity No. 59 – The Turner Study" (2006)
"Groundwater Recharge from the Gila River in Safford, Arizona" (2005)

RELEVANT EXPERIENCE -
DAM OPERATION

- **SALT RIVER SYSTEM** - Reviewed yields of various operation criteria for utilization in Indian Water Rights Hearings.

- **SALT RIVER FLOODING** - Computed means by which peak flood flows could have been reduced using snow survey data.

- **HOOVER 1983 FLOODING** - Represented Needles in litigation concerning flood releases from Hoover Dam.

- **CAP OPERATIONS** - Computed Colorado River Dam operations under proposed AWC operating criteria.

- **ALAMO DAM** - Provided testimony concerning downstream impacts of water releases on riparian habitats.

- **IDAHO** - Computed and routed maximum probable flood for dam safety analysis.

- **GE #59** – Prepared numerous Reservoir Operation Studies of Coolidge Dam to:
    1. Maximize water yield under provisions of the Gila Decree and
    2. Determine penstock capacities of Coolidge Dam at various “heads”.

- **INDIAN CLAIMS COMMISSION** – Determining sustainable yields of Buttes and Orme Dams under 1883 watershed conditions.

- **GRIC SETTLEMENT** – Prepare reservoir operations under “equal sharing” concepts. Also computed spill probabilities due to reserved storage.

- **HATCH** – Computed and testified to the amount of water that could be developed for municipal use in Tucsyan.

- **ARIZONA (BABBITT) SETTLEMENT** – Worked with representatives of the Arizona Water Commission and the Bureau of Reclamation to identify and prepare preliminary cost estimates of numerous water development scenarios.

- **BUREAU OF INDIAN AFFAIRS** - Prepared computer models to determine the impact and total usable supplies given various states of regulation on both the Salt and Gila Rivers, taking into account the interaction between the surface and groundwater regime.

- **CENTRAL ARIZONA PROJECT** - Prepared computer models to analyze yield situation under various scenarios of reservoir operation.

RELEVANT EXPERIENCE – SURFACE HYDROLOGY

- **LINCOLN RANCH** - Testified regarding water rights values and water exchanges as they relate to Lincoln Ranch on the Bill Williams River.

- **PAYSON** - Prepared study analyzing the ability of Payson to divert from the East Verde River.

- **NORTHERN PUEBLOS TRIBUTARY WATER RIGHTS ASSOCIATION** - Testified on the ability of an irrigation system to divert water and provide an integrated surface groundwater irrigation supply. Also analyzed and laid out an irrigation system and computed cost feasibility thereof.

- **PRESCOTT** - Analyzed flows of Verde River to compute various diversion schemes that would minimize the impact of riparian habitat downstream from the diversion. Responsible for report which analyzed potential for conservation through rate structures. Also worked on analyses of water requirements and savings.

- **GILA RIVER INDIAN COMMUNITY** -Computed the impact of depletions upstream from the Gila River Indian Reservation upon flows of the Gila River.

- **MAHONEY** - Reviewed evidence concerning water measurements.

- **SALT RIVER INDIAN COMMUNITY** - Determined the virgin surface water flow available from the Salt River and the surface virgin water flow available to the Central Arizona area as a whole.
- **SUPERIOR COMPANIES** - Prepared determinations of normal high flows at ungaged locations. Plotted mean high water channel boundaries.
- **TEMPE** - Prepared analysis showing adequacies of existing supplies and supplementation recommendations.

- **ARIZONA (BABBITT) SETTLEMENT** – Worked with representatives of the Arizona Water Commission and the Bureau of Reclamation to identify and prepare preliminary cost estimates of numerous water development scenarios.

- **ARIZONA WATER RIGHTS SETTLEMENT VALIDATION** – Prepared and presented depositional testimony quantifying available water right claims under PIA, Prior Appropriation and existing Court Decrees.

RELEVANT EXPERIENCE –
SURFACE HYDROLOGY

- **FIVE CENTRAL ARIZONA INDIAN TRIBES** - Studied the use of irrigation water of the five Central Tribes.

- **IRRIGATION DISTRICTS** - Computed agricultural, municipal and industrial water requirements as well as design of a tentative canal layout for the Queen Creek, San Tan, Harquahala, McMicken and Chandler Heights Citrus Irrigation Districts.

- **GLOBE EQUITY** – Study operation of Gila Decree (Globe Equity #59) and its impact on the Gila River Indian Community. Prepared numerous river operation studies for various settlement options.

- **SAN PEDRO HSR** - Reviewed, provided comments and detailed analysis on the HSR Report. Examined the Jenkins Surface/Groundwater Inter- action Formula.

- **TOHONO O'ODHAM NATION** - Designed gaging stations for surface stream measurements. Examined surface flows for San Simon Wash.

- **UPPER SALT RIVER HSR** - Reviewed and commented on Hydrographic Survey Report.

- **CALL SYSTEM** – Primary creator and co-author of the Globe Equity No. 59 Call System. The Call System is a computerized water rights administrative procedure and tool. The Call System is currently being used by the Gila Water Commissioner to "run the river."

- **SUBFLOW** – Testified before the Superior Court on the legal/physical characteristics of the Younger Alluvium and Subflow.

- **SUBFLOW II** – Testified before the Special Master on the interpretation of the Arizona Supreme Court Gila IV decision and application of that decision in delineating the Subflow zone.

- **CUFA** – Assisted in negotiations of the Consumptive Use Forbearance Agreement between the Arizona Parties and the State of New Mexico. Prepared analyses of divertible water from the upper Gila subject to restrictions of Arizona v. California, the Colorado River Basin Development Act and Globe Equity No. 59.

RELEVANT EXPERIENCE – HYDRAULICS

- **JOINT PROJECT** - Writing and utilizing computer programs for computation of natural and artificial streams for backwater, inflow and drawdown occurrences, as well as sizing pipelines and flood control channels.

- **SAN CARLOS IRRIGATION DISTRICT** - Designed interconnection between Hohokam main lateral and Pima lateral.

- **PRESCOTT** - Use of computer programs for computing natural and artificial streams for backwater inflow and drawdown occurrences.

- **SCOTTSDALE** - Utilization of computer programs to compute natural and artificial backwater inflow, as well as sizing and flood control channels.

- **WOOLLEY** - Responsible for calculating backwater and drawdown occurrences.

- **COOLIDGE DAM** - Computed penstock capacity curves.

- **DESERT MOUNTAIN** - Computed water hammer times and loads. Designed valving to prevent hammers in the high pressure main.

- **ADAMAN WATER COMPANY** - Supervised design of cast-in-place concrete pipeline to interconnect Beardsley Irrigation System to Adaman Water Company.

- **JAREN** - Prepared Master Plan of pipeline distribution system for Rawhide Water Co. Designed computer program for Pipe Network Solutions.

- **JOHN NORTON SUBDIVISIONS** - Assisted in design of waterlines and sewers for subdivision. The water systems involved loopback to the City system and pipelines, wells and a pressure system.

- **GRIFFIN** - Provided design of well and water production facilities.

- **DYSART** - Provided design of water line fire loops for Dysart High School and cafeteria expansion. Design and inspection of sewer line hookups and off-site lines with lift station to treatment plant. Computed Hardy Cross water system analysis and built necessary connections. Provided design alternatives to water hookups with El Mirage for treatment of nitrates.

- **BRW** - Consultant for the design and sizing of water production and transportation facilities.

- **NADABURG** – Designed water system for service to school including well, storage tank and pumps.

RELEVANT EXPERIENCE -
RIVER MOVEMENT STUDIES

- **THOMAS THODE** - Prepared testimony concerning avulsions and accretions near the Yuma Island and the confluence of the Gila and Colorado Rivers.

- **GILA RIVER INDIAN COMMUNITY** - Analyzed the historic meanderings of the Salt and Gila Rivers near their junction and their impact on the Gila River Indian Reservation boundary.

- **NATIONAL INDIAN YOUTH COUNCIL** - Testified to a sub-committee of the U. S. House of Representatives concerning river movements of the Arkansas River.

- **WOOLLEY** - Studied the cause of the migration of the flows from one channel to another on the Salt River during flooding.

- **PALO VERDE VALLEY FARMLAND ASSOCIATION** - Aided in research and testimony preparation in study concerned with accretion and avulsion for various lawsuits.

- **SALT RIVER INDIAN RESERVATION** - Aided in research, analyzed data, and participated in the preparation of a report concerning the thalwag of the Salt River and its movements.

- **PETERSON VS. USA** - Researched, reported and prepared testimony regarding river movements near Bullhead City.

- **SIMONS VS. RIO COLORADO DEVELOPMENT CO.** - Performed on-site inspection, research and prepared report concerning the influence of levees on river channels near Needles.

- **ARIZONA STATE NAVIGABILITY COMMISSION** – Presented testimony concerning changes in the Salt and Gila River channel characteristics.

RELEVANT EXPERIENCE – GROUNDWATER

- **NORTHERN PUEBLOS TRIBUTARY WATER RIGHTS ASSOCATION** - Supervised a portion of the highly technical and complex testing program used in preparing a 3 dimensional leaky artesian computer model.

- **SAFFORD VALLEY** - Analyzed interaction between the Gila River and the groundwater of the Safford Valley.

- **J. ED SMITH WELL** - Co-authored report that was submitted in evidence before the U. S. District Court about the impact of the well upon river flows.

- **PRESCOTT** - Supervised the well test on an exploration hole and wrote a comprehensive report concerning the results of the pump test and aquifer characteristics.

- **NADABURG** – Prepared specifications and field inspections for a well drilled as a part of a water system for the Nadaburg School.

- **FIVE CENTRAL ARIZONA INDIAN TRIBES** - Researched the impact of a well system for use by the Bureau of Indian Affairs.

- **BELLAMAH COMM. DEV.** - Studied groundwater reserves in the East Carefree basin. Determined physical and legal constraints on development potential.

- **GRIFFIN COMPANY** - Designed well and water system for truck stop west of Tolleson.

- **GILA RIVER INDIAN RESERVATION** - Conducted research of groundwater availability and location of wells. Co-authored report concerning the need for non-Project wells. Assisted in the construction of an emergency drought relief system as well as participating in negotiations, preparations of specifications, design of well screens and field /inspections.

- **GE #59 AND HISTORY OF PUMPING** – Provided testimony concerning pumping history and evidence of coverage of pumping by Globe Equity #59 impacts. Received the following accolade from U. S. District Court Judge Coughenour "…let me help them understand how enormously helpful I have found Mr. Gookin's testimony to be and how proud we should be to have somebody of his caliber helping you with this case."

- **ARIZONA GAME AND FISH** - Prepared a hydrologic analysis of the groundwater resource potential and reliability of Pinetop Springs and local wells.

- **MARICOPA ALLIANCE** - Studied the impact of landfills on groundwater in the western Phoenix area.

RELEVANT EXPERIENCE – GROUNDWATER

- **PAYSON** - Supervised pump test and evaluated reliability of and recharge to a fractured rock groundwater system.

- **FLETCHER FARMS** - Demonstrated an assured water supply on the west side of Phoenix.

- **CHANDLER HEIGHTS CITRUS IRRIGATION DISTRICT** - Responsible for all phases of the preparation of specifications and receipt of bids for the construction of a multi-purpose well.

- **SAFFORD** - Prepared analysis of the interrelationship between surface and groundwater in Safford Valley. Aided and reviewed computer modeling using MODFLOW.

- **SAN PEDRO HSR** - Prepared detailed analysis of the validity of failing to meet assumptions under the Jenkins Formula.

- **TOHONO O'ODHAM** - Computed groundwater recharge from all sources.

- **SUBFLOW** – Testified before the Court on the legal/physical characteristics of the Younger Alluvium and Subflow.

- **SUBFLOW II** – Testified before the Special Master on the interpretation of the Arizona Supreme Court Gila IV Decision and application of that decision in delineating the subflow zone.

- **W&EST, INC**. – Provide historic water use information and historic consumptive use data for use in a groundwater model for Central Arizona Basin area.

- **PAYSON WELL (GAIL TOVEY)** - Assist Gayle Tovey in performing pump test on her property in Payson.

- **ARIZONA (BABBITT) SETTLEMENT** – Worked with representatives of the Arizona Water Commission and the Bureau of Reclamation to identify and prepare preliminary cost estimates of numerous water development scenarios.

RELEVANT EXPERIENCE –
SURVEYING AND LEGAL DESCRIPTIONS

I have prepared numerous surveys for houses, commercial developments and schools that are not listed. The following represents the more complex studies performed.

- **DESERT SUN SUBDIVISION** - Assisted in the layout of Desert Sun Subdivision.

- **PALO VERDE VALLEY** - Responsible for examination and comparison on boundary surveys between Arizona and California along the Colorado River.

- **HANCOCK** - Prepared subdivision plat near Bullhead City, Arizona.

- **JOHN NORTON – SUBDIVISIONS** - Assisted in design of waterlines and sewers for subdivision. The water systems involved loopback to the City system and pipelines, wells and a pressure system.

- **FONTES – STARR** – Provided consultation to resolve survey difficulties.

- **VALTECH** - Provided ALTA Survey of Los Arcos Mall in Scottsdale, Arizona.

- **BLUE RIDGE UNIFIED SCHOOL DISTRICT #32** - Responsible for topographic site survey of property lines and existing physical conditions of the site, monument markers, bench marks, legal description, sidewalks, curbs and gutters, utility locations, topographic map and boundary survey drawing, playground area, as-built plans, traffic control signal, maintenance and transportation facility, parking lot.

- **DYSART** - Provided as-built survey of Dysart High School.

- **STATE OF ARIZONA PARKING** - Construction staking for parking lot and storm drainage line.

- **SAN CARLOS IRRIGATION & DRAINAGE DISTRICT** - Provided surveys for intertie of Central Arizona Project Aqueduct into Florence - Casa Grande Canal.

- **SQUATTER SURVEY** – Review survey history and survey site to locate property corners, section corners, encroachments, and to establish location of existing features on site.

- **WATER RIGHT TRANSFER** – Evaluate over 100 applications for the sever and transfer of water rights. Provide affidavits on inadequacy of legal descriptions Testified in U. S. District Court as to the inadequacies of 10 test case applications. Also provided testimony of the history, development and accuracy of the Gila Water Commissioner’s Decree map.

RELEVANT EXPERIENCE –
EXPERT WITNESS

- **LINCOLN RANCH** - Provided testimony regarding water rights values and water exchanges as they relate to Lincoln Ranch on the Bill Williams River.

- **NORTHERN PUEBLOS TRIB. WATER RIGHTS ASSOC.** - In charge of preparation of canal delivery systems. Presented testimony on P.I.A.

- **NEEDLES** - Prepared and presented expert testimony concerning power contracting with the Department of Energy.

- **HATCH** – Provide testimony concerning the amount of water being generated from an ungaged watershed during pre and post development conditions. Also testified concerning potential water contamination from a neighboring airport.

- **IDAHO** – Computed and routed maximum probable flood for dam safety analysis. Provide depositional testimony.

- **PRESCOTT** - Provided expert testimony concerning the magnitude of flooding on Willow Creek.

- **WINDOW ROCK** - Provided testimony concerning the value of a substandard sewer system.

- **GILA DECREE** - Provided testimony on numerous occasions concerning provisions of the Gila River Decree and its impacts on the allocation of water between different users.

- **FORT MOHAVE** - Provided testimony regarding hydropower contracting from Colorado River Storage Project.

- **ALAMO DAM** - Provided testimony concerning downstream impacts of water releases on riparian habitats.

- **WOOLLEY vs. SALT RIVER PROJECT** – Provided depositional testimony concerning the cause of the floods of 1978, 1979, 1980 and 1983 in the Salt River and their impact on the river channel. Evaluated damages in water elevations and determined scour in the channel during the flood events.

- **JOHN FRANK** – Provide testimony concerning the impact of breeches in levies along the Colorado River on neighboring lands.

- **THODE** - Presented testimony concerning historic river movements in the area where the Gila River joins with the Colorado River.

RELEVANT EXPERIENCE - EXPERT WITNESS

- **PETERSON VS. USA** - Researched, reported and prepared testimony regarding historic river movements near Bullhead City.

- **BOULDER CREEK** - Provide expert witness testimony for Boulder Creek Ranch, Inc. Provide deposition testimony on the value of surface water rights for water from the Agua Fria River and Boulder Creek. Perform water right valuation including the acreage at the headwaters of Lake Pleasant and the leased acreage appurtenant to and surrounding it. Subject property was used as part of a cattle ranching operation with fee lands leased from private parties, grazing lands leased from the State of Arizona, and grazing privileges leased from the BLM.

- **NATIONAL INDIAN YOUTH COUNCIL** - Presented testimony to a subcommittee of the U. S. House of Representatives of historic river movements of the Arkansas River.

- **COYOTE WASH**-Expert assistance regarding Plourd v. IID et al. break. Computed storm frequencies. Determined cause of channel failure and course of flood waters exiting channel breach. Reviewed Coyote Wash depositions. Provided deposition and expert witness testimony in El Centro, California.

- **SUBFLOW** – Testified before the Arizona Superior Court on the legal/physical characteristics of the Younger Alluvium and Subflow.

- **SUBFLOW II** – Testified before the Special Master on the interpretation of the Arizona Supreme Court Gila IV decision and application of that decision in delineating the subflow zone.

- **ARIZONA BILTMORE** – Provided review of studies by the Corps of Engineers concerning ACDC in Reaches 1, 2, 3 and 4. Provided detailed analyses of flows out of Cudia City Wash. Testified to the City of Phoenix.

- **AAMODT** - Evaluated quality of water for growth of crops in conjunction with various soils in the area and provided expert testimony.

- **SALT RIVER SYSTEM** - Reviewed yields of various operation criteria for utilization in Indian Water Rights Hearings.

- **SALT RIVER FLOODING** - Computed means by which peak flood flows could have been reduced using snow survey data.

- **HOOVER 1983 FLOODING** - Represented Needles in litigation concerning flood releases from Hoover Dam.

RELEVANT EXPERIENCE -
EXPERT WITNESS

- **CAP OPERATIONS** - Computed Colorado River Dam operations under proposed AWC operating criteria.

- **IDAHO** - Computed and routed maximum probable flood for dam safety analysis.

- **INDIAN CLAIMS COMMISSION** – Determining sustainable yields of Buttes and Orme Dams under 1883 watershed conditions.

- **GRIC SETTLEMENT COURT RATIFICATION** - Provided a PIA Justification for Court approval of the Arizona Water Rights Settlement. Presented depositional testimony.

- **DE MINIMIS** – Provided report and testimony on hydrologic impacts of "de minimis" domestic, stock- watering, and stockpond uses.

- **GOLD CANYO**N – Provided expert testimony on failure of flood control system and regulatory impacts of sewage spills.

- **SALTON SEA** – Expert testimony concerning the impact of tropical storms Doreen and Kathleen and irrigation practices of the irrigation district on the Salton Sea elevations.

- **GE #59 AND HISTORY OF PUMPING** – Provided testimony concerning pumping history and impacts. Received the following accolade from U. S. District Court Judge Coughenour "…let me help them understand how enormously helpful I have found Mr. Gookin's testimony to be and how proud we should be to have somebody of his caliber helping you with this case."

- **ALAMO DAM –** Provided expert testimony concerning impacts of water releases on downstream riparian habitats.

- **GE #59 –** Prepared testimony on numerous Decree provisions in comparison of historic operations. Provided design of the Call System computer program adopted by the United States District Court and currently being used by the Gila Water Commissioner to allocate river flows under Globe Equity #59.
  - Worked with the Gila River Indian Community on arranging fish pool exchanges in 1990, 1997, and 1999.
  - Worked with the Gila River Technical Committee to resolve issues concerning fish pool accounting and wells.
  - Prepared numerous Reservoir Operation Studies of Coolidge Dam to:
    Maximize water yield under provisions of the Gila Decree and
    Determine penstock capacities of Coolidge Dam at various "heads".

RELEVANT EXPERIENCE – EXPERT WITNESS

- **HATCH –** Computed and testified to the amount of water that could be developed for municipal use in Tucsyan. Provided expert testimony concerning water contamination potential from a neighboring airport.

- **ARIZONA WATER RIGHTS SETTLEMENT VALIDATION** – Prepared and presented depositional testimony quantifying available water right claims under PIA, Prior Appropriation and existing Court Decrees.

- **WATER RIGHT TRANSFER** – Evaluate over 100 applications for the sever and transfer of water rights. Provide affidavits on inadequacy of legal descriptions Testified in U. S. District Court as to the inadequacies of 10 test case applications. Also provided testimony of the history, development and accuracy of the Gila Water Commissioner's Decree map.

- **DUGAN** – Determine cause of home flooding and provide expert testimony relating to the cause and remedy.

RELEVANT EXPERIENCE -
HYDROLOGIC HISTORY

- **HYDROLOGIC HISTORY OF THE GILA RIVER INDIAN RESERVATION** – Author of a report determining irrigation development from 1876 to 1924 and hydrologic impacts of non-Indian irrigation on the Gila and Salt River system and tributaries. Prepare analysis of virgin state conditions in Arizona.

- **CIRCULARITY** – Provided historic research on San Carlos Apache buyout provisions of Globe Equity #59.

- **POOLING REPORT** – Prepare historic analysis of origination and changes in the Pooling provisions of the San Carlos Indian Irrigation Project.

- **236-C** – Prepared analysis of virgin flows and the progression of irrigation depletion of the Gila River.

- **NATIONAL INDIAN YOUTH COUNCIL** – Presented testimony to a subcommittee of the U. S. House of Representatives of historic river movements of the Arkansas River.

- **PALO VERDE VALLEY FARMLAND ASSOCIATION** - Aided in research and testimony preparation in study concerned with historic accretion and avulsion of the Colorado River for various lawsuits.

- **HATCH** – Provided testimony concerning the amount of water being generated from an ungaged watershed during pre and post development conditions.

- **GE #59 AND HISTORY OF PUMPING** – Provided testimony concerning pumping history and impacts. Received the following accolade from U. S. District Court Judge Coughenour "…let me help them understand how enormously helpful I have found Mr. Gookin's testimony to be and how proud we should be to have somebody of his caliber helping you with this case."

- **THODE** – Presented testimony concerning historic river movements in the area where the Gila River joins with the Colorado River.

- **PETERSON VS. USA** - Researched, reported and prepared testimony regarding historic river movements near Bullhead City.
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- **GILA RIVER INDIAN COMMUNITY** – Analyzed the historic meanderings of the Salt and Gila Rivers near their junction and their impact on the Gila River Indian Reservation boundary.

- **INDIAN CLAIMS COMMISSION** – Determining sustainable yields of Buttes and Orme Dams under 1883 watershed conditions.
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- **W&EST, INC.** – Provide historic water use information and historic consumptive use data for use in a groundwater model for central Arizona basin area.

- **FISH POOL –** Study history of San Carlos Reservoir operations and their impact on fish kills.