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TECHNICAL SERVICE CENTER
DENVER, COLORADO

UPPER GILA RIVER FLUVIAL GEOMORPHOLOGY STUDY

CATALOG OF HISTORICAL CHANGES
ARIZONA

PREPARED BY

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FLUVIAL HYDRAULICS & GEOMORPHOLOGY TEAM

U.S. Department of the Interior
U.S. Bureau of Reclamation

JUNE 8, 2001

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The Arizona Water Protection Fund Commission has funded all or a portion of this report or project. The views or findings represented in this deliverable are the Grantees and do not necessarily represent those of the Commission nor the Arizona Department of Water Resources.

Graham County, Arizona

COST SHARE AGREEMENT 00-GI 32-0054

Graham County, Arizona, and Reclamation are Cost Share Partners in the Upper Gila River Fluvial Geomorphology Study. The views or findings of Reclamation presented in this deliverable do not necessarily represent those of Graham County.

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The Fluvial Hydraulics & Geomorphology Team from the Technical Service Center is leading the Upper Gila Fluvial Geomorphology Study. The team consists of geomorphologists, engineers, and biologists. The members have expertise in water resources management, fluvial geomorphology, paleohydrology, hydraulics, sedimentation, photogrammetry, mapping, fisheries biology, wildlife biology, and riparian vegetation management.

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Catalog of Historical Changes Arizona

INTRODUCTION

The Catalog of Historical Changes documents changes in the alluvial channel of the Upper Gila River, Arizona from 1935 to 2000, with additional information from the late 1800's to 1935. This task includes an analysis of trends in channel behavior and stability of river reaches based on lateral migration and changes in channel widths. Rather than repeating the research from previous literature, this study complements previous studies that document channel changes on this reach of the Gila River.

The Catalog of Historical Changes is an important component of the overall project goals of the Upper Gila River Fluvial Geomorphology Study. This study will combine with Task 8B-Geomorphic Map task to provide the data necessary for Task 10-Geomorphic Analysis.

SETTING

The Gila River originates in the Gila River Wilderness in west-central New Mexico and flows to the south through the Cliff-Gila and Redrock Valleys of southwestern New Mexico. The Gila enters Arizona near Virden, New Mexico and flows northwest through Duncan, Sheldon, and York Valleys (Figure 1). The Gila River narrows markedly as it winds through the narrow canyon of the Gila Box. The Gila enters Safford Valley northeast of San Jose and flows to the west through the towns of Safford, Thatcher and Pima before turning to the northwest to flow through Eden and Fort Thomas to the San Carlos Indian Reservation. Major tributaries to the Gila River in the study reach include the San Francisco River, which enters the Gila Box from the north, and the San Simon River, which drains the San Simon Valley between the Pinaleno and Peloncillo Mountains and has its confluence with the Gila River east of Safford.

Physiographic features in the study area include the Pinaleno and Peloncillo mountains to the south, the Summit Mountains to the east in New Mexico, and the Gila Mountains to the north. Elevations range from 10,713 ft on Mount Graham in the Pinaleno Mountains to approximately 2800 ft at the reservation boundary in the Gila River valley.

The study area is located in the Mexican Highlands section in the Basin and Range Province of Arizona (Morrison, 1991). The Basin and Range Province in Arizona is characterized by a series of mountain ranges and intervening broad valleys, the majority of which were formed during the late Cenezoic era (30-5 m.y.) (Kamilli and Richard, 1998). The mountain ranges in the Mexican Highlands section are fairly regular in their orientation, trending north-northwest to north. For the most part, basins had internal drainage throughout the period of Basin and Range deformation (through later Miocene time) (Morrison, 1991).

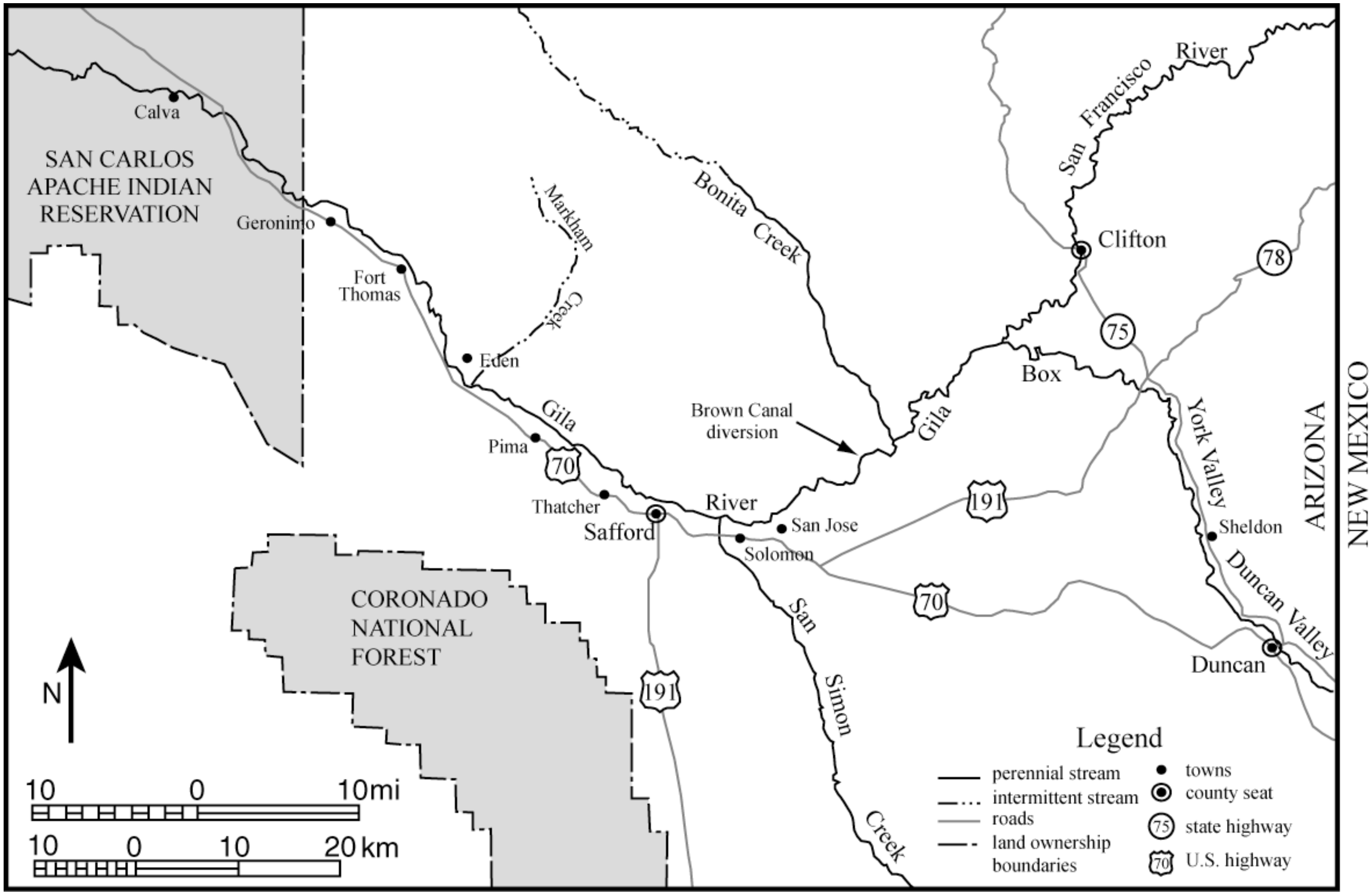


Figure 1. Study area location. The study area is located on the upper Gila River between the San Carlos Apache Indian Reservation boundary and the Arizona-New Mexico border. In this area, the Gila River flows through Duncan Valley, York Valley, the Gila Box, and Safford Valley. Since the alluvial portions of this reach were the focus of the study, the Gila Box was not included in the analysis. The several valleys in the upstream valley are grouped as Duncan Valley for the purposes of this study.

Prominent geologic units that form the physiography in the study area include extensive middle Miocene to Oligocene volcanic and sedimentary rocks and Pliocene to middle Miocene conglomerate and sandstone basin fill (Kamilli and Richard, 1998). Middle Pleistocene to latest Pliocene(?) (Kamilli and Richard, 1998) surficial deposits are composed of alluvial deposits that record through-going drainage of the upper Gila River and lacustrine deposits that record the formation of early Pleistocene lakes (Morrison, 1991). Three deep-lake episodes are recorded in the stratigraphy of Duncan Valley, while the number of deep-lake episodes in Safford Valley is unknown, although there is evidence for at least one deep lake (Morrison, 1965, 1985). Other deposits of the inner Gila River Valley include latest Pleistocene to modern alluvium and middle Pleistocene to Holocene alluvium and eolian deposits (Kamilli and Richard, 1998).

Peak discharge records for the upper Gila River show large floods at the turn of the century followed by a period of low-magnitude peak discharges from 1920 through 1965 (Figure 2). Beginning in the late 1960's, a period of high peak discharges began, a pattern that apparently continues. Although there is limited quantitative information pertaining to floods in the early 1900's, historical accounts state that floods were sizeable and erosive in nature on the San Francisco and Gila River in Safford Valley (Olmstead, 1919). There is very little information about floods in Duncan Valley during this time period. Following the early 1900's, the largest peak discharges in Safford Valley occurred in 1972, 1978, 1983, and 1993 (Table 1, Figure 3). It appears that the San Francisco basin was an especially important component during the 1972 and 1983 floods. The largest peak discharges in Duncan Valley occurred in 1978 and 1984.

PREVIOUS WORK

A substantial amount of previous work has been performed on the topic of channel change; however, the scope and purpose of previous studies are not always compatible with the scope and purpose of this study. Reports and articles discussed below are valuable pieces of information that will aid this project in accomplishing its objectives. Some information, such as the inundation studies, could only have been gathered at the time of the event and therefore are instrumental in evaluating channel behavior at the time of large floods. The Gila Phreatophyte Project, performed in the 1970's by the U.S. Geological Survey, provides voluminous data on a number of topics. Their goal was generally to evaluate the effects of phreatophyte control on water budget in the project area, to describe hydrological and ecological variables and to test these methods for viable extrapolation to other areas (Culler and others, 1970). Although their goal was much different than the goal of the present study, much of the data will be applicable in this study. For this report in particular, Burkham's (1972) documentation of historical channel changes through 1967, although limited in scope, is an important piece of research.

Olmstead (1919) prepared a document in response to erosion of farmlands during large floods at the turn of the century. The author proposed structures that could alleviate erosion both in alluvial areas (channelized reach and stabilized banks) and steep tributaries (check dams) in the upper watershed. Olmstead describes what is known about floods in the 1800's as well as in the early 1900's on the Gila and San Francisco Rivers and documents changes in channel width averages through this period. For the period of 1904-1916, he concluded that there were seven major floods. Prior to this period, channel width was approximately 150 to 200 ft wide as recalled by landowners in the area. Following the floods of the early 1900's, the channel in Safford Valley averaged 1,935 ft in width. Olmstead described floods prior to 1900 as non-erosive and as spreading out over the flood plain when the channel was not adequate to accommodate the flow. Flood years, mostly recorded by Pima Indian calendars, include 1833, 1869, and 1884. Olmstead concluded that floods of this period of observation were probably the result of long-duration precipitation events, rather than short-duration high magnitude rainfall in the early 1900's, because they were not erosive in nature like the early 1900's floods.

Burkham (1972) documented channel changes in Safford Valley from 1846 to 1970 using surveyor's maps for the early periods and aerial photographs for later periods. A stable, narrow, meandering channel with an average width of less than 150 ft existed in 1875 and expanded to less than 300 ft in 1903. From 1905-1917, large floods caused lateral erosion of the floodplain, with most of the widening occurring during 1905-1906 and 1915-1916. The average width increased to 2,000 ft. From 1918-1970, the floodplain was rebuilding and the average width of the channel decreased to less than 200 ft by 1964. This was accompanied by an increase in sinuosity. Salt cedar became a dominant species along the river corridor during 1920-1930 and reached its maximum extent during 1945-1955. In 1965 and 1967, floods caused minor widening of channel and by 1968; the average width measured 400 ft. Burkham concluded that major widening events are coincident with major floods in 1891, 1905-17, and 1965-67, and that grazing was not a big impact in sediment production, as the majority of livestock were below major flood producing source areas; however, he concluded that grazing may have accelerated erosion of flood plain in the lowlands.

Burkham also documented changes in channel patterns caused by alluvial fan deposition. He discussed in detail a tributary near Calva (Burkham, 1972, Plate 4), Salt Creek at Bylas, and the Gila River near Ft. Thomas. Generally, the erosion of alluvial fan toes during floods of early 1900's caused an increase in fan gradient, and new deposition of fan sediment into the main channel. This directed the main channel toward the opposite bank causing erosion of that bank.

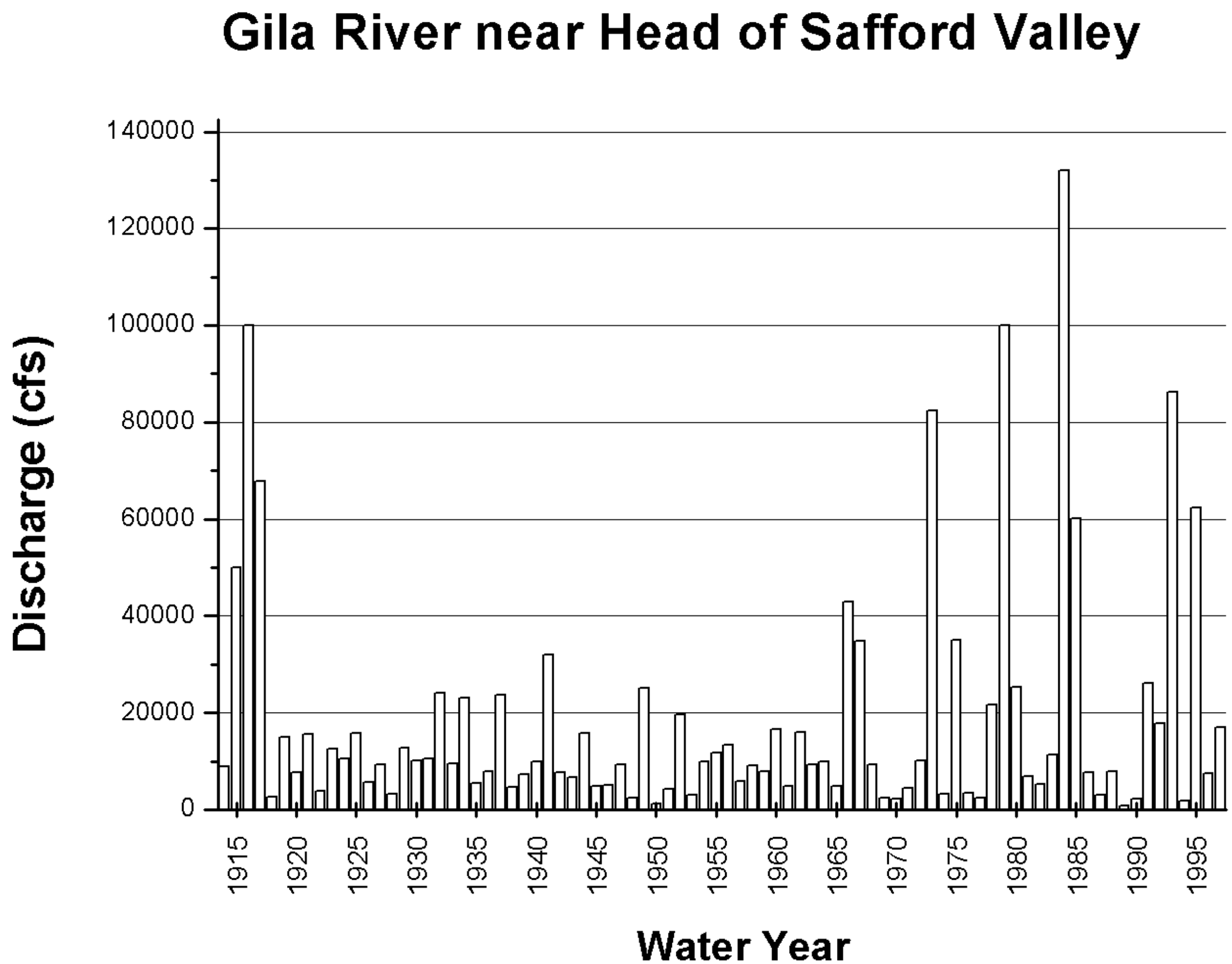


Figure 2. Annual peak discharge record, Gila River near Head of Safford Valley (station no. 09448500). The gaging station record shows a period of large-magnitude peak discharges in the early 1900's followed by a period of few large-magnitude peak discharges from the 1920's through 1965. From 1965 to 1997, large magnitude peak discharges are prevalent in the annual record.

Table 1. Peak discharges for the largest floods in cubic feet per second, Upper Gila River, Arizona.

DATE OF FLOOD	Gila River @ Calva	Gila River @ head of Safford Valley	Gila River nr. Clifton	San Francisco River nr. Clifton
PERIOD OF RECORD	Oct. 1929-current	April 1914-current	Nov. 1910-1996	Oct. 1910-current
Feb. 21, 1891				65000
Jan. 10, 1905				60000
Nov. 27, 1905				65000
Dec. 3, 1906				70000
Dec. 20, 1914		50000	12000	23000
Jan. 18-20, 1916	100000	100000	7600	59000
Oct. 14-15, 1916	--------	67900	19500	60000
Sept. 29-Oct. 1, 1941	27900	31900	28200	7300
Dec. 22-24, 1965	39000	43000	10700	30500
Oct. 19-21, 1972	80000	82400	33000	64000
Dec. 19, 1978	100000	100000	57000	56000
Oct. 2-3, 1983	150000	132000	15300	90900
Dec. 28-29, 1984	53700	60200	48800	27400
Jan. 18-20, 1993	109000	86200	35500	42900
Jan. 5-6, 1995	64500	62400	24800	22200

Hooke (1996) documented channel change in the Safford basin using aerial photographs. Hooke found that channel width increased from 1905-20 and gradually narrowed until 1960. During the 1960-70's widening occurred and continued to 1982. Major channel changes from high flows occurred in the 1972, 1974, and 1979 water years with some changes in response to the lower flows. Hooke questioned Burkham's model of geomorphic threshold needed to induce major channel changes, and indicated that the relation is not simple: "The research has shown that the morphological response to high flow events depends on sequences of events and critical combinations of conditions" (p. 191). Hooke also mentioned that vegetation may play a factor in channel change and that change does not correspond to size of event or wetness of period.

The Flood damage report by the Army Corps of Engineers (1973) describes the storm and associated flooding that occurred from October 17-21, 1972 and provides inundation maps along the Gila River for Duncan Valley and Safford Valley. Abundant precipitation earlier in the month preceded the late-October 1972 storm and flood. The storm of October 3-7, 1972 was produced by tropical storm Joanne and caused heavy rains over the Gila River basin. Additional precipitation from October 12-13, 1972, partially maintained high soil-moisture and water table levels.

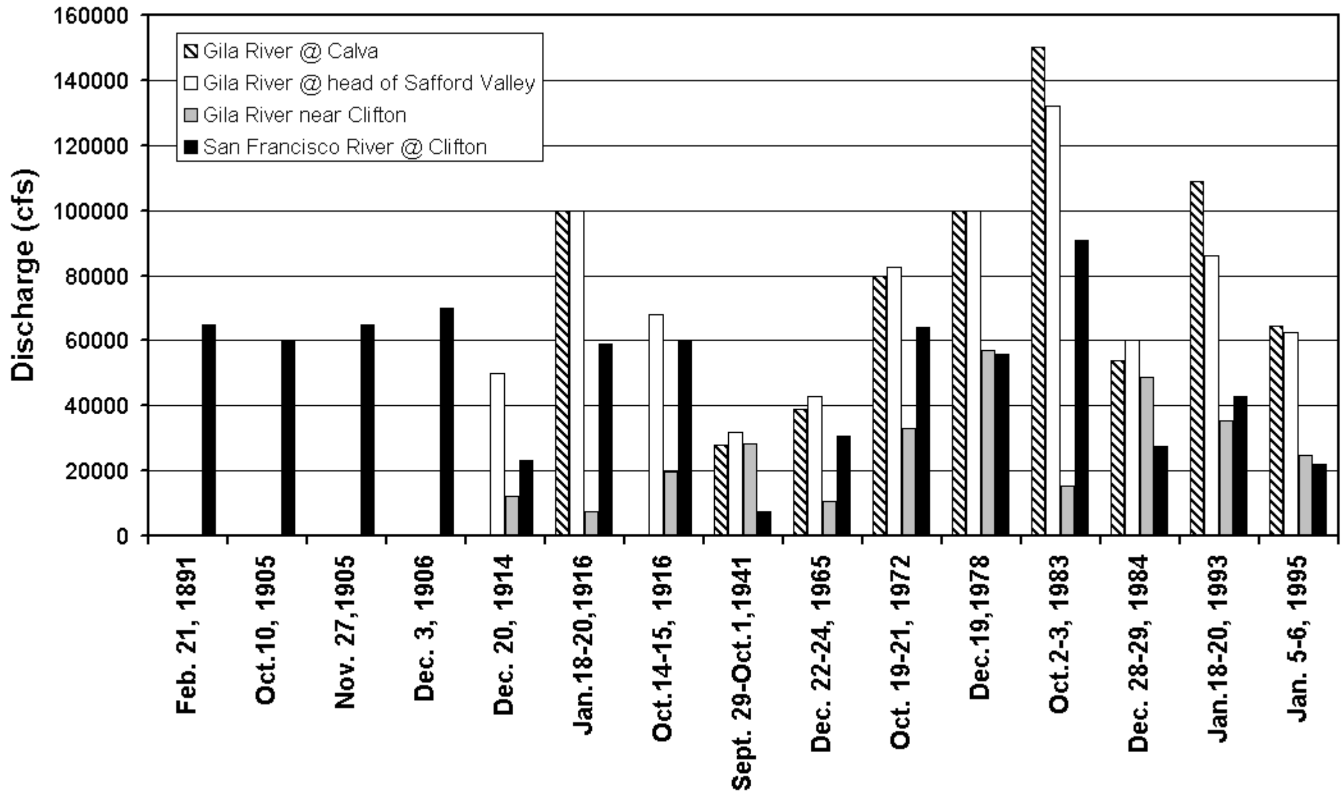


Figure 3. Largest peak discharges, Upper Gila River. Four gages are plotted for each flood, with the exception of the early 1900's floods during which only one gage was in operation. The largest floods recorded for Safford Valley include 1983, 1916, 1978, and 1993. The largest floods for Duncan Valley include 1978 and 1984.

In the Safford Valley, Hollywood was inundated with depths locally exceeding four ft. Irrigation structures, and approaches to the Solomon Bridge, Pima-Bryce Bridge, Reay Lane Bridge at Thatcher were heavily damaged. No bridges were washed out, but all bridges experienced damage to approaches and abutment erosion, with the exception of Safford Bridge. Other damages were reported included erosion of levees, washed out revetments, and channel siltation at lower ends of tributaries.

The report quoted the following in Duncan, AZ: "The residents of the town received several hours warning of the impending flood, but apparently the people had more faith in their levee than it deserved. Very few used the advance warning time to remove, raise or otherwise protect those possessions which could be protected. Most of the people were still in their homes when the levee finally failed (p. 16)."

Garrett et al. (1986) mapped the inundated area of selected reaches along the Gila River from the October 1983 flood. Safford Valley was one of the reaches they selected to map. The inundated area was mapped on aerial photographs taken on October 7, 1983 and reached a maximum width in Safford Valley of 6,400 ft. The flood caused erosion to large areas of farmland in Safford Valley, ruined crops and irrigation ditches, and caused siltation of irrigation systems and farm fields on the Gila River flood plain. During the flood, the highway bridges over the Gila River in Safford Valley were also impassable, stranding approximately 300 residents on the north side of the river during the flood. The 1983 flood was estimated to have a 100-150 year return period at the gaging stations of Gila River at Head of Safford Valley (station no. 09448500) and Gila River at Calva (station no. 09466500).

METHODOLOGY

DATA SOURCES

Data for this analysis derive mainly from aerial photography flown by U.S. government agencies and private aerial survey companies. Additional data was taken from literature described in the Previous Work section of this report and from Cadastral Land Office Surveys conducted in the early 1900's and obtained from the Bureau of Land Management office in Phoenix, Arizona.

DATA COLLECTION

Measurements of channel width for the Gila River were made on the aerial photographs with a digital caliper and measured to a hundredth of a millimeter (0.01 mm), which corresponds to an actual ground distance of 0.1 to 0.6 m depending on the scale of the photographs. On the large-scale photograph sets, which include year 2000 and 1983 post-flood photographs, measurements were recorded to a half a millimeter (0.5 mm) using a ruler. This corresponds to a ground distance of 2.0 to 2.8 m for the 2000 and 1983 photographs, respectively.

Conversions to ground distance from the aerial photograph distance were made by measuring corresponding distances on USGS 7.5 minute topographic maps and aerial photographs creating conversion factors. This option was chosen because the scale of the photographs was not always known and to account for minor changes in camera position and distortion from the camera lens on the unrectified photographs. Several distances of varying lengths and orientations were measured and the average taken for the conversion factor for each set of aerial photographs. A test of precision was also conducted by measuring the same point multiple times.

Channel width measurements provide a quantitative measurement for comparison of the Gila River channel between aerial photography from different years. Channel width measurements were made approximately every kilometer (~0.6 mile) by establishing points from which a width measurement was made perpendicular to flow direction. Sixty-two measurement points were established in Safford Valley; thirty-nine points were established for Duncan Valley. For each point, not including flood photographs, two channel width measurements were made:

(1) Recent flow width: that part of the channel that was being reworked by recent flows at the time the photographs were taken.

(2) Flood flow width: that part of the channel that was clearly inundated by high magnitude flows. These widths appeared to be the actual channel width during floods, not the result of lateral migration. In some cases where levees were built to protect structures or land from erosion and damage, the allowable width between levees was considered the flood flow width. This measurement should be considered a minimum value, as shallow inundation may not be visible long after a flood. In some cases, plowing of fields following floods obscured the evidence of flooding. Sometimes flood flow width could be inferred from adjacent plots that had not been obscured. In the case of photographs following major floods, the actual width of inundation was measured, independent of structures in the river.

In addition, qualitative assessments of lateral change were also made by analyzing photographs for differences in channel position over the time period considered, which spans 1935 to 2000.

At least one aerial photograph set was acquired for each decade, with exception of the 1940s, and following extreme floods on the Gila River, which include 1972, 1978, 1983 and 1993. Prior to 1935, General Land Office Cadastral Land Surveys, and earlier literature reviews were used to evaluate the nature and position of the river channel. Photograph sets used for Duncan Valley include: 1935, 1953, 1958, 1967, 1978, 1978 Flood, 1981, 1992, 1997, and 2000. Photograph sets used for Safford Valley include: 1935, 1953, 1958, 1967, 1972 Flood, 1973, 1978, 1981, 1983 Flood, 1992, 1993 Flood, 1997, and 2000. Refer to Appendix D for details on these aerial photograph sets. In this analysis, the number of channel width measurements total over 2,000 for Duncan Valley and Safford Valley.

RESULTS AND ANALYSIS

SAFFORD VALLEY

GENERAL TRENDS

Average width data: Comparison of Flood Years

When averaging the width measurements for each photograph year, a general pattern emerged, which was similar for both recent flow width measurements and flood width measurements (Figure 4). The 1935 channel was the widest channel recorded. From 1935 to 1967, channel width decreased, with the magnitude of change being larger for the recent flow width measurements. This decrease is concurrent with a period of relatively few large floods (see Figure 2). From 1967 to 1978, channel width increased, with a spike in the 1973 flood width measurements, corresponding to the 1972 flood. From 1978 to 1997, channel width gradually increased in the flood width measurements and approaches the flood width of 1935. The recent flow width set had a slight decrease in width from 1981 to 1997 and was actually much wider by 1997 than the 1935 channel. Year 2000 photographs show a decrease in average width from that of 1997 for both flood flow and recent flow widths.

Longitudinal trends

Safford Valley was split into two sections for this analysis: the first reach extends from the San Carlos Apache Indian Reservation boundary to Pima Bridge (points 1-32). The second reach extends from Pima Bridge to Brown Canal Diversion at the mouth of the Gila Box (points 33-62) (Figure 5). For flood widths measured at points 1-32, there does not appear to be a trend in channel width based on the distance upstream or downstream, but rather a greater range in widths when compared to points 33-62. For points 33-62, there appears to be a general decrease in width in the upstream direction. For recent flow widths, there did not appear to be a trend for either reach.

PHOTOGRAPH YEAR COMPARISON

Analysis of Channel changes

The statistical analysis of channel change identifies the reaches of greatest variability in channel width and also those of intermediate and small variability over the period measured (Figure 6). The standard deviation of the widths for all non-flood years at each measurement point was compared relative to other points so that reaches with high variability could be identified. This analysis only includes results for the flood width measurements, although the same could be performed for recent flow measurements. Flood width measurements appear to be the more important variable to analyze, as these are the measurements that reflect the greatest change in the river system. Low points on Figure 5 reflect low variance in flood width measurements, while high points reflect high variance in flood width measurements. The information contained on this chart does not correspond to narrow or wide points in the channel, but rather those points that experienced very little change in width and those points in the channel that experienced a high variability in width over the period measured. Several Case Studies were made in the reaches of greatest variability.

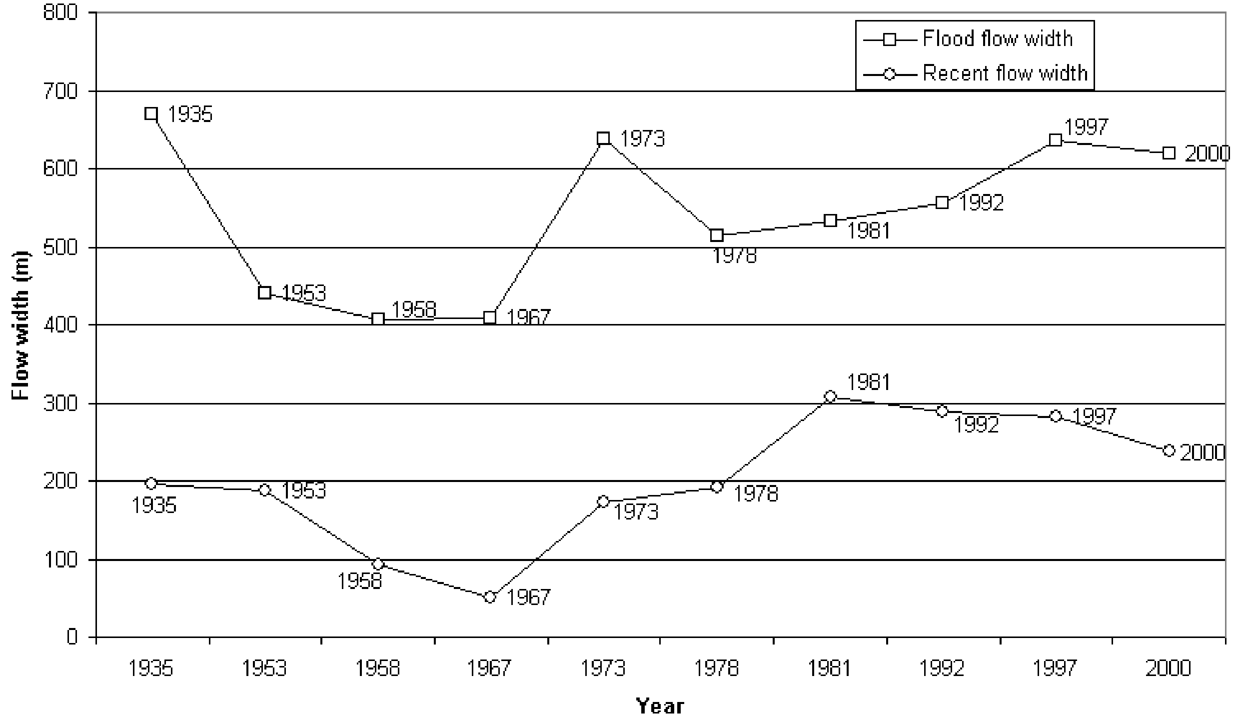


Figure 4. Safford Valley average width data by year. Data show a general decrease in average width from 1935 to 1967. This is followed by an increase in 1973, which was probably due to widening during the 1972 flood. Average flood widths continued to increase through 1997, while recent flood widths slightly decreased following 1981. Year 2000 measurements show a decrease in average channel width for both measurement sets.

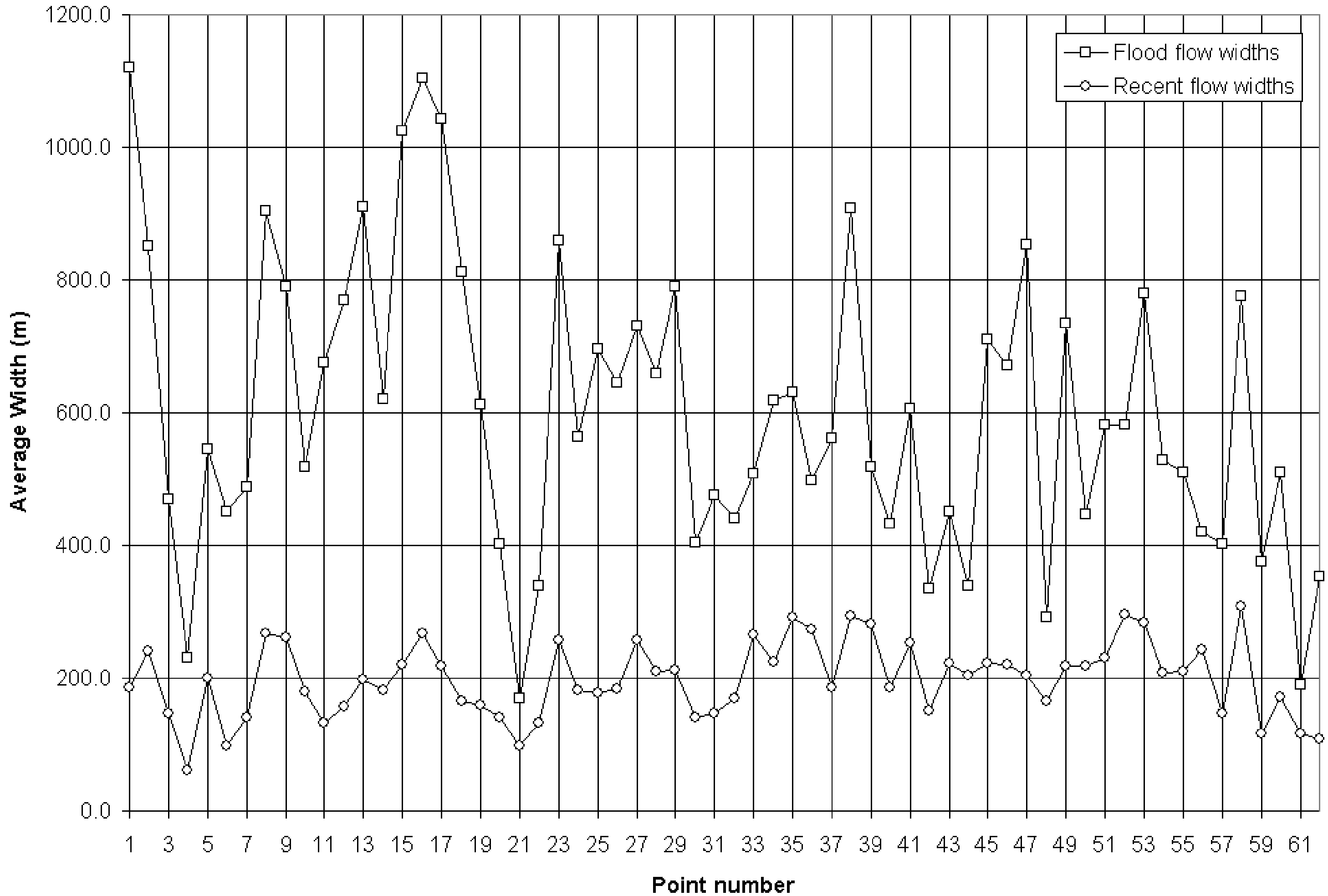


Figure 5. Safford Valley average width longitudinal trends. Flood width averages for each point show wide variations for points 1-32 and a general decrease in width from points 33-62. Recent flow width averages do not show a discernible trend. Downstream direction is from right to left.

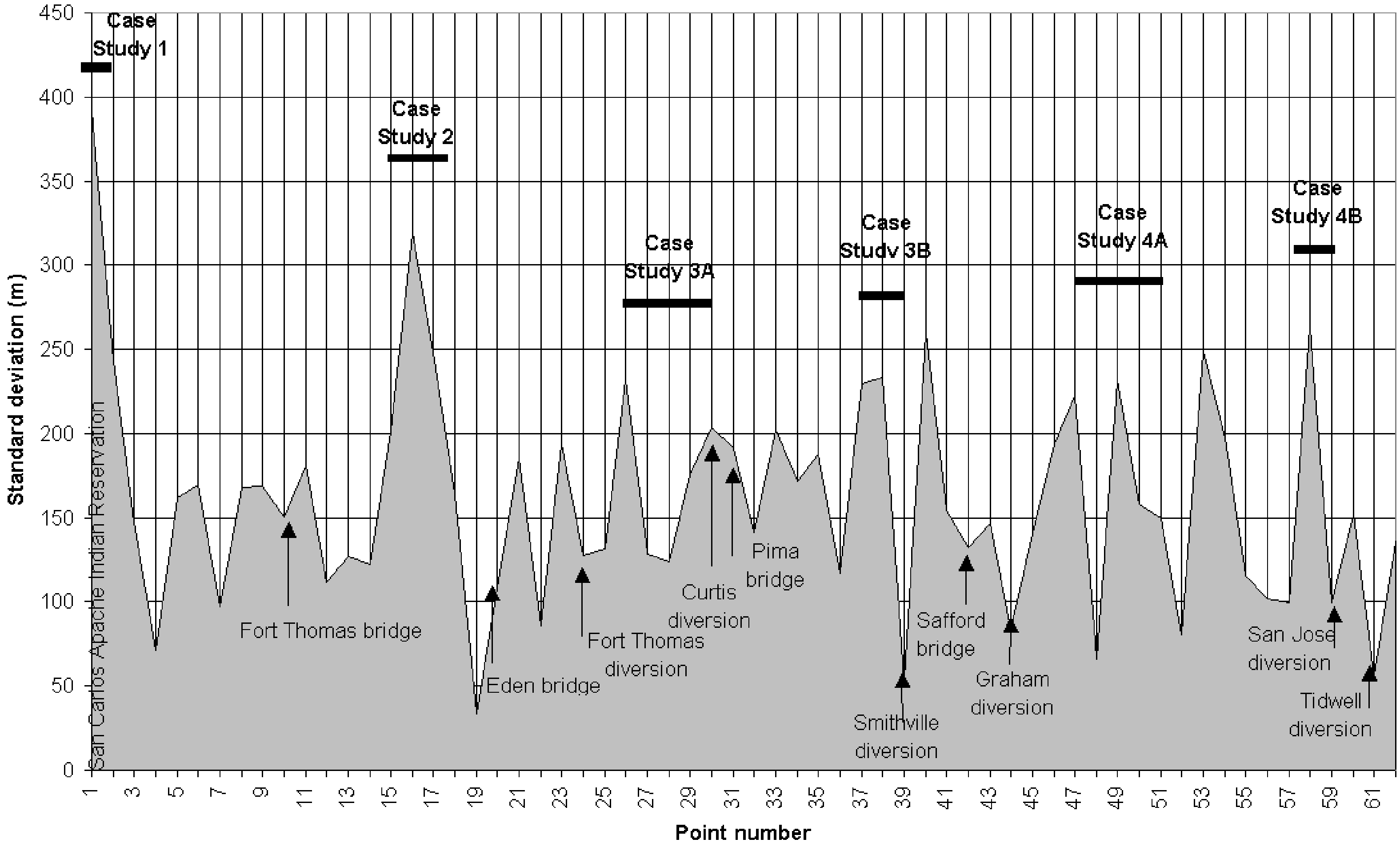


Figure 6. Analysis of channel changes, Safford Valley. The standard deviation for each measurement point is shown. High points on the plot indicate those reaches that have experienced the greatest amount of channel change over the period of study. Case study reaches are shown by the horizontal bars.

Reaches of Greatest Variability

Reaches of greatest variability include: (1) Near the San Carlos Apache Indian Reservation (points 1-3); (2) Ashurst to Teague Spring Canyon (points 15-18); (3) Markham Wash to Smithville Diversion (points 26-38); and (4) Graham Diversion to San Jose Diversion (points 45-58) (Figures 7 and 8).

Case Study 1: Near the San Carlos Apache Indian Reservation (points 1-3)
The overall channel pattern in this reach over the period of study is similar; however, channel narrowing and widening appears to be related to levees in the study reach (Figure 9). The 1935 channel was the widest channel recorded in the period of measurement. By 1953, the channel has narrowed by approximately 25%. By 1997, the channel pattern had changed dramatically to a more sinuous channel with nearly 90-degree bends from bank to bank. This pattern is associated with erosion into right and left bank levees and channel modification.

Case Study 2: Ashurst to Ft. Thomas (points 15-18)
In 1935, the Gila River channel in this reach appears to have multiple channels, some of which appear to be vegetated and only occupied by higher flows (Figure 10). From 1935 to 1967, channel flood width decreases in conjunction with an increase in the sinuosity of the low flow channel. The 1967 channel is the narrowest channel in this reach; channelization is apparent. By 1973, there has been some abandonment of right bank meanders and creation of new left bank meanders. The 1978 photographs show these meanders as well vegetated and also a less sinuous low flow channel. By 1981, the low flow channel had widened. In subsequent years the channel position continued to be highly variable and flood width increased so that by 1997, the flood width was larger than in 1935. It should also be noted that this reach is located directly downstream of point 19, which is a very narrow channel that exhibits low variance due to levees in the vicinity of the Eden Bridge.

Case Study 3A: Pima Bridge to Markham Wash (points 26-30)
This reach is a good example of lateral channel change in Safford Valley (Figure 11). The channel in this reach was generally wider in 1935 than in other photograph years. The 1953 photographs show a narrowing of the channel, imposed by levees near the Pima Bridge, and widening downstream of the bridge. In 1967, it is apparent that there was channelization that continued upstream to at least Thatcher. The 1967 photographs also show an increase in sinuosity downstream of Pima Bridge. The sinuosity is accentuated in 1973 in the same area and in 1978, new channelization efforts are apparent in the center of a meandering low flow channel. By 1997, meander locations and flood width values have changed, resulting in the high variability in channel location and width for this reach.

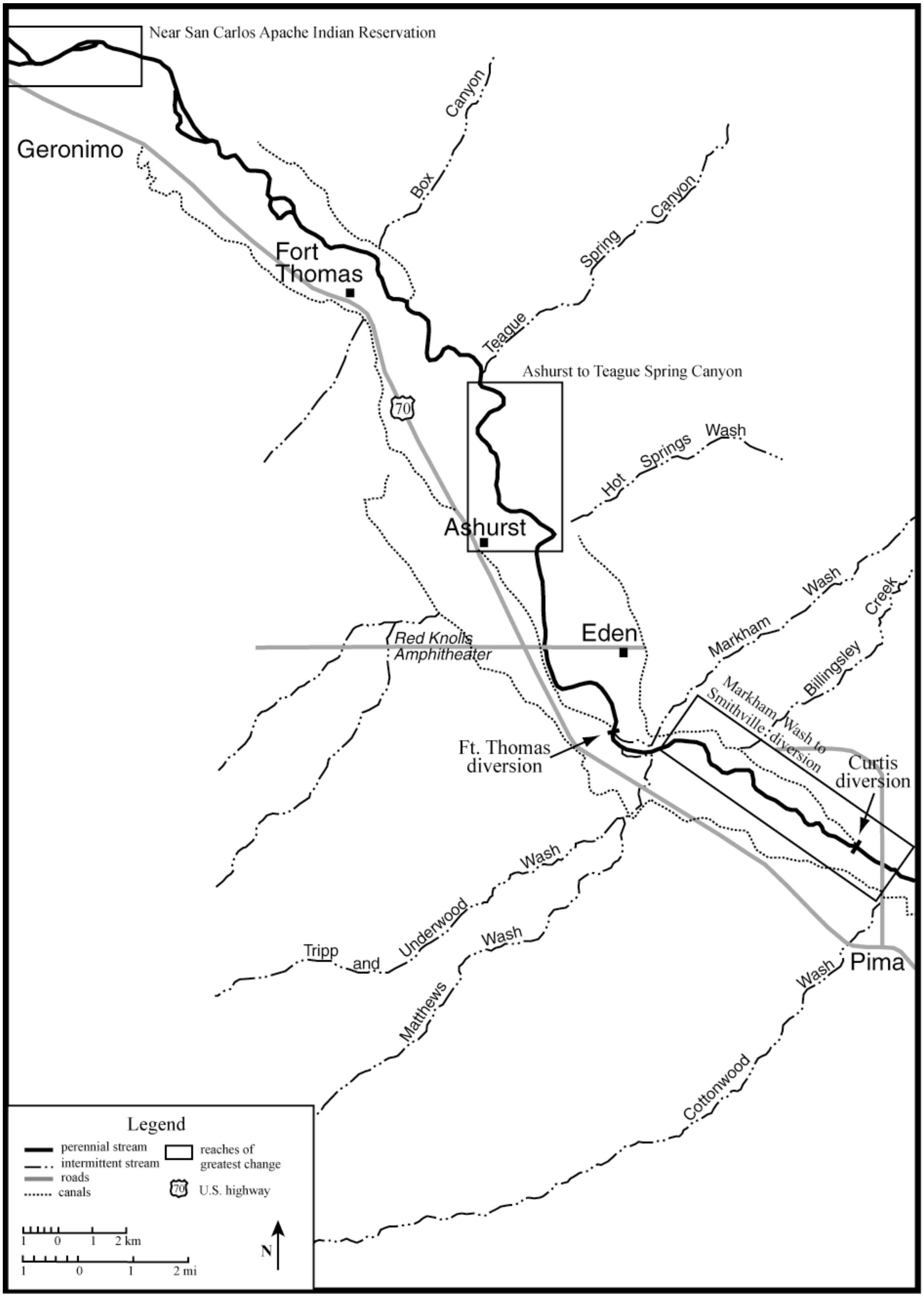


Figure 7. Reaches of greatest change: San Carlos Apache Indian Reservation to Pima, Arizona.

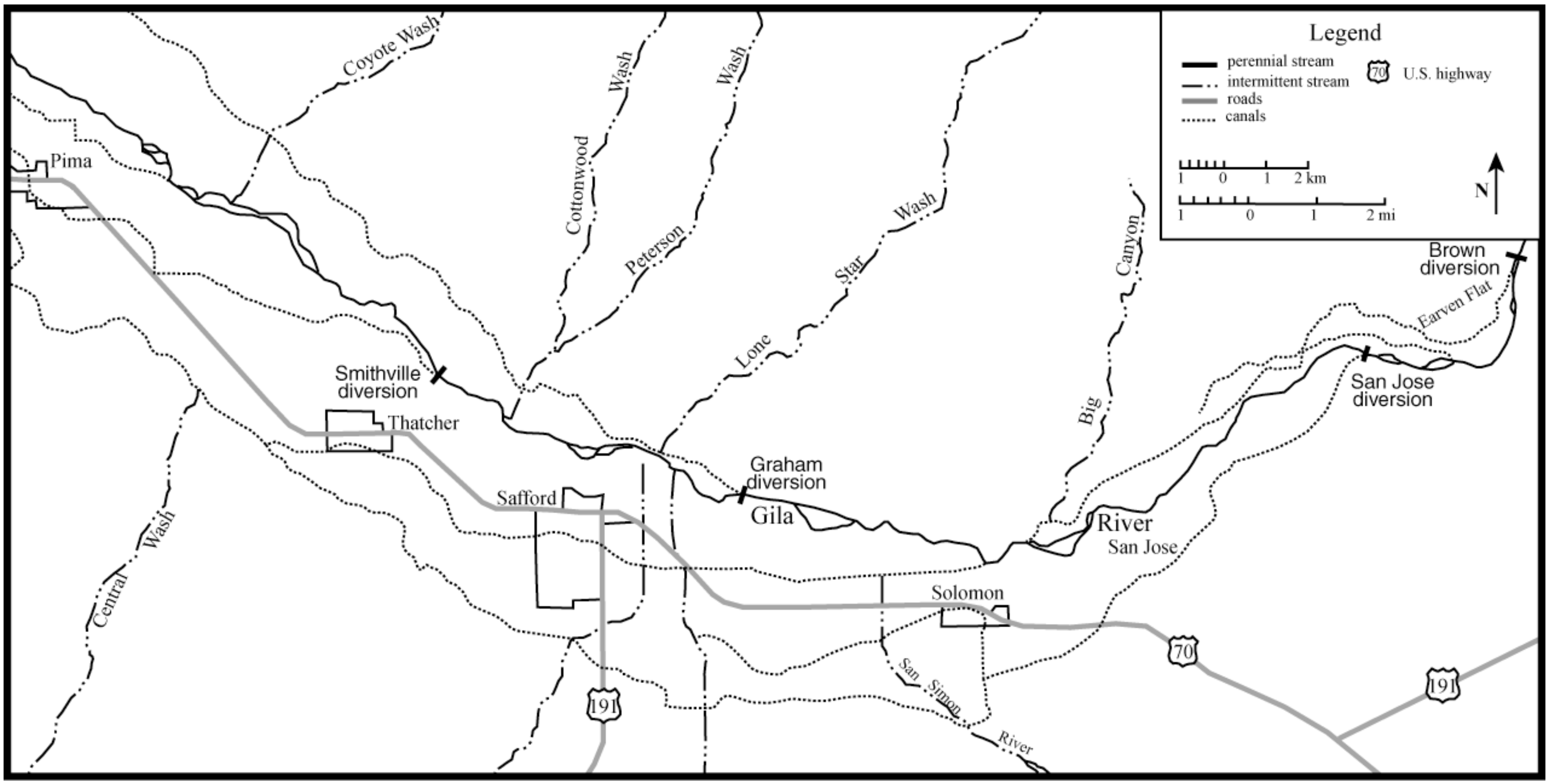
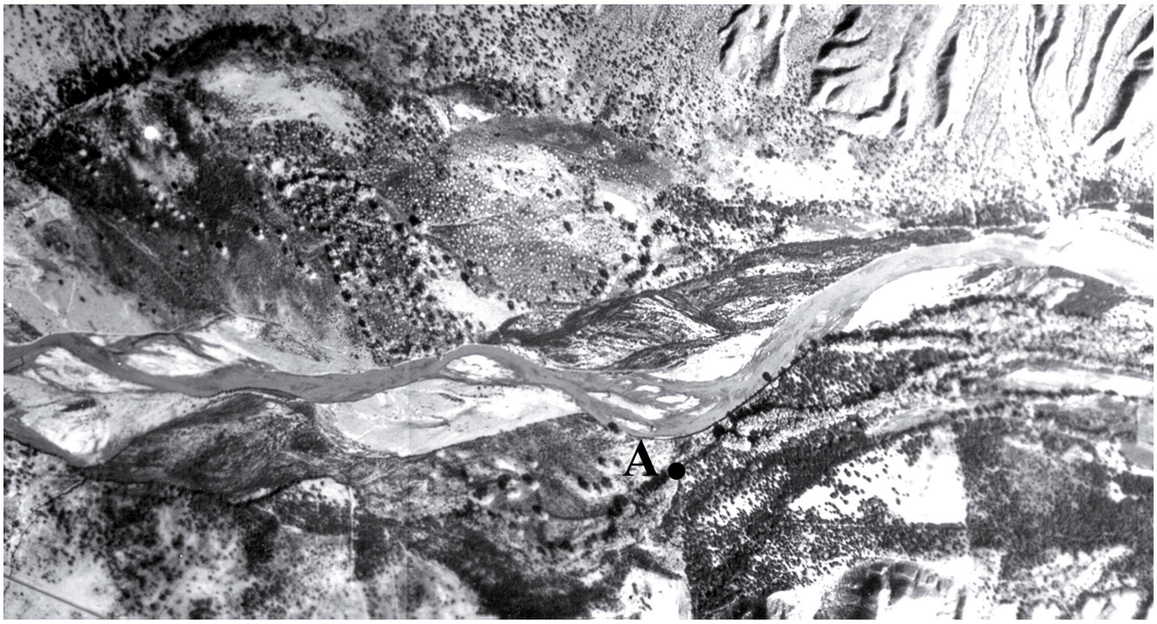


Figure 8. Reaches of greatest change: Pima, Arizona to Brown Diversion. Reaches of greatest change extend from Pima, Arizona to Smithville Diversion and from Graham Diversion to San Jose Diversion. Reaches of intermediate change are located between Safford Bridge and Graham Diversion, while reaches of smallest change are located upstream of San Jose Diversion.



(a) 1935

(b) 1953

Figure 9. Case Study 1: Near San Carlos Apache Indian Reservation. From (a) 1935 to (b) 1953, channel width had decreased significantly in the study reach. See point A for reference. Flow is from right to left.

(c) 1967

(d) 1978

Figure 9 (cont.) Levees built at point A in (c) 1967 further restrict the channel; by (d) 1978, these levees have disappeared. Flow is from right to left.

(e) 1992

(f) 1997

Figure 9 (cont.) By (e) 1992, the Gila River channel had reoccupied the left bank channel downstream of point A. By (f) 1997, the channel pattern had changed dramatically to a more sinuous channel with nearly 90-degree bends from bank to bank. This pattern is associated with erosion into right and left bank levees and channel modification. Flow is from right to left.

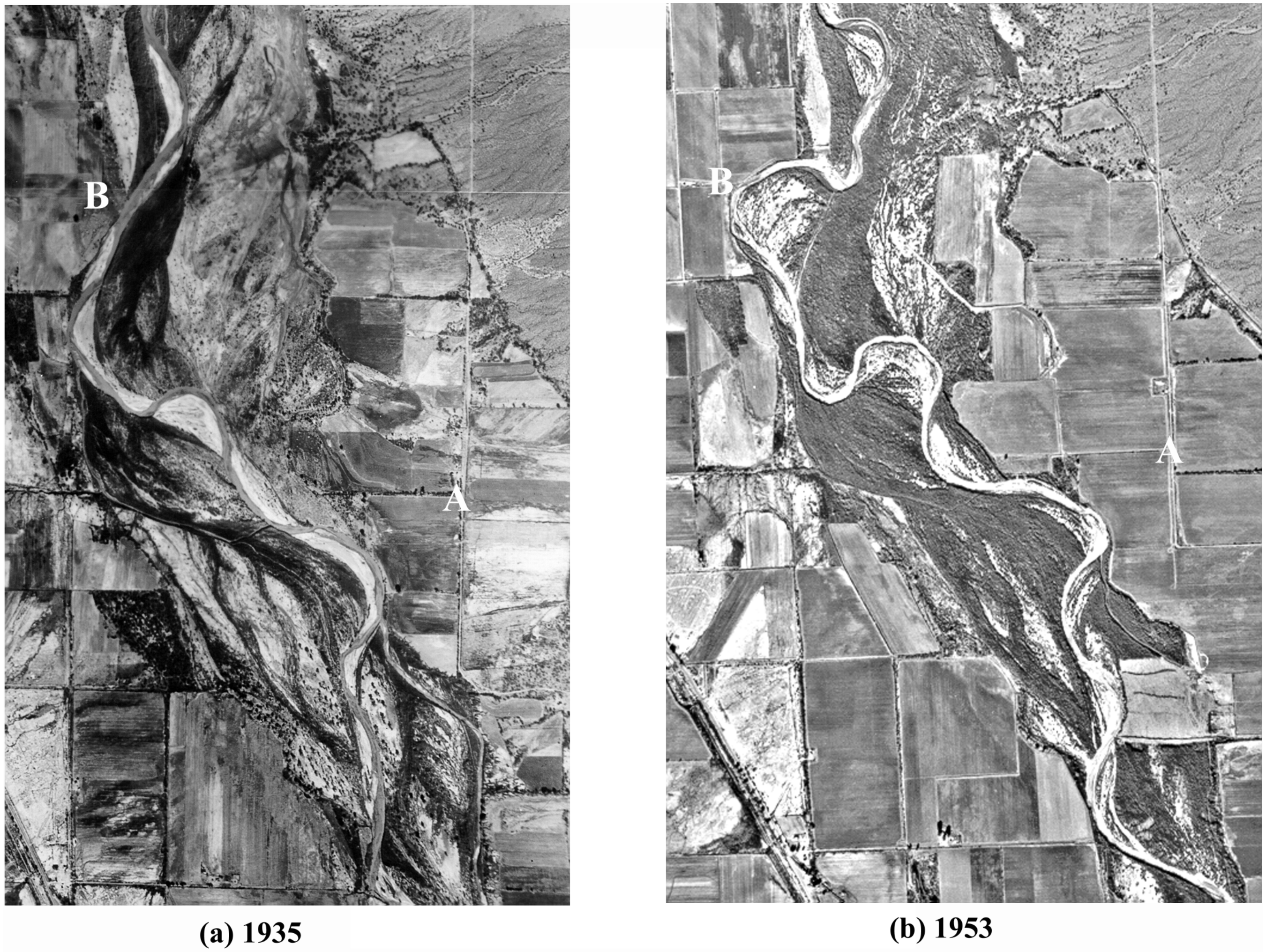
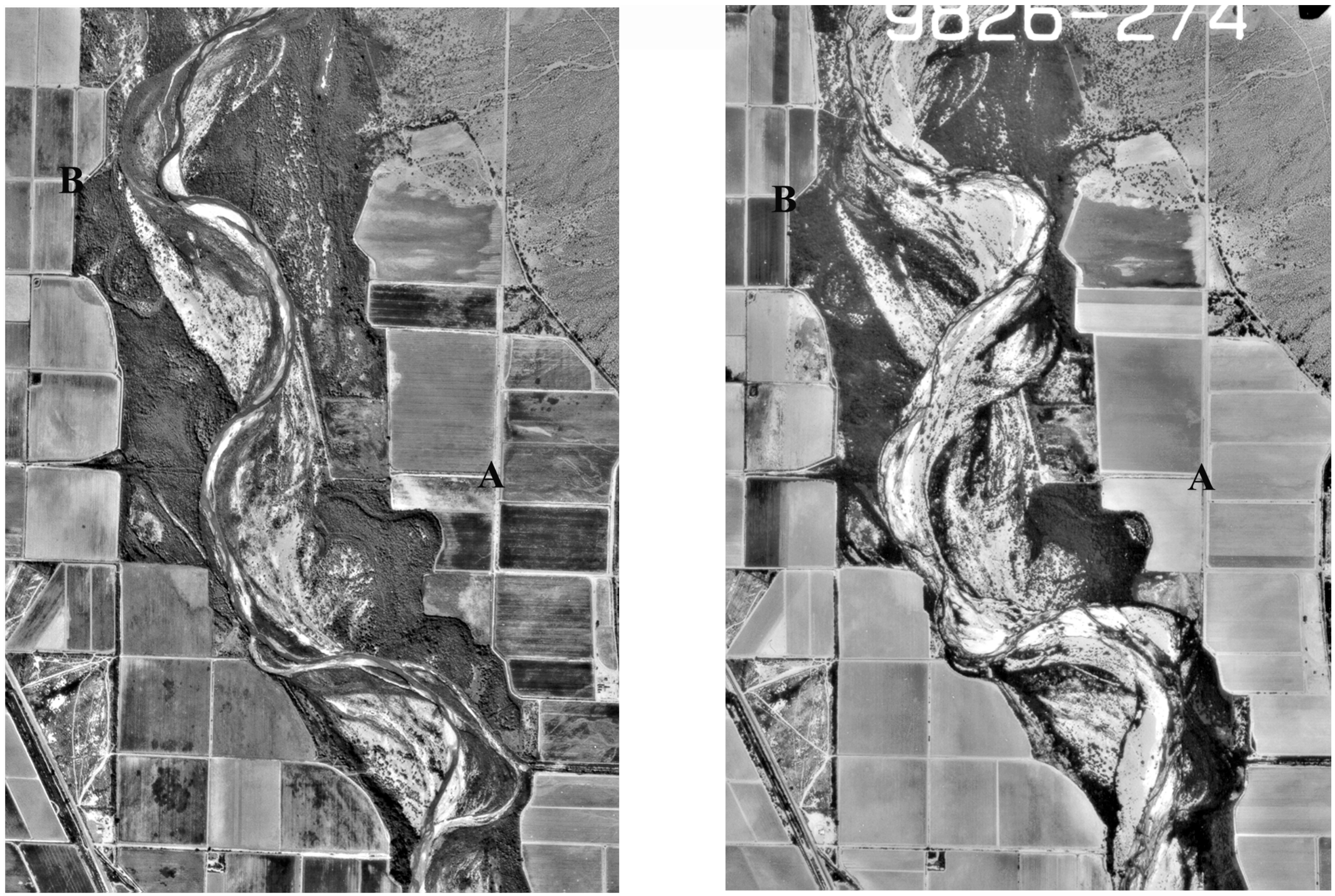


Figure 10. Case Study 2: Ashurst to Fort Thomas. From (a) 1935 to (b) 1953, flood widths decreased in conjunction with an increase in the sinuosity of the low flow channel. Note the right-bank meander at point A and the left bank meander at point B. Flow is from bottom to top in the figure.

(c) 1967

(d) 1973

Figure 10. (cont.) Attempts to channelize this reach are apparent in the 1967 photos, where flow has been partially rerouted down the new channel. By (d) 1973, right bank meanders at point A had been abandoned, while a new meander formed near point B. Flow is from bottom to top in the figure.

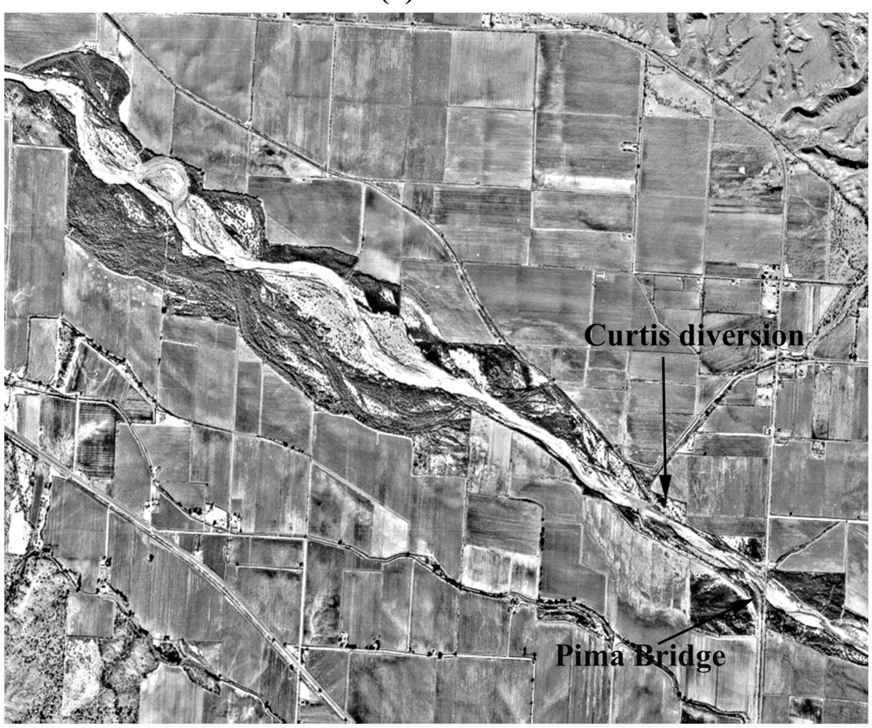


(g) 1992

(h) 1997

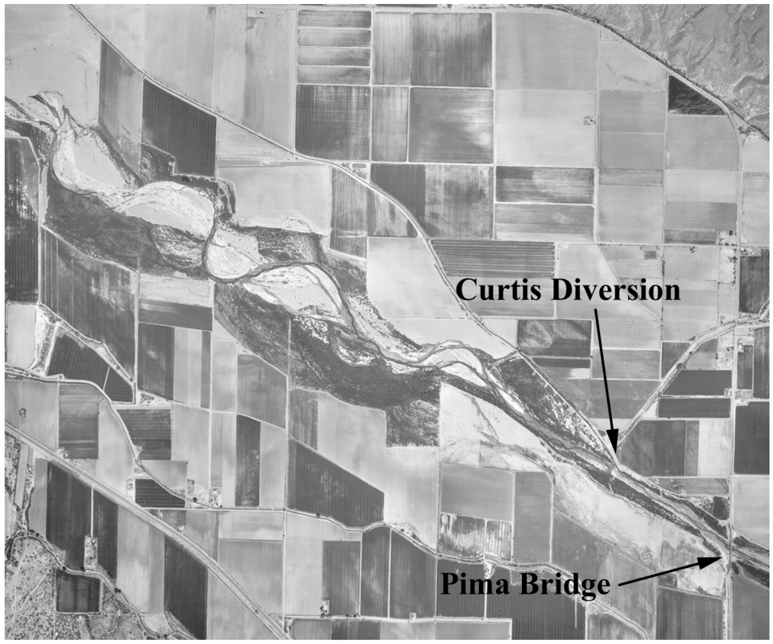
Figure 10 (cont.) (g) 1992 photos show additional change to a more sinuous meander pattern than that of 1973. Meanders at points A and B have been abandoned and vegetated. (h) The river channel continued to increase in sinuosity through 1997. Flow is from bottom to top in the figure.

(a) 1935



(b) 1953

Figure 11. Case Study 3A: Pima Bridge to Markham Wash. The photographs in this figure show channel narrowing from (a) 1935 to (b) 1953 downstream of Pima Bridge. Flow is from the right to left corner of the figure.



(c) 1967

(d) 1973

Figure 11 (cont.) (c) 1967 photographs show channelization and an increase in sinuosity downstream of Pima Bridge; (d) by 1973, the sinuosity had increased when compared to that of 1967. Flow is from the right to left corner in the figure.

(e) 1978

(f) 1997

Figure 11 (cont.) In (e) 1978, new channelization efforts are apparent; by (f) 1997, meanders had been accentuated and some incorporated into the flood flow channel. Flow is from the right to left corner in the figure.

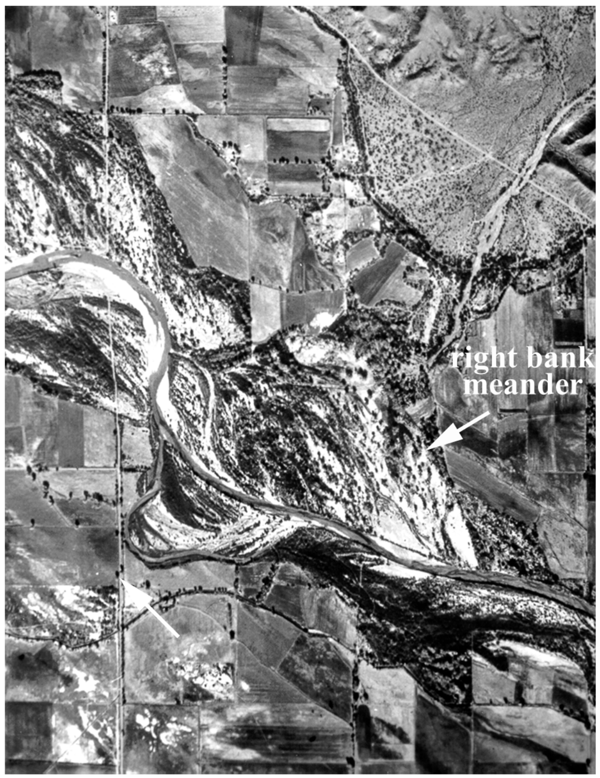
Case Study 3B: Thatcher Bridge and vicinity (points 37-38)
1935 photographs show the presence of a wide channel; from 1935 to 1967, the channel narrowed considerably on the right and left banks on account of the abandonment of 1935 meanders (Figure 12). In 1973, some widening is apparent following the 1972 flood and by 1981, the 1935 right and left bank meanders were again part of the flood channel. The 1981 photographs also show efforts to channelize this reach upstream and downstream of the Thatcher Bridge. 1992 and 1998 photographs show a channel similar to that of 1981 with added vegetation in the channel.

Case Study 4A: Solomon Bridge and vicinity (points 47-51)
This reach exhibits extremes between wide and narrow sections in the historical record (Figure 13). Most of the changes appear to be associated with infringement on the channel by agriculture and by the Solomon Bridge. In 1935, the channel near the future Solomon Bridge was relatively wide and a large meander existed upstream of the levied tributary. In 1953, the channel had been reduced considerably in width both at Solomon Bridge and at the levied tributary; evidence for inundation on the left bank agricultural fields is muted but noticeable. The effects of the 1972 flood in the accentuation of the right bank meander and inundation of farm fields on the left bank are evident in the 1973 photographs. By 1981, the main channel had widened further, with a marked contrast in channel width upstream and downstream of the levied tributary. By 1998, the channel had reoccupied the right bank immediately downstream of Solomon Bridge and had also widened its channel on the left bank at Solomon Bridge. It should also be noted that extreme channel width differences occur downstream of the levied tributary; for example, the 1953 photographs show part of the channel reoccupied by agriculture.

Case Study 4B: San Jose Diversion, downstream (point 58)
The San Jose Diversion creates a constriction in the channel, which then widens downstream of the diversion (Figure 14). This is illustrated by point 59, which is at the San Jose Diversion, and exhibits low variance and is also narrow relative to point 58, approximately 1 kilometer downstream of the diversion. The 1935 flood width was relatively wide. From 1935 to 1967, the flood width decreased slightly, while the position of the channel remained relatively constant. By 1981, significant lateral movement had occurred to the position of the abandoned Tidwell canal on the right bank and beyond the 1935 or 1967 channel on the left bank. The lateral movement of the channel toward the right bank continued into 1992 while the width also continued to increase. The 1997 channel was similar to that of 1992, with some increase in the sinuosity of the main channel.

Reaches of Intermediate Variability

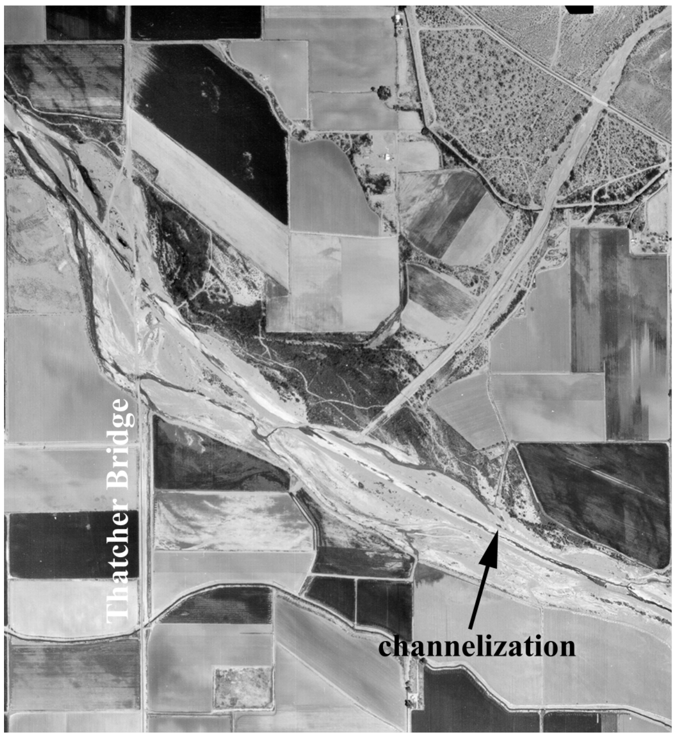
Reaches of intermediate variability include: (1) Fort Thomas Bridge (points 4-14); (2) Ashurst to Markham Wash (points 19-25); and (3) Graham Diversion to Safford Bridge (points 39-44). These reaches are relatively short in distance and are located between reaches of high variability. They show standard deviation values of less than 200m.



(a) 1935

(b) 1967

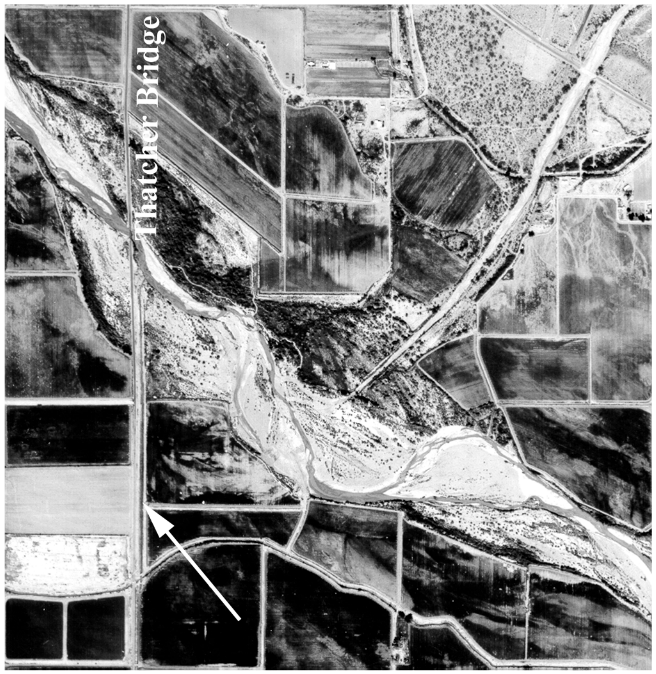
Figure 12. Case Study 3B: Thatcher Bridge and vicinity. From (a) 1935 to (b) 1967, the channel narrowed considerably due to the abandonment of a 1935 right bank meander and left bank meander (shown by the arrow). Flow is from right to left.



(c) 1967

(d) 1973

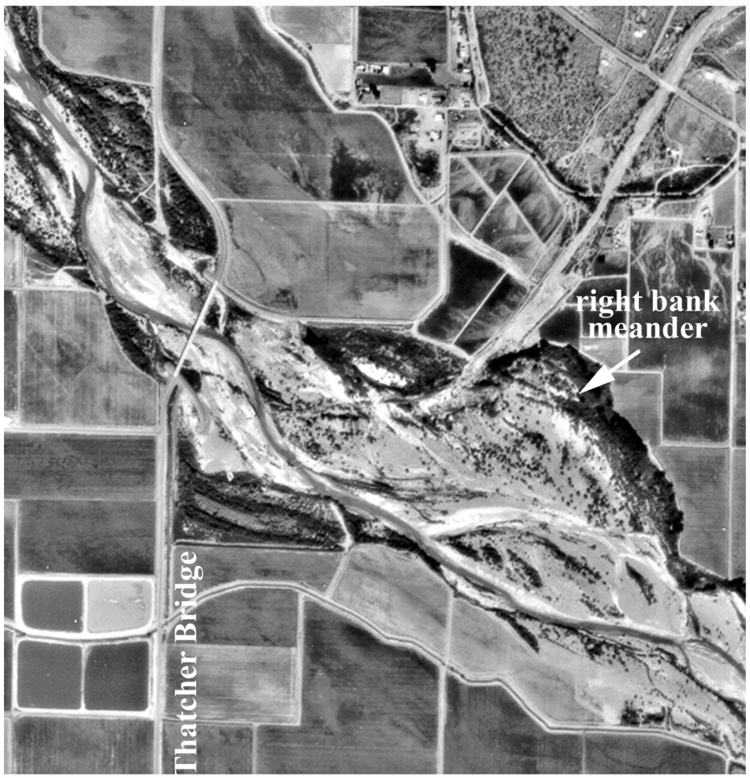
Figure 12 (cont.) From (c) 1967 to (d) 1973, channel widening is apparent due to the 1972 flood. Note the channelization in the 1967 photographs. Flow is from right to left.



(e) 1978

(f) 1981

Figure 12 (cont.) (e) 1978 photographs show migration of the right bank toward the old right bank meander; by (f) 1981, the river channel had fully cut into the 1935 right and left bank meanders. Note the change in width upstream from the Thatcher Bridge indicated by the white arrow. Flow is from right to left.

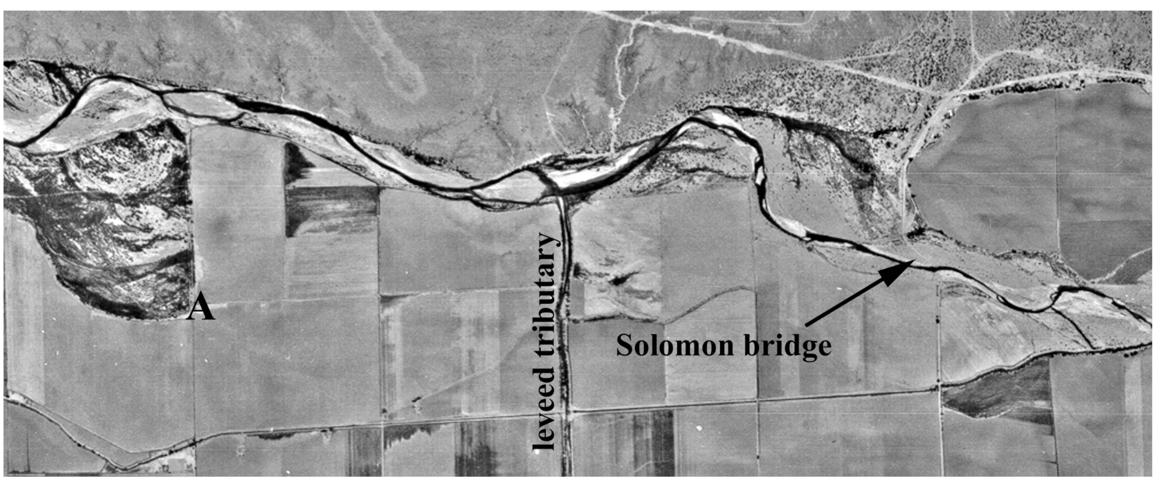


(g) 1992

(h) 1998

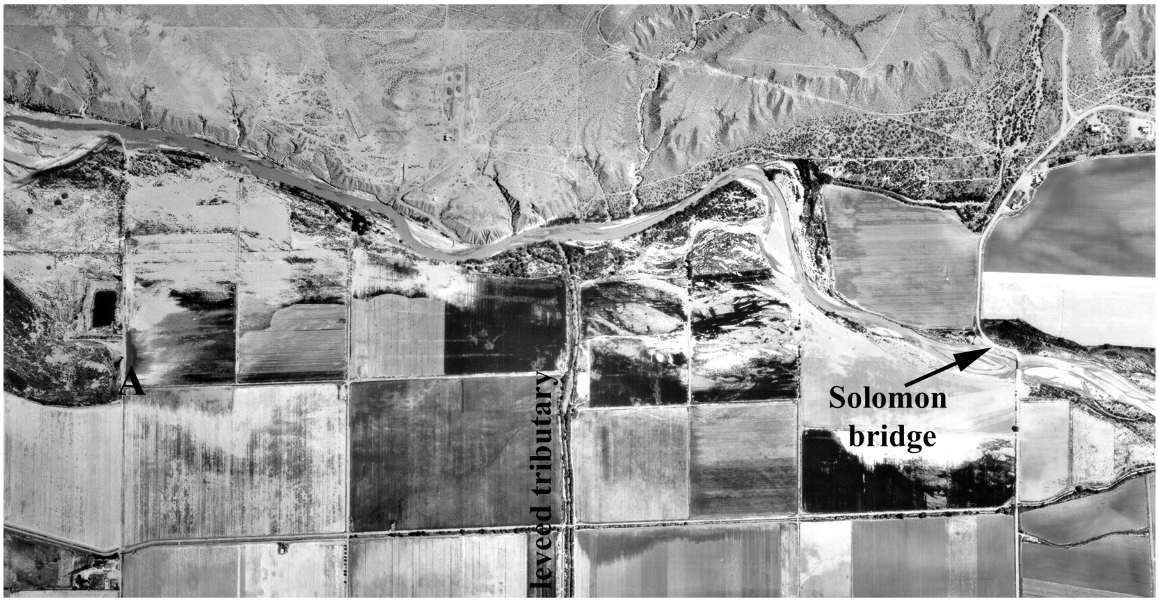
Figure 12 (cont.) (g) 1992 and (h) 1998 photographs show a channel similar to that of 1981 with additional vegetation in the channel. Flow is from right to left.

(a) 1935



(b) 1953

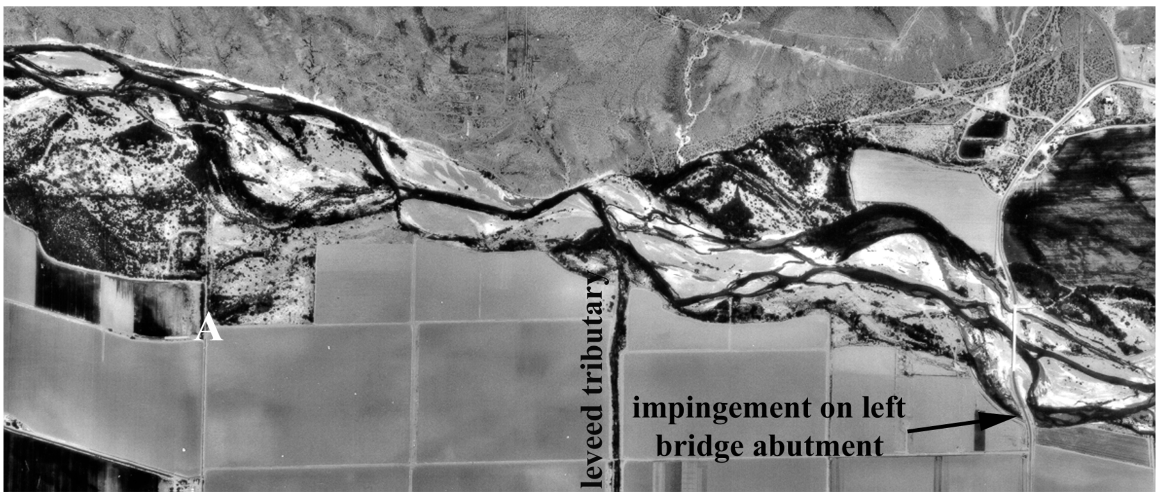
Figure 13. Case Study 4A: Solomon Bridge and vicinity. In (a) 1935, the channel was relatively wide and a meander existed on the left bank upstream of the levied tributary. By (b) 1953, the channel had reduced considerably in width for the reach as a whole and agriculture had reoccupied the channel upstream of point A. Flow is from right to left.



(c) 1973

(d) 1981

Figure 13 (cont.) (c) Channel widening occurred in response to the 1972 flood; (d) by 1981, the channel had widened further some channelization apparent downstream from the Solomon Bridge. Flow is from right to left.



(e) 1998

Figure 13 (cont.) By (e) 1998, the channel had widened and cut into the right bank downstream of Solomon Bridge. Flow is from right to left.

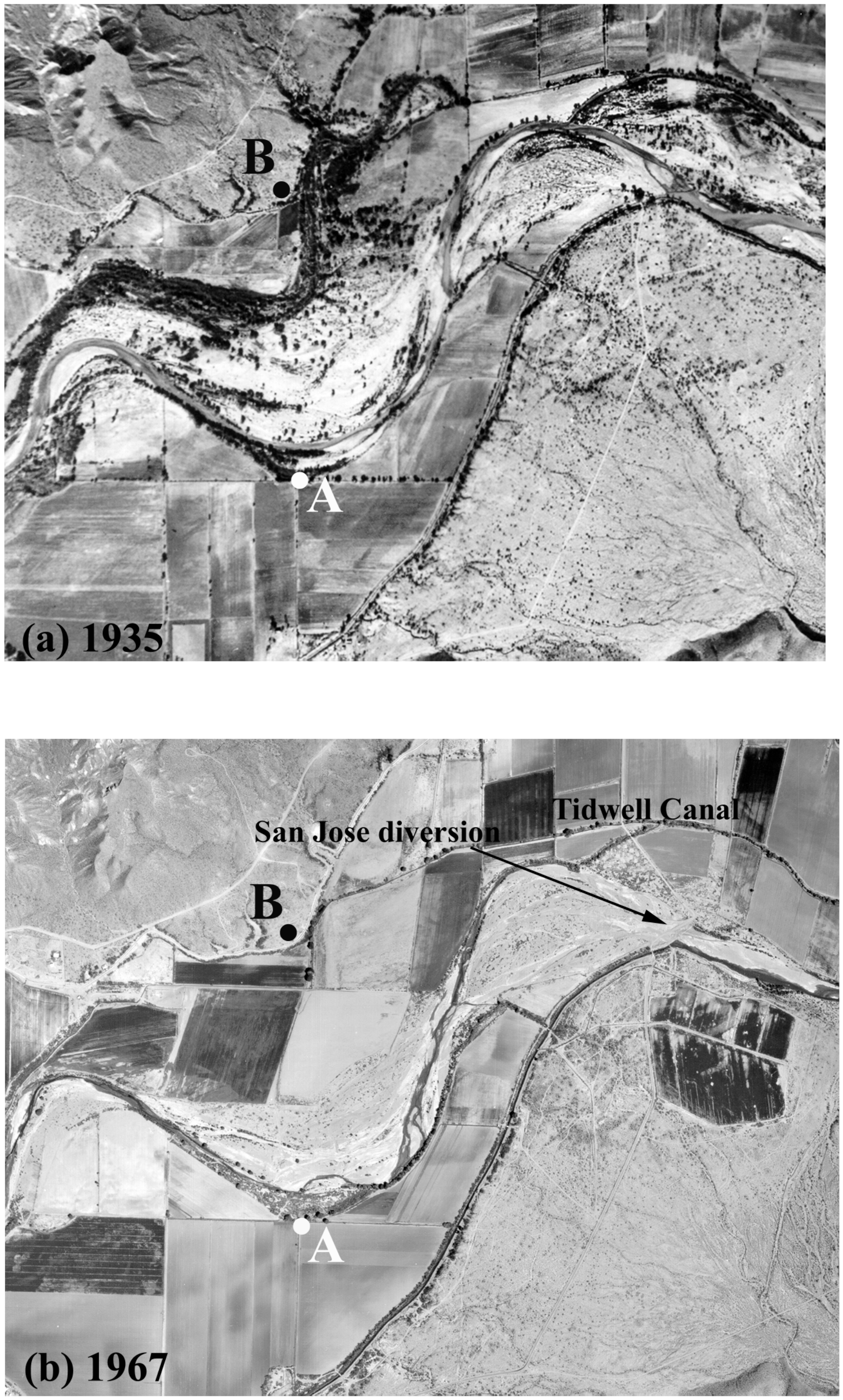


Figure 14. Case Study 4B: San Jose Diversion. From (a) 1935 to (b) 1967, the flood width decreased slightly, while the position of the channel remained similar. Note points A and B for reference. Flow is from right to left.

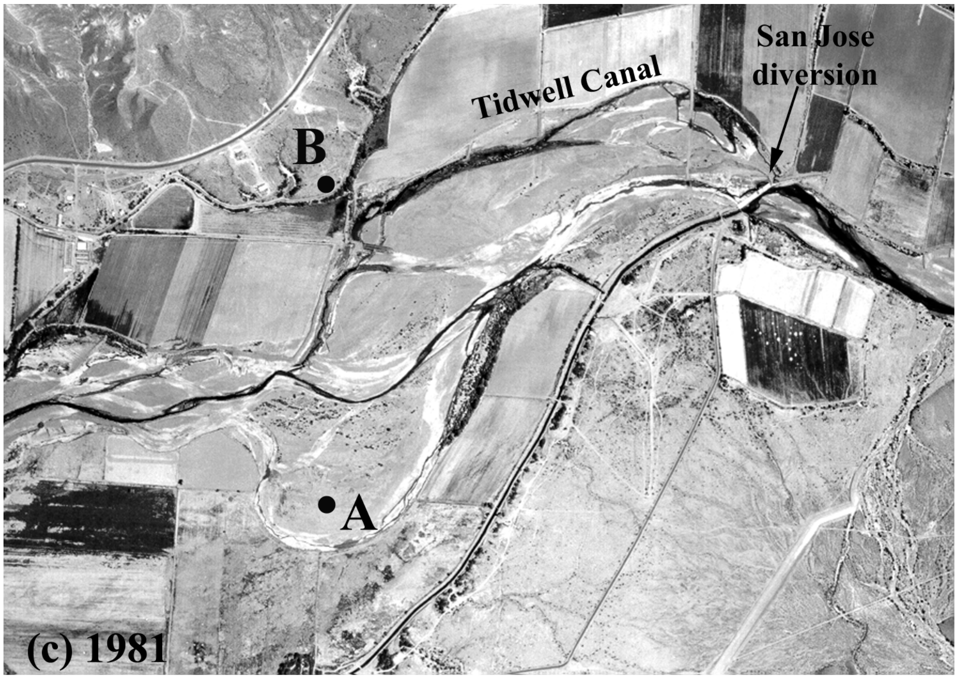


Figure 14 (cont.) By (c) 1981, lateral movement had occurred on the right and left banks (points A and B) downstream of the San Jose Diversion. Further lateral migration had occurred by (d) 1992 on the right bank at point B. Flow is from right to left.

Reaches of Smallest Variability

Reaches with the smallest variability include: (1) San Jose Diversion to Gila Box (points 59-62). This reach constitutes the upstream portion of the study area and is constricted by the downstream end of the Gila Box. The bedrock constraints on the Gila River channel in this reach account for the low variability in channel widths.

Wide and narrow channel locations

Channel locations that measured extremely wide or narrow on average with relatively low variance were identified and analyzed in order to determine the cause of the anomalous widths.

Wide

In Safford Valley, the widest channel locations were measured at points 1, 15, 16, and 17. These points are in reaches, which have been identified as reaches of greatest channel change, but also exhibit generally wider channels than other reaches upstream. Point 1 corresponds to the channel width at the boundary of the San Carlos Apache Indian Reservation (Case Study 1); points 15-17 correspond to the Ashurst Reach (Case Study 2) downstream of the Eden Bridge. Although the width seems to be at least in part a product of natural processes, there may be some connection with the anomalous narrow width at the Eden Bridge (point 21).

Narrow

The narrowest channel widths measured on average for Safford Valley correspond to points 4, 21, and 61. Points 4 and 61 are examples of channel locations that may be narrow through a combination of bedrock constrictions and levee construction; point 21 appears to be artificially narrow due to levee construction. Point 4 is located approximately one mile upstream of the Reservation boundary and is narrow due to the presence of consolidated Quaternary and Pliocene deposits that bound the river on both sides. In some years, the narrowness of the channel may be accentuated by levees on the left bank. Point 21 corresponds to the channel approximately 0.25 mile downstream of the Eden Bridge, where levees create an artificially narrow channel. Point 61 is located at the Tidwell Canal diversion, near the mouth of the Gila Box. At this location, the bedrock canyon and channelization at the diversion combine to produce the narrow width.

COMPARISON OF FLOOD INUNDATION WIDTHS TO FLOOD WIDTHS

Three major floods occurred in the past 65 years for which post-flood aerial photography was flown. These photograph sets provide valuable information on impacts of large floods on channel morphology and can be very useful in comparing the flood widths as interpreted in non-flood years to inundation widths from actual floods. Figure 3 shows that the largest floods in Safford Valley occurred in 1983 (peak of record), 1916, 1978, 1993, and 1972. Photograph sets from the flood of October 1972, October 1983, and March 1993 were available for this analysis. These sets were compared to the pre-flood sets of 1967, 1981, and 1992, respectively (Figure 15).

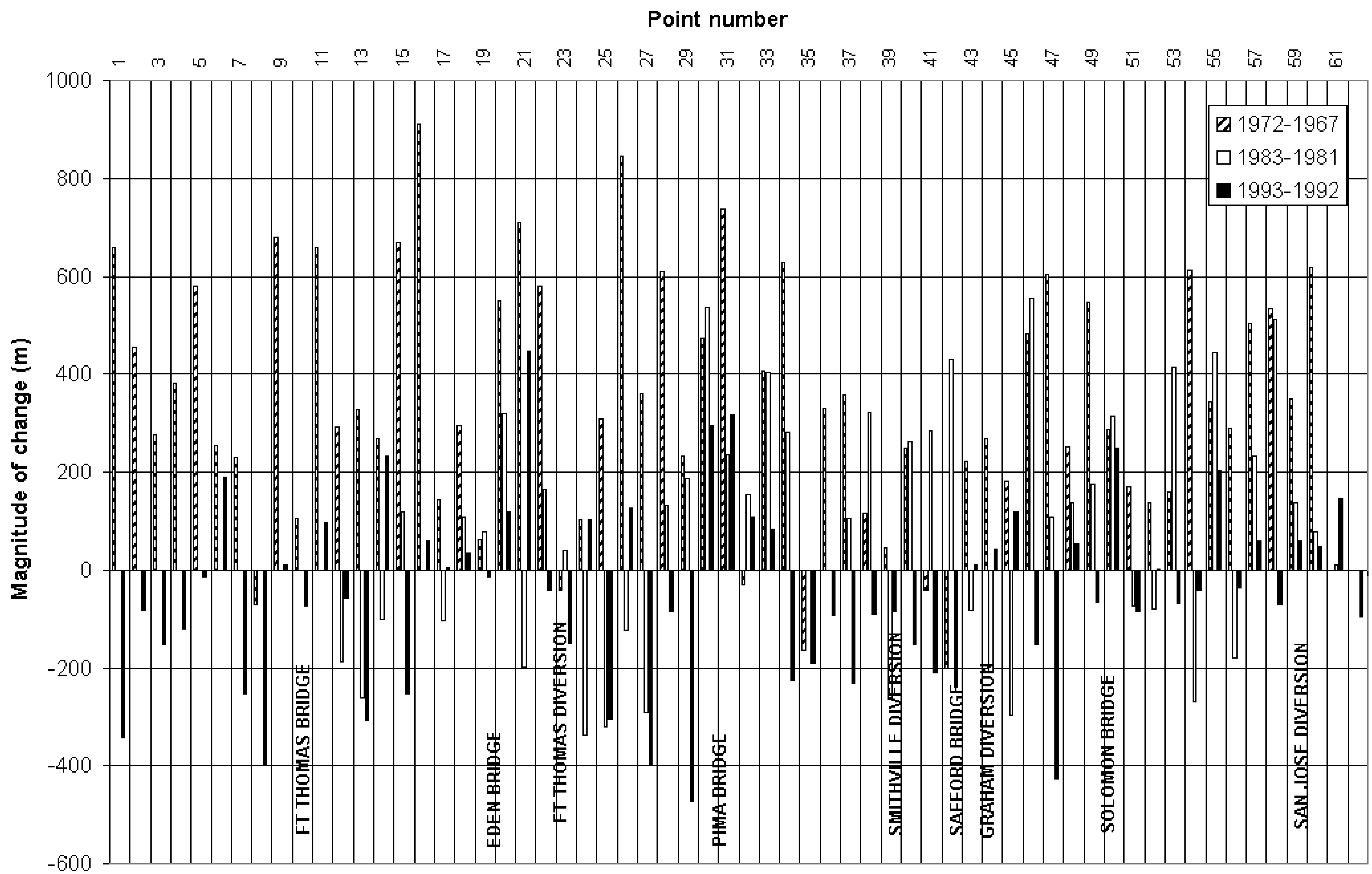


Figure 15. Comparison of flood inundation widths to flood widths. This figure shows the magnitude of difference between the inundation width during the largest floods in the historical record and the flood widths measured from pre-flood photographs.

Generally, the 1972 flood inundation width is much larger than the 1967 flood flow width, with the exception of a few isolated points. On average, the magnitude of the difference is 348 m, and reaches a maximum value of over 900 m. This disparity in width is an indication that the channel was too narrow to accommodate the 1972 discharge. This was due to the fact that the channel had not been subjected to high magnitude peak discharges for several decades. The 1983/1981 comparisons show that the flood width in 1981 is actually larger than the inundation width of the 1983 flood. This suggests that the channel had widened considerably during the 1972 flood to accommodate the larger flows. The 1993/1992 comparisons shows even more points, which have flood widths larger than the 1993 flood inundation widths. Since the 1993 flood was of much smaller magnitude than either the 1972 or 1983 flood, the channel was wide enough from the previous floods to accommodate the 1993 discharge.

DUNCAN VALLEY

GENERAL TRENDS

Average width data: Comparison of Flood Years

The average width data for Duncan Valley shows similar trends to that of Safford Valley (Figure 16). From 1935 to 1958, there was a general decrease in both recent flow width and flood width, especially from 1953 to 1958. This decrease followed a period of fewer and smaller magnitude floods. From 1958 to 1981, channel width increased, most likely due to the 1965, 1972 and 1978 floods in Duncan Valley. From 1981 to 1992, widths decreased slightly for the recent flows and increased for the flood flows, the latter of which may be associated with the 1984 flood, which is the second largest peak in the record at the Gila River near Clifton gaging station. From 1992 to 1997, average flood width appears to have remained constant and reached the average flood width of 1935 measurements in 2000. Recent flow width increased from 1992 to 2000.

Longitudinal trends

From analysis of all photograph years, there is a general decrease in flood flow width in the upstream direction, which is similar to the longitudinal trends for Safford Valley (Figure 17). Average recent flow widths do not show a discernible longitudinal trend.

PHOTOGRAPH YEAR COMPARISON

Analysis of channel changes

The analysis of channel changes documents the reaches of greatest and smallest variability in all non-flood photograph sets (Figure 18). Reaches of greatest and intermediate variability are selected for case studies to illustrate the types of channel changes that have occurred during the historical period. Generally, the reaches of smallest variability are much longer than any reaches that have high variance. This suggests that channel change in Duncan Valley has been minimal with the exception of a few select reaches. Qualitative information gathered by evaluating photograph sets prior to measurement confirms the nature of channel behavior in reaches of great variability and also those of small variability. One exception is the Willow Creek reach, which came out as a reach of high variability, whereas it was recorded through initial observations as a stable reach. This point was difficult to measure due to the contrast on some of the photograph sets; it is most likely the case that a high terrace was included in the flood width in some of the wider measurements. As in Safford valley, only flood width measurements are used in this analysis.

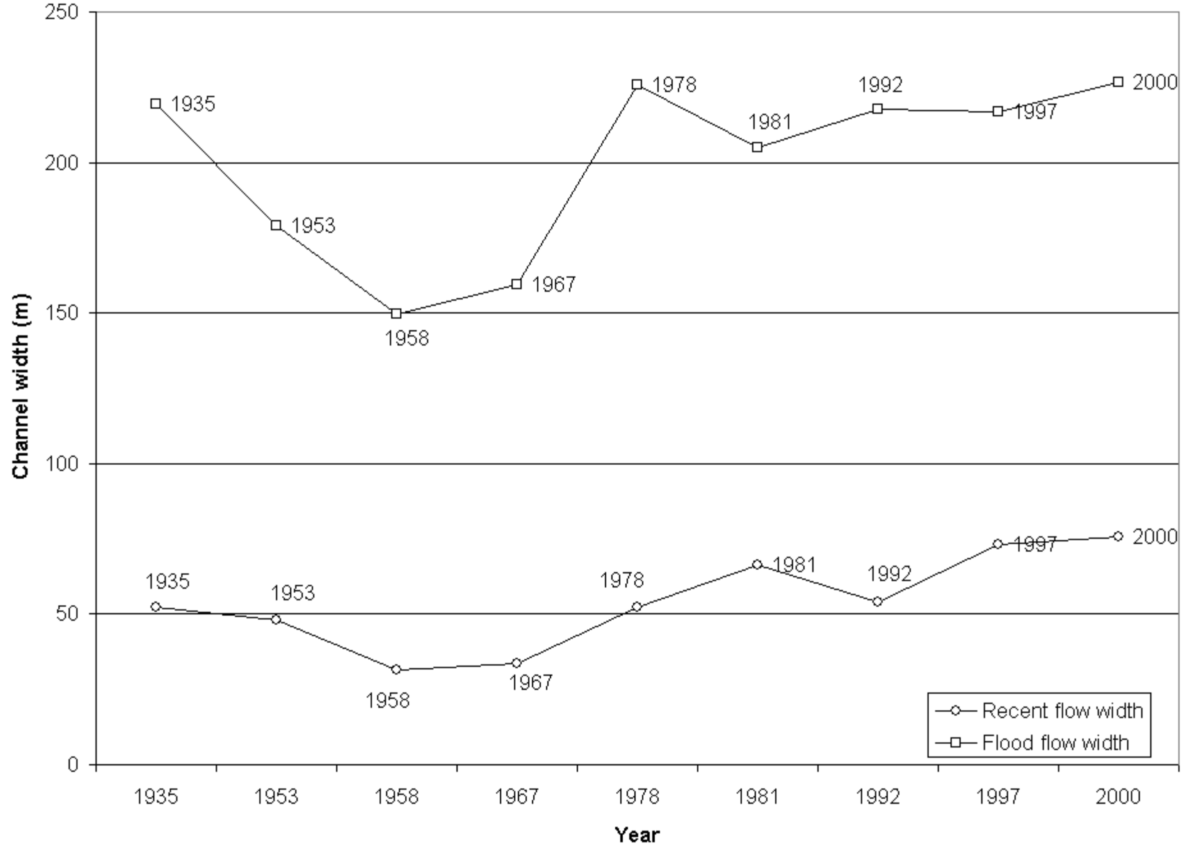


Figure 16. Duncan Valley average width data by year. Average width data show a general decrease in width from 1935 to 1958, followed by an increase in width from 1958 to 1981, with a spike in 1978 flood width due to the 1972 flood. Flood widths and recent flow widths gradually increased in width from 1981 to 2000, with a slight decrease in 1992 recent flow widths

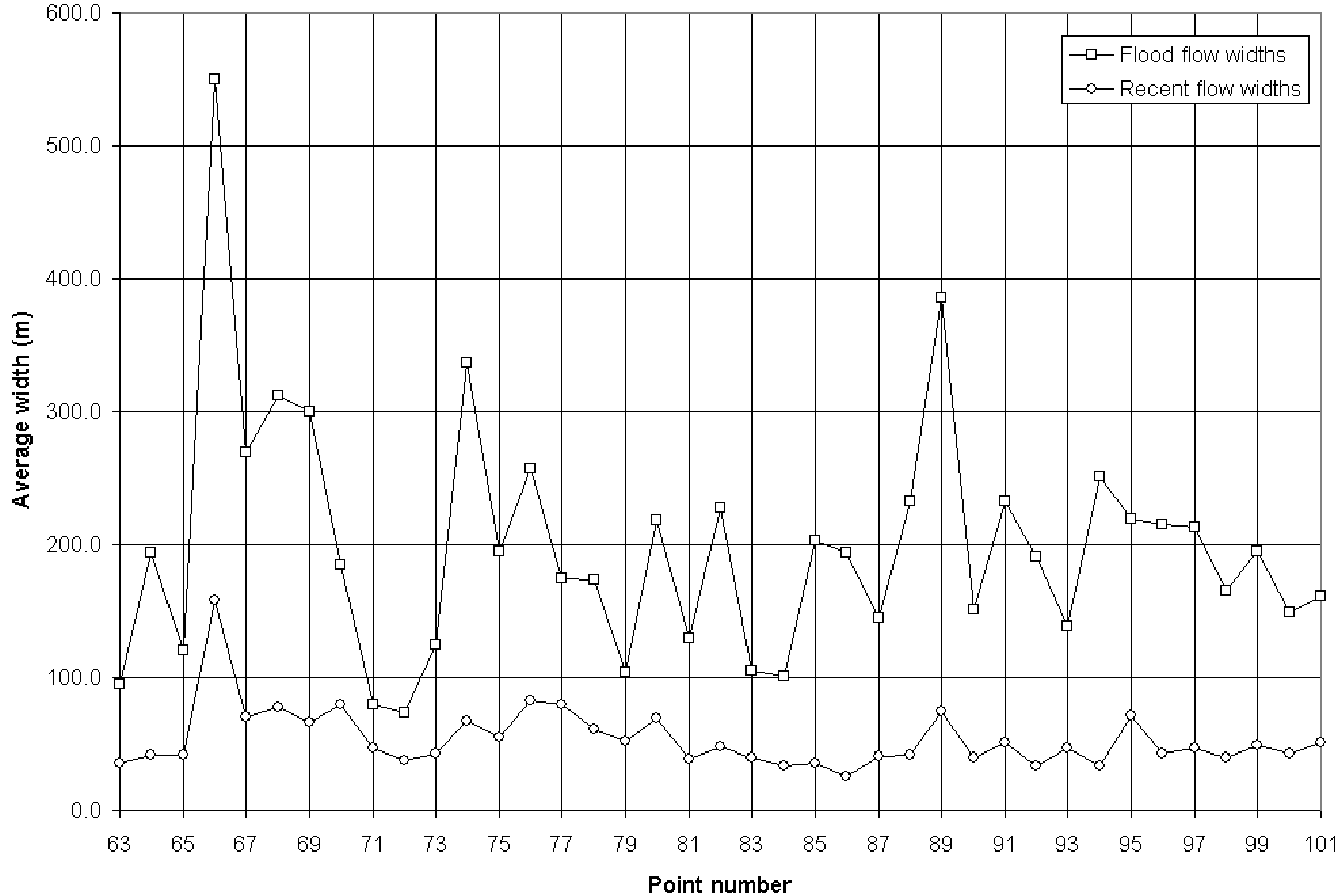


Figure 17. Duncan Valley average width longitudinal trends. Average flood widths for each point show a general decrease in width from downstream (point 63) to upstream (point 101); average recent flow widths show no discernible trend.

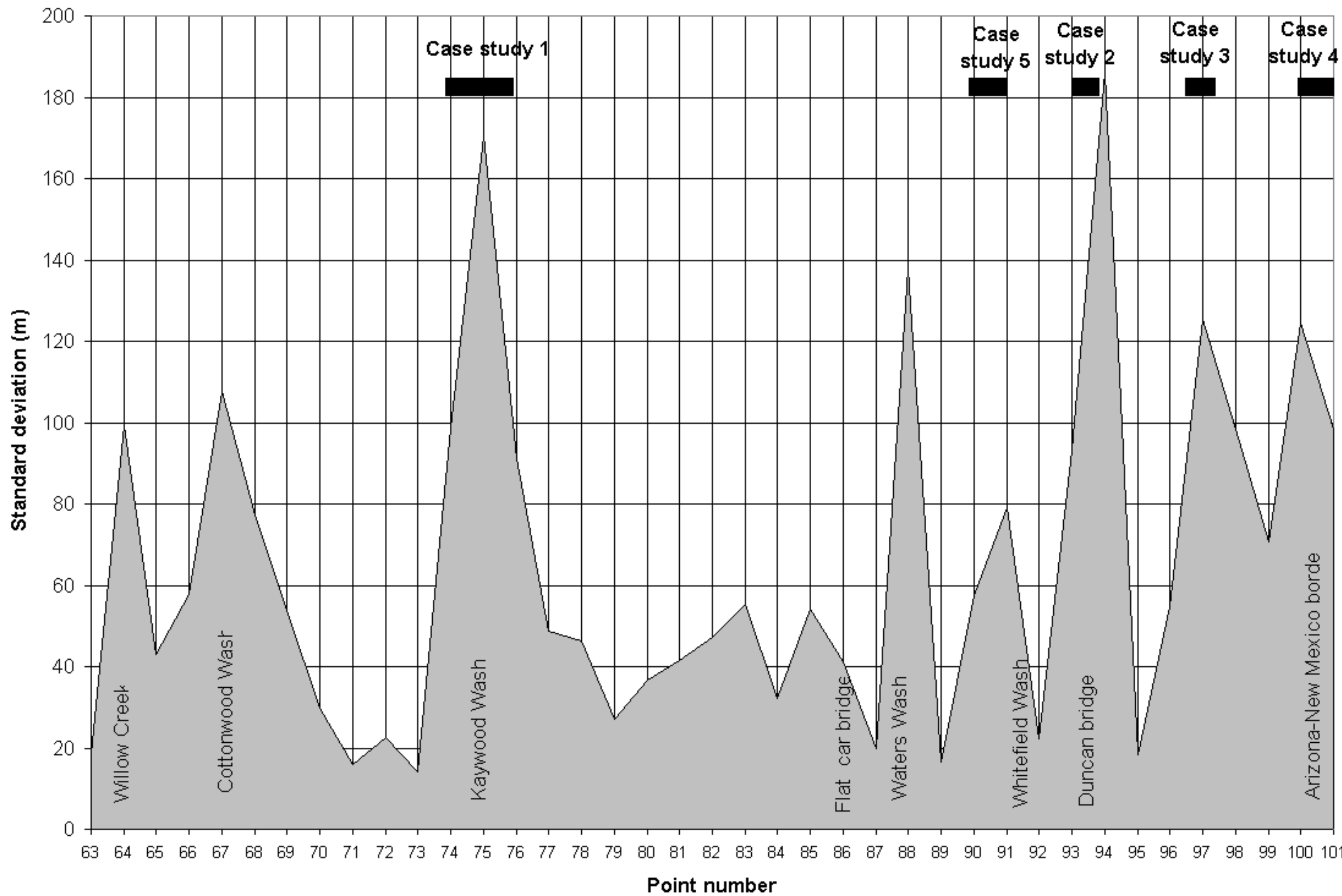


Figure 18. Analysis of channel changes, Duncan Valley. The standard deviation for each point is shown. Case studies highlight the greatest channel changes observed in Duncan Valley. Locations for the case studies are shown by the horizontal bars.

Reaches of Greatest Variability

Reaches of greatest variability in Duncan Valley include; (1) Kaywood Wash area (points 74-76); (2) Duncan Bridge (points 93-94); (3) Railroad Wash area (point 97); and (4) Arizona-New Mexico border (points 100-101) (Figure 19). Other reaches of high variability that are not discussed in the text include: (5) Willow Creek area (point 64); (6) Cottonwood Wash area (points 67-68); and (7) Waters Wash (point 88).

Case Study 1: Kaywood Wash area (points 74-76)
The 1935 channel was the widest documented during the measurement period; by 1958, the record of floods in adjacent fields had been obliterated (Figure 20). In 1967, the right bank meander was abandoned and the channel continued to decrease in width to 1978, which is the narrowest width in the record. Prominent levees were located at the upstream end of this study reach in 1978. In 1992, the right bank meander was reoccupied by lateral migration and in 1997 was further scoured presumably by floods in 1993 and 1995. Erosion also occurred behind the levees at the upstream end of the study reach prior to 1992 and between 1992 and 1997.

Case Study 2: Duncan Bridge (points 93-94)
In 1935, the channel exhibited a greater tendency to meander than in subsequent years and was an intermediate width when compared to other photograph sets (Figure 21). By 1958, levees were constructed in the reach, and the channel narrowed to its smallest width in 1967. By 1981, the channel increased to its widest extent for the period of record, most likely due to the 1978 flood of record, and by 1992, some of this channel had been revegetated. The 1997 photographs show erosion of the left bank upstream of the Duncan Bridge that occurred between 1992 and 1997, presumably in response to floods in 1993 and 1995.

Case Study 3: Railroad Wash area (point 97)
This reach is interesting because it shows the non-erosive behavior of floods on the Gila River channel. In this reach, the general position of the channel does not change; however, the flood width does change as it inundates the overbank areas and creates flood morphology evident on subsequent photographs (Figure 22). In 1935, the channel was wider than in later years, while the 1958 and 1967 channel were the narrowest in the record. Following 1967, the flood width increased in 1978, 1981, and 1992.

Case Study 4: Arizona-New Mexico Border (points 100-101)
Photograph sets for this reach show a relatively wide channel in 1935, narrowing of the channel and occupation of the channel by agriculture from 1935 to 1967 (Figure 23). The 1978 photographs show channel splays in the farmland adjacent to the channel; however, the channel narrows again by 1981 and is similar in 1992. Also note the left bank erosion just upstream of the Arizona-New Mexico border in 1992.

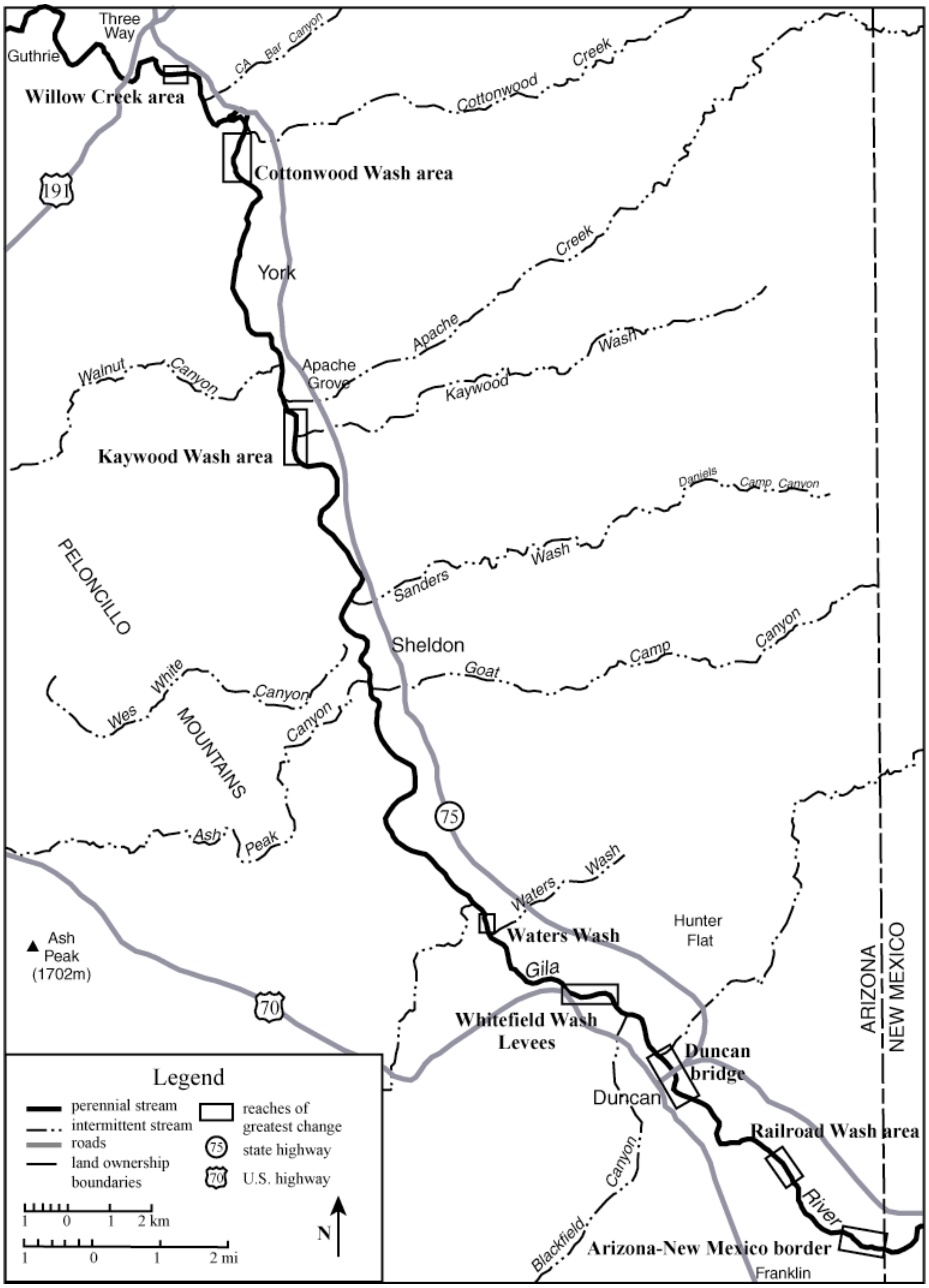
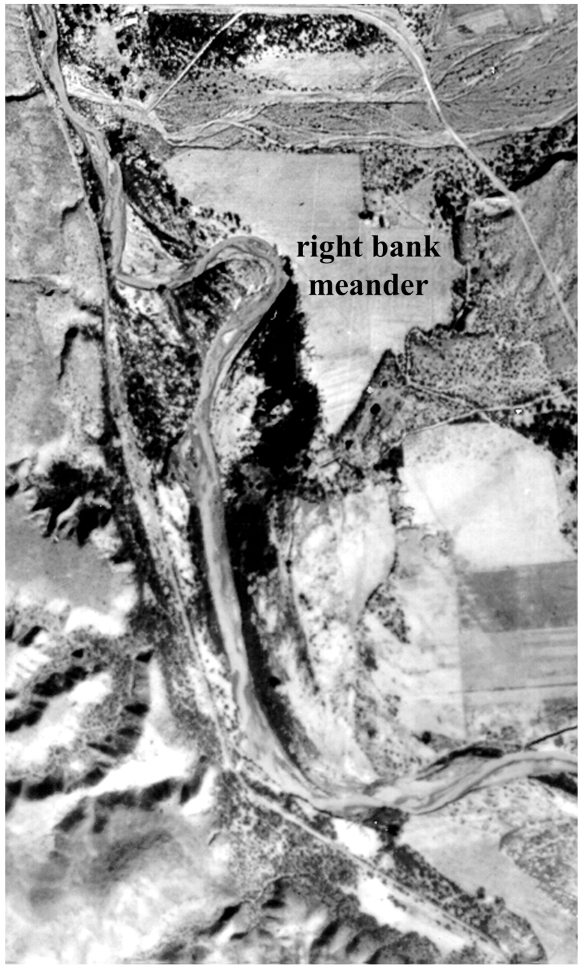


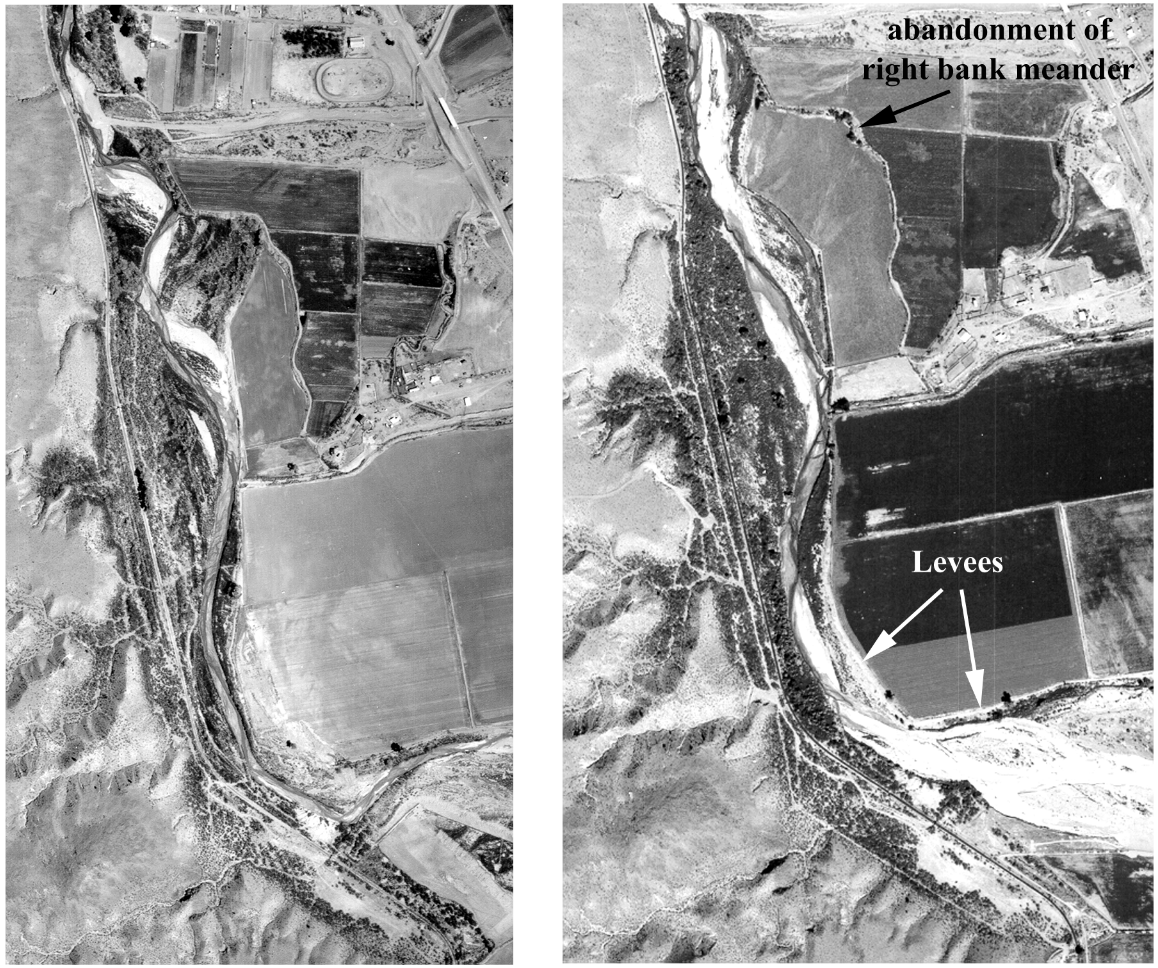
Figure 19. Reaches of greatest change: Duncan Valley. The reaches of greatest change are indicated by the boxed in reaches of the Gila River. Flow is from south to north.



(a) 1935

(b) 1958

Figure 20. Case Study 1: Kaywood Wash area. From (a) 1935 to (b) 1958, channel width decreased, especially on the right bank. Flow is from bottom to top in the figure.



(c) 1967 **(d) 1978**

Figure 20 (cont.) The right bank meander in (c) 1967 was abandoned and reoccupied by agriculture by (d) 1973. Levees were also constructed in 1973 on the right-bank at the upstream end of the study reach. Flow is from bottom to top in the figure.

(e) 1992

(f) 1997

Figure 20 (cont.) (e) Inundation behind levees on the right bank and lateral migration of the right bank in 1992 created a channel similar to that of 1958. By (f) 1997, the right bank had become the main channel.

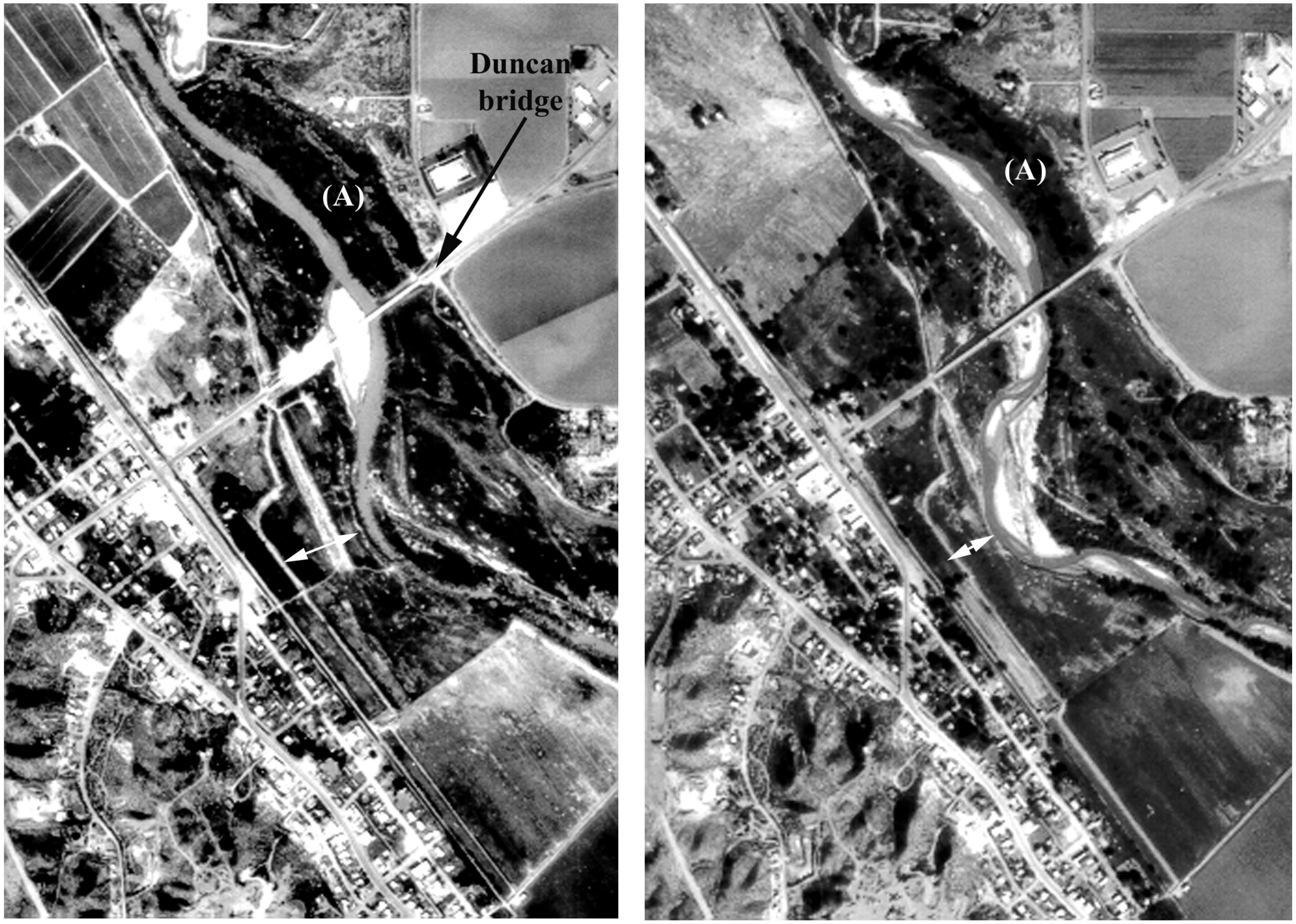
(a) 1935 (b) 1958

Figure 21. Case Study 2: Duncan Bridge. Channel narrowing occurred between (a) 1935 and (b) 1958, particularly on the right-bank at point A and upstream of Duncan Bridge. Flow is from bottom to top in the figure.

(c) 1967

(d) 1981

Figure 21 (cont.) (c) The 1967 channel was the narrowest channel in the historical period. By (d) 1981, the channel had increased to its widest extent in the historical period due to the 1978 flood.



(e) 1992

(f) 1997

Figure 21 (cont.) By (e) 1992, much of the 1981 flood width had been vegetated and in (f) 1997, the left bank upstream of the Duncan Bridge had been eroded presumably by floods in 1993 and 1995 (shown by arrows). Flow is from bottom to top in the figure.

(a) 1935

(b) 1967

Figure 22. Case Study 3: Railroad Wash area. From (a) 1935 to (b) 1967, the channel decreased in width although its position remained similar. The segment from A to A' illustrates this reduction in width. Flow is from bottom to top on the figure.

(c) 1981

(d) 1992

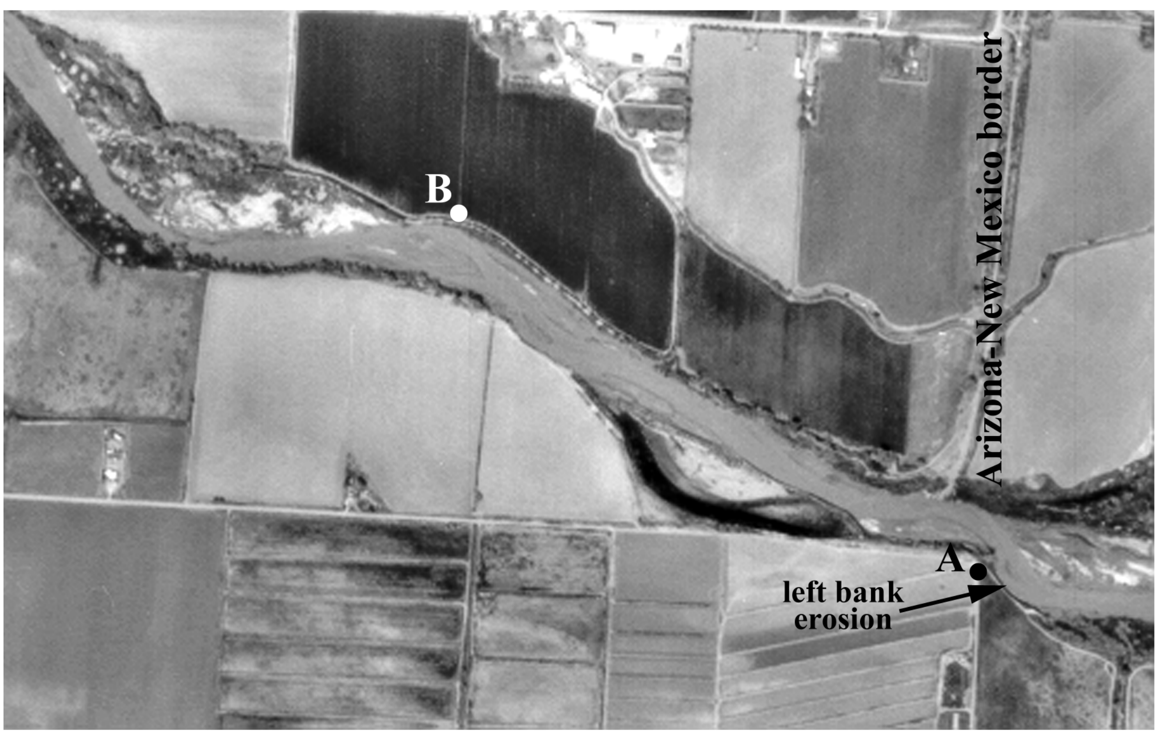
Figure 22 (cont.) In (c) 1981 and (d) 1992, overbank flooding is evident. The approximate flood width is illustrated by the A-A' segment and is an increase when compared to flood widths in previous decades. Flow is from bottom to top in the figure.

(a) 1935

(b) 1967

Figure 23. Case Study 4: Arizona-New Mexico border. From (a) 1935 to (b) 1967, the flood width decreased. Note that the channel widened downstream of point B in 1935, whereas in 1967, levees constricted its width. Point A is located at the Arizona-New Mexico border and in 1935 is located in the middle of the channel whereas in the 1967 it is located on the left bank. Flow is from right to left.

(c) 1978



(d) 1992

Figure 23 (cont.) (c) The 1978 photographs show channel splays downstream of point B and evidence of flooding on the left bank. (d) The channel was again constricted in 1992. Also note the erosion on the left bank upstream of point A. Flow is from right to left.

Reaches of Intermediate Variability

Reaches of Intermediate Variability include: (1) Whitefield Wash Levees (points 90-91)

Case Study 5: Whitefield Wash Levees (points 90-91)
This reach is generally similar throughout most of the period of record, but exhibits major channel changes between 1992 and 1997 (Figure 24). The 1935 channel exhibited more sinuous channel morphology, but was generally similar to subsequent years. This difference is most likely due to the construction of levees in 1953, which forced the channel to conform to a particular pattern. This pattern persisted through 1981, where levees were constructed in a slightly different arrangement and more thoroughly. This was probably in response to the 1978 flood, in which inundation is apparent behind the levees on reoccupied farmland on the 1981 photograph set. The 1992 channel had a similar configuration, although some levees had been eroded in the intervening years. In 1997, the left bank levee had been eroded where it was built up after the 1978 flood, and a new right bank meander cut into the floodplain that was previously a part of the flood width in 1935. In sum, although a seemingly new channel was created, high flows between 1992 and 1997 cut into areas that were previously part of the inundation area.

Reaches of Smallest Variability

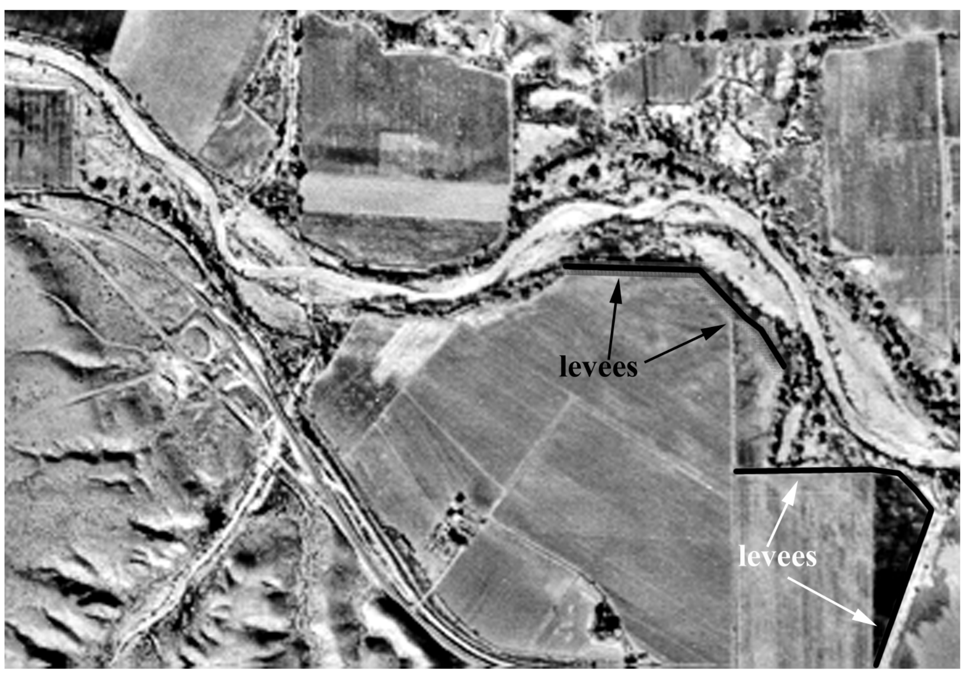
Reaches of smallest variability include: (1) Apache Grove to Greaser Wash (points 69-73); and (2) Sand Wash to Flat Car Bridge (points 77-87). These reaches exhibit minimal lateral movement, which implies that the channel has been stable in these reaches during the period of study.

Wide and narrow channel locations

Wide
Points that were recorded as abnormally wide compared to other channel widths in Duncan Valley include points 66, 74, and 89. Point 66 corresponds to an approximate 180 degree meander bend that has been in the same general location throughout the period of study. In this reach, bedrock obstructions and alluvial fans force the river into its present meandering pattern. Point 74 corresponds to the right bank meander in the Kaywood Wash area (Case Study 1). The channel width in this location is wide and may be responding to upstream constrictions on the right bank from the Kaywood Wash alluvial fan and levees (see Figure 20). Point 89 is located upstream of Waters Wash. The channel occupies the entire valley width for nearly all photograph years and appears to be abnormally wide compared to channel widths just downstream especially during periods of few floods. This site will be explored further during the Geomorphic Analysis.

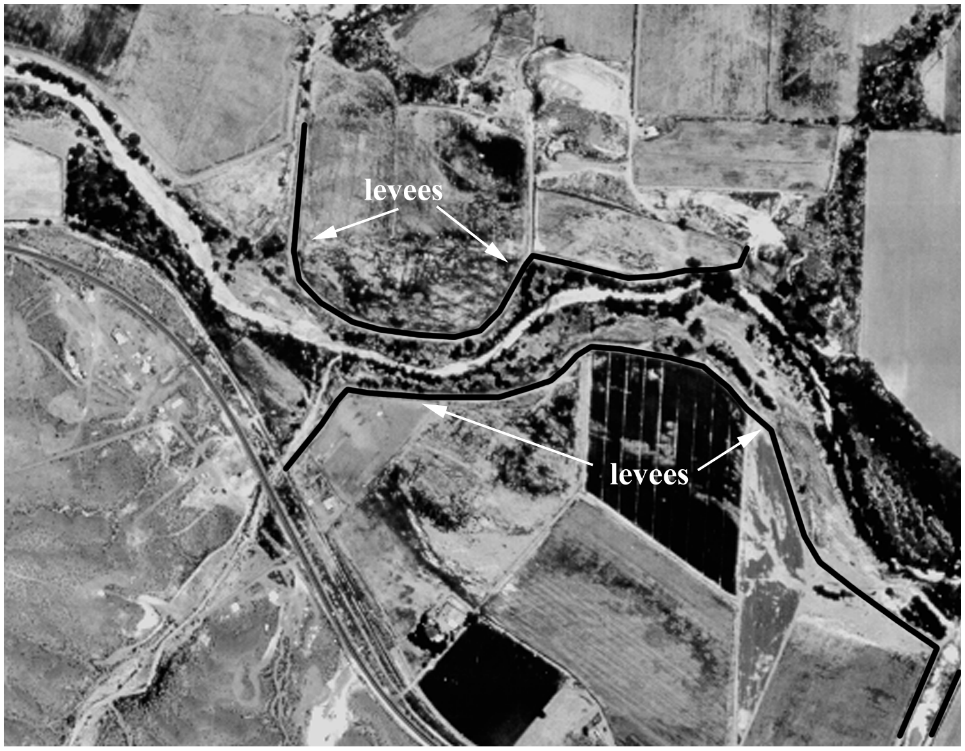
Narrow
The narrowest channel widths measured in Duncan Valley include points 63, 71, and 72 and correspond to canyon reaches where the channel is narrow due to bedrock constrictions. Point 63 is located just upstream of the Route 191 North bridge over the Gila River. Points 71 and 72 correspond to channel widths in the narrow canyon between York and Apache Grove.

(a) 1935

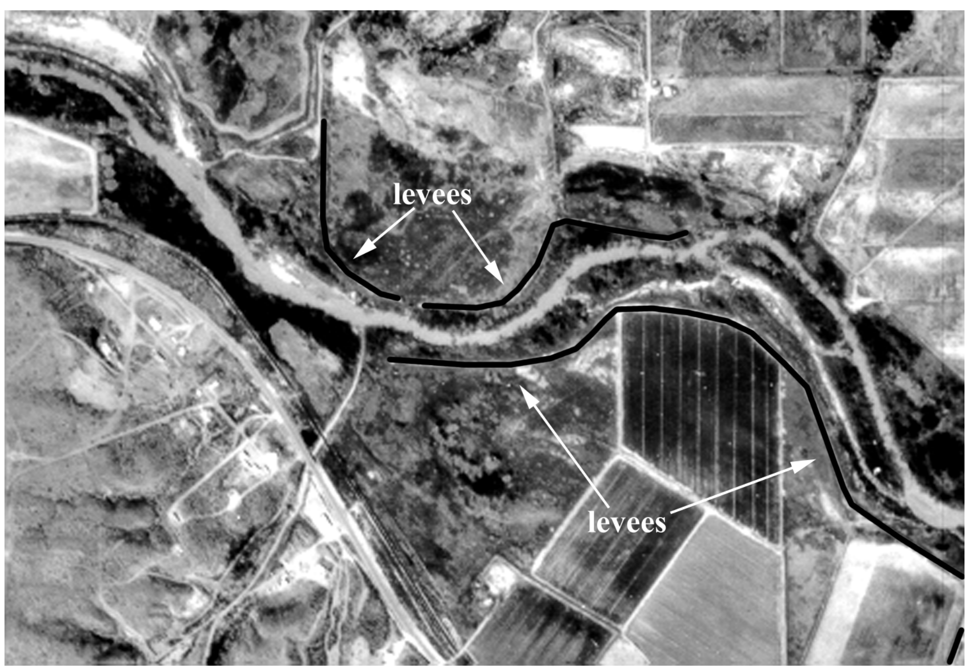


(b) 1953

Figure 24. Case Study 5: Whitefield Wash levees. Levees imposed on the left bank caused changes in channel morphology from (a) 1935 to (b) 1953. Flow is from right to left.

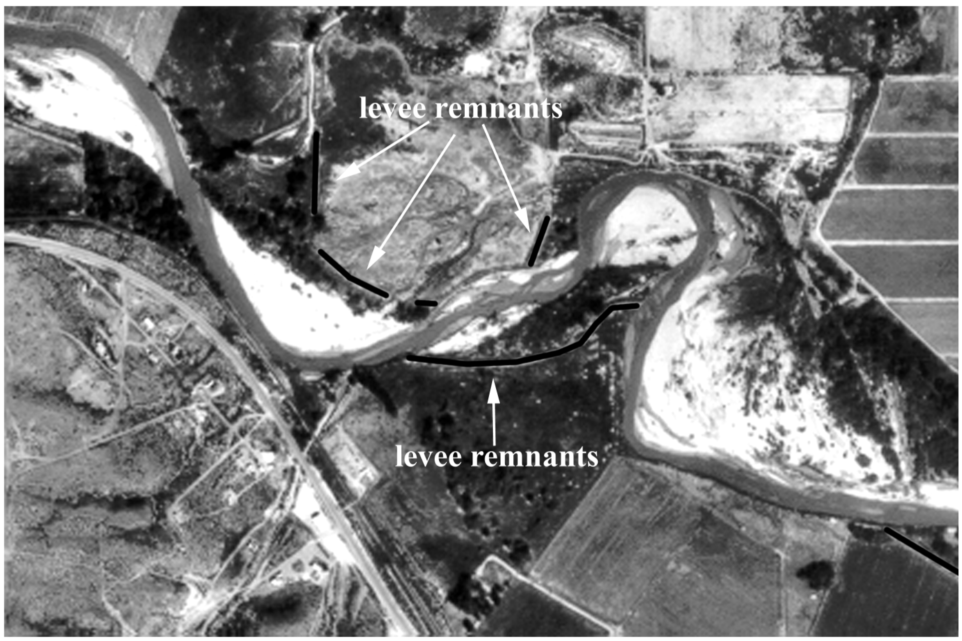


(c) 1981



(d) 1992

Figure 24 (cont.) (c) Additional levees constructed by 1981 on the right and left banks imposed further restrictions on the channel and by (d) 1992, some of these levees had been eroded and not replaced. The majority of the erosion probably occurred during the 1984 flood. Flow is from right to left.



(e) 1997

Figure 24 (cont.) (e) In 1997, the majority of the left bank levee and parts of the right bank levee had been eroded and a new right bank meander had been cut into the floodplain that was previously part of the flood channel in 1935. Flow is from right to left.

COMPARISON OF FLOOD INUNDATION WIDTHS TO FLOOD WIDTHS

The December 1978 post-flood inundation width was compared to the pre-flood October 1978 photographs (Figure 25). Generally, the inundation widths from the 1978 flood were larger in magnitude than the 1978 pre-flood widths, especially from Whitefield Wash to the Arizona-New Mexico border. It is possible that this section of the channel responds quite differently to large floods in that floodplain areas are inundated during large floods, but not eroded, creating the wide disparity in values for this reach. The sub reaches of high variance within this reach would seem to be exceptions to this hypothesis. Downstream of Whitefield Wash, the 1978 flood inundation width is larger, with some exceptions where the pre-flood width is equal or greater. It may be that the 1972 flood was responsible for some channel widening and floodplain inundation so that the 1978 flood could be accommodated by pre-existing flood widths in some reaches.

DISCUSSION

NATURE OF CHANNEL CHANGES, DUNCAN VALLEY AND SAFFORD VALLEY

This study has shown that although high variability exists in channel width and position in both Safford Valley and Duncan Valley, many channel positions are not new and channel widths are similar or smaller than 1935 channel widths for the Gila River during the period of study. In many of the case studies, the channel simply reoccupied old channel positions from earlier in the historical period. Average flood widths also show that by 2000, the river channel had reached an average flood width similar to the 1935 average flood width. Some channel changes; however, in recent decades do seem to be unprecedented in the period of study. Examples of such cases include the channel changes upstream of the Duncan Bridge, where severe erosion between 1992 and 1997 caused lateral migration of the left bank toward the town of Duncan. Another dramatic area of channel change occurs downstream of the San Jose Diversion, where lateral movement of the channel toward the right bank has been observed on photograph years of 1981, 1992 and 1997. The causation behind these changes will be further explored in Task 10-Geomorphic Analysis and Task 12-Causal Analysis.

Comparisons between Duncan Valley and Safford Valley show that Duncan Valley appears to be more stable, with less channel change in the historical period. In Safford Valley, the perturbations are prevalent, as many reaches were identified as having high variability in width. Some reaches in Safford Valley appear to be varying between channel locations that experience very little change in channel width, and locations where channel widths are in constant flux. This creates the high-low pattern to Figure 5; this will be examined more completely once all necessary information for additional study has been developed. Patterns of channel narrowing and widening in the flood plain are expected behavior for a river system over a decadenal time scale and become ephemeral features over the hundreds to thousands of years time scale. Task 8-Geomorphic Map will be an important component that will complement the Catalog of Historical Changes by showing the long-term behavior of the Gila River system in conjunction with this study's examination of fluctuating channel widths in the short term.

The impact of floods on the Gila River channel is evident based corresponding large channel changes following flood years. In Duncan Valley, the most changes in flood width occurred following the 1978 flood and the floods in the 1990's. In Safford Valley, changes occurred following the 1972, 1983, and 1993 floods.

UNCERTAINTY IN WIDTH MEASUREMENTS

Width measurements used in this study have uncertainty associated with them based on non-rectified aerial photographs and measurement error. The conversion measurements were used to analyze error that may be incurred from using non-rectified aerial photographs. Approximately 13 measurement segments on 7.5 minute USGS topographic maps were made along the length of Safford Valley and eight along the length of Duncan Valley; the same segments were then measured on each aerial photograph set. Ratios of the two lengths were then compared among points to determine the error involved in measuring widths. In the data sets for both Safford Valley and Duncan Valley, uncertainty was larger for small-scale photograph sets and smaller for

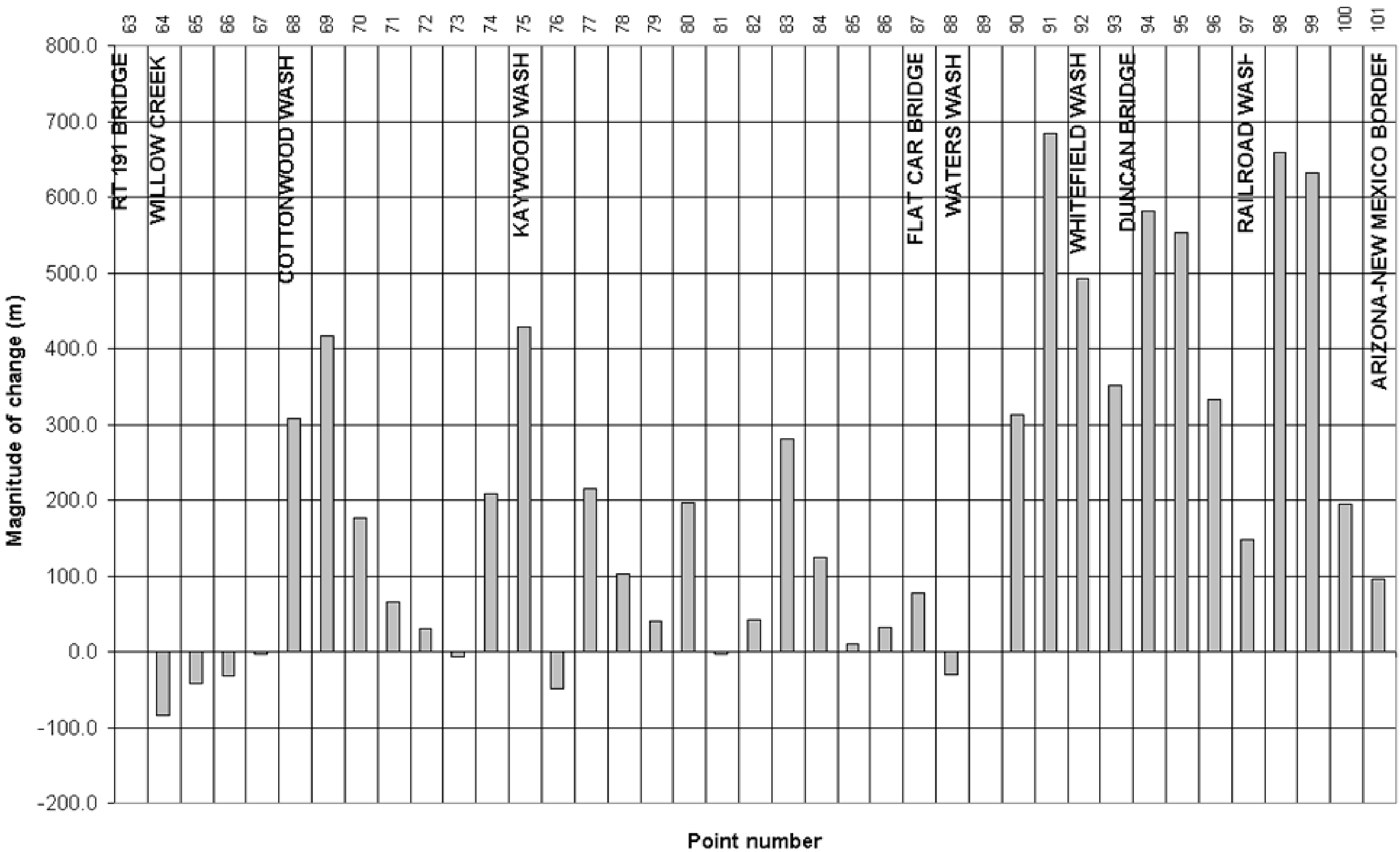


Figure 25. Comparison of December 1978 flood inundation widths to October 1978 flood widths. For the majority of measurement points, flood inundation widths are larger than flood widths, indicating that the flood width prior to December 1978 was not sufficient to accommodate the 1978 peak discharge.

the large-scale photograph sets (Figures 26 and 27). This seems logical, as more accurate measurements can be made in more detailed photographs. The largest errors occurred in the 1953, and 1990's data sets, which were also the smallest scale photographs used in the study, on the order of 1:60,000 and 1:40,000, respectively. The largest error values for these sets are ±2.7m in Duncan Valley and ±2.3m in Safford Valley. These values are small compared to average channel widths of 50-250m.

Measurement error also incorporates the error associated with the repeatability in the measurement, or the precision, and the error associated with the measurement device. Measurements were made multiple times on random points to determine the precision associated with the data set. Error measurements were on the order of ± 2 m (Table 2). Measurements of channel width for the Gila River were made on the aerial photographs with a digital caliper and measured to a hundredth of a millimeter (0.01 mm), which corresponds to an actual ground distance of 0.12 to 0.56 m depending on the scale of the photographs. On the large-scale photograph sets, which include year 2000 and 1983 post-flood photographs, measurements were recorded to a half a millimeter (0.5 mm) using a ruler. This corresponds to a ground distance of 2.0 to 2.8 m for the 2000 and 1983 photographs, respectively.

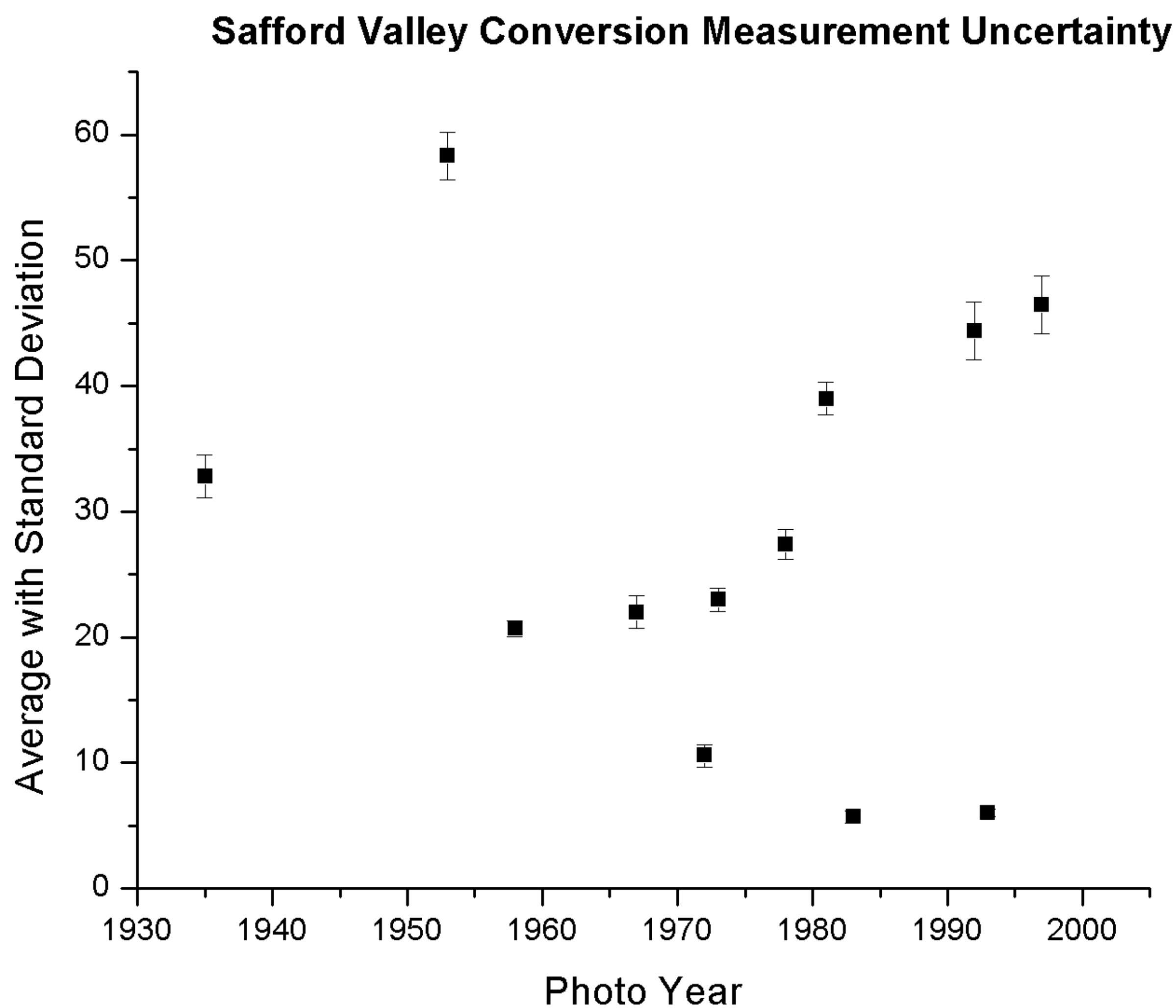


Figure 26. Uncertainty in flood width measurements, Safford Valley. The largest uncertainties occur for the smallest scale photos and have a maximum value of ±2.3m.

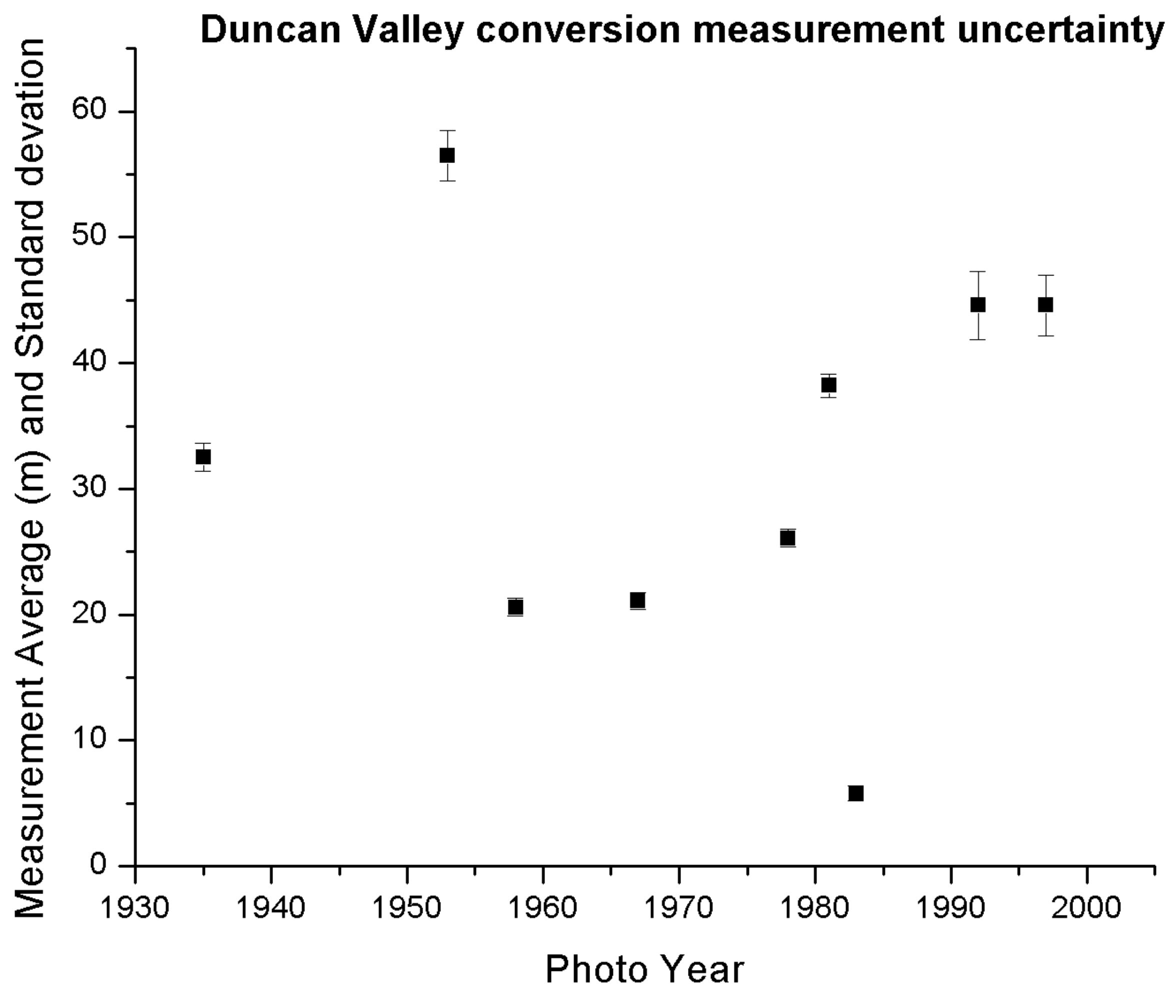


Figure 27. Uncertainty in flood width measurements, Duncan Valley. The largest uncertainties occur for the smallest scale photos and have a maximum value of ±2.7m.

Table 2. Test of precision: error in repeat measurements. This example is taken from the 1978 photographs (1:24,000 scale) in which the same straight-line segment was measured ten times. The error associated with these measurements is ± 2.3 m.

Width (mm)	Distance (m)
16.71	457.9
16.78	459.8
16.88	462.5
16.84	461.4
16.85	461.7
16.95	464.4
16.79	460.0
16.67	456.8
16.74	458.7
16.86	462.0
AVERAGE (m)	460.5
STANDARD DEVATION (m)	2.3

CONCLUSIONS

General trends in channel changes from this study parallel those described by Burkham (1972). The early 1900's experienced several extreme floods, causing channel widening to 1935 (Burkham, 1972; Olmstead, 1919). This early information was gathered for Safford Valley and may or may not apply to Duncan Valley. From 1935 to the early 1960's, the channel narrowed by sedimentation, vegetation growth, and levee, dike, and agricultural development. From the late 1960's to 2000, the channel widened in response to large floods and is approximately the same width on average as it was in 1935. In most cases, flood flow widths at specific channel locations are variable, but not unprecedented in the historical record.

The analysis of change using flood flow widths for Duncan Valley and Safford Valley show that Safford Valley has experienced many more perturbations in the period of study than Duncan Valley. This is shown best by the presence of several long, stable reaches in Duncan Valley, compared to a few short stable reaches in Safford Valley. Major channel changes generally occurred following large floods; this highlights the important point that the largest floods in the Gila River system have lasting effects that can be observed in channel morphology for decades following their occurrence.

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U.S. Army Corps of Engineers, 1973, Flood Damage Report, Flood of October 1972, Gila River Basin above San Carlos Reservoir, Arizona and New Mexico.

APPENDICES

APPENDIX A. LIST OF CONTACTS

Arizona Department of Transportation Photogrammetry and Mapping Services 1655 W. Jackson Phoenix, AZ 85007 (602) 255-8561
Cooper Aerial Surveys Company 1692 W. Grant Rd. Tucson, AZ 85745 (520) 884-7580 Internet: www.cooperaerial.com
Fairchild Aerial Photography Collection Whittier College Whittier, CA 90608 (562) 907-4220
Dave Fisher, District Conservationist Natural Resources Conservation Service 305 E. Fourth St Safford, AZ 85546 (520) 428.0635 x3 email: david.fisher@az.usda.gov
Michelle Pointon National Air Survey Center Corp. 4321 Baltimore Avenue Bladensburg, MD 20710 (301) 927-7180 email: nascc.com
Steve Reiter U.S. Geological Survey, Denver Bldg. 810 , Denver Federal Center Denver, CO 80225 (303) 202-4168
Connie Slusser U.S. Bureau of Land Management, Denver Bldg. 50, Denver Federal Center Denver, CO 80225 (303) 445-7991
U.S. Geological Survey EROS Data Center Sioux Falls, SD 57198-0001 Internet: edc.www.cr.usgs.gov/webglis

APPENDIX B: CHANNEL WIDTH MEASUREMENT POINT LOCATIONS

Channel width measurement points are recorded in UTM coordinates as an eight-digit number that lists the easting in the first four digits and the northing in the last four digits. To obtain the full easting coordinate, add 06 to the beginning of the easting, so that the value reads “06xxxx”. To obtain the full northing, add 36 to the beginning, so that the value reads “36xxxx”. For example, point number 1 would have an easting of 068889 and a northing of 366284. These values reflect the northings and eastings for a 10-meter square.

Point No.	UTM Coordinates	Point No.	UTM Coordinates
1	88896284	52	30193337
2	89746145	53	31423300
3	90426146	54	31603461
4	91766166	55	33283300
5	92876049	56	33883511
6	92345990	57	34553666
7	93525986	58	34863688
8	94965954	59	36523756
9	95915882	60	37573704
10	96345783	61	38663637
11	97005588	62	39383746
12	97005588	63	65144520
13	97885460	64	65984519
14	99425383	65	66634506
15	01425342	66	67854492
16	99445220	67	67524395
17	01455144	68	67844288
18	99804981	69	67464238
19	00274932	70	68344124
20	02304882	71	68164052
21	01284772	72	68283950
22	01404658	73	68783750
23	02734739	74	68823670
24	03984574	75	68823670
25	03984574	76	69573598
26	05044548	77	69553499
27	06984542	78	70003398
28	07414424	79	69993316
29	08364345	80	71173221
30	09774342	81	71383118
31	10564262	82	70923026
32	11384206	83	71922934
33	12184147	84	71742832
34	13404146	85	71342742
35	13404107	86	72582717
36	15154043	87	73002620
37	16063973	88	74342570
38	17003872	89	73872485

Point No.	UTM Coordinates	Point No.	UTM Coordinates
39	18203778	90	75582470
40	18873703	91	75902330
41	19303600	92	76722287
42	20063598	93	77282240
43	21093556	94	77892158
44	21863392	95	79452118
45	23103448	96	80252119
46	23983386	97	80261987
47	25083370	98	80811918
48	26003338	99	81501884
49	27143368	100	82361882
50	28083298	101	83061884
51	29123380		

APPENDIX C: CHANNEL WIDTH MEASUREMENTS

Channel width measurements are listed from year 2000 to 1935 for Safford Valley and Duncan Valley. Rows that are left completely blank in the tables indicate that data were not available for the measurement point. Flood photographs list only flood flow widths, splay widths, and total widths, while non-flood photographs list recent flow and flood flow widths. Abbreviations for the photography sources and other details on the aerial photography can be found in Appendix D.

SAFFORD VALLEY

2000 USBR

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	70	276.5	350	1382.5
2	70	276.5	217	857.15
3	50	197.5	98	387.1
4	17	67.15	58	229.1
5	108	426.6	172	679.4
6	40	158	80	316
7	55	217.25	94	371.3
8	82	323.9	282	1113.9
9	80	316	214	845.3
10	48	189.6	136	537.2
11	68	268.6	192	758.4
12	96	379.2	198	782.1
13	63	248.85	234	924.3
14	77	304.15	165	651.75
15	110	434.5	270	1066.5
16	113	446.35	313	1236.35
17	49	193.55	293	1157.35
18	75	296.25	220	869
19	68	268.6	160	632
20	55	217.25	119	470.05
21	20	79	46	181.7
22	43	169.85	80	316
23	89	351.55	208	821.6
24	34	134.3	164	647.8
25	45	177.75	179	707.05
26	17	67.15	172	679.4
27	57	225.15	194	766.3
28	30	118.5	162	639.9

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
29	80	316	197	778.15
30	32	126.4	105	414.75
31	50	197.5	123	485.85
32	48	189.6	121	477.95
33	82	323.9	133	525.35
34	72	284.4	144	568.8
35	60	237	140	553
36	62	244.9	118	466.1
37	45	177.75	149	588.55
38	106	418.7	226	892.7
39	63	248.85	123	485.85
40				
41	80	316	119	470.05
42	42	165.9	94	371.3
43	32	126.4	114	450.3
44	55	217.25	90	355.5
45	48	189.6	175	691.25
46	22	86.9	166	655.7
47	32	126.4	201	793.95
48	73	288.35	80	316
49	59	233.05	179	707.05
50	119	470.05	140	553
51	79	312.05	145	572.75
52	88	347.6	147	580.65
53	126	497.7	207	817.65
54	93	367.35	144	568.8
55	54	213.3	150	592.5
56	65	256.75	112	442.4
57	28	110.6	110	434.5
58	111	438.45	165	651.75
59	22	86.9	114	450.3
60	37	146.15	131	517.45
61	22	86.9	50	197.5
62	18	71.1	85	335.75

1997 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	7.68	357.1	27.1	1260.2
2	6.18	287.4	19.25	895.1
3	7.71	358.5	11.23	522.2
4	1.42	66.0	5.39	250.6
5	4.28	199.0	11.03	512.9
6	1.85	86.0	15.23	708.2
7	4.98	231.6	12.6	585.9
8	6.98	324.6	14.67	682.2
9	13.01	605.0	17.7	823.1
10	6.62	307.8	10.44	485.5
11	6.05	281.3	16.26	756.1
12	4.1	190.7	16.9	785.9
13	6.91	321.3	19.63	912.8
14	5.76	267.8	13.44	625.0
15	8.43	392.0	19.55	909.1
16	3.75	174.4	26.18	1217.4
17	4.28	199.0	23.73	1103.4
18	4.04	187.9	18.44	857.5
19	5.76	267.8	12.87	598.5
20	6.2	288.3	8.96	416.6
21	2.11	98.1	3.58	166.5
22	3.46	160.9	7	325.5
23	8.69	404.1	18.54	862.1
24	2.28	106.0	13	604.5
25	4.25	197.6	15.85	737.0
26	8.1	376.7	14.49	673.8
27	8.89	413.4	13.68	636.1
28	8.14	378.5	15.47	719.4
29	7.16	332.9	16.67	775.2
30	4.13	192.0	8.59	399.4
31	4.37	203.2	10.48	487.3
32	4.51	209.7	9.24	429.7
33	6.09	283.2	13.14	611.0
34	12.45	578.9	13.02	605.4
35	9.22	428.7	16.2	753.3
36	5.96	277.1	11.36	528.2

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
37	2.45	113.9	13.52	628.7
38	9.94	462.2	21.21	986.3
39	5.98	278.1	11.73	545.4
40	1.9	88.4	16.72	777.5
41	3.89	180.9	15.66	728.2
42	3.46	160.9	5.01	233.0
43	4.06	188.8	10.05	467.3
44	2.62	121.8	7.36	342.2
45	4.04	187.9	18.89	878.4
46	6.48	301.3	15.76	732.8
47	3.12	145.1	18.29	850.5
48	7.09	329.7	7.09	329.7
49	4.83	224.6	15.83	736.1
50	6.04	280.9	9.41	437.6
51	7.87	366.0	14.97	696.1
52	7.14	332.0	13.7	637.1
53	15.96	742.1	15.96	742.1
54	11.18	519.9	11.7	544.1
55	4.99	232.0	13.2	613.8
56	7.86	365.5	9.25	430.1
57	4.26	198.1	8.11	377.1
58	14.5	674.3	21.71	1009.5
59	3.7	172.1	8.57	398.5
60	10.83	503.6	10.83	503.6
61	4.2	195.3	4.2	195.3
62	2.18	101.4	7.53	350.1

1993 FLOOD NRCS

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
1	24.75	148.5	37.3	rb	223.9				372.4
2	49.65	297.9	69.9	rb	419.2				717.1
3	58.07	348.4							348.4
4	15.33	92.0							92.0
5	70.93	425.6							425.6

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
6	28.47	170.8	57.6	lb	345.4				516.2
7	42	252.0							252.0
8	86.64	519.8							519.8
9	118.25	709.5							709.5
10	41.51	249.1	34.5	lb	206.9				456.0
11	43.13	258.8	58.3	lb	349.7				608.5
12	65.7	394.2	47.7	lb	286.2				680.4
13	44.15	264.9	54.1	lb	324.3				589.2
14	43.88	263.3	91.9	lb	551.4				814.7
15	81.69	490.1	59.4	lb	356.2				846.4
16	97.98	587.9	54.7	rb	328.0				915.8
17	94.7	568.2	50.9	lb	305.3				873.5
18	123.99	743.9							743.9
19	98.66	592.0							592.0
20	72.44	434.6							434.6
21	100.97	605.8							605.8
22	55	330.0							330.0
23	123.59	741.5							741.5
24	89.48	536.9							536.9
25	56.6	339.6							339.6
26	92.26	553.6	25.6	lb	153.7				707.3
27	65.43	392.6							392.6
28	89.39	536.3							536.3
29	57.57	345.4							345.4
30	47.23	283.4	68.8	rb	412.9				696.2
31	38.21	229.3	47.3	rb	283.6	42.97	lb	257.82	770.6
32	87.36	524.2							524.2
33	79.18	475.1							475.1
34	76.03	456.2							456.2
35	65.58	393.5							393.5
36	67.99	407.9							407.9
37	39.45	236.7							236.7
38	126.26	757.6							757.6
39	73.5	441.0							441.0
40	62.03	372.2							372.2
41	68.78	412.7							412.7

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
42	26.75	160.5							160.5
43	74.55	447.3							447.3
44	59.85	359.1							359.1
45	90.4	542.4	22.9	lb	137.6				680.0
46	79.13	474.8							474.8
47	81.44	488.6							488.6
48	47.07	282.4							282.4
49	116.45	698.7							698.7
50	99.26	595.6							595.6
51	65.55	393.3							393.3
52	88.35	530.1							530.1
53	119.07	714.4							714.4
54	71.51	429.1							429.1
55	88.1	528.6							528.6
56	58.57	351.4							351.4
57	74.89	449.3							449.3
58	98.69	592.1							592.1
59	56.19	337.1							337.1
60	92.53	555.2							555.2
61	53.84	323.0							323.0
62	45.82	274.9							274.9

1992 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	1.88	83.5	16.12	715.7
2	4.5	199.8	18.01	799.6
3	6.45	286.4	11.26	499.9
4	1.53	67.9	4.78	212.2
5	3.96	175.8	9.93	440.9
6	3.33	147.9	7.34	325.9
7	4.93	218.9	11.35	503.9
8	6.12	271.7	20.65	916.9
9	9.14	405.8	15.73	698.4
10	5.69	252.6	11.95	530.6

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
11	3.64	161.6	11.51	511.0
12	7.34	325.9	16.61	737.5
13	4.21	186.9	20.16	895.1
14	2.91	129.2	13.13	583.0
15	8.4	373.0	24.73	1098.0
16	9.74	432.5	19.32	857.8
17	11.65	517.3	19.58	869.4
18	7.48	332.1	15.99	710.0
19	1.65	73.3	13.66	606.5
20	4.58	203.4	7.14	317.0
21	1.92	85.2	3.61	160.3
22	6.38	283.3	8.38	372.1
23	8.26	366.7	20.1	892.4
24	4.92	218.4	9.79	434.7
25	5.81	258.0	14.49	643.4
26	8.45	375.2	13.1	581.6
27	8.99	399.2	17.76	788.5
28	9.57	424.9	13.98	620.7
29	8.4	373.0	18.41	817.4
30	2.61	115.9	9.03	400.9
31	3.92	174.0	10.2	452.9
32	7.34	325.9	9.39	416.9
33	7.26	322.3	8.81	391.2
34	5.58	247.8	15.37	682.4
35	4.37	194.0	13.14	583.4
36	4.75	210.9	11.27	500.4
37	6.41	284.6	10.55	468.4
38	13.15	583.9	19.08	847.2
39	9.39	416.9	11.86	526.6
40	3.52	156.3	11.79	523.5
41	7.07	313.9	14.02	622.5
42	3.22	143.0	9.01	400.0
43	4.41	195.8	9.84	436.9
44	5.02	222.9	7.15	317.5
45	11.7	519.5	12.67	562.5
46	11.59	514.6	14.12	626.9
47	11.37	504.8	20.58	913.8

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
48	3.54	157.2	5.17	229.5
49	15	666.0	17.19	763.2
50	5.78	256.6	7.83	347.7
51	7.58	336.6	10.79	479.1
52	11.87	527.0	11.87	527.0
53	10.23	454.2	17.61	781.9
54	8.4	373.0	10.61	471.1
55	4.14	183.8	7.34	325.9
56	8.71	386.7	8.71	386.7
57	8.82	391.6	8.82	391.6
58	12.79	567.9	14.95	663.8
59	2	88.8	6.26	277.9
60	4.53	201.1	11.45	508.4
61	2.39	106.1	4.02	178.5
62	2.12	94.1	8.37	371.6

1983 FLOOD NRCS

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
1									
2	30.8	175.6	47.49	lb	270.7				446.3
3	37.9	216.0	49.1	lb	279.9				495.9
4	19.06	108.6	46.38	lb	264.4	17.34	lb	98.8	471.8
5									
6	30.13	171.7	77.25	lb	440.3				612.1
7	122.04	695.6							695.6
8	77.64	442.5	unknown	rb					442.5
9									
10	28.89	164.7	56.56	rb	322.4	unknown	lb		487.1
11	64.98	370.4	unknown	lb					370.4
12	65.04	370.7	52.92	lb	301.6				672.4
13	43.71	249.1	61.79	lb	352.2				601.4
14	27.52	156.9	127.85	lb	728.7	32.31	lb	184.2	1069.8
15	85.05	484.8	17.47	rb	99.6	94.39	lb	538.0	1122.4
16									

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
17	79.83	455.0							455.0
18	55.37	315.6	19.1	rb	108.9				424.5
19	46.38	264.4							264.4
20	108.92	620.8							620.8
21	109.53	624.3							624.3
22	100.99	575.6							575.6
23	74.16	422.7	52.01	lb	296.5				719.2
24	39.31	224.1							224.1
25	58.21	331.8							331.8
26	96.7	551.2							551.2
27	82.86	472.3							472.3
28	87.87	500.9							500.9
29	76.05	433.5							433.5
30	113.67	647.9	48.31	lb	275.4				923.3
31	128.74	733.8							733.8
32	109.23	622.6							622.6
33	56.84	324.0	81.85	lb	466.5	22.9	rb	130.5	921.1
34	76.38	435.4	49.52	rb	282.3				717.6
35									
36									
37	103.16	588.0							588.0
38	165	940.5							940.5
39	84.87	483.8							483.8
40	97.1	553.5							553.5
41	128.18	730.6							730.6
42	130.96	746.5							746.5
43	104.95	598.2							598.2
44	73.62	419.6							419.6
45	117.93	672.2							672.2
46	106.32	606.0	27.47	lb	156.6				762.6
47	168	957.6							957.6
48	83.7	477.1							477.1
49	117.3	668.6							668.6
50	123.16	702.0							702.0
51	101.2	576.8							576.8
52	74.16	422.7							422.7

Point no.	Flood flow width (mm)	Flood flow width (m)	Splay width (mm)	Bank	Splay width (m)	Splay width (mm)	Bank	Splay width (m)	Total width (m)
53	129.87	740.3							740.3
54									
55	131.42	749.1							749.1
56	81.72	465.8							465.8
57	88.09	502.1							502.1
58	105	598.5	52.73	lb	300.6				899.1
59	52.46	299.0							299.0
60	84.76	483.1							483.1
61	95.22	542.8							542.8
62	59.41	338.6							338.6

1981 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14	3.13	122.1	22.09	861.5
15	11.87	462.9	22.1	861.9
16	8.73	340.5	30.03	1171.2
17	8.69	338.9	25.75	1004.3
18	6.97	271.8	17.8	694.2
19	6.3	245.7	14.34	559.3
20	5	195.0	8.14	317.5
21	4.78	186.4	4.78	186.4

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
22	6.81	265.6	7.76	302.6
23	7.72	301.1	21.12	823.7
24	6.22	242.6	10.52	410.3
25	9.35	364.7	17.4	678.6
26	11.88	463.3	14.36	560.0
27	7.07	275.7	16.76	653.6
28	10.24	399.4	17.27	673.5
29	10.16	396.2	19.56	762.8
30	4.16	162.2	9.45	368.6
31	5.33	207.9	6.3	245.7
32	6.86	267.5	9.95	388.1
33	4.54	177.1	12.77	498.0
34	4.33	168.9	12.05	470.0
35	4.66	181.7	13.26	517.1
36	7.74	301.9	11.18	436.0
37	10.43	406.8	12.3	479.7
38	19.11	745.3	19.11	745.3
39	11.14	434.5	12.37	482.4
40	8.59	335.0	15.89	619.7
41	10.67	416.1	19.16	747.2
42	4.75	185.3	7.43	289.8
43	8.17	318.6	11.46	446.9
44	5.22	203.6	8.11	316.3
45	14.9	581.1	17.44	680.2
46	10.11	394.3	16.09	627.5
47	2.45	95.6	24.8	967.2
48	5.32	207.5	5.32	207.5
49	15.96	622.4	21.8	850.2
50	7.38	287.8	8.71	339.7
51	4.54	177.1	12.64	493.0
52	9.95	388.1	9.95	388.1
53	10.64	415.0	16.7	651.3
54	10.6	413.4	12.84	500.8
55	7.87	306.9	8.37	326.4
56	6.21	242.2	6.92	269.9
57	7.82	305.0	7.82	305.0
58	13.28	517.9	16.58	646.6

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
59	2.4	93.6	6.91	269.5
60	9.91	386.5	9.91	386.5
61	4.17	162.6	4.17	162.6
62	2.26	88.1	10.4	405.6

1978 BLM

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	10.64	291.5	24.05	659.0
2	2.13	58.4	22.98	629.7
3	1.75	48.0	23.35	639.8
4	0.92	25.2	7.8	213.7
5	0.89	24.4	27.93	765.3
6	1.12	30.7	12.73	348.8
7	0.95	26.0	22.35	612.4
8	1.98	54.3	25.41	696.2
9	5.39	147.7	21.39	586.1
10	3.78	103.6	29.57	810.2
11	1.82	49.9	25.12	688.3
12	2.38	65.2	20.17	552.7
13	6.71	183.9	31.5	863.1
14	1.5	41.1	21.33	584.4
15	3.45	94.5	32.74	897.1
16	12.32	337.6	41.39	1134.1
17	13.84	379.2	21.04	576.5
18	3.7	101.4	32.47	889.7
19	12.62	345.8	22.72	622.5
20	2.37	64.9	6.75	185.0
21	2.81	77.0	2.81	77.0
22	4.43	121.4	7.05	193.2
23	15.43	422.8	31	849.4
24	11.92	326.6	16.48	451.6
25	7.35	201.4	22.7	622.0
26	7.02	192.3	16.35	448.0
27	9.25	253.5	20.17	552.7
28	12.49	342.2	33.3	912.4
29	7.05	193.2	27.67	758.2

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
30	3.73	102.2	15.91	435.9
31	4.97	136.2	8.49	232.6
32	2.84	77.8	12.54	343.6
33	15.07	412.9	17.68	484.4
34	4.52	123.8	20.17	552.7
35	13.91	381.1	19.5	534.3
36	7.76	212.6	16.52	452.6
37	5.66	155.1	9.64	264.1
38	11.19	306.6	15.19	416.2
39	11.67	319.8	16.94	464.2
40	8.22	225.2	16.45	450.7
41	14.44	395.7	26.66	730.5
42	4.8	131.5	14.02	384.1
43	11.44	313.5	19.56	535.9
44	10.37	284.1	13.02	356.7
45	11.58	317.3	19.01	520.9
46	11.38	311.8	33.25	911.1
47	2.95	80.8	36.87	1010.2
48	4.12	112.9	7.34	201.1
49	8.31	227.7	29.36	804.5
50	5.08	139.2	11.86	325.0
51	8.04	220.3	9.45	258.9
52	9	246.6	19.37	530.7
53	10.87	297.8	15.01	411.3
54	8.78	240.6	8.78	240.6
55	6.2	169.9	14.02	384.1
56	9.02	247.1	11.12	304.7
57	5.4	148.0	5.4	148.0
58	13.66	374.3	14.76	404.4
59	3.75	102.8	6.76	185.2
60	8.44	231.3	8.44	231.3
61	5.35	146.6	5.35	146.6
62	3.1	84.9	12.67	347.2

1973 USDA

Point no.	recent flow width (mm)	recent flow width (m)	flood flow width (mm)	flood flow width (m)
1				
2	6.58	151.3	40.82	938.9
3	4.13	95.0	22.02	506.5
4	0.97	22.3	9.31	214.1
5	1.27	29.2	31.38	721.7
6	3.36	77.3	22.48	517.0
7	9.86	226.8	24.7	568.1
8	4.08	93.8	44.02	1012.5
9	3.44	79.1	43.48	1000.0
10	4.12	94.8	40.6	933.8
11	6.08	139.8	31.67	728.4
12	7.68	176.6	32.25	741.8
13	5.23	120.3	34.7	798.1
14	7.38	169.7	36.3	834.9
15	2.58	59.3	40.13	923.0
16	9.04	207.9	51.79	1191.2
17	8.42	193.7	42.7	982.1
18	6.39	147.0	49.35	1135.1
19	8.39	193.0	29.58	680.3
20	4.82	110.9	19.88	457.2
21	3.31	76.1	19.28	443.4
22	4.34	99.8	13.09	301.1
23	2.46	56.6	33.62	773.3
24	9.03	207.7	18.39	423.0
25	9.59	220.6	29.54	679.4
26	10.18	234.1	38.86	893.8
27	12.55	288.7	31.07	714.6
28	9.92	228.2	27.92	642.2
29	7.86	180.8	37.38	859.7
30	6.5	149.5	29.74	684.0
31	7.18	165.1	21.45	493.4
32	7.11	163.5	30.33	697.6
33	12.85	295.6	30.49	701.3
34	10.36	238.3	36.26	834.0
35	12.2	280.6	33.45	769.4
36	13.71	315.3	22.12	508.8

Point no.	recent flow width (mm)	recent flow width (m)	flood flow width (mm)	flood flow width (m)
37	10.77	247.7	15.85	364.6
38	8.5	195.5	20.4	469.2
39	9.64	221.7	27.41	630.4
40	14.21	326.8	38.11	876.5
41	15.77	362.7	33.92	780.2
42	4.5	103.5	12.13	279.0
43	13.71	315.3	28.41	653.4
44	5.63	129.5	13.63	313.5
45	14.58	335.3	23.14	532.2
46	10.36	238.3	29.88	687.2
47	3.3	75.9	43.44	999.1
48	4.67	107.4	11.9	273.7
49	8.07	185.6	32.59	749.6
50	6.93	159.4	20.55	472.7
51	6.69	153.9	25.07	576.6
52	8.94	205.6	28.01	644.2
53	9.76	224.5	17.62	405.3
54	6.39	147.0	35.38	813.7
55	6.1	140.3	21.35	491.1
56	10.01	230.2	22.11	508.5
57	6.04	138.9	9.83	226.1
58	8.23	189.3	25.5	586.5
59	9.14	210.2	13.33	306.6
60	8.23	189.3	20.75	477.3
61	3.73	85.8	5.62	129.3
62	3.36	77.3	15.13	348.0

1972 FLOOD ADOT

Point no.	Flood Width (mm)	Splay width (mm)	Bank	Flood width (m)	Splay width (m)	Total Flood Width (m)
1	115.11			1220.2		1220.2
2	93.45			990.6		990.6
3	63.3			671.0		671.0
4	68.34			724.4		724.4
5	86.67			918.7		918.7
6	8.26	50.86	lb	87.6	539.1	626.7

Point no.	Flood Width (mm)	Splay width (mm)	Bank	Flood width (m)	Splay width (m)	Total Flood Width (m)
7	59.11			626.6		626.6
8	38.92	41.2	rb	412.6	436.7	849.3
9	117.14			1241.7		1241.7
10	59.61	26.93	lb	631.9	285.5	917.3
11	118.18			1252.7		1252.7
12	81			858.6		858.6
13	54.94	45.01	lb	582.4	477.1	1059.5
14	18.93	58.67	lb	200.7	621.9	822.6
15	63.53	39.2	rb	673.4	415.5	1088.9
16	50.21	55.08	rb	532.2	583.8	1116.1
17	103.93			1101.7		1101.7
18	89.92			953.2		953.2
19	64.99			688.9		688.9
20	65.82			697.7		697.7
21	77.17			818.0		818.0
22	68.82			729.5		729.5
23	70.54			747.7		747.7
24	50.69			537.3		537.3
25	68.13			722.2		722.2
26	105.79			1121.4		1121.4
27	82.81			877.8		877.8
28	102.9			1090.7		1090.7
29	77.97			826.5		826.5
30	59.27			628.3		628.3
31	88.55			938.6		938.6
32	62			657.2		657.2
33	63.23			670.2		670.2
34	78.04			827.2		827.2
35	77.17			818.0		818.0
36	64.99			688.9		688.9
37	83.92			889.6		889.6
38	49.91			529.0		529.0
39	50.11			531.2		531.2
40	59.47			630.4		630.4
41	45.87			486.2		486.2
42	15.82			167.7		167.7

Point no.	Flood Width (mm)	Splay width (mm)	Bank	Flood width (m)	Splay width (m)	Total Flood Width (m)
43	67.89			719.6		719.6
44	57.39			608.3		608.3
45	54.31			575.7		575.7
46	61.67			653.7		653.7
47	81.45			863.4		863.4
48	40.07			424.7		424.7
49	71.91			762.2		762.2
50	58.39			618.9		618.9
51	32.43	22.72		343.8	240.8	584.6
52	54.47			577.4		577.4
53	50.51			535.4		535.4
54	73.35			777.5		777.5
55	70.72			749.6		749.6
56	45.43			481.6		481.6
57	63.04			668.2		668.2
58	73.51			779.2		779.2
59	47.93			508.1		508.1
60						766.9
61						
62						

1967 USDA

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	1.14	25.08	25.51	561.2
2	1.38	30.36	24.34	535.5
3	1.1	24.2	17.91	394.0
4	1	22	15.61	343.4
5	1.07	23.54	15.4	338.8
6	1.53	33.66	16.92	372.2
7	0.8	17.6	17.98	395.6
8	1.17	25.74	41.8	919.6
9	1.6	35.2	25.5	561.0
10	1.74	38.28	36.88	811.4
11	1.64	36.08	27.05	595.1
12	1.17	25.74	25.7	565.4

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
13	1.68	36.96	33.24	731.3
14	1.08	23.76	25.2	554.4
15	2.62	57.64	19.11	420.4
16	3.08	67.76	9.34	205.5
17	2.44	53.68	43.54	957.9
18	3.2	70.4	29.98	659.6
19	1.29	28.38	28.49	626.8
20	1.93	42.46	6.72	147.8
21	2.71	59.62	4.91	108.0
22	1.13	24.86	6.79	149.4
23	3.48	76.56	35.9	789.8
24	2.68	58.96	19.78	435.2
25	4.18	91.96	18.78	413.2
26	1.96	43.12	12.5	275.0
27	2.55	56.1	23.56	518.3
28	1.15	25.3	21.85	480.7
29	8.24	181.28	27.01	594.2
30	1.85	40.7	7.04	154.9
31	2	44	9.2	202.4
32	2.42	53.24	31.32	689.0
33	3.73	82.06	11.96	263.1
34	2.76	60.72	8.98	197.6
35	1.89	41.58	44.67	982.7
36	2.71	59.62	16.28	358.2
37	1.36	29.92	24.15	531.3
38	0.97	21.34	18.76	412.7
39	8.82	194.04	22.14	487.1
40	2.1	46.2	17.36	381.9
41	1.63	35.86	23.96	527.1
42	2.18	47.96	16.75	368.5
43	2.71	59.62	22.64	498.1
44	3.89	85.58	15.51	341.2
45	2.6	57.2	17.98	395.6
46	4.47	98.34	7.8	171.6
47	2.13	46.86	11.78	259.2
48	2.11	46.42	7.9	173.8
49	1.4	30.8	9.72	213.8

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
50	2.78	61.16	15.13	332.9
51	3.07	67.54	18.86	414.9
52	1.59	34.98	19.93	438.5
53	2.91	64.02	17.12	376.6
54	1.87	41.14	7.47	164.3
55	3.56	78.32	18.48	406.6
56	2.74	60.28	8.67	190.7
57	2.06	45.32	7.51	165.2
58	2.11	46.42	11.22	246.8
59	1.6	35.2	7.25	159.5
60	2.15	47.3	6.81	149.8
61	1.51	33.22	4.12	90.6
62	2.47	54.34	3.98	87.6

1958 USDA

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	1.31	27.1	32.26	667.8
2	13.07	270.5	27.76	574.6
3	2.41	49.9	9.9	204.9
4	1.2	24.8	9.95	206.0
5	0.99	20.5	18.1	374.7
6	3.51	72.7	13.69	283.4
7	1.21	25.0	18.33	379.4
8	7.34	151.9	34.41	712.3
9	2.47	51.1	29.56	611.9
10	11.17	231.2	34.53	714.8
11	1.63	33.7	17.74	367.2
12	3.42	70.8	25.37	525.2
13	5.75	119.0	35.25	729.7
14	9.58	198.3	27.84	576.3
15	4.39	90.9	40.23	832.8
16	5.58	115.5	35.29	730.5
17	4.59	95.0	29.71	615.0
18	2.91	60.2	29.15	603.4
19	4.23	87.6	28.1	581.7
20	1.14	23.6	17.26	357.3

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
21	1.31	27.1	12.19	252.3
22	1.61	33.3	4.87	100.8
23	4.08	84.5	17.31	358.3
24	3.77	78.0	11.52	238.5
25	6.26	129.6	22.8	472.0
26	1.8	37.3	9.95	206.0
27	6.78	140.3	29.52	611.1
28	9.15	189.4	29.78	616.4
29	4.25	88.0	17.21	356.2
30	2.77	57.3	7.22	149.5
31	3.56	73.7	12.82	265.4
32	4.75	98.3	15.98	330.8
33	4.41	91.3	21.35	441.9
34	3.95	81.8	20.55	425.4
35	7.07	146.3	28.91	598.4
36	6.02	124.6	13.98	289.4
37	1.82	37.7	11.43	236.6
38	8.2	169.7	14.78	305.9
39	2.25	46.6	24.73	511.9
40	3.34	69.1	17.93	371.2
41	5.85	121.1	15.62	323.3
42	9.64	199.5	13.13	271.8
43	2.64	54.6	7.7	159.4
44	2.63	54.4	9.02	186.7
45	4.86	100.6	21.99	455.2
46	4.89	101.2	34.87	721.8
47	2.88	59.6	47.54	984.1
48	5.56	115.1	6.7	138.7
49	5.43	112.4	37.96	785.8
50	2.15	44.5	7.16	148.2
51	2.61	54.0	13.49	279.2
52	4.79	99.2	23.56	487.7
53	4.59	95.0	7.29	150.9
54	1.5	31.1	12.08	250.1
55	14.26	295.2	30.08	622.7
56	4.2	86.9	13.5	279.5
57	2.7	55.9	10.55	218.4

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
58	5.85	121.1	10.73	222.1
59	6.11	126.5	13.93	288.4
60	2.13	44.1	7.02	145.3
61	2.84	58.8	7.14	147.8
62	2.47	51.1	4.74	98.1

1953 AMS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	3.89	226.8	6.37	371.4
2	8.15	475.1	8.81	513.6
3	1.46	85.1	3.46	201.7
4	0.89	51.9	2.69	156.8
5	6.42	374.3	11.25	655.9
6	1.89	110.2	5.15	300.2
7	1.61	93.9	9.61	560.3
8	8.28	482.7	10.77	627.9
9	4.56	265.8	11.14	649.5
10	2.08	121.3	12.36	720.6
11	1.55	90.4	4.5	262.4
12	2.54	148.1	9.35	545.1
13	2.03	118.3	9.05	527.6
14	3.72	216.9	9.46	551.5
15	4.22	246.0	14.58	850.0
16	9.42	549.2	15.99	932.2
17	2.81	163.8	7.23	421.5
18	2.41	140.5	10.24	597.0
19	0.83	48.4	9.96	580.7
20	0.95	55.4	6.02	351.0
21	1.33	77.5	3.59	209.3
22	0.86	50.1	4.32	251.9
23	3.42	199.4	7.08	412.8
24	2.18	127.1	4.66	271.7
25	1.29	75.2	7.82	455.9
26	1	58.3	2.61	152.2
27	3.95	230.3	14.19	827.3
28	1.43	83.4	8.22	479.2

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
29	2.34	136.4	7.33	427.3
30	2.06	120.1	7.79	454.2
31	2.42	141.1	3.94	229.7
32	3.7	215.7	9.31	542.8
33	1.61	93.9	8.29	483.3
34	1.5	87.5	8.66	504.9
35	4.76	277.5	8.23	479.8
36	4.96	289.2	9.7	565.5
37	3.64	212.2	4.24	247.2
38	5.72	333.5	8.97	523.0
39	4.54	264.7	10.25	597.6
40	8.71	507.8	8.71	507.8
41	6.2	361.5	7.65	446.0
42	3.33	194.1	8.8	513.0
43	4.29	250.1	7.62	444.2
44	3.56	207.5	3.56	207.5
45	5.26	306.7	8.28	482.7
46	3.36	195.9	13.38	780.1
47	2.33	135.8	16.16	942.1
48	2.51	146.3	2.51	146.3
49	1.44	84.0	4.09	238.4
50	3.26	190.1	6.22	362.6
51	4.41	257.1	4.41	257.1
52	9.05	527.6	9.05	527.6
53	1.58	92.1	2.97	173.2
54	1.34	78.1	8.7	507.2
55	4.01	233.8	9.28	541.0
56	2.49	145.2	4.53	264.1
57	1.57	91.5	4.75	276.9
58	1.83	106.7	3.17	184.8
59	1.86	108.4	4.68	272.8
60	1.15	67.0	7.76	452.4
61	1.6	93.3	3.07	179.0
62	1.9	110.8	1.9	110.8

1935 FAIRCHILD COLLECTION

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
1	6.06	198.8	40.52	1329.1
2	12.7	416.6	38.47	1261.8
3	5.5	180.4	15.07	494.3
4	6.02	197.5	11.61	380.8
5	15.91	521.8	21.39	701.6
6	4.96	162.7	21.34	700.0
7	6.24	204.7	12.74	417.9
8	20.71	679.3	27.01	885.9
9	13.6	446.1	30.13	988.3
10	8.35	273.9	21.81	715.4
11	3.8	124.6	21.52	705.9
12	1.79	58.7	17.78	583.2
13	5.59	183.4	22.41	735.0
14	3.89	127.6	24.49	803.3
15	3.38	110.9	34.91	1145.0
16	2.45	80.4	33.17	1088.0
17	4.21	138.1	31.55	1034.8
18	3.64	119.4	23.86	782.6
19	3	98.4	18.53	607.8
20	4.11	134.8	12.99	426.1
21	3.09	101.4	21.12	692.7
22	4.12	135.1	8.58	281.4
23	7.6	249.3	26.65	874.1
24	2.95	96.8	15.8	518.2
25	4.35	142.7	11.95	392.0
26	1.53	50.2	14.78	484.8
27	5.38	176.5	28.28	927.6
28	4.56	149.6	17.49	573.7
29	3.57	117.1	25.14	824.6
30	7.29	239.1	24.8	813.4
31	4.85	159.1	24.68	809.5
32	5.58	183.0	20.12	659.9
33	17.53	575.0	30.78	1009.6
34	7.62	249.9	20.49	672.1
35	15.78	517.6	30.03	985.0
36	7.56	248.0	22	721.6

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
37	5.03	165.0	30.28	993.2
38	3.48	114.1	19.58	642.2
39	12.57	412.3	16.14	529.4
40	7.69	252.2	24.96	818.7
41	4.07	133.5	19.91	653.0
42	4.9	160.7	20.59	675.4
43	4.4	144.3	21.55	706.8
44	9.83	322.4	14.99	491.7
45	3.47	113.8	16.83	552.0
46	4.58	150.2	23.23	761.9
47	7.21	236.5	27.23	893.1
48	1.61	52.8	7.65	250.9
49	7.2	236.2	22.56	740.0
50	5.71	187.3	22.53	739.0
51	3.86	126.6	11.86	389.0
52	6.75	221.4	15.12	495.9
53	1.84	60.4	9.45	310.0
54	1.3	42.6	18.69	613.0
55	7.82	256.5	16.45	539.6
56	3.74	122.7	7.79	255.5
57	5.82	190.9	10.89	357.2
58	5.24	171.9	21.97	720.6
59	1.96	64.3	13.64	447.4
60	6.12	200.7	15.1	495.3
61	1.61	52.8	9.31	305.4
62	3.07	100.7	3.07	100.7

DUNCAN VALLEY

2000 USBR

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	11	43.5	26	100.2
64	14.5	57.3	65	250.5
65	12	47.4	22	84.8
66	59	233.1	120	462.4
67	38	150.1	92	354.5
68	37	146.2	97	373.8
69	45	177.8	70	269.8
70	22	86.9	45	173.4
71	14.5	57.3	27	104.0
72	9	35.6	16	61.7
73	11	43.5	34	131.0
74	24	94.8	87	335.3
75	16	63.2	33	127.2
76	34	134.3	92	354.5
77	25	98.8	55	212.0
78	29	114.6	38	146.4
79	11	43.5	29	111.8
80	24	94.8	72	277.5
81	12	47.4	34	131.0
82	10	39.5	43	165.7
83	12	47.4	59	227.4
84	12	47.4	20	77.1
85	21	83.0	76	292.9
86	5	19.8	57	219.7
87	21	83.0	29.5	113.7
88	15	59.3	104	400.8
89	12	47.4	96	370.0
90	11	43.5	43	165.7
91	17.5	69.1	76	292.9
92	12	47.4	58	223.5
93	17	67.2	56	215.8
94	12	47.4	95	366.1
95	12.5	49.4	62	238.9
96	19	75.1	62	238.9
97	32	126.4	67	258.2

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
98	16	63.2	103.5	398.9
99	20.5	81.0	66	254.3
100	8	31.6	36	138.7
101	12	47.4	29	111.8

1997 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	1.6	71.4	2.12	94.6
64	1.66	74.0	4.78	213.2
65	0.81	36.1	2.2	98.1
66	1.13	50.4	12.56	560.2
67	2.08	92.8	7.36	328.3
68	1.63	72.7	6.92	308.6
69	1.42	63.3	5.79	258.2
70	2.63	117.3	5.26	234.6
71	1.13	50.4	1.89	84.3
72	1.4	62.4	1.4	62.4
73	0.73	32.6	2.38	106.1
74	1.2	53.5	8.71	388.5
75	1.69	75.4	3.22	143.6
76	1.63	72.7	6.4	285.4
77	1.75	78.1	5.17	230.6
78	2.38	106.1	3.6	160.6
79	1.39	62.0	2.38	106.1
80	1.79	79.8	5.59	249.3
81	1.08	48.2	3.2	142.7
82	3.38	150.7	3.38	150.7
83	1.54	68.7	3.05	136.0
84	1.42	63.3	2.31	103.0
85	0.68	30.3	4.97	221.7
86	0.77	34.3	4.01	178.8
87	1.85	82.5	2.5	111.5
88	2.15	95.9	8.54	380.9
89	4.13	184.2	8.24	367.5
90	2.06	91.9	3.18	141.8
91	1.84	82.1	5.91	263.6
92	0.97	43.3	4.86	216.8
93	1.31	58.4	1.94	86.5
94	1.81	80.7	9.7	432.6
95	1.35	60.2	4.76	212.3
96	1.37	61.1	7.05	314.4
97				
98				

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99				
100				
101				

1992 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	0.5	22.3	1.97	87.9
64	1.27	56.6	3.91	174.4
65	0.81	36.1	2.48	110.6
66	0.66	29.4	12.45	555.3
67	1	44.6	6.97	310.9
68	2.49	111.1	10.36	462.1
69	1.3	58.0	6.09	271.6
70	1.21	54.0	4.86	216.8
71	0.83	37.0	1.96	87.4
72	0.93	41.5	1.79	79.8
73	1.85	82.5	2.57	114.6
74	1.05	46.8	8.24	367.5
75	1.75	78.1	3	133.8
76	1.12	50.0	7.46	332.7
77	1.91	85.2	4.91	219.0
78	1.06	47.3	4	178.4
79	1.72	76.7	2.1	93.7
80	1.21	54.0	5.9	263.1
81	0.72	32.1	2.33	103.9
82	1.29	57.5	6.07	270.7
83	0.75	33.5	2.33	103.9
84	0.57	25.4	2.25	100.4
85	0.71	31.7	5.67	252.9
86	0.78	34.8	5.96	265.8
87	0.59	26.3	3.5	156.1
88	0.99	44.2	1.74	77.6
89	1.44	64.2	9.47	422.4
90	0.66	29.4	5.67	252.9
91	2.29	102.1	5.35	238.6
92	0.92	41.0	4.64	206.9
93	0.95	42.4	4.07	181.5
94	0.48	21.4	10.47	467.0
95	3.39	151.2	5.71	254.7
96	0.59	26.3	3.29	146.7
97	0.72	32.1	6.65	296.6
98	1.07	47.7	3.56	158.8

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	1.54	68.7	5.48	244.4
100	2.16	96.3	2.77	123.5
101	1.81	80.7	2.44	108.8

1983 FLOOD NRCS

Point no.	Flood flow width (mm)	Splay width (mm)	Bank	Flood flow width (m)	Splay width (m)	Total width (m)
63	7.12			41.3		41.3
64	7.43			43.1		43.1
65	21.46			124.5		124.5
66	92			533.6		533.6
67	45.14			261.8		261.8
68	49.13			285.0		285.0
69	17.4			100.9		100.9
70	25.48			147.8		147.8
71	9.98			57.9		57.9
72	7.74			44.9		44.9
73	21.18			122.8		122.8
74	30.14			174.8		174.8
75	12.9			74.8		74.8
76	26.24			152.2		152.2
77	35.42			205.4		205.4
78	18.15			105.3		105.3
79	13.38			77.6		77.6
80	33.69			195.4		195.4
81	27.59			160.0		160.0
82	49.15			285.1		285.1
83	8			46.4		46.4
84	8.59			49.8		49.8
85	29.66			172.0		172.0
86	25.56			148.2		148.2
87	5.93			34.4		34.4
88	36			208.8		208.8
89	32.61			189.1		189.1
90	18.13			105.2		105.2
91	35.75			207.4		207.4
92	6.44	5.94		37.4	34.5	77.7
93	10.99			63.7		63.7
94	16.27			94.4		94.4
95	21.6			125.3		125.3
96	42.02	22.63	lb	243.7	131.3	397.6
97	54.97	22.06	rb	318.8	127.9	468.8
98	20.91			121.3		121.3

Point no.	Flood flow width (mm)	Splay width (mm)	Bank	Flood flow width (m)	Splay width (m)	Total width (m)
99	15.59			90.4		90.4
100	38.05			220.7		220.7
101	17.71			102.7		102.7

1981 USGS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	1.32	50.4	1.79	68.4
64	1.15	43.9	6.35	242.6
65	0.83	31.7	2.54	97.0
66	7.44	284.2	14.01	535.2
67	1.91	73.0	8.73	333.5
68	4.11	157.0	9.38	358.3
69	2.32	88.6	9.88	377.4
70	3.01	115.0	4.49	171.5
71	1.61	61.5	1.61	61.5
72	0.87	33.2	3.27	124.9
73	1.02	39.0	2.84	108.5
74	2.11	80.6	11.28	430.9
75	1.34	51.2	4.36	166.6
76	4.54	173.4	6.09	232.6
77	4.95	189.1	5.89	225.0
78	2.78	106.2	4.43	169.2
79	1.73	66.1	3.08	117.7
80	2.78	106.2	4.57	174.6
81	1.02	39.0	3.42	130.6
82	0.52	19.9	5.87	224.2
83	1.08	41.3	2.22	84.8
84	0.63	24.1	4	152.8
85	0.55	21.0	6.15	234.9
86	0.64	24.4	5.03	192.1
87	0.75	28.7	3.73	142.5
88	0.43	16.4	7.01	267.8
89	1.23	47.0	9.92	378.9
90	0.59	22.5	2.93	111.9
91	0.8	30.6	4.15	158.5
92	0.59	22.5	4.31	164.6
93	0.72	27.5	2.06	78.7
94	0.67	25.6	12.9	492.8
95	3.45	131.8	5.45	208.2
96	0.73	27.9	6.34	242.2
97	1.17	44.7	6.69	255.6
98	0.43	16.4	2.05	78.3

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	2.01	76.8	6.2	236.8
100	1.51	57.7	1.87	71.4
101	2.28	87.1	2.28	87.1

1978 FLOOD NRCS

Point no.	Flood flow width (mm)	Flood flow width (m)
63	6.28	74.1
64	20.28	239.3
65	14.64	172.8
66	52.5	619.5
67	29.53	348.5
68	53.21	627.9
69	54.35	641.3
70	29.23	344.9
71	9.73	114.8
72	6.62	78.1
73	11.26	132.9
74	29.29	345.6
75	46.75	551.7
76	29.3	345.7
77	29.38	346.7
78	23.85	281.4
79	9.64	113.8
80	33.91	400.1
81	15.22	179.6
82	26.57	313.5
83	30.97	365.4
84	17.37	205.0
85	19.3	227.7
86	19.8	233.6
87	19.45	229.5
88	31.75	374.7
89	33.65	397.1
90	38.97	459.8
91	78.14	922.1
92	57.64	680.2
93	56.23	663.5
94	55.32	652.8
95	65.47	772.5
96	51.22	604.4
97	51.98	613.4
98	68.19	804.6
99	74.57	879.9

Point no.	Flood flow width (mm)	Flood flow width (m)
100	54.11	638.5
101	29.95	353.4

1978 BLM

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	1.17	30.5	2.87	74.9
64	1.05	27.4	12.39	323.4
65	1.35	35.2	8.23	214.8
66	8.74	228.1	24.95	651.2
67	2.09	54.5	13.48	351.8
68	2.09	54.5	12.27	320.2
69	1.51	39.4	8.61	224.7
70	3.98	103.9	6.43	167.8
71	1.88	49.1	1.88	49.1
72	0.97	25.3	1.85	48.3
73	2.65	69.2	5.38	140.4
74	2.83	73.9	5.27	137.5
75	1.34	35.0	4.74	123.7
76	4.68	122.1	15.13	394.9
77	1.67	43.6	5.03	131.3
78	1.15	30.0	6.87	179.3
79	1.83	47.8	2.79	72.8
80	7.77	202.8	7.77	202.8
81	1.23	32.1	7.02	183.2
82	0.95	24.8	10.4	271.4
83	1.37	35.8	3.26	85.1
84	0.79	20.6	3.07	80.1
85	0.95	24.8	8.32	217.2
86	0.6	15.7	7.74	202.0
87	0.91	23.8	5.81	151.6
88	0.76	19.8	15.52	405.1
89	2.02	52.7	15.23	397.5
90	0.96	25.1	5.66	147.7
91	0.89	23.2	9.13	238.3
92	0.83	21.7	7.18	187.4
93	1.93	50.4	11.96	312.2
94	0.78	20.4	2.76	72.0
95	5.04	131.5	8.43	220.0
96	1.31	34.2	10.4	271.4
97	1.37	35.8	17.81	464.8
98	1.72	44.9	5.59	145.9

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	1.54	40.2	9.51	248.2
100	1.82	47.5	16.98	443.2
101	1.65	43.1	9.87	257.6

1967 USDA

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	0.85	17.9	5.54	116.9
64	1.02	21.5	3.36	70.9
65	1.46	30.8	5.13	108.2
66	5.54	116.9	25.32	534.3
67	1.67	35.2	16.74	353.2
68	3.19	67.3	11.28	238.0
69	2.14	45.2	18.4	388.2
70	3.33	70.3	6.63	139.9
71	1.77	37.3	3.55	74.9
72	1.3	27.4	3.68	77.6
73	1.24	26.2	6.6	139.3
74	1.73	36.5	14.03	296.0
75	1.1	23.2	7.94	167.5
76	1.36	28.7	9.24	195.0
77	2.82	59.5	4.61	97.3
78	1.03	21.7	6.94	146.4
79	1.68	35.4	4.56	96.2
80	0.92	19.4	9.54	201.3
81	1.38	29.1	6.09	128.5
82	1.04	21.9	12.87	271.6
83	1.88	39.7	1.88	39.7
84	1.15	24.3	2.76	58.2
85	1.16	24.5	6.73	142.0
86	0.85	17.9	5.63	118.8
87	0.95	20.0	7.83	165.2
88	1.23	26.0	4.02	84.8
89	2.73	57.6	18.23	384.7
90	1.23	26.0	4.2	88.6
91	2.16	45.6	7.03	148.3
92	1.2	25.3	8.57	180.8
93	1.25	26.4	2.59	54.6
94	1.41	29.8	2.61	55.1
95	1.15	24.3	10.74	226.6
96	1.25	26.4	9.31	196.4
97	0.87	18.4	3.26	68.8
98	0.84	17.7	5.89	124.3

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	1.36	28.7	4.61	97.3
100	0.76	16.0	1.86	39.2
101	1.69	35.7	4.65	98.1

1958 USDA

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63				
64	0.73	15.0	4.03	83.0
65	1.58	32.5	4.66	96.0
66	3.32	68.4	25.67	528.8
67	1.13	23.3	8.84	182.1
68	0.94	19.4	10.34	213.0
69	1.38	28.4	14.11	290.7
70	2.95	60.8	8.29	170.8
71	1.82	37.5	4.13	85.1
72	1.6	33.0	4.24	87.3
73	0.86	17.7	6.26	129.0
74	1.98	40.8	11.37	234.2
75	2.13	43.9	5.78	119.1
76	1.51	31.1	6.82	140.5
77	2.97	61.2	6.77	139.5
78	1.67	34.4	8.31	171.2
79	2.22	45.7	4.56	93.9
80	1.15	23.7	8.61	177.4
81	1.44	29.7	1.72	35.4
82	1.35	27.8	9.48	195.3
83	1.13	23.3	2.35	48.4
84	1.36	28.0	4.97	102.4
85	1.57	32.3	6.48	133.5
86	1.22	25.1	7.59	156.4
87	1.35	27.8	8.01	165.0
88	0.96	19.8	4.14	85.3
89	2.23	45.9	18.69	385.0
90	1.18	24.3	3.37	69.4
91	1	20.6	6.16	126.9
92	1.43	29.5	9.9	203.9
93	1.49	30.7	2.81	57.9
94	1.27	26.2	4.03	83.0
95	0.98	20.2	10.01	206.2
96	1.54	31.7	8.5	175.1
97	1	20.6	3.15	64.9
98	1.76	36.3	5.6	115.4

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	0.96	19.8	5.94	122.4
100	0.95	19.6	5.49	113.1
101	1.59	32.8	5.06	104.2

1953 AMS

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	0.5	28.3	1.68	94.9
64	0.39	22.0	1.33	75.1
65	0.84	47.5	1.78	100.6
66	2.02	114.1	8.88	501.7
67	1.45	81.9	2.4	135.6
68	0.6	33.9	4.72	266.7
69	0.52	29.4	5.42	306.2
70	1.52	85.9	3.11	175.7
71	0.83	46.9	1.54	87.0
72	0.35	19.8	1.06	59.9
73	0.77	43.5	2.49	140.7
74	2.4	135.6	7.5	423.8
75	1.36	76.8	2.29	129.4
76	1.23	69.5	2.53	142.9
77	1.31	74.0	2.56	144.6
78	0.72	40.7	5.07	286.5
79	0.89	50.3	2.91	164.4
80	0.42	23.7	3.7	209.1
81	0.74	41.8	2.81	158.8
82	0.79	44.6	4.16	235.0
83	0.75	42.4	2.12	119.8
84	0.49	27.7	1.5	84.8
85	0.74	41.8	3.11	175.7
86	0.62	35.0	3.75	211.9
87	0.63	35.6	2.49	140.7
88	0.58	32.8	3.87	218.7
89	1.49	84.2	6.81	384.8
90	0.81	45.8	3.62	204.5
91	0.79	44.6	4.34	245.2
92	0.68	38.4	2.96	167.2
93	0.59	33.3	0.98	55.4
94	0.56	31.6	1.7	96.1
95	0.68	38.4	3.79	214.1
96	0.97	54.8	3.11	175.7
97	0.49	27.7	2.41	136.2
98	0.64	36.2	2.33	131.6

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	0.75	42.4	1.95	110.2
100	0.47	26.6	1.87	105.7
101	0.87	49.2	2.84	160.5

1935 FAIRCHILD COLLECTION

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
63	0.76	24.7	3.79	123.2
64	1.73	56.2	9.64	313.3
65	2.32	75.4	5.22	169.7
66	9.11	296.1	19.21	624.3
67	2.4	78.0	2.4	78.0
68	1.24	40.3	8.2	266.5
69	2.07	67.3	9.59	311.7
70	0.74	24.1	6.48	210.6
71	1.31	42.6	2.5	81.3
72	1.91	62.1	1.91	62.1
73	1.04	33.8	3.54	115.1
74	1.39	45.2	12.69	412.4
75	1.49	48.4	19.93	647.7
76	1.91	62.1	7.24	235.3
77	0.81	26.3	5.25	170.6
78	1.45	47.1	3.72	120.9
79	1.18	38.4	2.37	77.0
80	0.71	23.1	6.55	212.9
81	1.57	51.0	4.6	149.5
82	1.35	43.9	8.1	263.3
83	0.88	28.6	3.04	98.8
84	1.35	43.9	4.63	150.5
85	0.94	30.6	4.85	157.6
86	0.81	26.3	6.02	195.7
87	1.18	38.4	4.75	154.4
88	1.97	64.0	5.39	175.2
89	2.58	83.9	11.65	378.6
90	1.52	49.4	5.45	177.1
91	1.22	39.7	11.65	378.6
92	1.18	38.4	5.22	169.7
93	2.67	86.8	6.37	207.0
94	0.58	18.9	6.04	196.3
95	1.03	33.5	5.99	194.7
96	1.53	49.7	5.48	178.1
97	1.28	41.6	4.95	160.9
98	1.83	59.5	5.2	169.0

Point no.	Recent flow width (mm)	Recent flow width (m)	Flood flow width (mm)	Flood flow width (m)
99	1.04	33.8	7.54	245.1
100	1.54	50.1	4.78	155.4
101	0.94	30.6	11.16	362.7

APPENDIX D. SOURCE DATA

Table D1. List of Aerial Photographs.

DATE	SOURCE[1]	SCALE	FILM TYPE[2]	COVERAGE
1935	SCS (NRCS) FAIRCHILD AERIAL SURVEYS, INC.	~1:30,000	B/W	Entire study area
APR/DEC 1953-54 (2 SETS)	AMS	1:54,000	B/W	Entire study area
1958	USDA	1:20,000	B/W	Entire study area
1967	USDA	1:20,000	B/W	Entire study area
OCT 21 1972	ADOT	1:12,000	B/W	Safford Valley
1973	USDA	1:22,000	B/W	Safford Valley
SEPT-OCT 1978	BLM	1:24,000	CLR	Entire study area
1978	NRCS	1:24,000	B/W	Entire study area
JUN 1 1981	USGS	1:38,000	CLR/IR	Partial Safford Valley, Duncan Valley
1983	COOPER AERIAL	1:20,000	B/W	Safford Valley
1983	NRCS	1:6,000	B/W	Entire study area, many photos missing from set
1985	NRCS	1:12,000	B/W	Duncan Valley
1992	USGS	1:40,000	B/W	Entire study area
1993	NRCS	1:6,000	B/W	Safford Valley
1997	USGS	1:40,000	B/W	Entire study area except Duncan Valley
2000	USBR	1:10,000	B/W	Entire study area

[1] SOURCE ABBREVIATIONS:
ADOT Arizona Department of Transportation
AMS Army Map Service
ASLD Arizona State Land Department
BLM Bureau of Land Management
GRPP Gila River Phreatophyte Project
NASA National Aeronautics and Space Administration
SCS/NRCS Soil Conservation Service/Natural Resource Conservation Service
USAF United States Air Force
USGS United States Geological Survey

[2] FILM TYPE ABBREVIATIONS:
B/W Black and White
B/W IR Black and White Infrared
CLR Color
CLR/IR Color Infrared

Table D2. List of Maps.

YEAR	SOURCE	SCALE	MAP TYPE	CONTOUR INTERVAL	COVERAGE
1903/1916	OLMSTEAD, 1919	1:10,560	PLANIMETRIC*	---	Safford Valley
1914-15	SCS	1:12,000	TOPOGRAPHIC	5 ft (1.5 m)	
1944	PHELPS DODGE CORPORATION	1:7,200	PLANIMETRIC*	---	lower Safford Valley
1960	USGS 7.5' SERIES	1:24,000	TOPOGRAPHIC	40 ft (12.2 m)	Entire study area
1964	GILA RIVER PHREATOPHYTE PROJECT	1:7,200	TOPOGRAPHIC	2 ft (0.6 m)	Safford Valley
1985-86	USGS 7.5' SERIES	1:24,000	TOPOGRAPHIC	40 ft (12.2 m)	Partial coverage
1989-90	USGS 7.5' SERIES	1:24,000	TOPOGRAPHIC	40 ft (12.2 m)	Partial coverage
VARIOUS	BLM /GLO CADASTRAL SURVEYS		PLANIMETRIC*	---	Entire study area

*Map shows location of channel relative to Township and Range coordinates; no contour lines are drawn.