17

GEOMORPHIC CHARACTER OF THE UPPER SALT RIVER

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028

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A study of the Upper Salt River upstream of the Granite Reef Dam was undertaken to determine the character of the river at statehood on February 14, 1912. To accomplish this, there was a review of published and unpublished reports, a low-level helicopter flight over the river (September 24, 2004), a study of U.S. Geological Survey topographic maps, and of 1934 aerial photographs. These activities provide a firm basis for the development of conclusions regarding the morphologic character of the river and the dynamics of the channel, both before and after statehood.

RIVER TYPES

In order to understand the morphologic character and the behavior of the Upper Salt River, it is necessary to consider the range of river types that exist and the Salt River's place within the continuum of river types. Depending on the nature of the materials through which a river flows, there are three major categories of stream channels: (1) confined, (2) constrained, and (3) alluvial. The confined channel is fixed in position by bedrock or resistant alluvium, and it is stable over long periods of time. The constrained channel is controlled only locally by bedrock or resistant alluvium. The alluvial channel has bed and banks composed of sediment transported by the stream. Therefore, the alluvial channel is susceptible to major pattern change and to significant shifts in channel position as the alluvium is eroded, transported, and deposited, and as the sediment load and water discharge change. The position of the confined and constrained channels is fixed by resistant material. For example, width is limited by valley walls, but the channel can aggrade or degrade.

For simplicity and convenience of discussion, the range of common alluvial channel patterns can be grouped into five basic patterns (**Figure 1**). These five patterns illustrate the overall range of channel patterns to be expected in nature. Figure 1 is more meaningful than a purely descriptive classification of channels because it is based on cause-and-effect relations and illustrates the differences to be expected when the type of sediment load, flow velocity, and stream power differ among rivers. It also explains pattern differences along the same river (Schumm, 1977).

Numerous empirical relations demonstrate that channel dimensions are largely due to water discharge, whereas channel shape and pattern are related to the type and amount of sediment load moved through the channel. As indicated by Figure 1, when the channel pattern changes from 1 to 5, other morphologic aspects of the channel also change; that is, for a given discharge, both the gradient and the width-depth ratio increase. In addition, sediment size and sediment load increase from Pattern 1 to Pattern 5. With such geomorphic and hydrologic changes, hydraulic differences can be expected, and flow velocity, tractive force, and stream power also increase from Pattern 1 to Pattern 5. Therefore, the stability of a stream decreases from Pattern 1 to Pattern 5.

The braided Pattern 5 is of most interest because it is the Salt River pattern even where the channel is confined. A braided river is defined by the American Geological Institute (1972) as a *stream that divides into or follows an interlacing or tangled network of several, small branching and reuniting shallow channels separated from each other by branch islands or channel bars, resembling in plan the strands of a complex braid.* Braided rivers have a high width-depth ratio and relatively steep gradient, as a result of high bed load and large floods, which produce a relatively unstable pattern and a relatively variable channel in time and location. This is a good description of the Upper Salt River.

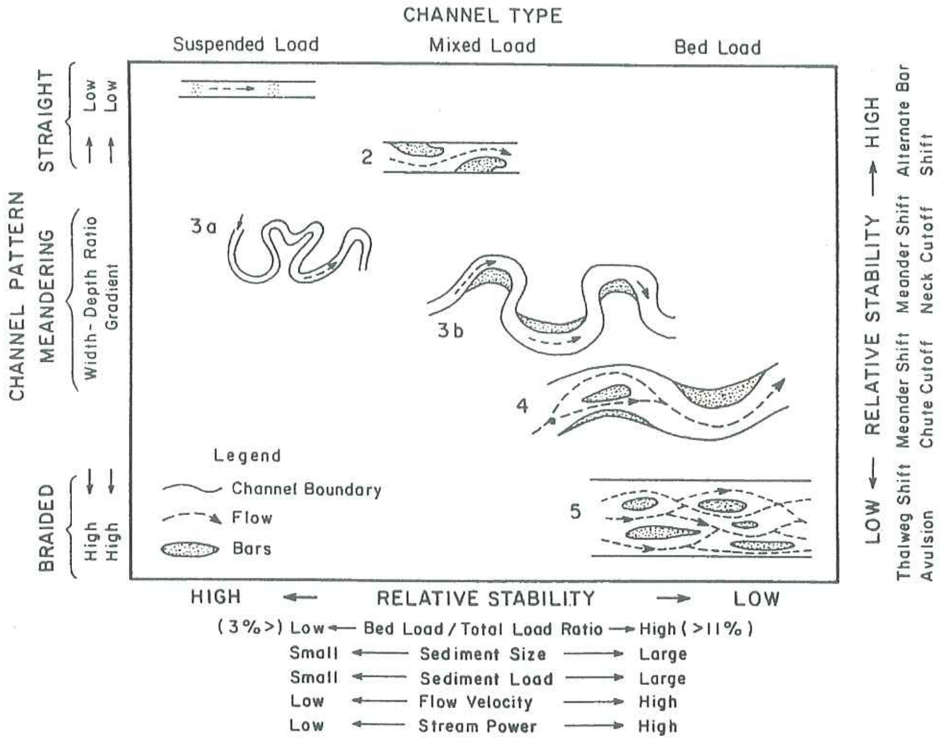

Figure 1. Channel classification based on pattern and type of sediment load, showing types of channels, their relative stability, and some associated variables (after Schumm, 1977).

Although bedrock and geologic structures strongly control valley and channel morphology within the Salt River valley, the channel is braided (**Figures 2 and 3**). However, in the steepest reaches, a riffle and pool pattern may exist (Fuller, 2003).

UPPER SALT RIVER

The Upper Salt River, from Granite Reef Dam to the junction of the Black and White Rivers, is mostly confined. Throughout most of its length, it flows in deep canyons, and it is controlled by bedrock and resistant terrace sediments (**Figures 4 and 5**). At present, the river between Stewart Mountain Dam and the head of Roosevelt Reservoir no longer exists, as the canyons are flooded. For example, **Figures 6 and 7** show such flooded reaches that are confined between bedrock canyon walls. The pre-Roosevelt Dam channel would have flowed on bedrock at many locations. For example, note the bedrock outcrop in the center of what was the channel (Figure 6), and the rapids (Figure 5). Especially striking is the bedrock control at the confluence of the Verde and Salt Rivers (**Figure 8**).

The U.S. Forest Service's (1995) description of the river between Roosevelt Reservoir and the Highway 60 bridge (**Table 1**) provides evidence of many bedrock controls, including 18 rapids, and steep gradients ranging from 17 to 31 feet per mile. The submerged reaches downstream of Roosevelt Dam must have been similar. The topographic map (**Figure 9**) shows the character of the river in a deep canyon near Cherry Creek (Figure 7). Clearly, the bedrock controls along the Upper Salt River prohibit navigation.

Figure 2. Braided Salt River below confluence with Verde River (T2N, R7E, Sec 18). Note variability of channel width; probably as a result of bedrock control.

Figure 3. Braided Salt River between Blue Point and confluence with Verde River (T3N, R7E, Sec 34). Note gravel bars in low-water channel. Large areas of channel are dry and flow is controlled by upstream reservoirs.

Figure 4. Salt River about 5 miles upstream of Highway 288 bridge.

Figure 5. Salt River about 3 miles upstream of Cherry Creek (see Figure 9). Note rapids.

Figure 6. Salt River downstream of Roosevelt Dam. Note bedrock island.

Figure 7. Salt River upstream of Mormon Flat Dam.

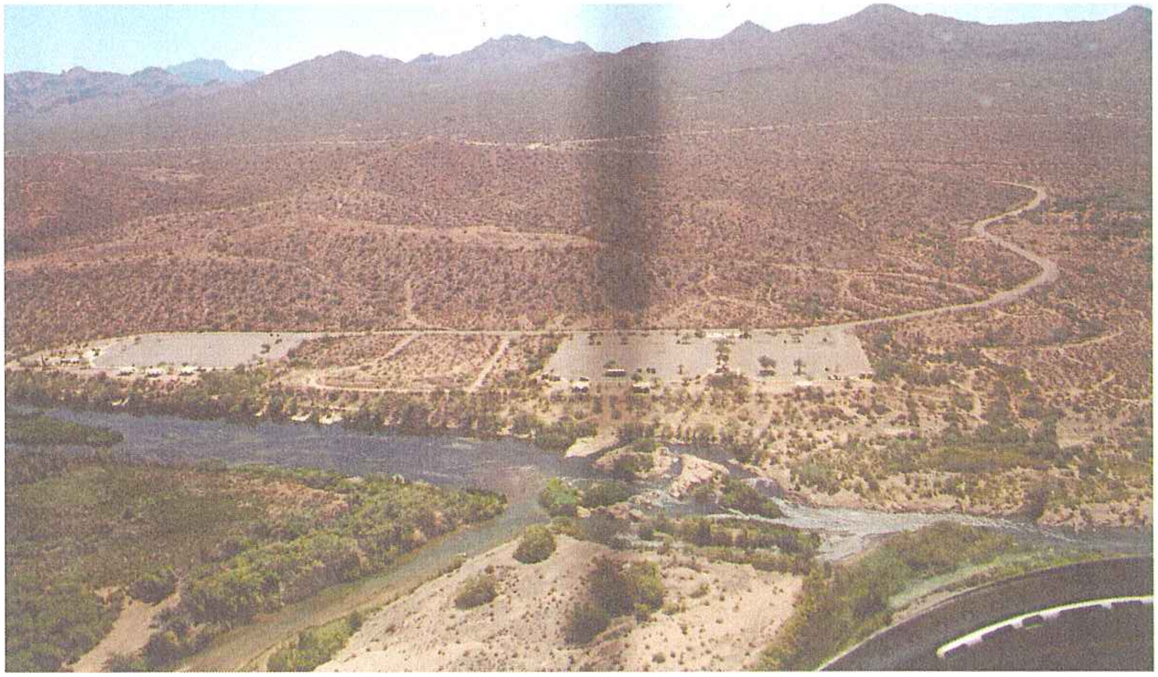

Figure 8. Salt River at confluence of Verde River. Note bedrock at confluence.

Table 1. Upper Salt River, U.S. Forest Service Guide (1995).

River Mile	Description
0	Roosevelt Dam Spillway Elevation
7.8	Tertiary conglomerate
8.3	Pinal Creek
9.4	Conglomerate
10.3	Entering Goose Necks
13.0	Granite
14.7	River drops 17 feet/mile for next 6 miles downstream
15.8	Coon Creek
16.3	Basalt—conglomerate
17.4	Conglomerate
20.8	River drops 16 feet/mile for next 6 miles downstream
21.0	Rhyolite flow
21.7	Bedrock
24.2	Cherry Creek
25.1	McGee's Pond—slow water
25.7	Cliff Hanger Rapid
26.9	River drops 16 feet/mile for next 6 miles downstream
28.2	Corkscrew Chute
28.3	Quartzite Rapid
30.1	The river will drop 31 feet/mile for 3 miles downstream
30.2	The Maze—large rocks block river
30.9	Lower Corral Rapid
32.7	Upper Corral Rapid
33.2	Pendajo Curve—stay off left wall
37.6	Black Rock Rapid
38.2	Eye of the Needle—narrow passage, rocks
42.1	Petes Pond—slow water
43.1	River will drop 21 feet/mile for next 5 miles downstream
43.4	Granite Rapid
45.8	White Rock Rapid
46.0	The Rat Trap—sharp drop
46.6	River drops 29 feet/mile for next 3.5 miles downstream
48.3	Little Boat Eater Rapid
48.9	Ledger Rapid
49.4	Salt Banks Rapid
50.5	River drops 26 feet/mile for next 4 miles downstream
50.8	Salt River Draw Rapid
52.2	Three-way Rapid
53.9	Exhibition Rapid
27.2	Overboard Rapid
57.5	Mother Rock—major rock in center of river
57.6	Reforma Rapid
58.2	Maytag Chute
58.4	Bump and Grind Rapid
59.5	Island Rapid
59.8	Highway 60 bridges
59.9	Baptism Rapid

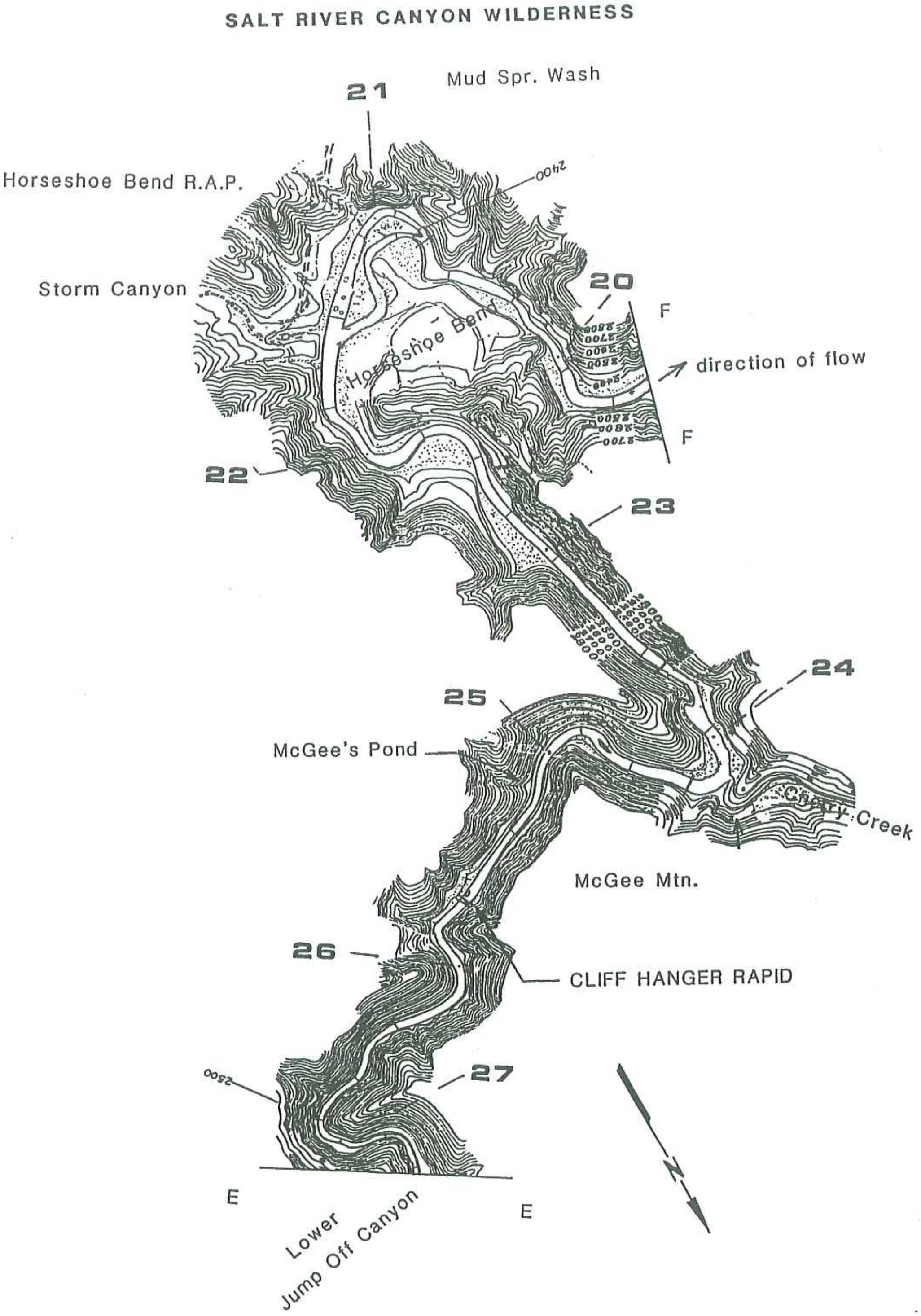

Figure 9. Map of Salt River (miles 20-27) in deep canyon showing location of Cherry Creek (see Figure 5).

The hydrologic history of the Upper Salt River is very similar to that of the Gila and Verde Rivers. All were subject to large floods just prior to statehood (**Table 2**). The floods of 1905-1909 would have caused or maintained a wide-braided channel.

The 1934 aerial photographs show a Salt River channel that was wide, occupying all of or much of the valley floor (Figures 2 and 3). This undoubtedly was the condition of the channel in 1912, following the series of major floods (Table 2) that significantly widened the Gila River and its tributaries (**Figure 10**), including the Upper Salt River.

According to Burkham (1972), the major floods were the cause of the dramatic channel changes along the upper Gila River prior to statehood. He summarizes the changes by plotting channel area in the reach between San Simon and Pima for the period 1875 to 1970 (Figure 10).

Huckleberry (1996) reached the same conclusion regarding the middle Gila River (**Figure 11**). The early surveys showed the middle Gila as a narrow single channel until 1891. In 1891, the middle Gila River experienced a large flood that caused channel widening and large floods in 1905 and 1906 radically transformed the relatively narrow channel to a wide braided channel. Huckleberry (1996) concluded that major channel changes are related more to the duration of a flood than to its magnitude. Beginning in 1905, the channel experienced great widening as a result of bank cutting during periods of sustained flow. During two years, there were five months of high flow in 1905 and six months of high flow in 1906. Prolonged flow of this magnitude undoubtedly contributed to channel widening.

During the floods of 1905-1906, the Geological Survey had difficulty maintaining their gaging stations, and indeed, the gage at McDowell was washed out during the flood of 1905 (USGS, 1906).

Table 2. Mean annual discharge (cfs), Salt River at Roosevelt and McDowell (USGS, 1954).

Year	Mean Annual Discharge (cfs)	
	Salt River at Roosevelt	Salt River at McDowell
1889	1,463	
1890	1,626	
1891	2,861	
1892	240	
1893	563	
1894	344	
1895	1,073	
1896	639	
1897	1,161	
1898	439	466
1899	362	384
1900	204	----
1901	679	----
1902	273	----
1903	358	----
1904	336	342
1905	3,811	4,146
1906	2,364	2,749
1907	1,763	1,982
1908	---	1,513
1909	---	1,805
1910	----	371
1911	1,105	
1912	757	
1913	560	

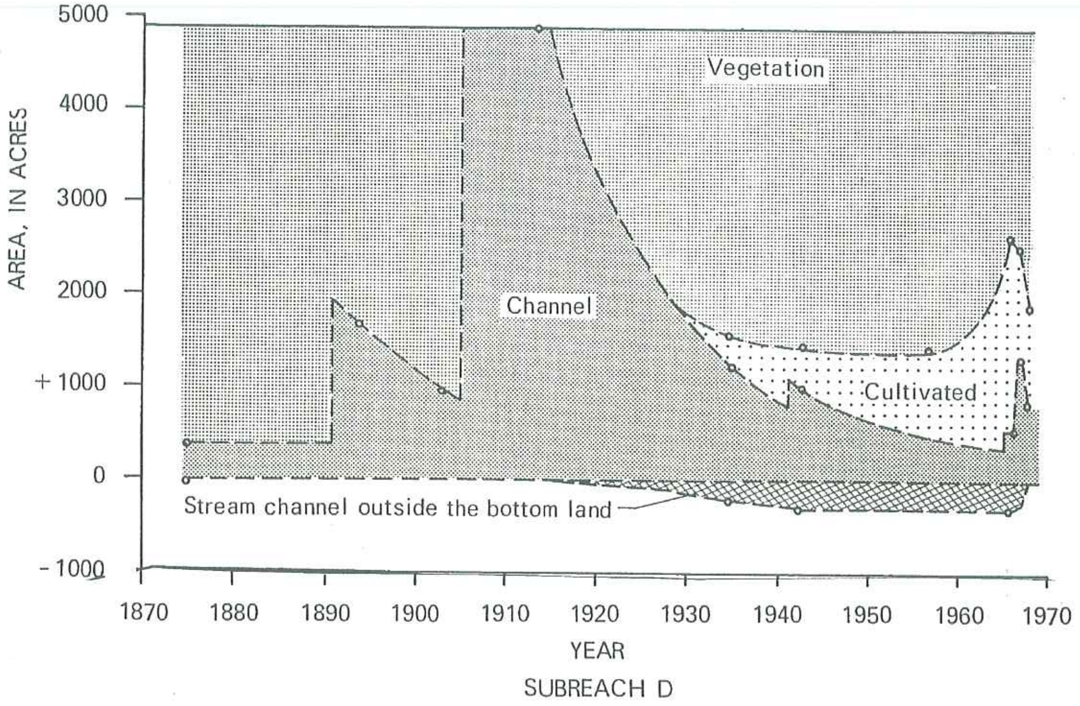

Figure 10. Historical changes of channel area, upper Gila River, San Simon to Pima (Burkham, 1972).

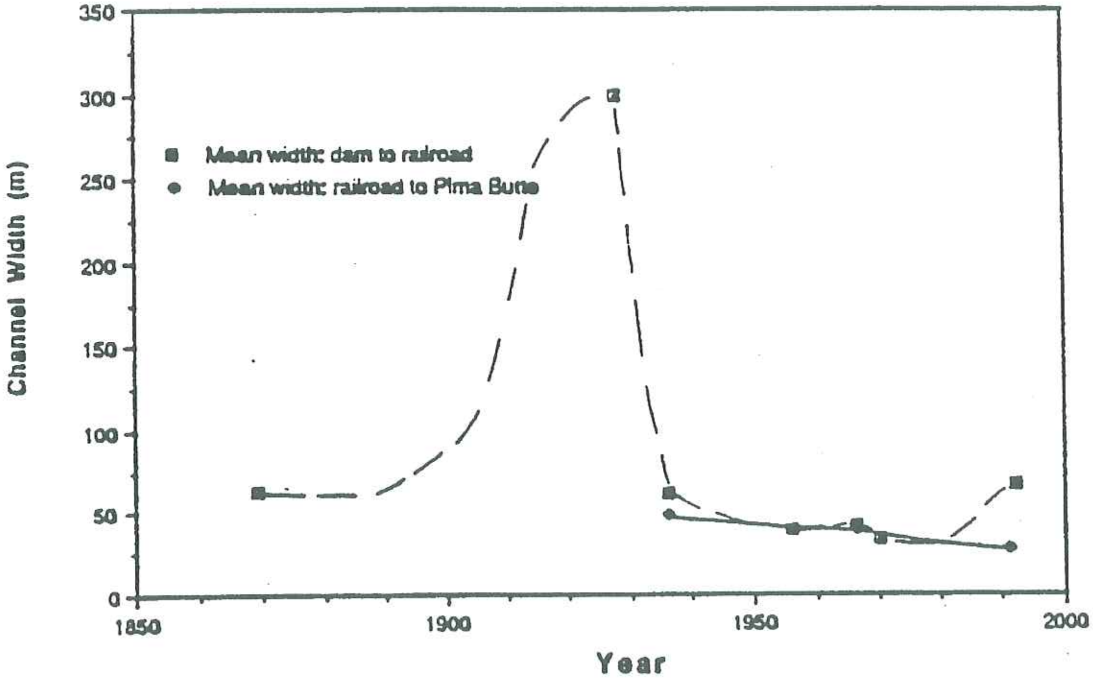

Figure 11. Historical changes of channel width, middle Gila River (Huckleberry, 1996).

CONCLUSIONS

The large floods prior to statehood would have created a wide-braided channel probably occupying the entire valley floor, as occurred along the Gila, Verde (Schumm, 2004), and lower Salt Rivers (Schumm, 2003). The canyon reaches of the upper Salt River, including the now submerged reaches (Roosevelt Dam to Stewart Mountain Dam) are very steep and rapids are frequent. These conditions make navigation impossible.

Braided rivers are wide, shallow, and steep, a condition not conducive to navigation. The marked changes of valley width cause dramatic alterations of water depth and velocity, which would make navigation hazardous. The numerous rapids (Table 1) clearly prevent navigation, and the bedrock that controls the Verde and Salt Rivers at their confluence prevents navigation upstream on both rivers (Figure 8).

Obviously, the numerous rapids and bedrock impacts on the river prevent navigation, but even more important are the very steep gradients ranging from 17 to 31 ft/mile. These gradients are significant because Captain John a. Mellon, with over 40 years experience on the Colorado River (Lingenfelter, 1978, p. 51), stated in a letter to the Bureau of Corporations (1907) that, "I have come to the conclusion that any river that has over 4 feet fall to the mile cannot compete with a railroad for freight or passengers" (Littlefield, 1997; commissioner of Corporations (1909). If at 4 feet per mile, commercial navigation is inhibited, certainly at 17 to 31 feet per mile, the gradients measured on the Upper Salt River, navigation would be impossible.

These conclusions are supported by Fuller (2003, p. 4-15) who summarizes the character of the river as follows: "*The channel geomorphology is substantially unchanged from its condition at or before statehood, except where the river has been inundated by reservoir impoundments. Most of the Upper Salt River is formed within deep bedrock canyons. Bedrock along the channel margins in these canyons precludes significant movement of the river channel or other channel changes. In addition, the bedrock geology of the Upper Salt River area made access to the river difficult during the period around statehood, prevented development of extensive irrigation systems, and prevented the development of large population centers near the river. Bedrock outcrops in the channel created waterfalls, rapids, and narrow canyons,*" which would have prevented commercial navigation.

REFERENCES

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

Commissioner of Corporations, 1909. Report on transportation by water in the United States, Water-borne traffic. U.S. Govt Printing Office, p. 370-371.

Fuller, J.E., 2003. Geomorphology of the Upper Salt River. Report prepared for SFC Engineering Company and Arizona State Land Dept., 17 p.

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

Lingenfelter, R.E., 1978. Steamboats on the Colorado River. Univ. Arizona Press, Tucson, 195 p.

Littlefield, D.R., 1997. Assessment of the Verde River's Navigability Prior to and on the date of Arizona's Statehood. Unpublished report, Littlefield Research Assoc., Oakland, 199 p.

Schumm, S.A., 2003. Geomorphic character of the lower Salt River. Unpublished report, 12 p.

Schumm, S.A., 2004. Geomorphic character of the Verde River. Unpublished report, 18 p.

U.S. Forest Service, 1997. Recreation Opportunity Guide, Upper Salt River, 22 p.

U.S. Geological Survey, 1906. Report of progress of stream measurements for 1905, Gila River at Dome (Gila City) Arizona. Water Supply Paper 175, 194 p.

U.S. Geological Survey, 1954. Compilation of records of surface waters of the United States through September 1950, Part 9, Colorado River Basin. Water Supply Paper 1313, 749 p.

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EXPERIENCE:

Dr. Schumm is an internationally recognized geomorphologist who has published over 150 papers and authored numerous books. His primary experience has been in the investigation and analysis of fluvial systems. He has applied the concepts of geomorphology, fluvial hydraulics and geology to analyze alluvial river form and shape, sediment transport and effects of man-induced changes on river systems through the United States, including the upper Midwest and in numerous foreign countries.

Dr. Schumm's experience includes research and application of geomorphic principles to riverbank erosion and avulsion, gully erosion and incised channel formation, long-term stability of mine tailings storage sites, and sedimentology and geomorphology of fan deltas. He worked from 1954-1967 as a geologist with the United States Geological Survey and taught at Colorado State University from 1967 to 1997. Dr. Schumm is recognized by professional groups for his outstanding work in geomorphic analysis of erosional processes. He is a past Chairman of the Geomorphology Division of the Geological Society of America, has served on other technical and advisory committees of the National Research Council, Geological Society of America, American Geophysical Union, International Geographical Union, American Society of Civil Engineers, U.S. Forest Service, U.S. National Park Service, the National Science Foundation and NASA. He has performed research, lectured and advised government agencies in Australia, New Zealand, Japan, Taiwan, South Africa, Canada, United Kingdom, Poland, Israel, Venezuela, Colombia and the Peoples Republic of China.

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