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Managing Water in the West

Historical channel change on the Upper Gila River, Arizona and New Mexico in response to anthropogenic modifications and extreme floods

U.S. Department of the Interior
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Upper Gila River Fluvial Geomorphology Study

Catalysts for study

- **Extreme floods during the 1970's-1990's**
- **Erosion of agricultural land, critical infrastructure**
- **Flooding of emergency routes and communities**

Objectives

- **To provide an understanding of the physical processes operating in the Upper Gila River corridor**
- **To explain recent (1935-2000) geomorphic change on the Upper Gila River in Safford and Duncan valleys**

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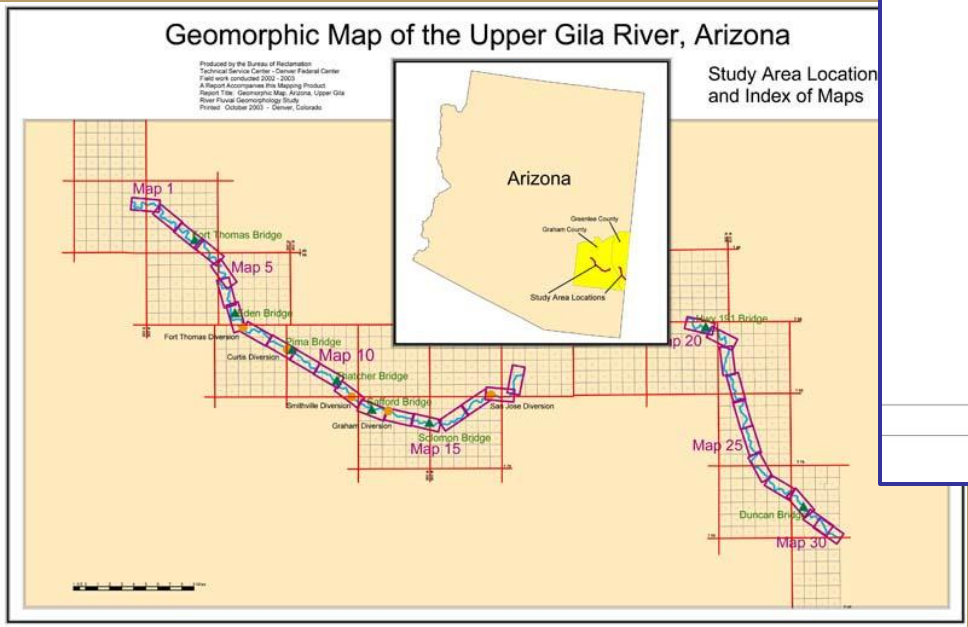
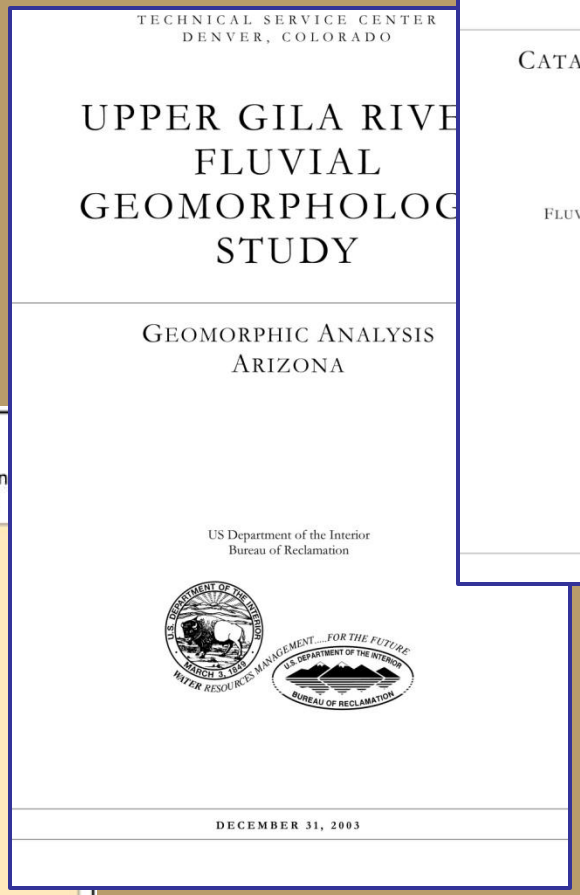
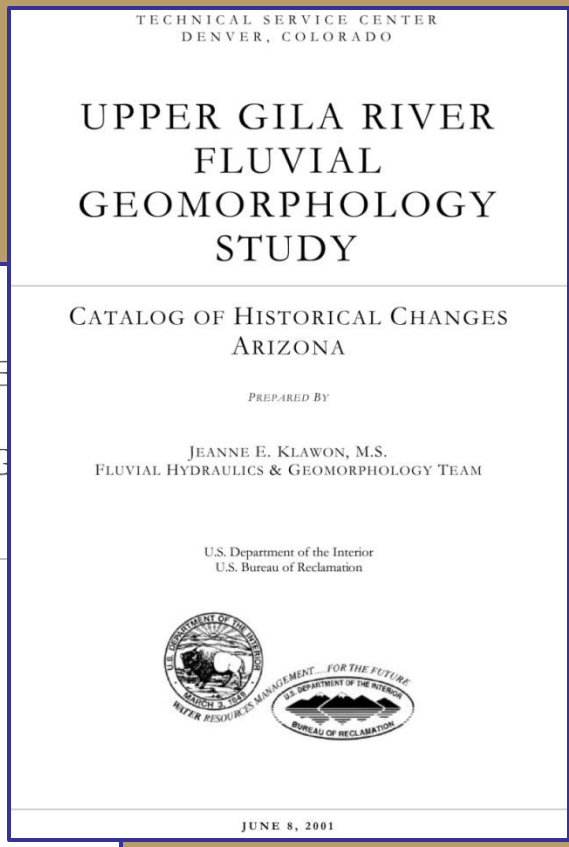
Upper Gila River Fluvial Geomorphology Study

- Background Information
- Field Data Collection Plan
- Hydrologic Analysis
- ***Catalog of Historical Changes***
- ***Geomorphic Analysis***
- Stable Channel Analysis
- Stream Corridor Assessment
- Final Report







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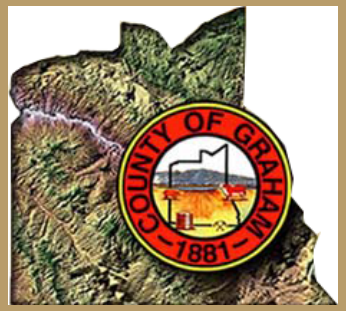
Partnerships

- **Arizona Water Protection Fund**
  - **GRANT NO. 98-054WPF**
- **Graham County**
  - **COST SHARE AGREEMENT 00-GI 32-0054**
- **Bureau of Land Management**
- **Gila Watershed Partnership**
- **Landowners**
  - **Property access, accounts of river history, flooding, property history**



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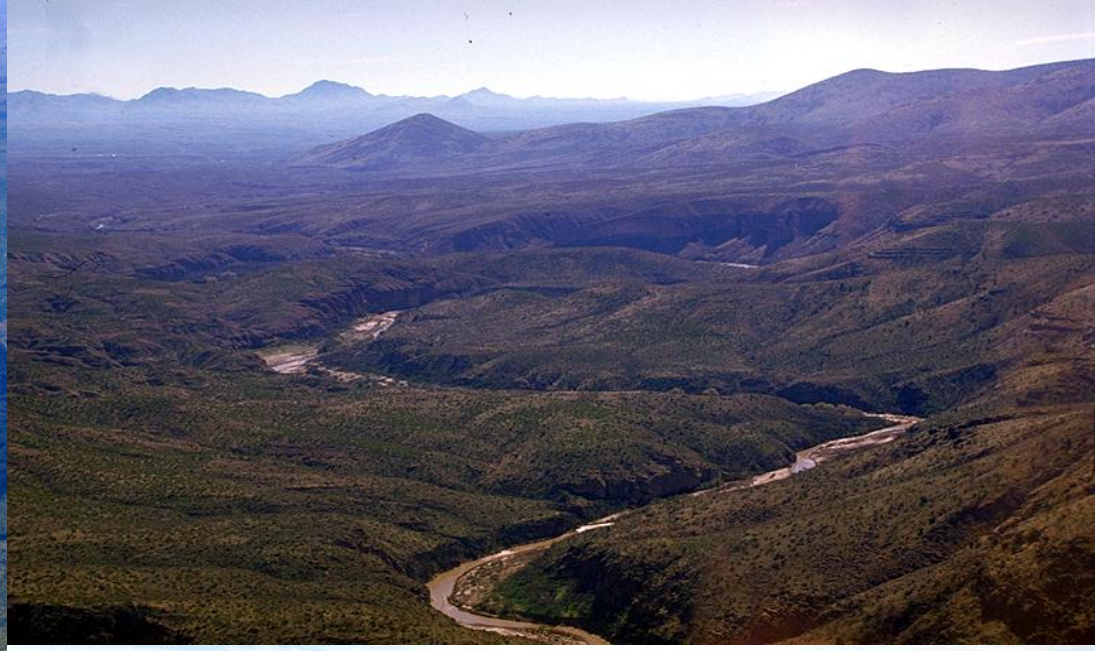

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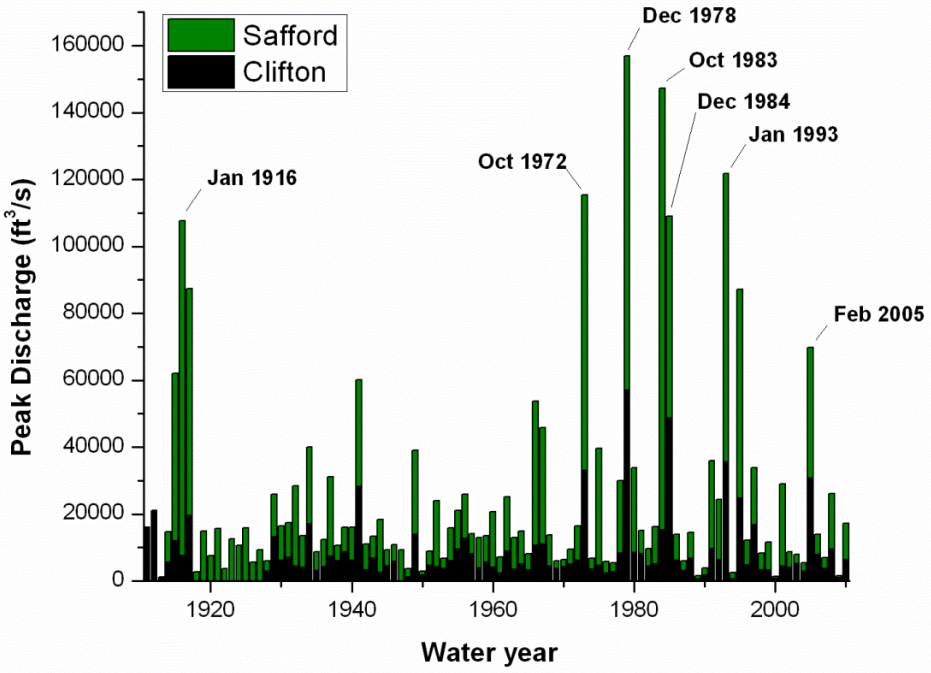

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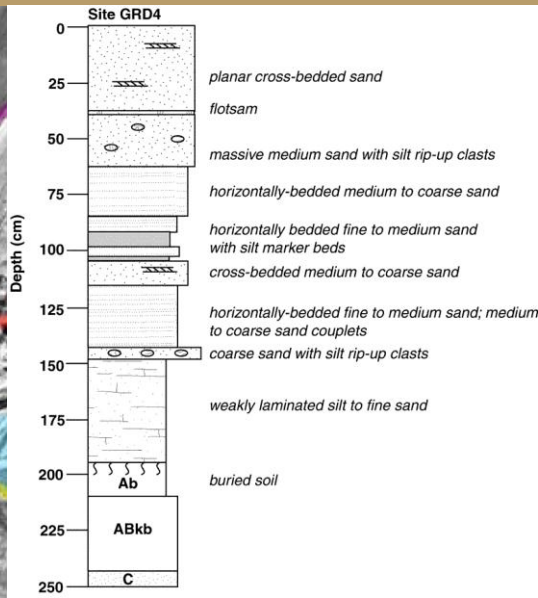
Practically Speaking…

- **Erosion/sedimentation of agricultural land**
- **Limited emergency access across river (flooding across bridge approaches)**
- **Damage to infrastructure**
  - **Bridges: overtopping/erosion of abutments, undercutting**
  - **Levees: overtopping, breaching, lateral erosion**
  - **Diversion dams: flanking, sedimentation and scour, siltation of irrigation ditches**
  - **Bank protection: lateral erosion**

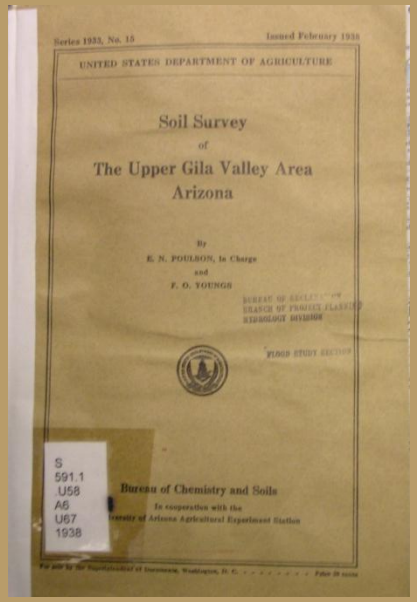
Geomorphic Analysis

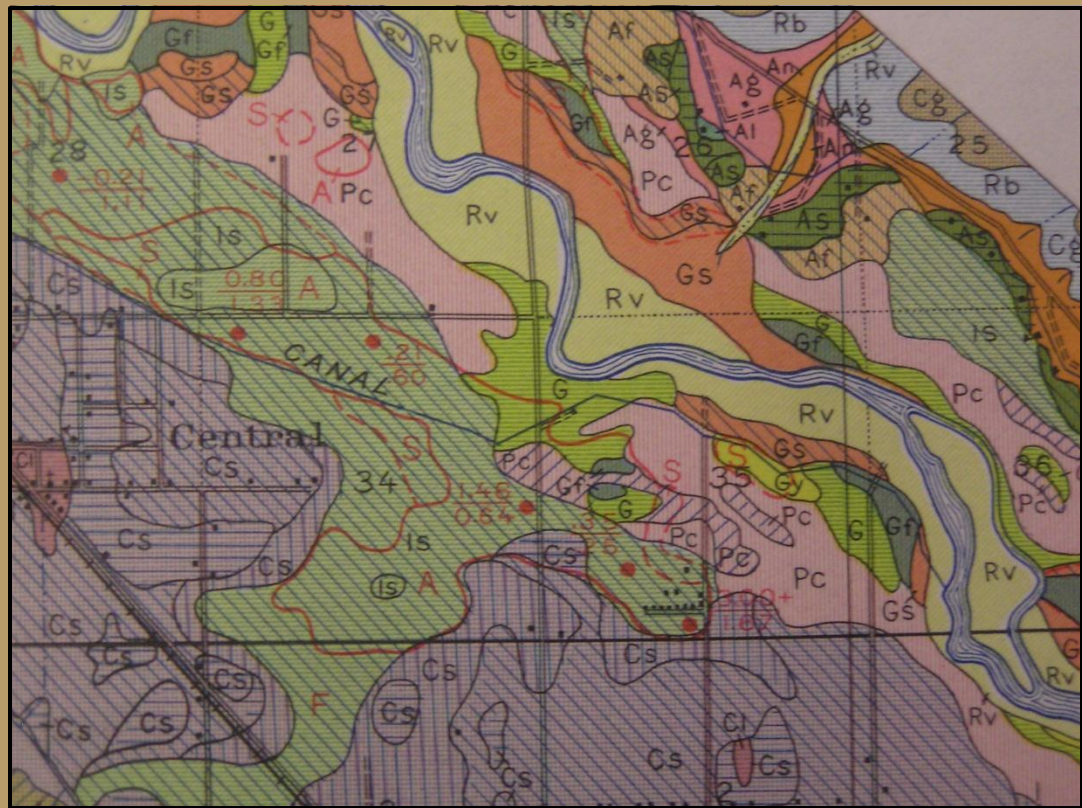
- Geomorphic mapping
  - Landform delineation (i.e., river channel, stream terraces…)
  - Human features (levees, dams…)
  - Areas of erosion (1967-2000 in Safford Valley; 1978-2000 in Duncan Valley)
- Soil descriptions
  - USDA soils mapping and descriptions
  - Site descriptions of bank exposures
- Laboratory analysis
  - Macrobotanical identification
  - ^{14}C dating of charcoal fragments

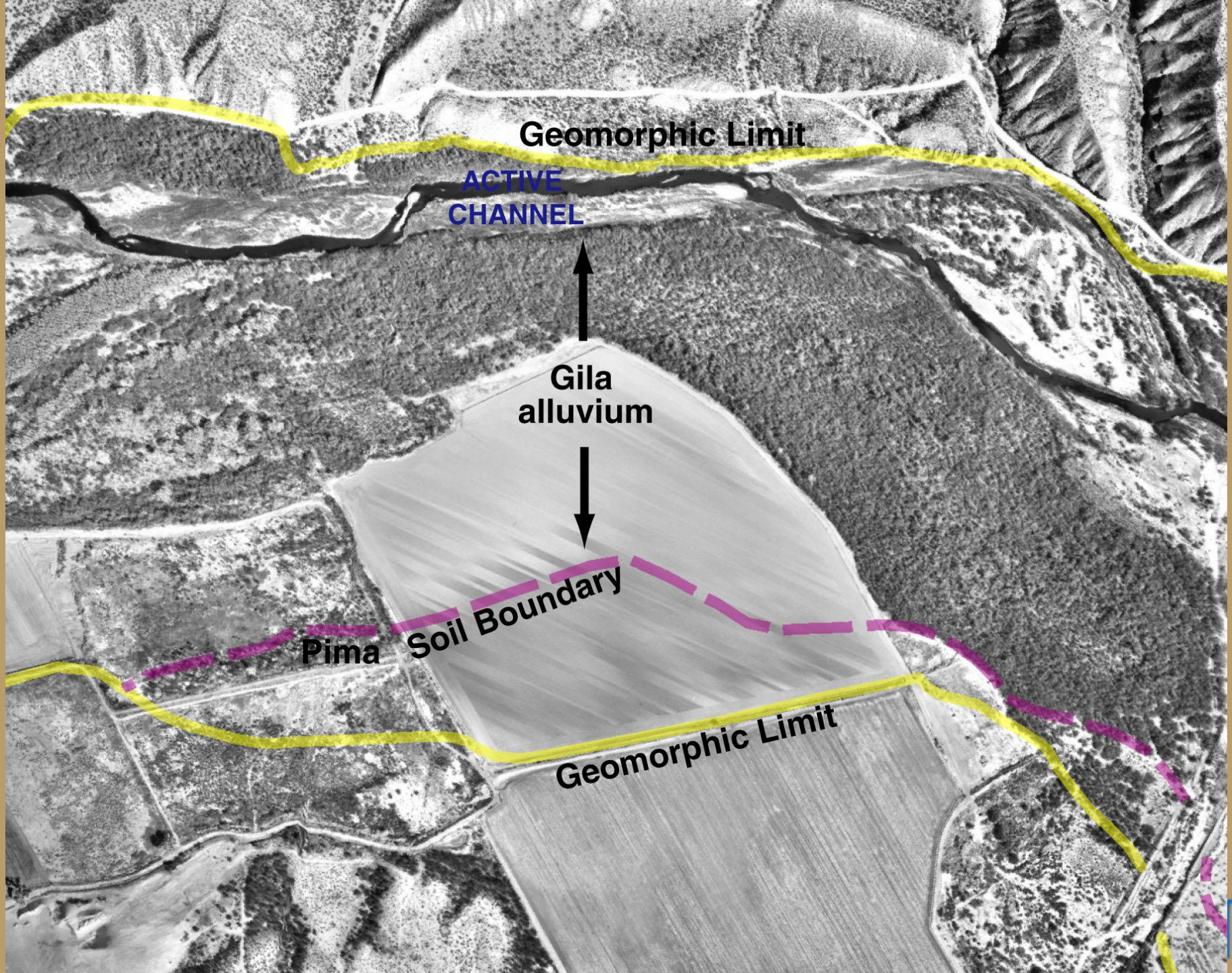


Soils (Poulson and Young, 1938)

- **Gila alluvium (G, Rv)**
  - **Weakly developed soils**
  - **Stratified alluvium**
  - **Recently occupied by the river channel**
- **Pima alluvium (P)**
  - **Weakly to moderately developed soils**
  - **Floodplain alluvium**
- **Upland soils (A,C, I)**
  - **Alluvial fans**
  - **older stream terraces**
  - **bedrock**






Geomorphic Limit
ACTIVE
CHANNEL
Gila
alluvium
Pima Soil Boundary
Geomorphic Limit

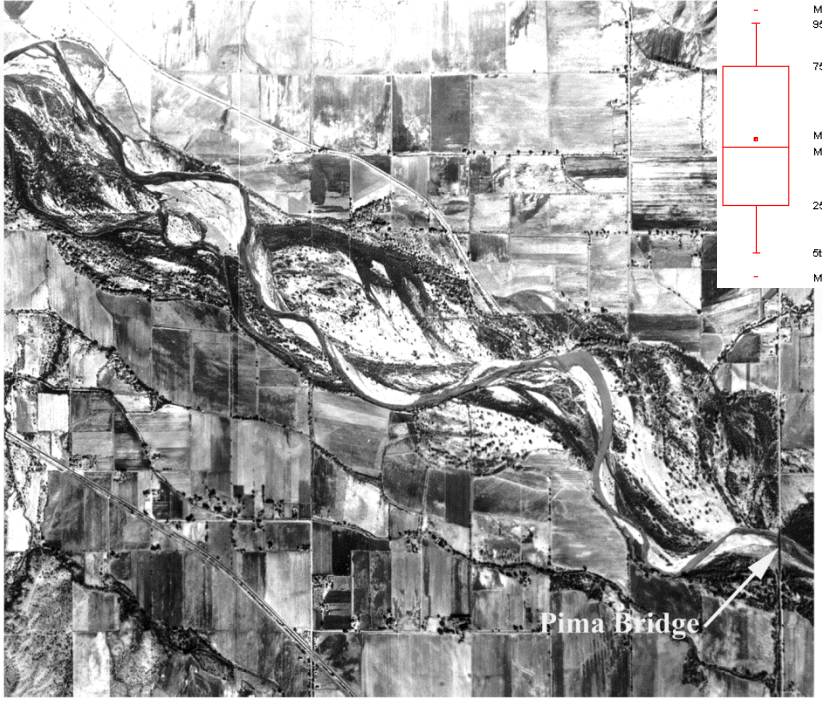
Historical channel change

Channel width measurements

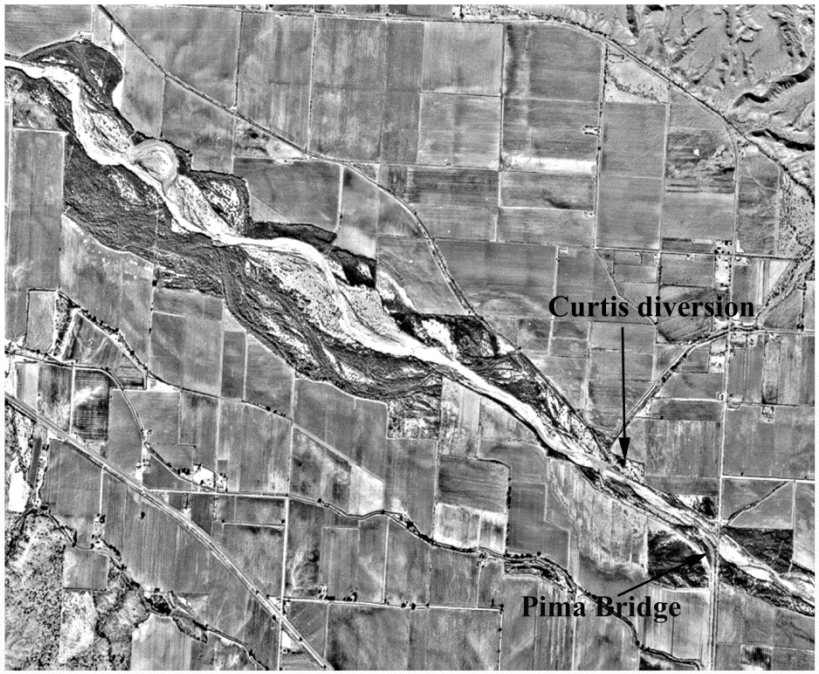
- by photo year (recent flow and flood flow width, 1935-2000)
- by location in channel (variability)
- changes before and after extreme floods

☆ 1995 ☆ 1993 ☆ 1984 ☆ 1983 ☆ 1978 ☆ 1972

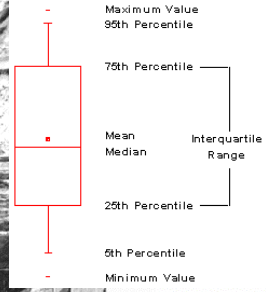
DATE	*SOURCE*	*SCALE*	*FILM TYPE*	*COVERAGE*
1935	SCS (NRCS) FAIRCHILD AERIAL SURVEYS, INC.	~1:30,000	B/W	Entire study area
APR/DEC 1953-54 (2 SETS)	AMS	1:54,000	B/W	Entire study area
1958	USDA	1:20,000	B/W	Entire study area
1967	USDA	1:20,000	B/W	Entire study area
OCT 21 1972	ADOT	1:12,000	B/W	Safford 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

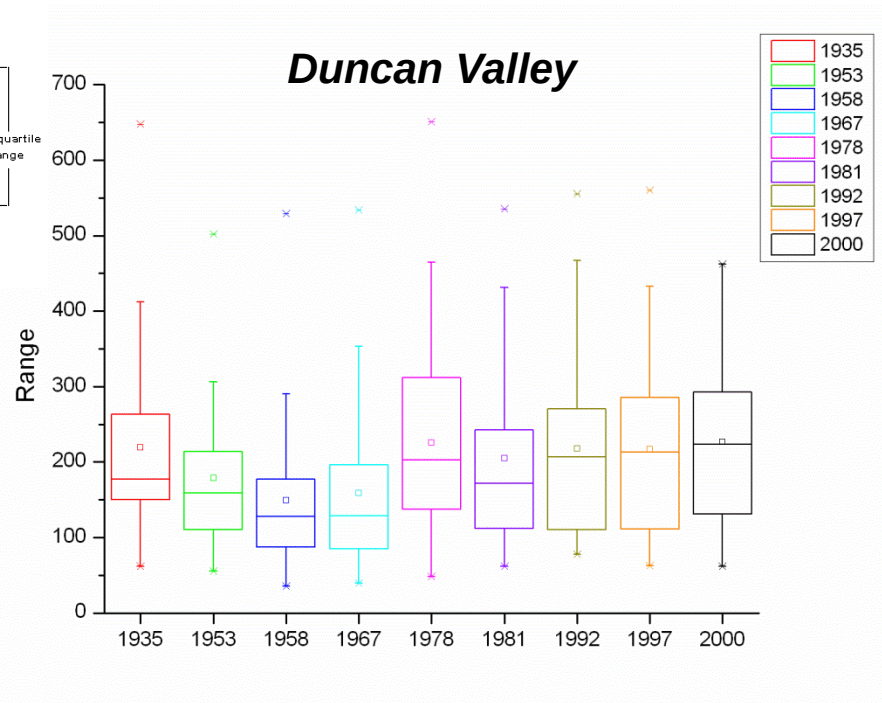

Pima Bridge

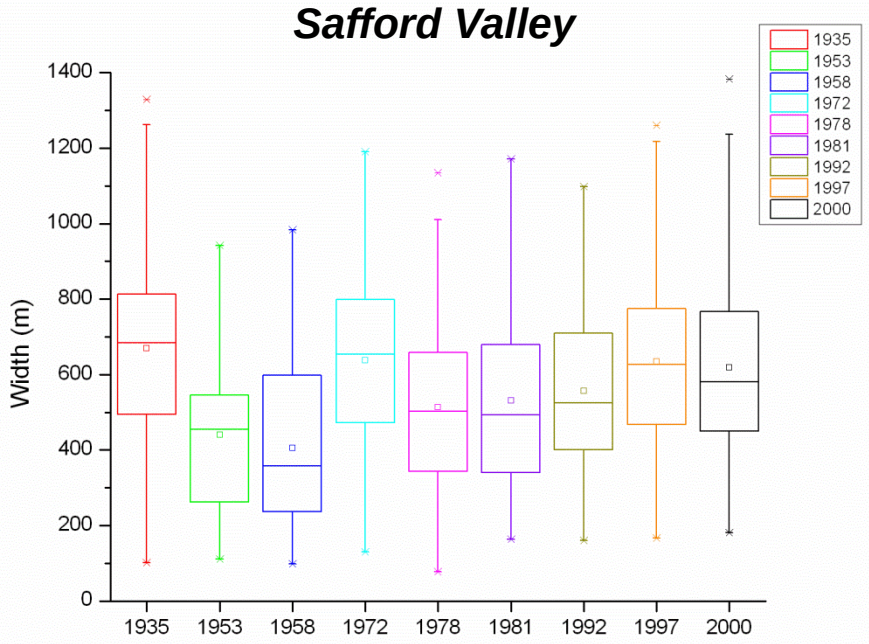
(a) 1935


Curtis diversion
Pima Bridge

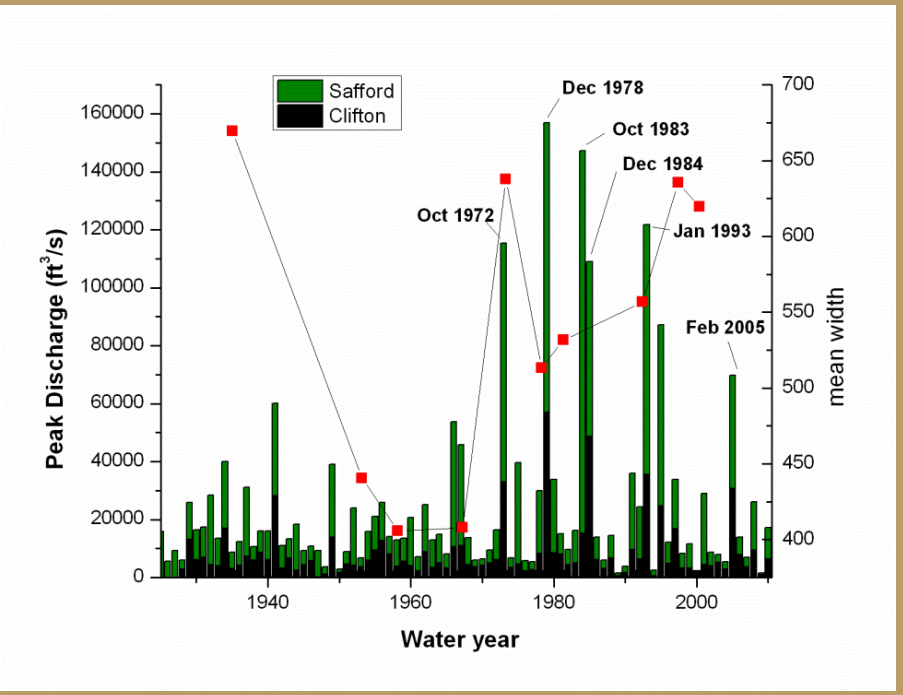
(b) 1953


Maximum Value
95th Percentile
75th Percentile
Mean
Median
Interquartile Range
25th Percentile
5th Percentile
Minimum Value


Duncan Valley
Range
0
100
200
300
400
500
600
700
1935
1953
1958
1967
1978
1981
1992
1997
2000


Safford Valley
Width (m)
0
200
400
600
800
1000
1200
1400
1935
1953
1958
1972
1978
1981
1992
1997
2000

Patterns of historical changes in channel width



Large floods: increase in width

- lateral erosion to accommodate flood flows

Few large floods: decrease in width

- floodplain rebuilding
- vegetation encroachment
- levee construction

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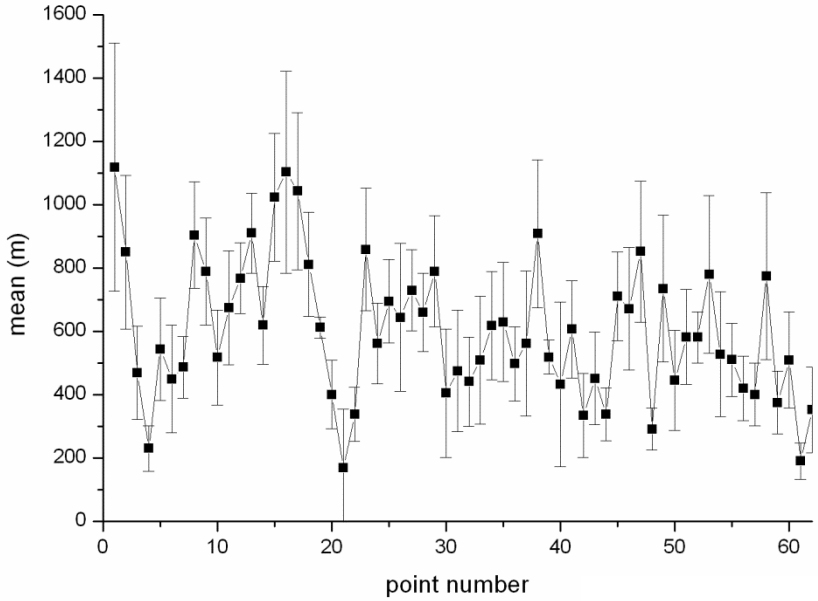
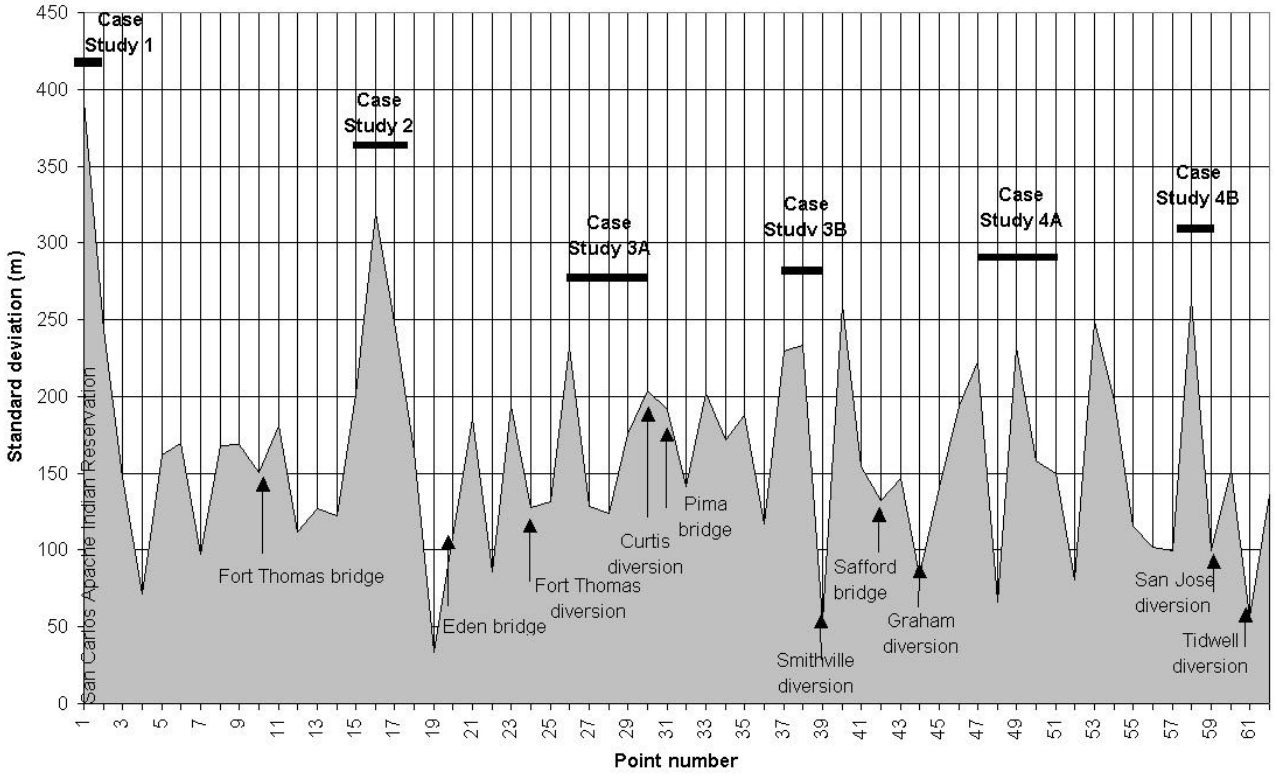


Variability in channel width

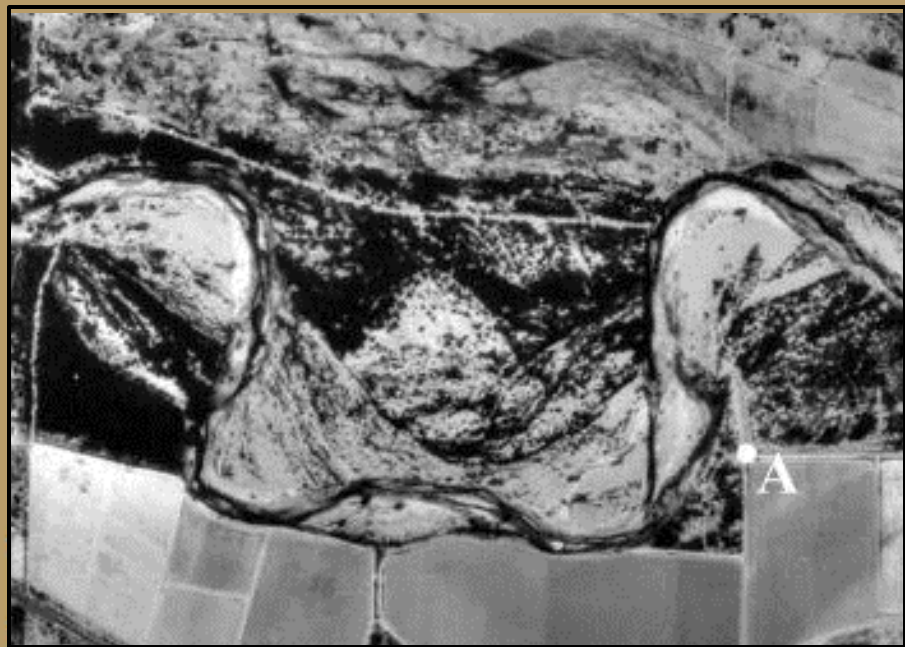
- highlights wide and narrow sections in the river corridor
- Identifies sections of greatest historical channel change



Dog ear erosion scars located Lateral to channelized sections

Scalloped meander scrolls along margins of diversion structures

Right angle bends in alluvial reaches with no apparent geologic control



Channel change processes

- Channel widening and narrowing in response to hydrologic regime
- Channel avulsion
- Meander cutoffs
- Overbank channel splays

Factors in channel change

- Levee construction/failure
- Land leveling
- Propagation of erosion
- Channel straightening
- Diversion dam orientation
- Vegetation
- Alluvial fans

1935

1998

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Areas of greatest change: Safford Valley

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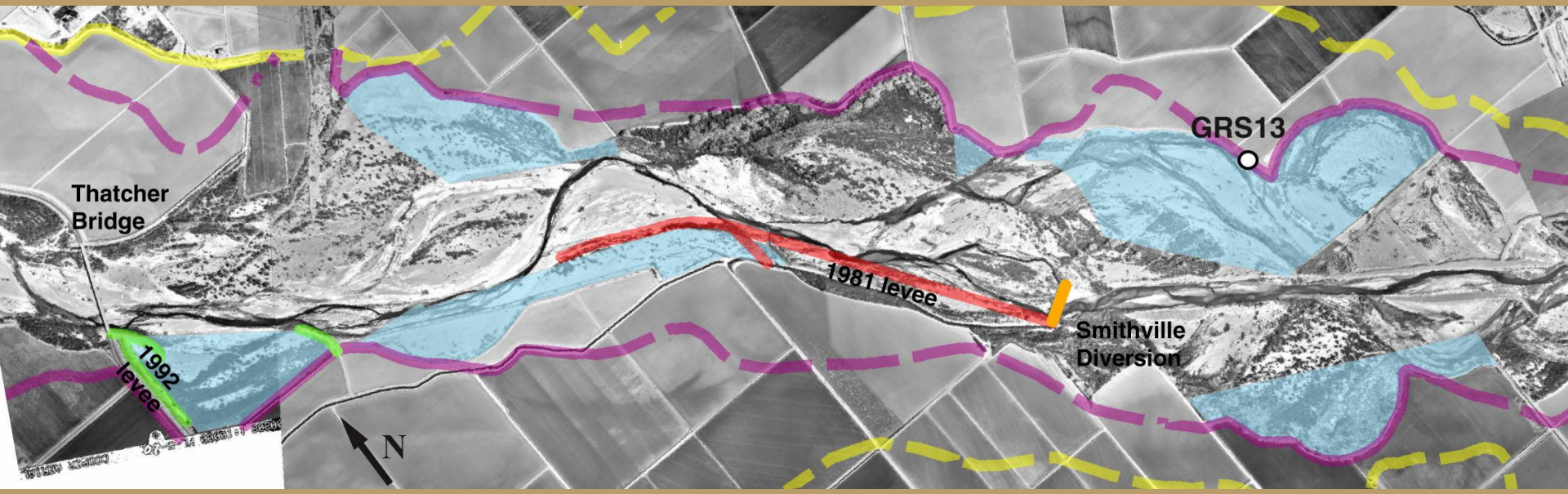
- **Thatcher Bridge to Smithville diversion**
  - **Flow redirection following levee breach in channelized section upstream of Smithville Div.**
  - **Flow redirection by diversion dam and levees**
  - **Erosion of alluvium upstream of bridge**



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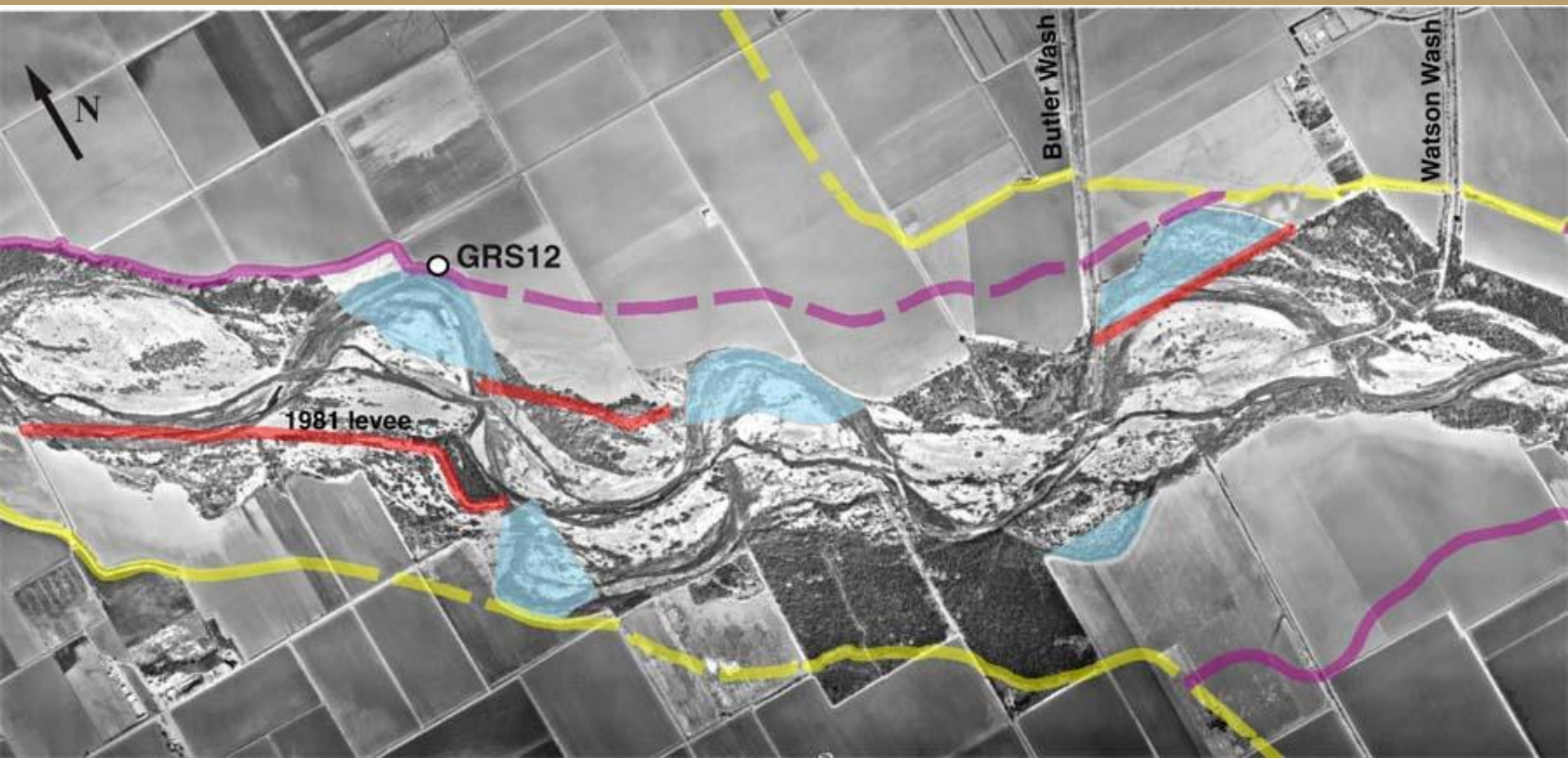
- **Watson and Butler Washes**
  - **propagation of lateral erosion following levee breach up stream of Butler Wash**



- **San Jose Diversion**
  - Channel widening
  - Flow redirection downstream of diversion structure
  - Propagation of lateral erosion

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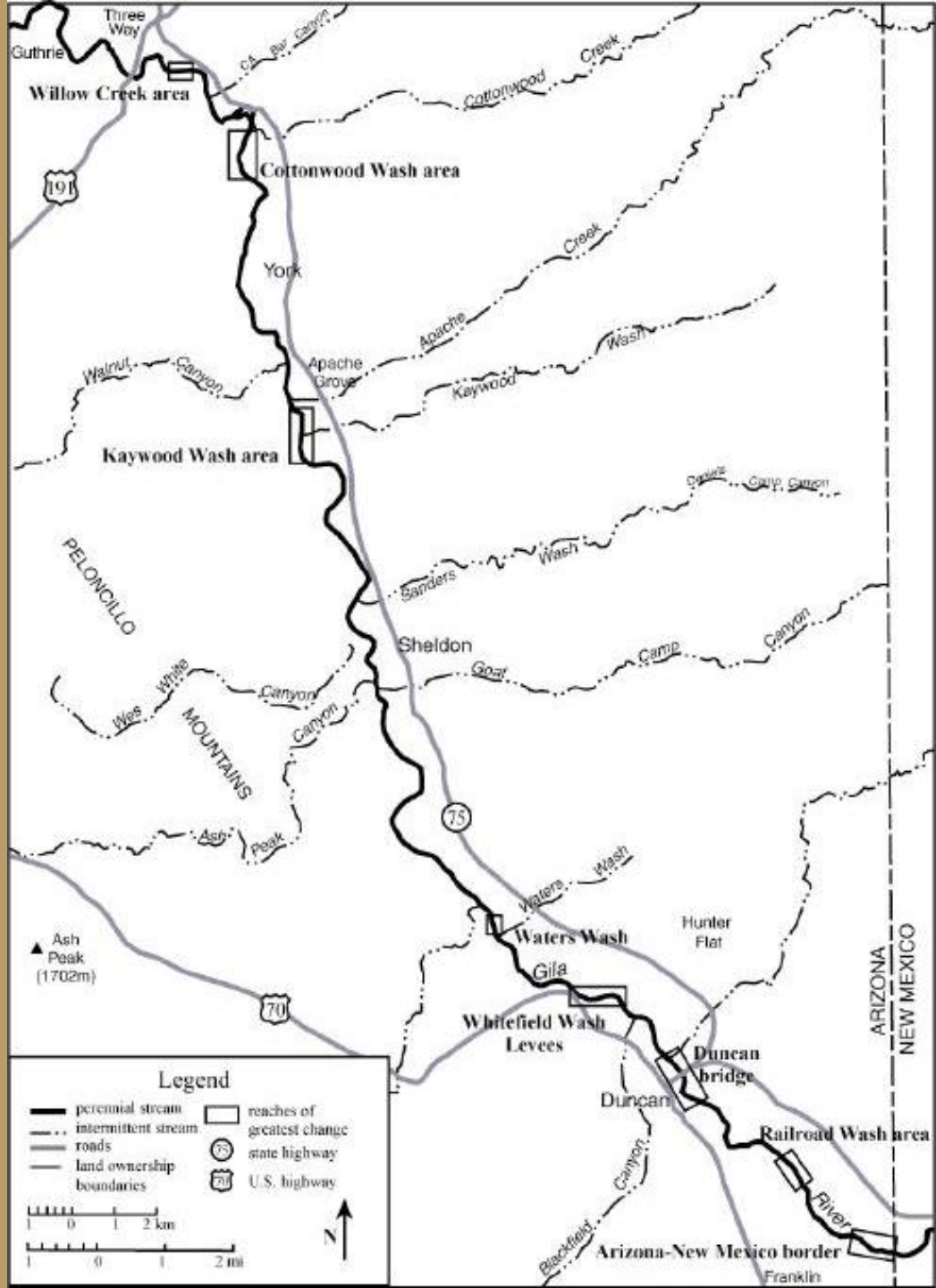
- **Fort Thomas Bridge**
  - **Levee breach**
  - **Isolation of floodwaters by vegetation, prevented water from reentering channel downstream**

Duncan Valley

- Willow Creek
- Cottonwood Wash
- Kaywood Wash
- Waters Wash
- Whitefield Wash
- Duncan Bridge
- Railroad Wash
- AZ-NM border

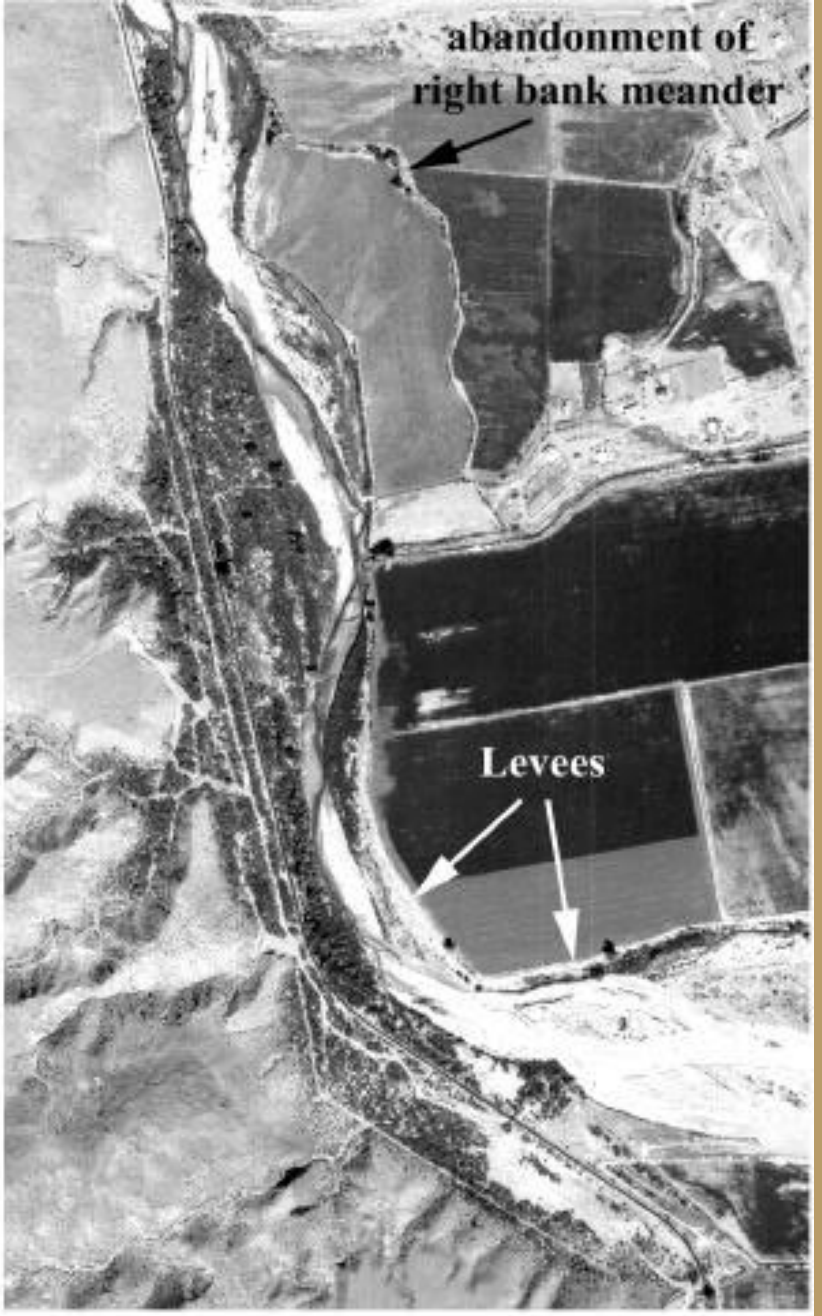


Apache Grove/Kaywood Wash area

(a) 1935

(b) 1958

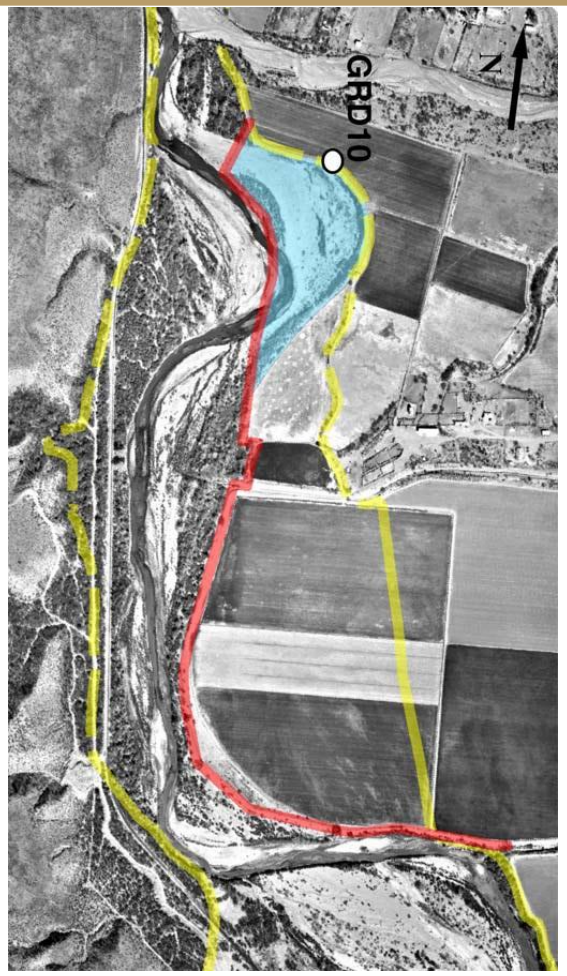
(c) 1967



(d) 1978

(e) 1992

(f) 1997



2000

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Railroad wash area

1935 1967 1992

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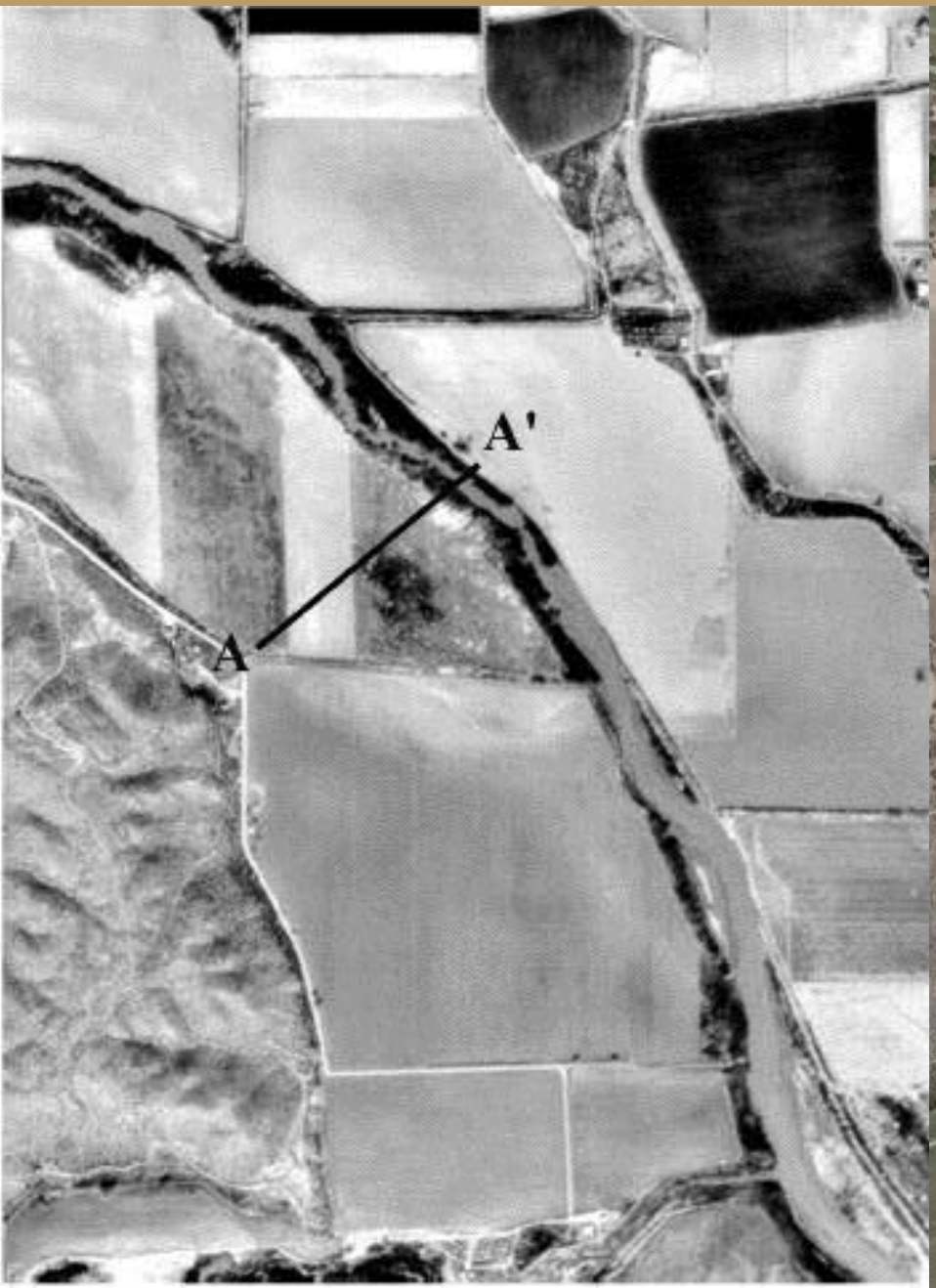
1992

2012



- **Railroad Wash area**
  - Levee breach, flow redirection, creating scalloped features
  - Continued erosion behind levee
  - Erosion followed previous channel paths

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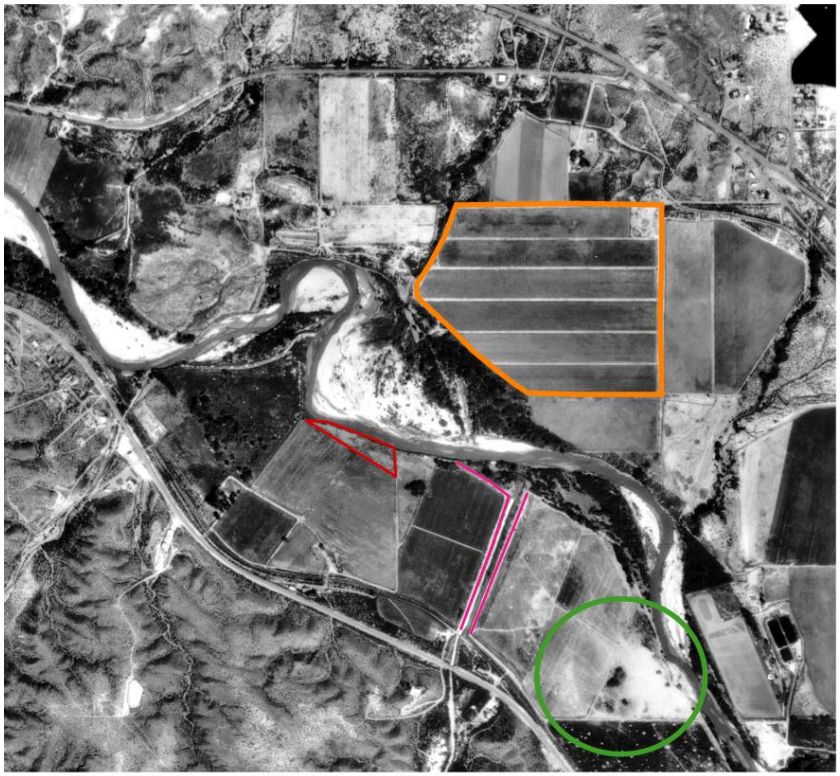
March 14, 1992



October 13,1997

Gila River near Duncan, AZ

Effects of the 1993 and 1995 floods:

Red: erosion of floodplain around outside bends
Green: deposition behind levees
Pink: damage/destruction of flood control structures

- **Influence of alluvial fans**
  - **Restricts channel width, expansion zones u/s and d/s of fan feature**
  - **Control on location of channel**
  - **alternating channel position in areas of multiple tributaries**

Summary and Conclusions

- Channel narrowing during periods of few large floods
- Channel widening during periods of multiple large floods
- Gila River channel width readily adjusts to accommodate the largest floods
- In some cases, human modifications have profound effects on channel geometry
- Geomorphic response to human modifications
  - Lateral erosion associated with levees, dikes and bridges
  - Redirection of flow over diversion dams into opposite banks
  - Propagation of erosion downstream from levee breaches

Previous studies

- **Burkham, D.E., 1972. Channel changes of the Gila River in Safford Valley, Arizona, 1846-1970: U.S. Geological Survey Professional Paper 655-G, 24 pp.**

  Channel widening during periods of large floods and floodplain building during periods of few floods

- **Graf, W.L., 1981. Channel Instability in a Braided, Sand-Bed River: Water Resources Research, v. 17, no. 4, p. 1087-1093.**

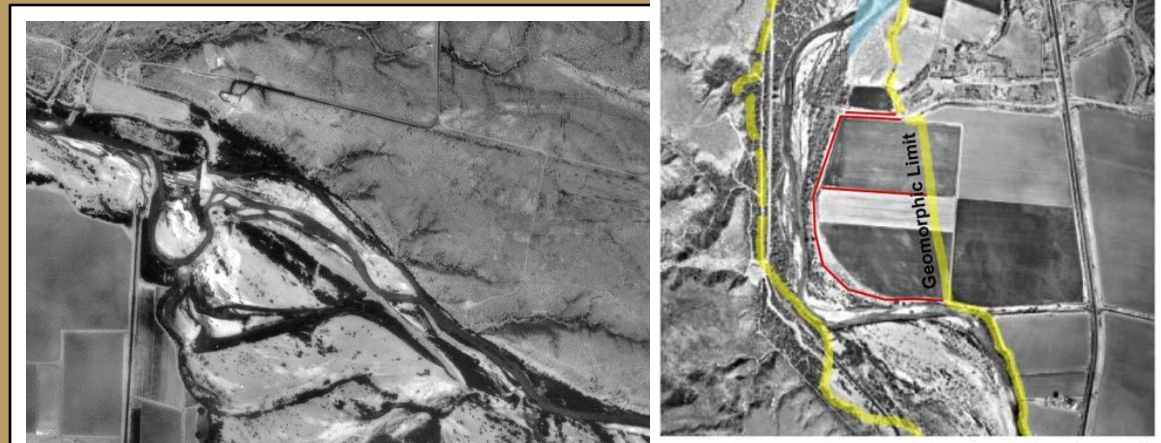
  stable channel zones correspond to places were control is located (i.e., bedrock or man-made structures). Unstable channel zones were located in sections dominated by deep alluvial fill, in areas with heavy human impacts, and in areas of dense phreatophyte growth

- **Hooke, J.M., 1996, River Responses to Decadal-Scale Changes in Discharge Regime: The Gila River, SE Arizona: Geological Society Special Publication No. 115, p. 191-204.**

  the morphological response to high flow events depends on sequences of events and critical combinations of conditions

Recommendations

- **Levees**
  - **Setback to average historical channel width**
  - **Setback to width of Gila alluvium**
  - **Levee/revetment maintenance in areas with critical infrastructure**
- **Diversion dams**
  - **lengthening, reorientation and/or redesign**
  - **Continued maintenance—sediment removal, direct low flow**
- **Bridges**
  - **Lengthen bridge span to width of flood channel**
- **Monitoring plan to document effects of activities**



= approximate location of levees within the Gila alluvium

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Thank you!

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