FLOODFLOW CHARACTERISTICS OF THE SACRAMENTO RIVER IN THE VICINITY OF GIANELLA BRIDGE, HAMILTON CITY, CALIFORNIA

By J. C. Blodgett

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Flood of January 1970. Looking west over the Sacramento River and Gianella Bridge on State Highway 32. Hamilton City in background. (Photograph courtesy of CALTRANS.)

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CONVERSION FACTORS

For readers who prefer metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
ft (feet)	0.3048	m (meters)
ft/s (feet per second)	0.3048	m/s (meters per second)
ft^2 (square feet)	0.0929	m^2 (square meters)
ft^3/s (cubic feet per second)	0.0283	m^3/s (cubic meters per second)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)

National Geodetic Vertical Datum of 1929 (NGVD 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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ABSTRACT

Floodflow, channel, and geomorphic data were assembled to evaluate the characteristics of flooding of the Sacramento River at the Gianella Bridge on State Highway 32, at Hamilton City, Glenn County, Calif. The bridge, constructed in 1908 with a large center pier and drawrest structure, significantly constricts floodflows at the site. The Sacramento River in the vicinity of Hamilton City is a sinuous, gravel-bed stream. Lateral erosion of the banks and chute cutoffs cause the alinement of the river in the vicinity of the bridge site to be unstable. The river-bed elevation varies as a result of alternating scour and fill.

The area of overflow on the flood plain extends about 12 miles upstream and 5 miles downstream from State Highway 32. Soils on the flood plain are sandy-silt loam, easily eroded by streamflow. Overflow to the flood plain is limited by levees along both banks that confine most flows to the main channel at the bridge site. Overbank flow occurs when the discharge exceeds about 90,000 cubic feet per second. During floods exceeding about 130,000 cubic feet per second, overflows bypass the upstream end of the levees. The levees are subject to damage or overtopping, with consequent overflows that inundate the flood plain on both banks and the State Highway 32 approach embankment.

Changes in the location of levees and in agricultural operations have altered the flood plain and the magnitude and distribution of overflow. Variations in river sinuosity, slope, and alinement between 1946 and 1980, indicate that channel changes are significant during short (2- or 3-year) intervals of time. Over long periods, however, the channel appears to be in equilibrium.

Flood frequency relations indicate that the average recurrence interval for overbank flow is about 2 years. For floods with a recurrence interval of 100 years, discharge in the main channel (between levees) is about 175,000 cubic feet per second.

Computed profiles indicate that maximum backwater at the approach section to the bridge is about 0.6 foot for flows exceeding 159,000 cubic feet per second in the main channel. Backwater conditions may extend more than 1.9 miles upstream from the bridge, depending on the magnitude of flooding.

The Gianella Bridge piers and drawrest support structure occupy 10 to 14 percent of the channel for all conditions of flow. An analysis of the distribution of flow across the channel at the bridge indicates that flows are affected by the piers for about 13 percent of the total channel width. The highest velocity of flow, 13 feet per second, occurs in the bridge openings adjacent to the center (main) pier.

Surveys of the streambed between 1956 and 1980 indicate no degradation of the channel bed. Surveys made in 1976 and 1980 show that the elevation of the channel bed is affected by the bridge constriction for a distance of about 500 feet upstream and 500 feet downstream from the crossing.

INTRODUCTION

The California Department of Transportation, Division of Highways (CALTRANS) is planning to construct a new bridge across the Sacramento River at Hamilton City to improve the traffic handling capability and safety of State Highway 32. Proposed improvements include replacement of the existing bridge and construction of a new approach roadway alinement and grade. Under consideration is the retention of the existing bridge as an historical structure. This would require placement of the new bridge so as to minimize hydraulic problems that may be caused by the existing bridge.

In cooperation with CALTRANS, the U.S. Geological Survey made a study in 1979-80 of the hydraulic characteristics of floodflow at Gianella Bridge where State Highway 32 crosses the Sacramento River at Hamilton City (fig. 1).

The purpose of this study was to evaluate the characteristics of flooding at the State Highway 32 approach and bridge across the Sacramento River. Scope of the study included the determination of historical flood levels and discharges in the vicinity of Hamilton City, frequency of flooding, backwater effects related to the bridge, and the velocity and distribution of flow in the main channel. The project also included evaluating such geomorphic features as the levee system, which affects the location and extent of overflow during floods, and the extent of channel changes.

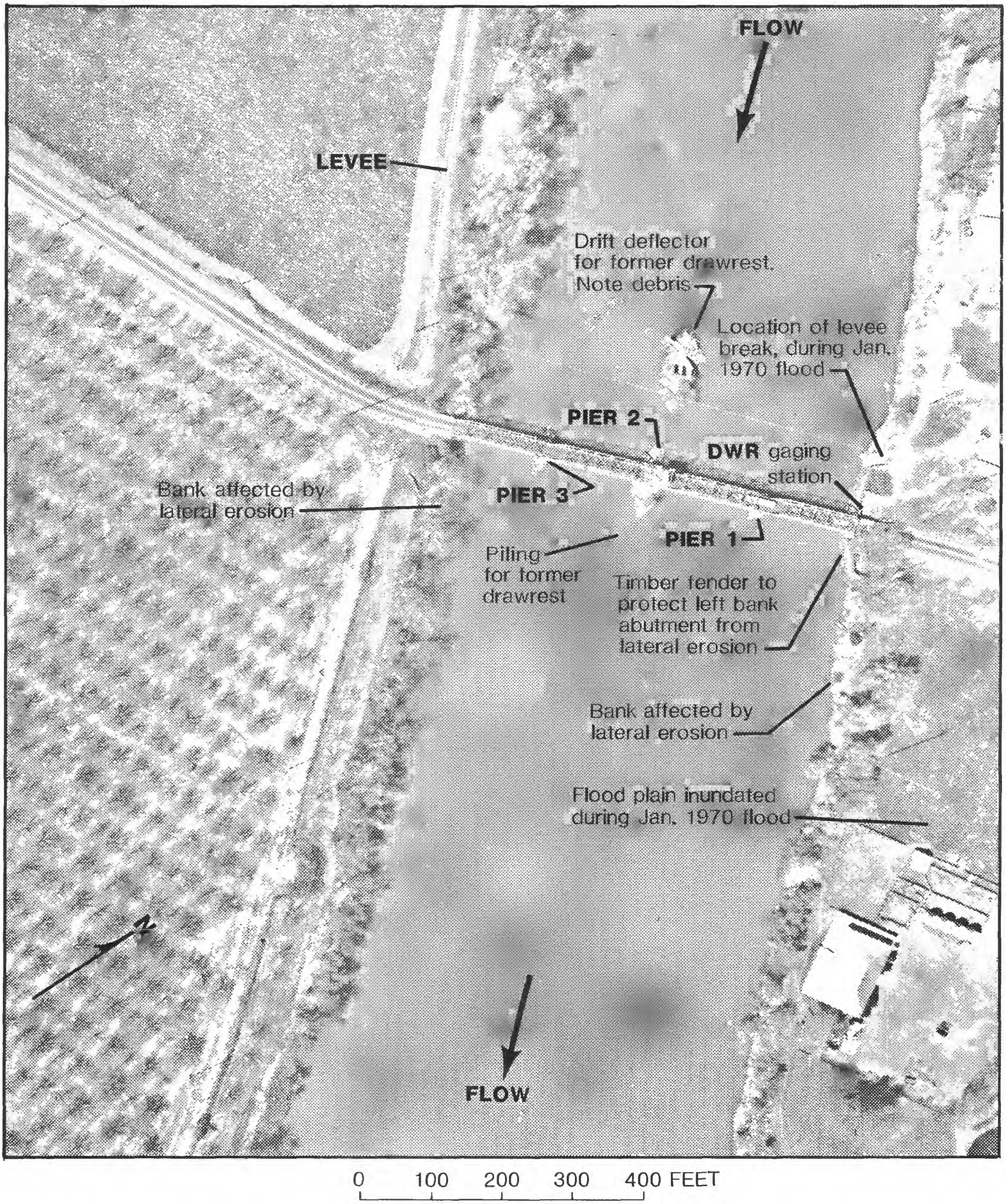

FIGURE 1.--Aerial view of Gianella Bridge on State Highway 32, showing structure and hydraulic features of site, April 2, 1980.

DESCRIPTION OF STUDY AREA

Bridge Site

State Highway 32 crosses the Sacramento River by a steel truss swing span constructed in 1908 and called the Gianella Bridge (fig. 1). The 583-foot-long bridge was built with a cutwater-shaped center pier designed to prevent the lodging of debris (Brice and Blodgett, 1978, p. 75) and to support the swing span mechanism. There appears to have been concern that the cutwater-shaped center pier might not adequately protect the bridge, so a large concrete monolith was constructed at the upstream end of the former drawrest to deflect drift. The upstream monolith, however, does not successfully deflect all drift approaching the bridge, as shown in figure 1.

Flood Plain

According to Olmsted and Davis (1961, p. 22), the reach of channel between Red Bluff and Hamilton City is unusual because on both banks the well-defined flood plain is several feet lower than the nearly level adjoining lands (high-terrace lands), and the channel bed is 10 to 20 ft lower than the flood plain. The 1- to 4-mile-wide flood plain is occupied by many abandoned sinuous channels, sloughs, islands, and sand bars.

Soils of the flood plain on both banks of the river are predominantly of the recent-alluvial group known as the Columbia series (Watson and others, 1929, p. 48, and Begg, 1968, p. 24) and are considered the richest and best agricultural soils in the area. Soils of the Columbia series are described as moderately well-drained sandy or silty loam (d_{50} median diameter of particle size = 0.09 mm) on recent alluvium. Both Watson and Begg refer to the close proximity of these soils to the river, the occasional flooding, and the serious problem of streambank erosion. Clements (1979, p. 8) reports that the Columbia series of soils are highly vulnerable to erosion by flowing water. The soils are readily identified along the riverbank in areas of lateral channel migration because they are predominately fine sand and silt with sufficient cohesion to maintain vertical faces 20 to 30 ft high when eroded by the action of streamflow.

The Sacramento River upstream from Hamilton City is bordered on the right bank (in this report, the left and right banks are referenced looking downstream) by high-terrace lands that are seldom subject to flooding. Downstream at Hamilton City, the left levee of the Glenn-Colusa Canal and other levees near the river normally prevent overflow to the flood plain (low-terrace lands) on the right bank (fig. 2).

On the left bank, the flood plain is composed of numerous overflow channels and sloughs and is historically subject to flooding whenever flows exceed about 90,000 ft^3/s (bankfull discharge) or overtop existing levees. The left bank overflow area is about 3 mi wide and 17 mi long, extending about 12 mi upstream and 5 mi downstream from the State Highway 32 crossing (fig. 2). Approximately 3 mi east of the river, channels of Pine and Rock Creeks, subject to runoff from upstream parts of their basins, also act as overflow channels during periods of high flow in the river.

Overflow to the flood plain on the left bank near the latitude of Hamilton City generally occurs at several locations between river miles 199 and 211 (U.S. Army Corps of Engineers, 1973). This overflow reaches the channels of Pine and Rock Creeks by overland flow and channels such as Harbean and Snaden Sloughs. Most of the overflow reenters the main channel downstream from State Highway 32 at the mouth of Pine Creek. During large floods, such as the peak flow of January 1970, some of the overflow continues farther downstream on the left bank flood plain via Kusal Slough and enters the main channel at the mouth of Mud and Big Chico Creeks (fig. 2). Levees on the left (south) bank of Big Chico Creek prevent further overflow downstream on the flood plain.

Levee and Flood-Plain Alterations

To prevent or limit the amount of overflow during periods of flooding, levees were constructed on both banks of the river. Continued improvements to these levees, such as strengthening and maintenance operations, have increased their capability to confine high flows to the main channel at the Gianella Bridge. The latest levee was constructed on the left bank flood plain in 1976. For example, the flood of January 1969, gage height 144.68 ft (National Geodetic Vertical Datum of 1929), at the California Department of Water Resources (DWR) gaging station (fig. 2), contributed extensive overflow to the left bank flood plain, overtopping State Highway 32 east of the bridge to a depth of 0.8 ft on January 13 and 14, 1969. During the February 1980 flood (gage height 144.41 ft), however, there was some overflow on the left bank flood plain, but flows did not overtop the highway east of the bridge.

Many of the channels and depressions on the left bank flood plain have been altered or obliterated by the clearing and leveling of land for agricultural operations. In the process, impediments to overland flow such as trees and brush have been removed. These changes in the landform will affect the velocity and distribution of flow on the flood plain and the magnitude of flows in the established Pine and Rock Creeks and Kusal Slough channels at the State Highway 32 crossing (fig. 2). Because the flood plain and levees along the river are continually changing, the characteristics of inundation on the flood plain probably will vary during future floods.

COLLECTION OF DATA

Field Surveys

The geometry of the channels and flood plain was determined from surveys conducted between 1955 and 1980. All elevations given in this report are referenced to NGVD unless otherwise identified. The datum of the DWR gaging station, Sacramento River at Hamilton City, is referenced to the datum of the U.S. Army Corps of Engineers. The conversion from U.S. Army Corps of Engineers datum to NGVD is -2.92 ft.

To aid in the hydraulic analysis, channel and flood-plain cross sections and intermediate points were surveyed at various locations in the study area (fig. 2) during 1979 and 1980. Areas of inundation and location of channel changes were determined, using topographic maps (7.5-minute series) and aerial photographs taken between 1946 and 1980.

Instrumentation

A record of the river stage in the main channel is obtained by a water-stage recorder at the DWR gaging station located on the left bank, 50 ft upstream from the Gianella Bridge.

In October 1979, crest-stage gages to record maximum water levels were installed on each bank at cross section 3 (downstream side of the bridge), on the right bank at cross section 6, and on the left bank at cross section 8 (fig. 2). These gages provide a record of peak stages at locations selected to describe the hydraulics of the river channel at the highway crossing.

CHARACTERISTICS OF FLOODFLOW

Channel Morphology

The characteristics of floodflow at the Highway 32 crossing are affected by continuing channel migration and other changes in the Sacramento River in the study area. Some of the elements that describe the morphologic and hydrologic properties of the river are channel pattern, river length, valley length, longitudinal slope, discharge, bed-material size, and channel width and depth.

An analysis of channel form and migration of the river between Chico Landing (near site E-10, fig. 2) and Colusa was made by Brice (1977, p. 28), using data collected between 1896 and 1974. In his study, Brice also classified the channel pattern of various reaches between Collinsville (in the Sacramento River Delta) and Red Bluff. For all reaches upstream from Colusa, the channel pattern is considered relatively unstable in terms of width, with numerous meander loops that are potential sites for channel changes. The channel pattern in the vicinity of the Gianella Bridge is similar to reaches described by Brice, and changes in the morphologic properties of the river near the bridge site are expected in the future.

Lateral Migration and Chute Cutoffs

The Sacramento River channel near the Gianella Bridge is characterized as a gravel-bed stream with an unstable alinement caused by lateral migration, and an unstable bed caused by alternate scour and fill during periods of high water. Rapid lateral migration of the channel averaging 15 ft per year at some locations in the study area has been reported (Brice and Blodgett, 1978, p. 75). Lateral migration of the river affects the location and extent of overflow to the flood plain, that in turn affects the magnitude of flow confined to the channel at the Gianella Bridge. Channel changes also affect the location and amount of overflow, channel slope, and downstream from Gianella Bridge, the location of the mouth of Pine Creek (fig. 2) and backwater effects on Pine Creek.

In his study of lateral migration on the middle Sacramento River, Brice (1977, p. 27) indicated that the channel sinuosity in the reach between Chico Landing and Thomes Creek (river miles 194 to 225) decreased during the period 1964 to 1973. The decrease in sinuosity is reflected by a reduction in the number of meander loops. Associated with changes in the meander pattern of the river, chute cutoff of meander loops near the Gianella Bridge (river mile 199.4) occurred over a period of time at river miles 195.5 to 197 (years 1970-80), river miles 203 to 205 (years 1964-70) (fig. 2), and river miles 212 to 215 (years 1970-73) (not shown in fig. 2).

The chute cutoff between river miles 195.5 to 197 at the junction of Pine Creek (fig. 2) has moved the mouth of the creek 0.5 mi farther downstream. In the vicinity of the Gianella Bridge, the altered and straighter channel alinement has caused new angles of approach at the banks, higher average velocities of flow, and increased bank erosion. The chute cutoff between river miles 203 to 205 is contributing to extensive erosion of both banks near river mile 202 (fig. 2).

Morphologic and Hydraulic Properties

To evaluate the effect of chute cutoffs of meander loops on river hydraulics at the Gianella bridge, changes in the morphologic and hydraulic properties of the river were determined by analyzing aerial photographs of three reaches between Chico Landing and Woodson Bridge (not shown on fig. 2) for the period 1946-80. A description of the three reaches and the changes, measured by the variation in channel centerline length, sinuosity, and slope during the period of study, are given in table 1.

Channel sinuosity was determined as the ratio of a reach length measured along the channel centerline to the reach length measured as a straight line (airline) distance between ends of the reach. Stream slope was computed as the change in water-surface elevation during various floods in a reach divided by the reach length measured along the channel centerline. The valley slope represents the maximum slope of the river for a reach and is based on the airline distance between ends of the reach. The computed values of length and slope used to indicate channel change are considered to be within the limits of error of measurement. To reduce errors in the analysis related to differences in scale of various maps and aerial photographs, identical reference points were used wherever possible.

The data presented in table 1 indicate that changes in centerline length and sinuosity, as a result of chute cutoff and other alinement changes, tend to affect the slope of the river by several percentage points during short intervals of time. For the entire reach (1-3) over longer intervals of time, however, none of the elements show more than negligible changes and the channel appears to be in a state of equilibrium. For example, no net change occurred during the period 1946-80 in channel sinuosity, and the increase in the longitudinal slope was only minor.

The data in table 1 suggest that local channel changes, such as meander chute cutoffs, have significantly affected the hydraulic properties of the river for a period of a few years. Over a longer period of time, however, the channel slope and sinuosity have remained fairly constant. The magnitude of change in channel conditions and the frequency of short-term changes are probably related to floods exceeding bankfull stage, about 90,000 ft^3/s.

Flood Profiles

Longitudinal profiles of several floods for the reach between river miles 194 and 205, shown in figure 3, indicate the gradient of the river. These profiles reflect the height of levees relative to historical flood levels and locations where the channel capacity varies as represented by break-points in the overall trend of the profiles. The channel-bed profile (fig. 3) shows a deep channel upstream from the bridge, and a shallower channel downstream.

TABLE 1. - Morphologic and hydraulic properties of the Sacramento River between Chico Landing (site E-10) and Woodson Bridge

Reach				Centerline length and sinuosity of channel							
				April 11, 1946[2]		March 4, 1972[2]		June 21, 1979 July 25, 1979[2]		April 2, 1980[2]	
Number	Description	River miles[1]	Valley length (feet)	Length (feet)	Sinuosity	Length (feet)	Sinuosity	Length (feet)	Sinuosity	Length (feet)	Sinuosity
1	Chico Landing Gianella Bridge	194 to 199	19,520	24,920	1.28	27,083	1.39	22,056	1.13	23,373	1.20
2	Gianella Bridge Freer/Barchett	199 to 206	24,210	25,181	1.04	25,975	1.07	27,190	1.12	27,715	1.14
3	Freer/Barchett Woodson Bridge	206 to 218	40,660	60,803	1.50	62,412	1.54	53,660	1.32	59,199	1.46
	Total		84,390	110,904	1.31	115,470	1.37	102,906	1.22	110,287	1.31

Reach		Valley slope[3] (ft/1,000 ft)	Water-surface elevation (feet, NGVD), and slope[4] (ft/1000 ft), for selected floods									
			December 15, 1950		December 23, 1964		January 24, 1970		January 17, 1978		February 20, 1980	
Number	Description		Elevation	Slope[5]	Elevation	Slope[5]	Elevation	Slope[6]	Elevation	Slope[7]	Elevation	Slope[8]
1	Chico Landing to Gianella Bridge	0.523	[9]128.5 138.70	0.409	[9]136.9 146.72	0.394	137.3 147.85	0.390	134.2 144.26	0.372	134.1 144.47	0.443
2	Gianella Bridge to Freer/Barchett	.587	138.70 [9]152.9	.564	146.72 [9]161.3	.579	147.85 161.3	.543	144.26 --	--	144.47 158.52	.507
3	Freer/Barchett to Woodson Bridge	.635	[9]152.9 178.7	.424	[9]161.3 188.1	.441	161.3 188.63	.428	-- 184.33	--	158.52 184.37	.437
	Average	0.595		0.453		0.462				0.487		0.456

[1]After U.S. Army Corps of Engineers, 1973.
[2]Date of aerial photography.
[3]Determined from distances derived from USGS 7.5-minute topographic maps, Foster Island, Hamilton City, Ord Ferry, Nord, and Woodson, and elevations of water surface during flood of December 15, 1950.
[4]Date of photography used in defining channel length and slope:
[5]1946
[6]1972
[7]1979
[8]1980
[9]Estimated using data from nearby data-collection sites.

Between cross sections 2 and 6 in the vicinity of the Gianella Bridge (fig. 2), profiles (dated January 16, 1980, and April 2, 1980, respectively) for flows of 72,500 and 10,200 ft^3/s indicate minor changes in slope and small amounts of flow constriction by the bridge piers and abutments. Higher flows, represented by profiles dated January 14, 1980, and February 20, 1980, indicate that the bridge constriction affects water-surface profiles upstream from the bridge by about 0.2 ft. The small amount or lack of backwater at the site is attributed to local scour at the bridge, as illustrated by the channel-bed profile between cross sections 1 and 6 in figure 3. The steep water-surface profile between cross sections 4 and 6 (fig. 3) for the flood of January 24, 1970, represents the combined effects of the bridge constriction and flow through breaks in the left bank levee.

Stage-Discharge Relation

A stage-discharge relation was developed for flows in the main channel exceeding 10,000 ft^3/s at the DWR gaging station located at cross section 4 near the Gianella Bridge (fig. 2). Rating number 1 (fig. 4) was defined by all measurements obtained between 1958 and 1980 with 14 measurements made by the USGS and 16 by DWR. The measurements of discharge range from 10,400 ft^3/s to 186,000 ft^3/s. All of the measurements used in the analysis agree with rating number 1 within 6.2 percent except one measurement made in 1961 that differs by 8 percent. The measurement of the flood of February 20, 1980, indicates that rating number 1 may have shifted to the right (giving a higher discharge) by about 4 percent for flows exceeding bankfull stage. The slope of the February 20, 1980, flood profile (fig. 3) is steeper than profiles of earlier floods. The increase in slope indicates improved flow conditions downstream from the bridge, possibly caused by the chute cutoff of the meander loop (fig. 2) downstream near river mile 197. A comparison of the January 1970 and February 1980 slopes could not be made because overflow to the left bank flood plain occurred at several locations during the 1970 flood.

The shape of the stage-discharge relation above an elevation of 146 ft reflects the influence of overbank flow, especially on the left bank downstream from the Gianella Bridge. The effect of the bridge constriction on water-surface profiles is discussed under the section "Magnitude of Flow."

Frequency and Duration

Annual flood peaks for flows in the main channel of the Sacramento River at Hamilton City have been compiled (table 2) for the period of record through the 1980 water year. Flood frequency and duration of flow relations were prepared using flood data recorded after regulation of flows began at Shasta Dam in 1943. The analysis was based on regulated flow conditions, and it was assumed that future patterns of regulation on the Sacramento River and the proportion of total flow confined to the main channel would be similar.

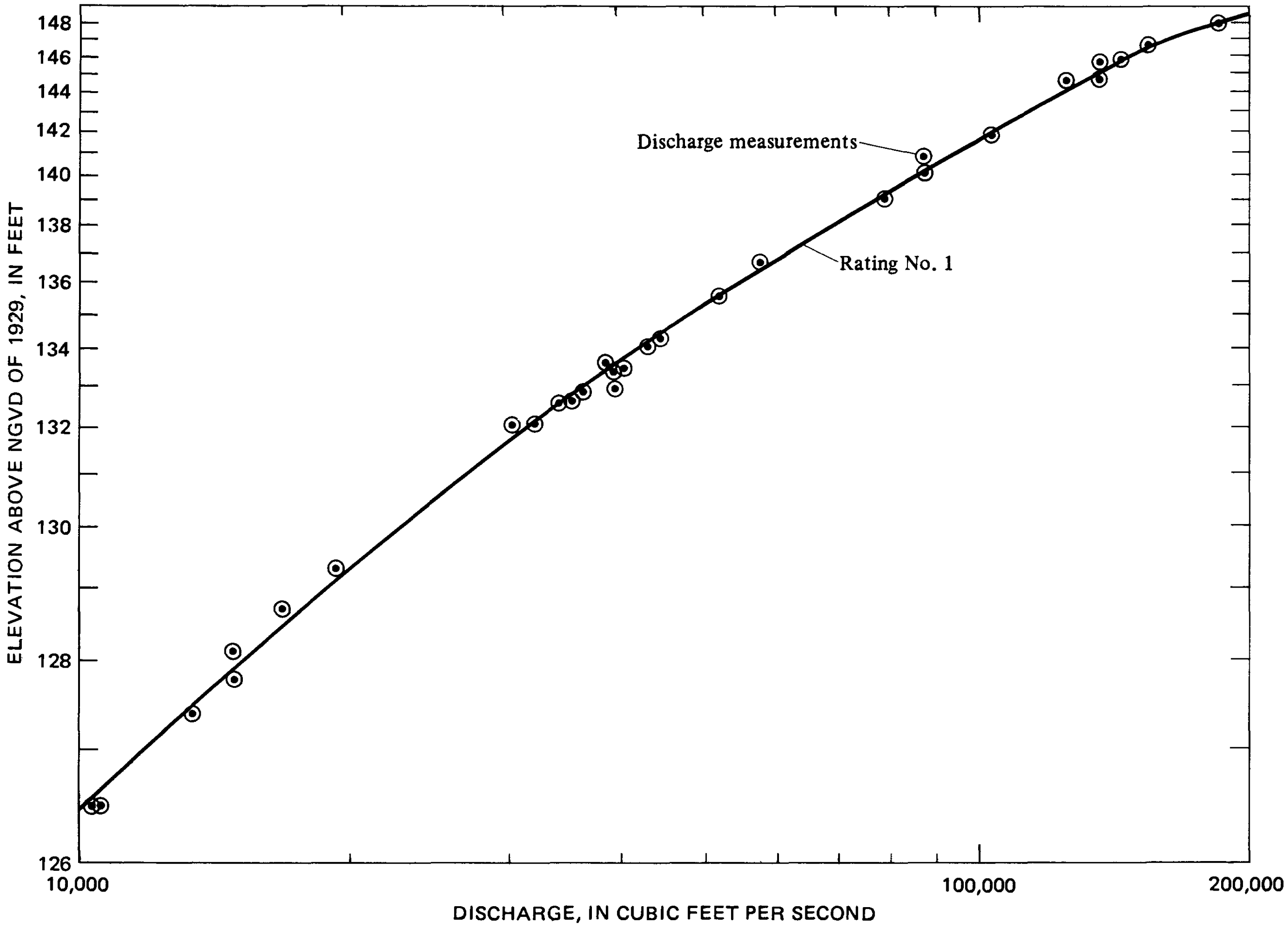

FIGURE 4.--Relation of water-surface elevation and discharge in the main channel at cross section 4, Sacramento River at Hamilton City.

TABLE 2. - Annual peak flow elevation and discharge, Sacramento River at Hamilton City

[Entries for 1975 and earlier are derived from reports by California Department of Public Works (1913-62) and California Department of Water Resources (1963-75). USED, U.S. Engineer Department, now U.S. Army Corps of Engineers; ND, data not determined or not available]

Water year	Date	Time	Peak stage[1] (ft) USED or local gage datum	Peak stage[1] (ft) NGVD	Peak discharge[2] (ft^3/s) Instantaneous	Peak discharge[2] (ft^3/s) Revised instantaneous[3]	Remarks
1915	2-03-15	0700	149.7	146.8	--	--	Daily gage reading.
1917	2-26-17	1700	147.8	144.9	--	--	Do.
1918	3-20-18	0700	139.7	136.8	--	--	Do.
1921	1-30-21	2400	149.7	146.8	--	--	--
1928	3-27-28	2200	149.1	146.2	--	--	Crest stage.
1929	2-04-29	0700	140.5	137.6	--	--	Daily gage reading.
1930	12-16-29	0700	143.6	140.7	--	--	Do.
1931	1-24-31	0700	137.6	134.7	--	--	Daily gage reading; staff reading.
1932	12-27-31	1200	145.0	142.1	--	--	Daily gage reading.
1933	3-29-33	0700	139.3	136.4	--	--	Do.
1936	2-22-36	2200	148.3	145.4	--	--	--
1937	3-13-37	0700	144.9	142.0	--	--	Daily gage reading.
1938	12-11-37	1700	150.7	147.8	--	--	--
1939	3-14-39	0900	138.7	135.8	--	--	--
1940	2-28-40	1600	150.5	147.6	350,000	--	Estimated.
1941	2-11-41	1100	148.55	145.63	203,000	--	Peak discharge occurred at gage height 148.4 ft.
			Floodflows affected by operation of Shasta Dam				
1944	2-04-44	0700	136.1	133.2	--	--	Daily gage reading; staff reading.
1945	2-01-45	1130	139.9	137.0	58,000	--	--
1946	12-28-45	1300	143.60	140.68	95,000	--	--
1947	2-12-47	2100	138.38	135.46	47,900	--	--
1948	3-24-48	0900	141.58	138.66	70,100	--	--
1949	3-12-49	0330	142.97	140.05	90,000	--	--
1950	2-05-50	0230	140.14	137.22	65,000	--	--
1951	12-15-50	0500	141.62	138.70	68,000	--	--

1952	12-28-51	1430	146.39	143.47	143,000	--	--
1953	1-18-53	1130	143.73	140.81	85,000	--	Daily mean discharge.
1954	2-18-54	0900	142.28	139.36	77,200	--	--
1955	11-15-54	1900	135.96	133.04	38,000	--	--
1956	12-23-55	0600	146.29	143.39	109,000	--	Station destroyed January 1956; station rebuilt June 19, 1956, datum 100.00 USED.
1957	2-25-57	1525	141.0	138.08	68,200	--	--
1958	2-25-58	0800	149.18	146.26	150,000	--	--
1959	2-17-59	ND	141.8	138.9	ND	77,000	Daily mean gage height estimated.
1960	2-09-60	0130	143.33	140.41	91,900	--	--
1961	12-02-60	0700	143.30	140.38	92,900	--	--
1962	2-15-62	1320	142.64	139.72	86,500	--	--
1963	4-15-63	0350	143.85	140.93	93,900	--	Stage 143.86 ft USED on 2-1-63. Peak discharge estimated.
1964	1-21-64	1300	139.28	136.36	61,600	57,800	Peak discharge estimated.
1965	12-23-64	1220	149.64	146.72	151,000	160,000	Do.
1966	1-05-66	0000	140.54	137.62	70,600	67,100	Do.
1967	2-01-67	0230	144.61	141.69	102,000	--	--
1968	2-25-68	1600	140.56	137.64	67,000	--	--
1969	1-13-69	2130	147.60	144.68	126,000	134,000	--
1970	1-24-70	0730	150.77	147.85	156,000	186,000	--
1971	1-17-71	1300	145.05	142.13	103,000	--	--
1972	2-29-72	1545	134.96	132.04	32,700	--	--
1973	1-18-73	2315	144.47	141.55	97,500	--	--
1974	1-17-74	1415	149.65	146.73	158,000	--	--
1975	2-13-75	2345	144.99	142.07	103,000	--	--
1976	3-01-76	0930	134.56	131.64	29,400	--	--
1977	1-03-77	0730	130.82	127.90	14,400	--	--
1978	1-17-78	ND	147.18	144.26	123,000	--	--
1979	2-14-79	ND	139.51	136.59	59,400	--	--
1980	2-02-80	ND	147.33	144.41	131,000	--	--

[1]A datum adjustment of -2.92 ft was used when converting stages from USED to NGVD.

[2]During extreme floods, some flow bypasses gage on the east bank flood plain. Peak discharges for 1940, 1941, and 1942 apparently represent total discharge at latitude of Hamilton City.

[3]Discharge based on rating curve number 1 in report.

Levees constructed along the main channel on both banks have tended to reduce the occurrence of overbank flow. The increase in main channel flow as a result of reduced opportunity for overbank flow will affect the magnitude and frequency of floods in the main channel at the bridge site in the future. Several of the annual peaks for the period 1957-78 were revised, using stage-discharge relation number 1 (fig. 4). Only peaks that differed from published values by more than 5 percent were revised.

The probability of exceedance for annual peaks of selected magnitudes can be determined by using the flood-frequency relations in figure 5. The duration, in days, of flows above 92,000 ft^3/s during any one year for various probabilities may also be determined by using figure 5. These relations indicate that discharge in the main channel during a flood of 50-year recurrence interval would be about 168,000 ft^3/s, and would exceed 92,000 ft^3/s (approximate bankfull discharge) an average of about 13 days.

Overflow on Flood Plain

The most recent inundation of State Highway 32 east of the Gianella Bridge, caused by overflow from the river (and high flows on Pine and Rock Creeks), occurred during the flood of January 1978 when the river stage was 144.26 ft (NGVD). Overflow to the left bank flood plain generally occurs in the reach between river miles 202 and 211 (fig. 2). The amount of overflow depends on the magnitude and duration of flooding, condition of the levees along the river, and location of the river alinement with respect to depressions and sloughs on the flood plain. Overflow of State Highway 32 on the left bank flood plain is caused by overflow from the Sacramento River, and flooding of Pine and Rock Creeks has been observed by CALTRANS (from maintenance reports) at least 10 times during the period 1956-80. On these occasions, flows in the main channel exceeded 107,000 ft^3/s. During the February 1980 flood, levees constructed along the left bank of the main channel restricted overflow, and flows on Pine Creek, combined with overbank flow, were not large enough to cause flooding of the highway.

Sloughs on the left bank flood plain serve as supplemental waterways away from the main channel. During the flood of January 1970, levees failed at about four locations in the study area (fig. 2) and were overtopped at numerous other locations. Inundation of the right bank flood plain during the flood of January 1970 was caused by a levee failure near Hamilton City, with water backing upstream and across State Highway 32 through low areas on the flood plain. Figure 6 shows the approximate boundary of the area inundated on both banks during the flood of April 2, 1974. This flood was chosen to illustrate areas of inundation because depressions and channels on the flood plain can be seen most clearly during floods that do not cause complete inundation.

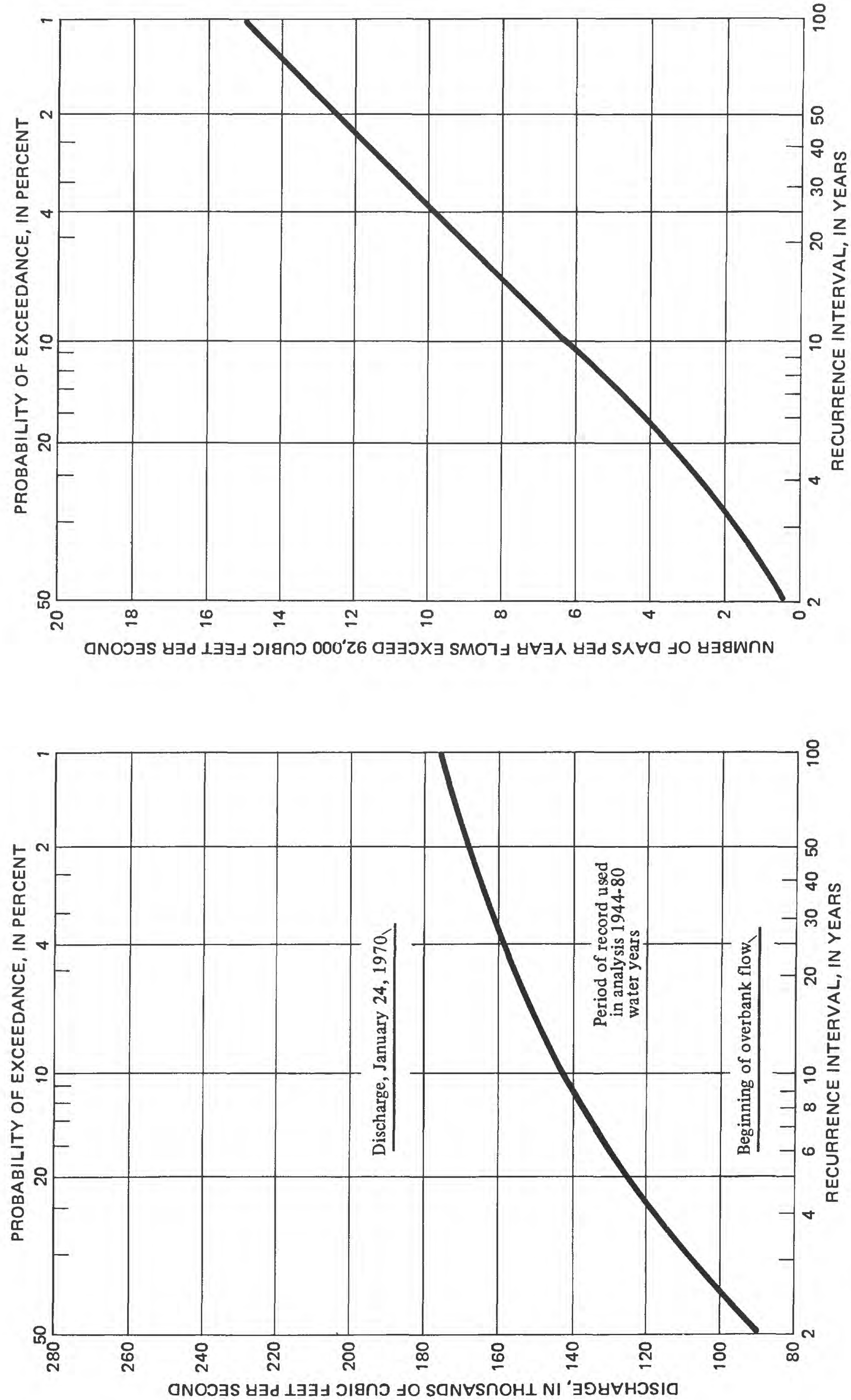

FIGURE 5.--Frequency relations of annual maximum discharge and duration of flow in the main channel for Sacramento River at Hamilton City.


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FIGURE 6.--Areas of inundation (I) during flood of April 2, 1974.

HYDRAULIC CHARACTERISTICS OF PRESENT BRIDGE

Computation of Water-Surface Profiles and Backwater

The constriction of a stream channel at a bridge creates a change in water-surface elevation between the approach section (cross section 6, fig. 2) and the downstream side of the bridge (cross section 3). Backwater is defined as the increase in water-surface elevation above the stage that would occur for river conditions unconfined by the bridge opening. The equation for determining water-surface elevations in the vicinity of a bridge constriction is based on the continuity and energy equations between the approach section and the constricted section. Details of procedures for computing the hydraulics of bridge constrictions are discussed by Matthai (1967) and Bradley (1970).

TABLE 3. - Elevation of water surface at

[See figure 2 for locations of site E-10 and cross

Flood frequency (year)	Discharge (ft^3/s)	Channel condition	Cross section, followed by distance				
			I.P. 24,880	M.S. 25,452	0.2 26,244	2 26,365	3 26,415
			Elevation of water				
2	88,400	W/bridge	139.5	139.9	140.2	140.2	140.2
		No bridge	139.5	139.9	140.2	--	--
5	125,000	W/bridge	143.2	143.6	143.9	144.0	144.0
		No bridge	143.2	143.6	143.9	--	--
10	142,000	W/bridge	144.4	144.8	145.1	145.2	145.2
		No bridge	144.4	144.8	145.1	--	--
25	159,000	W/bridge	145.9	146.3	146.6	146.7	146.7
		No bridge	145.9	146.3	146.6	--	--
50	168,000	W/bridge	146.4	146.8	147.1	147.2	147.2
		No bridge	146.4	146.8	147.1	--	--
100	[1]175,000	W/bridge	146.9	147.2	147.6	147.7	147.7
		No bridge	146.9	147.2	147.6	--	--

[1]Water-surface elevations for the reach between cross sections bank flood plain in this reach probably would reduce the discharge

The analysis for backwater conditions upstream from the Gianella Bridge consisted of computing the water-surface profile for the reach between cross sections IP (initial point) and 9 (figs. 2 and 3). Water-surface profiles were computed for the bridge in position (as-is) and for conditions in which the bridge, piers, and abutments are removed. A comparison of the two profiles for six different flows is given in table 3. The maximum amount of backwater determined at the approach section (cross section 6) was 0.6 ft for discharges exceeding 159,000 ft^3/s, a size similar to the flood of January 17, 1974 (25-year recurrence interval). Backwater conditions for this magnitude of flow extend upstream past cross section 9 before converging with the profile determined for unconstricted flow conditions.

The computed profiles given in table 3 are based on channel and levee conditions as surveyed in 1979 and 1980. At locations where levees would be overtopped by the selected discharge, such as the flood of January 1970, levees were artificially extended to contain all flow.

cross sections I. P. to 9 for selected discharges

sections. I.P., initial point. M.S., measuring section]

(feet) to cross section from data collection site E-10								Backwater at cross section 6 (feet)
4	5	6	6.2	6.3	7	8	9	
26,522	26,649	27,237	28,185	29,045	30,062	34,227	36,437	
surface, in feet (NGVD) at cross section								
140.3	140.6	140.7	141.1	141.5	141.8	143.6	144.5	0.2
--	--	140.5	140.9	141.2	141.7	143.4	144.4	
144.0	144.4	144.7	145.2	145.6	146.0	147.9	148.8	.4
--	--	144.3	144.8	145.3	145.7	147.7	148.6	
145.3	145.8	146.0	146.5	147.0	147.4	149.5	150.5	.4
--	--	145.6	146.0	146.6	147.0	149.2	150.2	
146.7	147.4	147.6	148.1	148.6	149.0	151.2	152.2	.6
--	--	147.0	147.6	148.1	148.5	150.8	151.8	
147.2	147.9	148.2	148.7	149.2	149.6	151.9	152.9	.6
--	--	147.6	148.2	148.7	149.2	151.5	152.6	
147.7	148.5	148.7	149.2	149.7	150.2	152.4	153.4	.6
--	--	148.1	148.7	149.2	149.7	152.1	153.2	

I.P. and 4 are based on the discharge of 175,000 ft^3/s. Overflow to left
to about 173,000 ft^3/s (see view of overflow in frontispiece).

Factors Affecting Profiles

The amount of backwater caused by the bridge constriction is affected by such factors as the bridge geometry; magnitude of flow; alinement, shape, and slope of channel; bed fill and scour; lateral erosion of the banks; and presence of levees that confine the flow. The location and dimensions of the individual bridge openings relative to the centroid of flow are primary factors that govern the magnitude of discharge that can pass through an individual opening. If the opening is too small, a large change in water-surface elevation will result between the approach section (cross section 6, fig. 2) and the downstream side of the bridge (cross section 3).

Bridge Geometry

The Gianella Bridge, constructed with large piers and drawrest structure placed in midstream, occupies 10 to 14 percent of the channel for all conditions of flow (table 4). The reference elevation used in table 4 varies according to the slope in water surface for the reach surveyed on January 14, 1980, when flows were approximately at bankfull stage.

TABLE 4. - Proportion of channel occupied by the Gianella Bridge structure

Cross section	Date of survey	Reference elevation (feet, NGVD)[1]	Discharge at time of survey (ft^3/s)	Area of channel below reference elevation: Gross opening (ft^2)	Net opening (ft^2)	Reduction in flow area (percent)
Measuring section	4- 2-80	141.2	10,200	13,363	13,363	0
3	1-23-70	141.7	125,000	14,307	12,295	14.1
	1-17-74		154,800	14,589	12,688	13.0
3	8-15-79		([2])	13,452	11,982	10.9
3	10-25-79		5,810	13,606	11,952	12.2
3	1-18-80		59,600	13,864	12,245	11.7
3	4- 2-80	141.7	10,200	14,006	12,199	12.9
5	10-25-79	141.9	5,810	14,065	12,674	9.9
6	10-25-79	142.2	5,810	12,947	12,947	0

[1]Reference elevations based on water-surface profile surveyed January 14, 1980.
[2]Not determined.

Magnitude of Flow

Profiles for the several floods presented in figure 3 show that between cross sections 3 and 6 the fall in water surface varies between 0.1 and 1.1 ft, depending on the magnitude of flow. When flows exceed bankfull stage (about 140.5 ft [NGVD] or 90,000 ft^3/s at cross section 4), the slope of the water surface between cross sections 3 and 6 increases more rapidly than slopes in nearby reaches of the channel. This increase in slope is attributed to the constriction of flow through the bridge openings and by the levees on both banks.

In the reach between cross sections IP and 1 downstream from the bridge (fig. 3), the stream is not as confined and the fall or slope in water surface, which is less than that for the upstream reach, approximates the average channel slope. An expansion of the channel between cross sections MS (measuring section) and 3 is indicated by the local increase in water-surface elevation along the left bank downstream from the bridge (fig. 7). Associated with the increase in water-surface elevation is the occurrence of reverse (eddy) flow along the left bank between cross sections MS and 3 that causes lateral erosion of the bank. Near cross section 1, the left bank has eroded laterally about 10 ft between 1965 and 1980.

The amount of backwater caused by the bridge constriction during the February 20, 1980, flood was compared with a computed profile based on channel conditions assuming no bridge in place (fig. 7). Backwater during this flood was 0.3 ft at cross section 6, and 0.4 ft at cross section 5. The computed profile also indicates that, because the gage is in the drawdown area, the measured water-surface elevation at the DWR gage at cross section 4 is nearly equal to the elevation that would occur if the bridge were not present.

The measured and computed profiles in figure 7 indicate that the stage-discharge relation for the gaging station reflects channel control conditions unaffected by the bridge constriction because the two profiles intersect at cross section 4. During low-flow conditions, the bridge does not constrict the flows, and profiles computed assuming no bridge in place closely approximate the actual water-surface profile. Relocation of the gage from its present site would change the shape of the stage-discharge relation shown in figure 4.

Channel Alinement and Shape

The alinement of the stream near the Gianella Bridge tends to place the centroid of flow toward the left part of the channel (fig. 8). Surveys of the river channel between 1955 and 1980 at the bridge indicate that the flow alinement during this period has consistently been directed toward the left side of the channel.

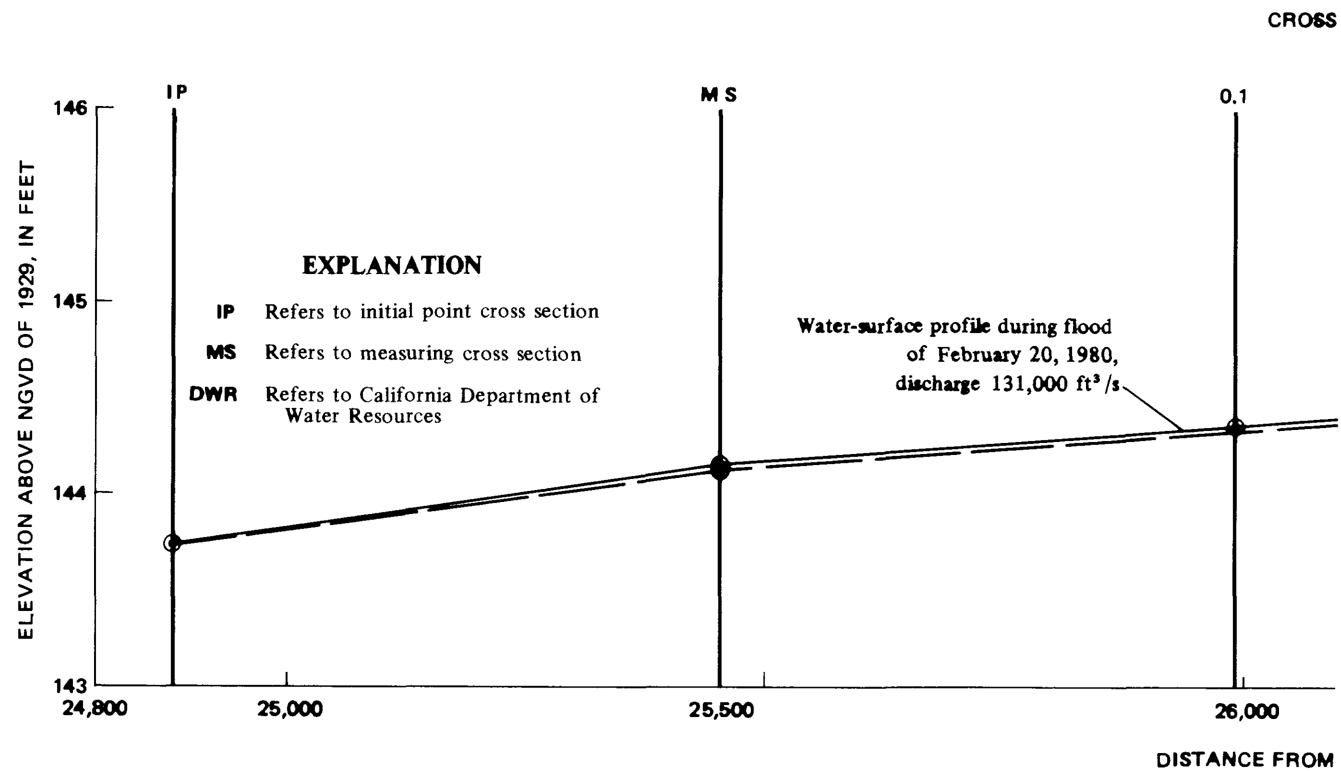
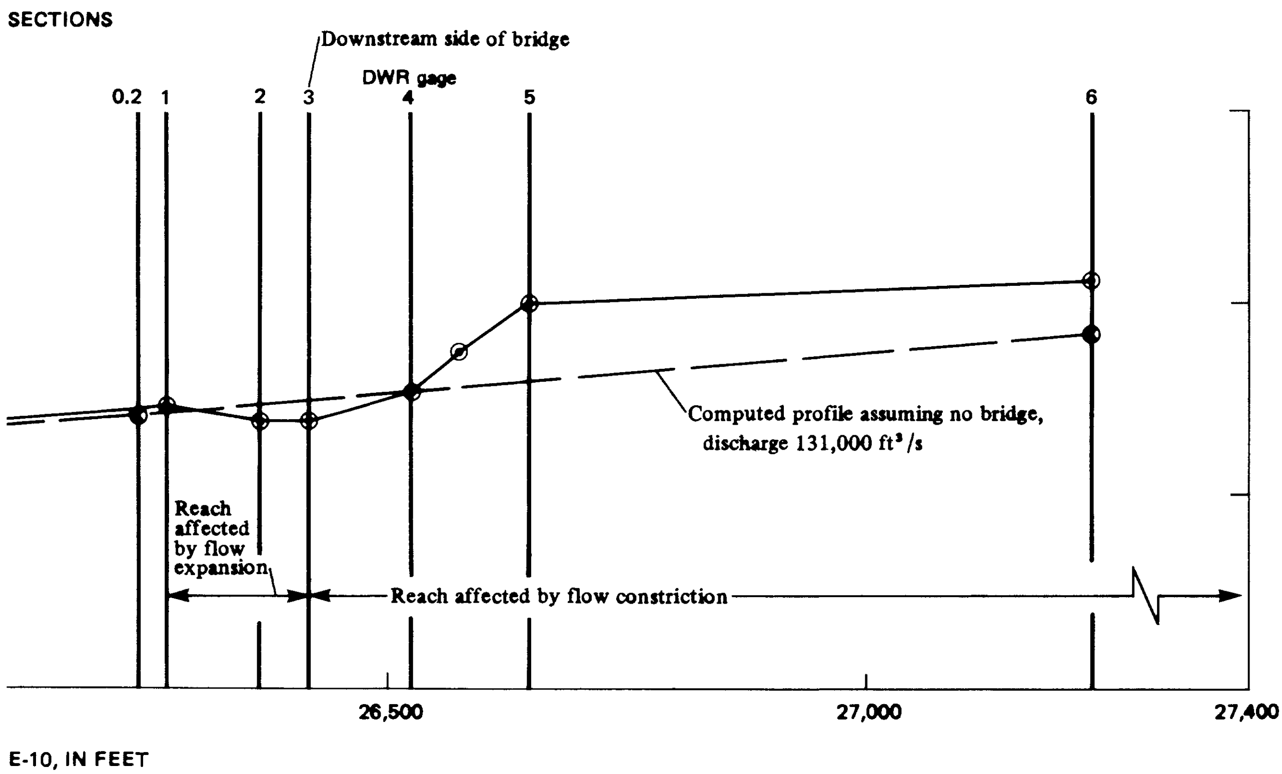


FIGURE 7.--Water-surface profile showing effects of flow constriction and

Water-surface profiles in the reach between cross sections 9 and IP are affected by the bridge and channel constrictions. Between these cross sections, flows are constricted as the channel size decreases in a downstream direction (fig. 8). Between cross sections 3 and 7, the channel is relatively deep and narrow with all flows laterally confined by levees on both



expansion at Gianella Bridge during flood of February 20, 1980.

banks and by the bridge opening. Between cross sections 3 and MS, flows are not confined by levees on the left bank, but are vertically constricted by an increase in elevation of the channel bed. Downstream from cross section MS, the channel is larger, overflow occurs on both banks, and the water-surface slope decreases (fig. 3).

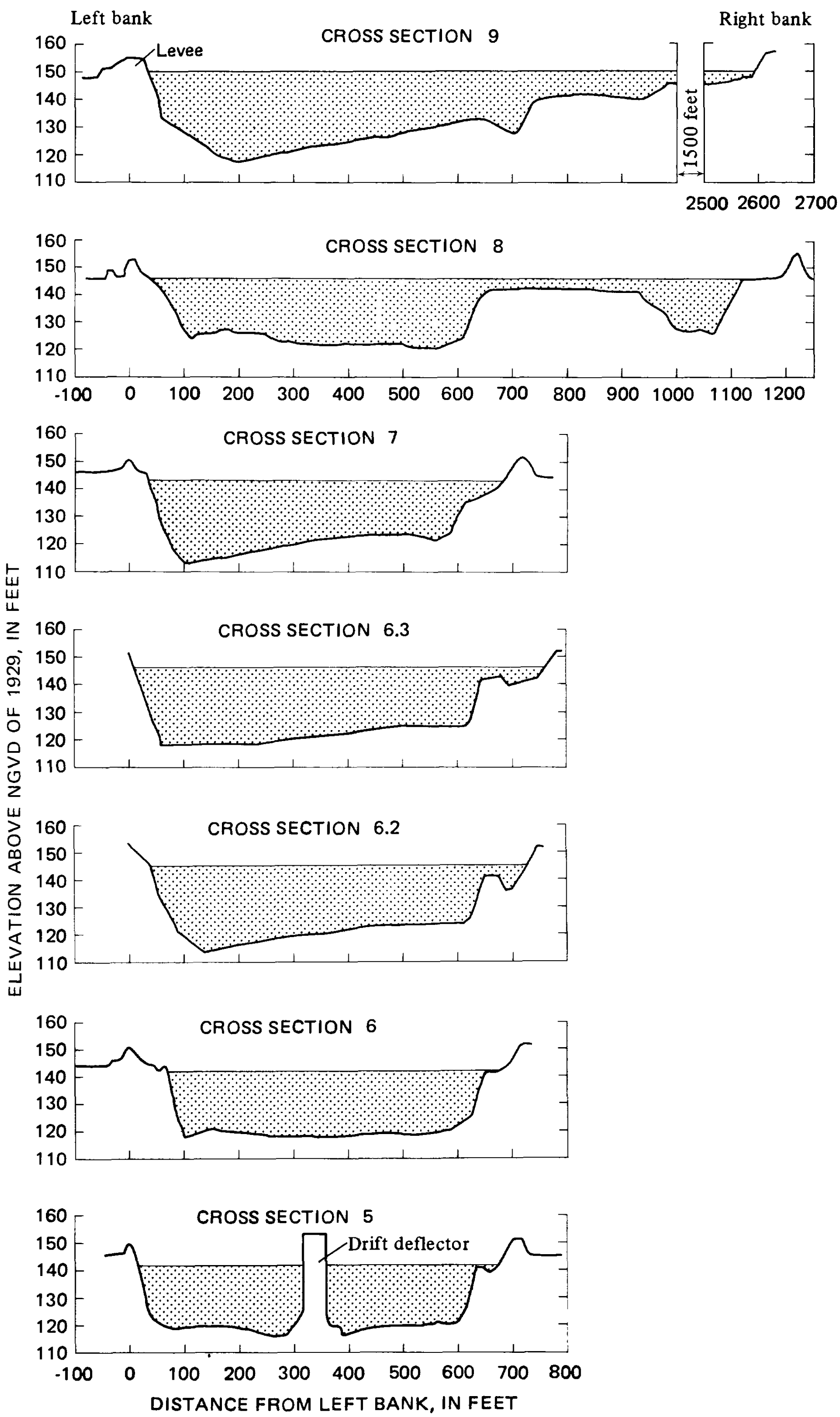
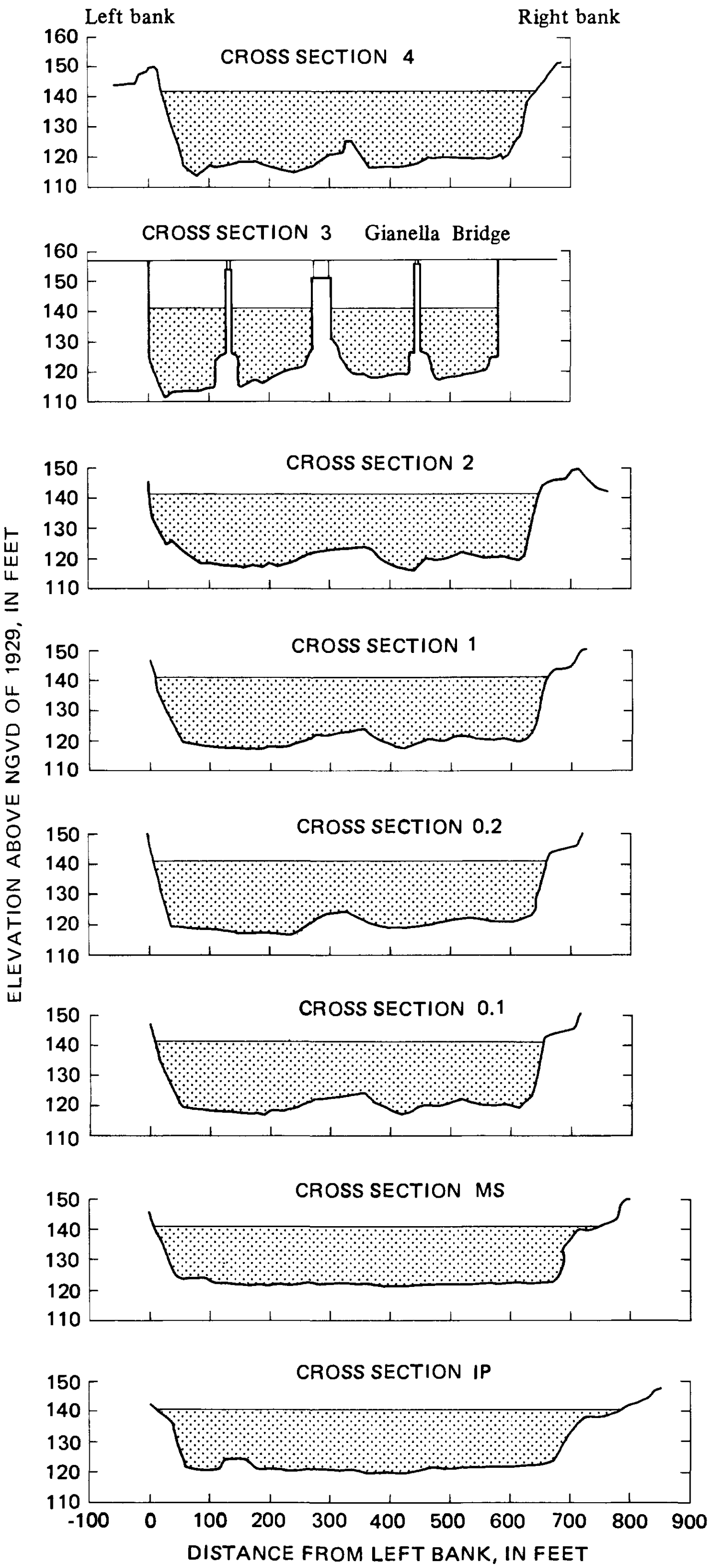


FIGURE 8.--Sacramento River in the vicinity of Gianella Bridge.



Notes:

Water-surface elevations surveyed February 20, 1980

Cross sections 1-9 surveyed by USGS in October 1979

Cross sections 0.1, 0.2, 6.2, and 6.3 surveyed by CALTRANS in August 1979

Cross sections IP and MS surveyed by USGS in April 1980

Cross section 8 is upstream and cross section IP is downstream from Gianella Bridge

IP Initial point

MS Measuring section

FIGURE 8.--Continued.

Channel-Bed Scour

Cross-section surveys of the channel at the downstream side of the bridge (cross section 3) were obtained during discharge measurements made between 1956 and 1980. Changes in channel-bed elevation and shape of the cross section are shown in figure 9. During this period, the lowest elevation of the channel bed was always located near the left bank. To determine whether the channel-bed elevation is degrading, the mean bed elevation was computed by the equation:

$$D=A/T,$$

where D is the mean depth in feet, A is the area of cross section 3, and T is the water-surface width in feet.

The mean bed elevations for various surveys of cross section 3 (table 5) show a variation in elevation that is attributed to scour during floods, but do not indicate degradation of the channel bed. Mean bed elevations in 1956 and 1980 differ by 0.4 ft, and vary from the long-term mean by 0.2 ft.

The greatest depth of scour observed is about 11 ft at cross section 3 based on channel depths surveyed during the measurement of January 17, 1974 (table 5, discharge 155,000 ft^3/s), and an assumed normal (unscoured) bed elevation of 119 ft. Greater depths of scour may occur during periods of high flow. For the measurements included in table 5, maximum depths are about 10 percent greater than mean depths.

TABLE 5. - Channel-bed elevations at cross section 3 (downstream side of Gianella Bridge) between 1956 and 1980

Date of measurement	Stage (feet, NGVD)	Width (feet)	Area (ft^2)	Mean depth (feet)	Mean bed elevation (feet)	Minimum bed elevation (feet)
1-06-56	137.41	575	10,300	17.9	119.5	114.0
1-26-56	141.02	575	12,069	21.0	120.0	113.7
2-03-58	139.20	570	10,862	19.1	120.1	113.8
2-10-58	140.18	570	11,578	20.3	119.9	114.1
2-25-58	145.75	575	14,367	25.0	120.8	112.2
1-23-70	142.55	574	14,302	24.9	117.6	111.7
1-28-70	145.53	574	14,329	25.0	120.5	112.6
1-17-74	146.66	574	15,920	27.7	119.0	108.3
1-18-80	136.73	578	9,735	16.8	119.9	112.0
Mean					119.7	

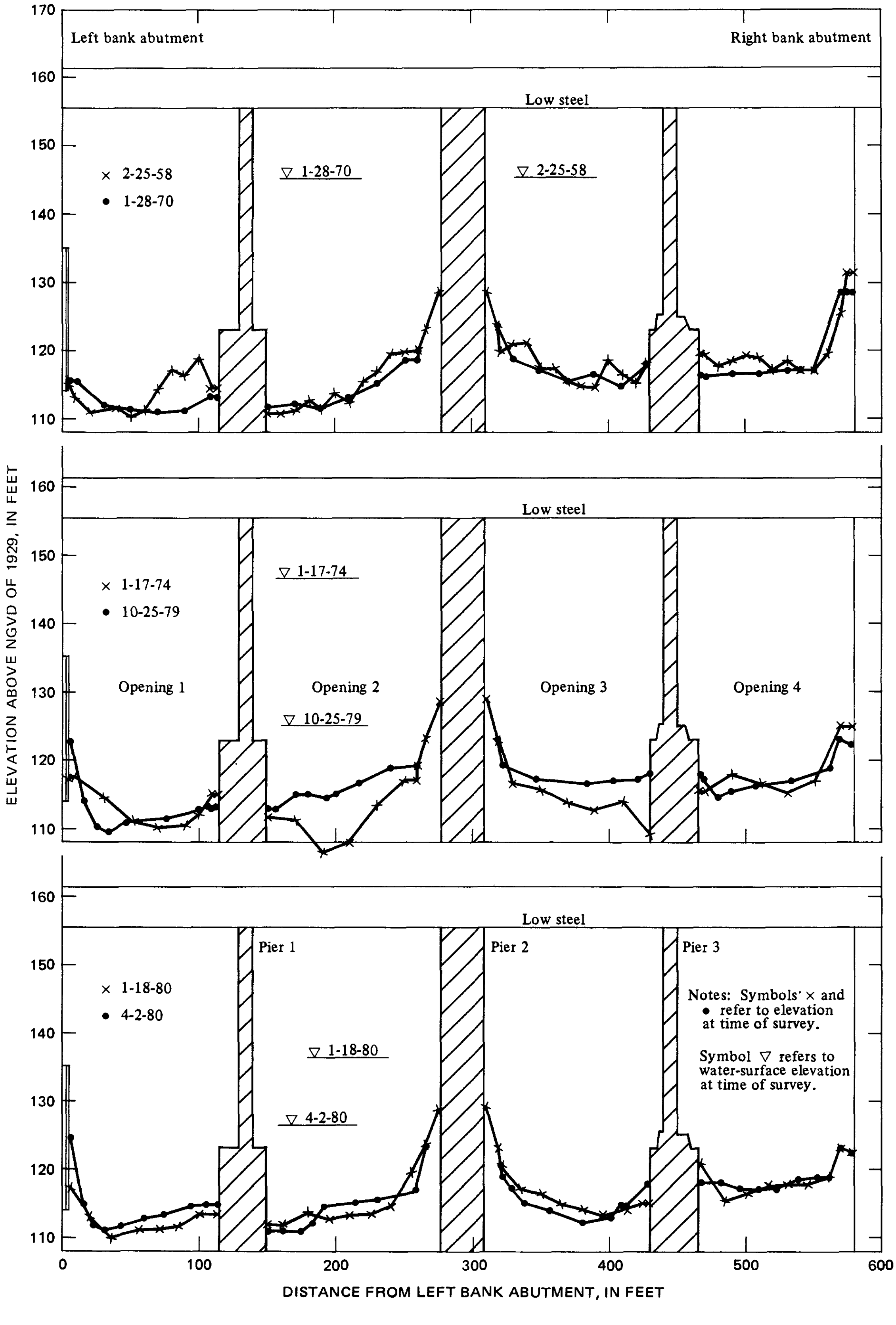


FIGURE 9.--Changes in channel shape at cross section 3 (downstream side of Gianella Bridge) between 1958 and 1980.

Surveys of the channel-bed profile in the vicinity of the bridge were made in 1976 and 1980 during low-flow conditions. These profiles (fig. 10) show that the elevation of the channel bed about 500 ft upstream and downstream from the bridge is affected by the bridge constriction.

Velocity of Flow

The velocity of flow in the channel is related to the discharge of the river and is affected by local features such as bridge piers and abutments that tend to concentrate flows to part of the channel. The variation in velocity of flow across the channel at the downstream side of the bridge (cross section 3), as determined during three discharge measurements, is shown in figure 11. The mean velocity in a given vertical is an average of point velocities measured at 20 and 80 percent of depth at the various stations. The maximum point velocity measured at cross section 3 during the measurement of January 17, 1974, was 13.4 ft^3/s.

Highest velocities of flow are usually located near pier 2 in openings 2 or 3. The high velocities in this part of the channel are caused by the upstream channel alinement which directs flows toward the left bank (fig. 2), and by the concrete drift deflector located at cross section 5. The effect of the drift deflector on flow lines is illustrated by the lines of turbulence in the vicinity of the bridge shown on the frontispiece.

Distribution of Flow

The effect of the bridge piers, abutments, and the large drift deflector at cross section 5 (fig. 2) on the distribution of flow is illustrated by a plot of cumulative discharge expressed in percent (fig. 12) for several measurements. The flatter slopes of the cumulative discharge plot indicate locations of low flow velocity and discharge as represented by the symbol A in figure 12. The line of uniform distribution of flow at a cross section in figure 12 represents the ideal condition where all parts of the section are utilized efficiently. In terms of the total channel width of 583 ft between abutments, flows in about 77 ft, or 13 percent of the total width, are affected by the bridge structure. A comparison of measurements made between 1958 and 1980 indicates little change during this period in the distribution of flow through the various bridge openings.

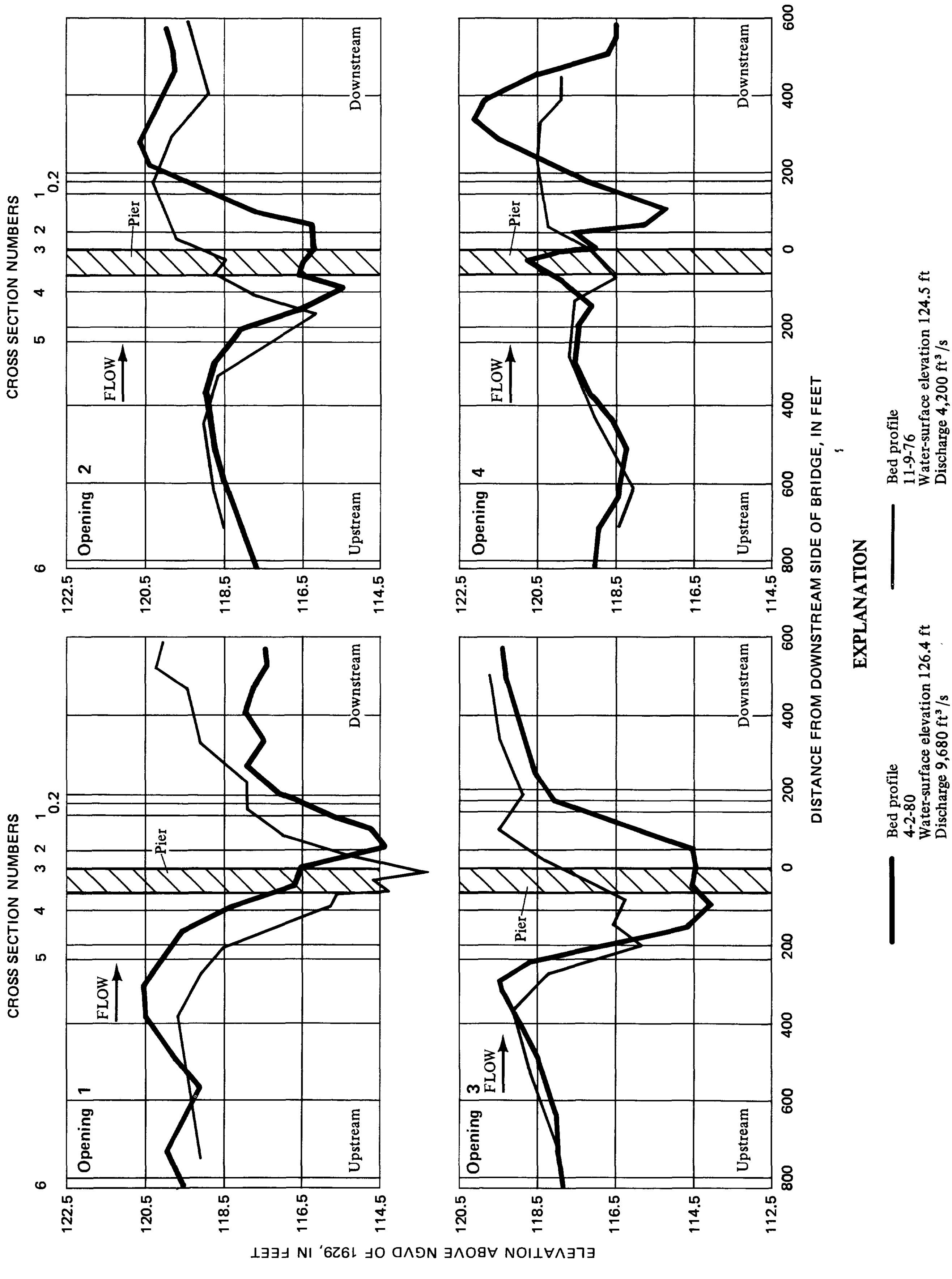


FIGURE 10.--Channel-bed profiles through openings of the Gianella Bridge, 1976 and 1980.

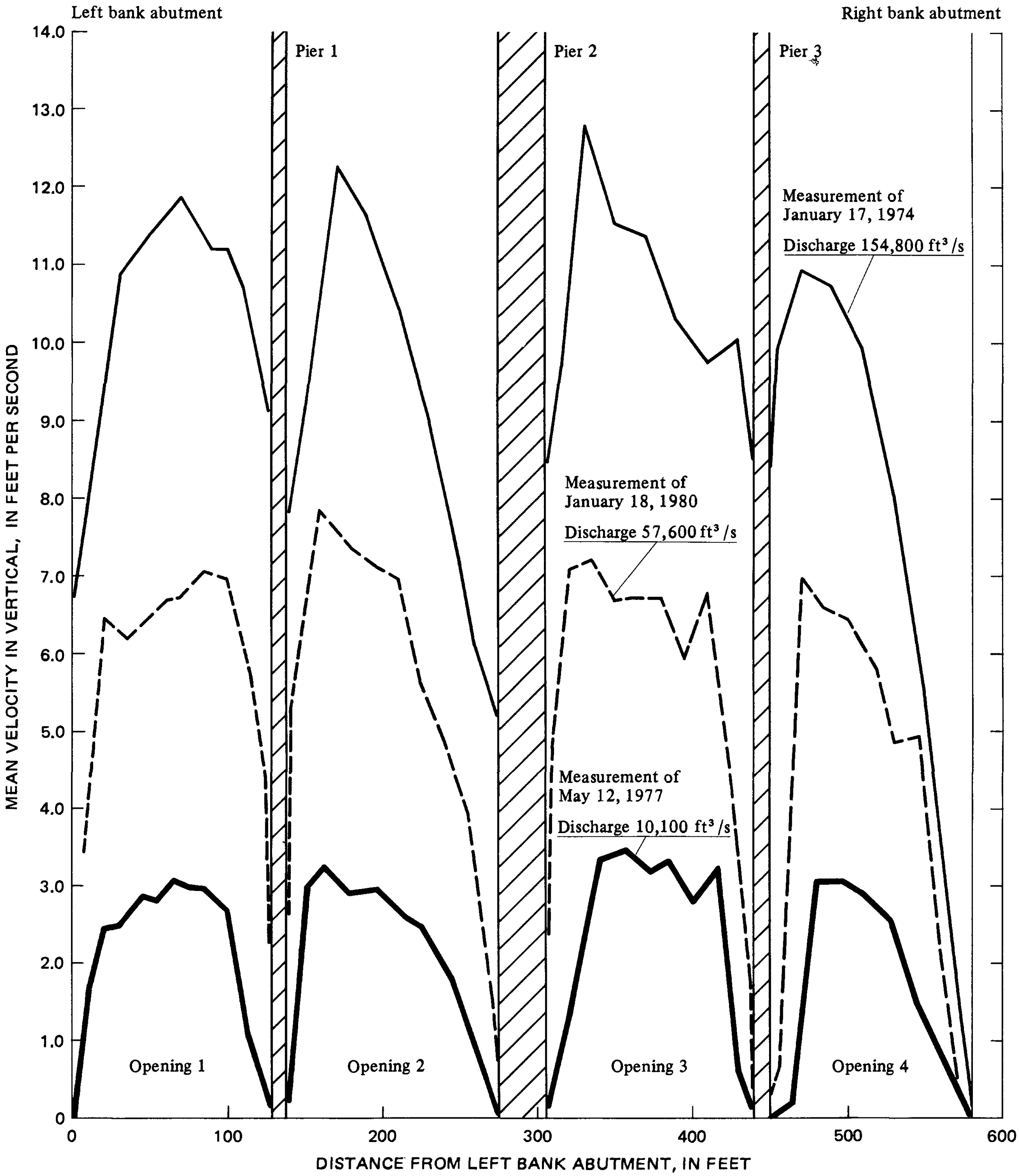


FIGURE 11.--Variation in velocity of flow through each opening of Gianella Bridge for selected floods.

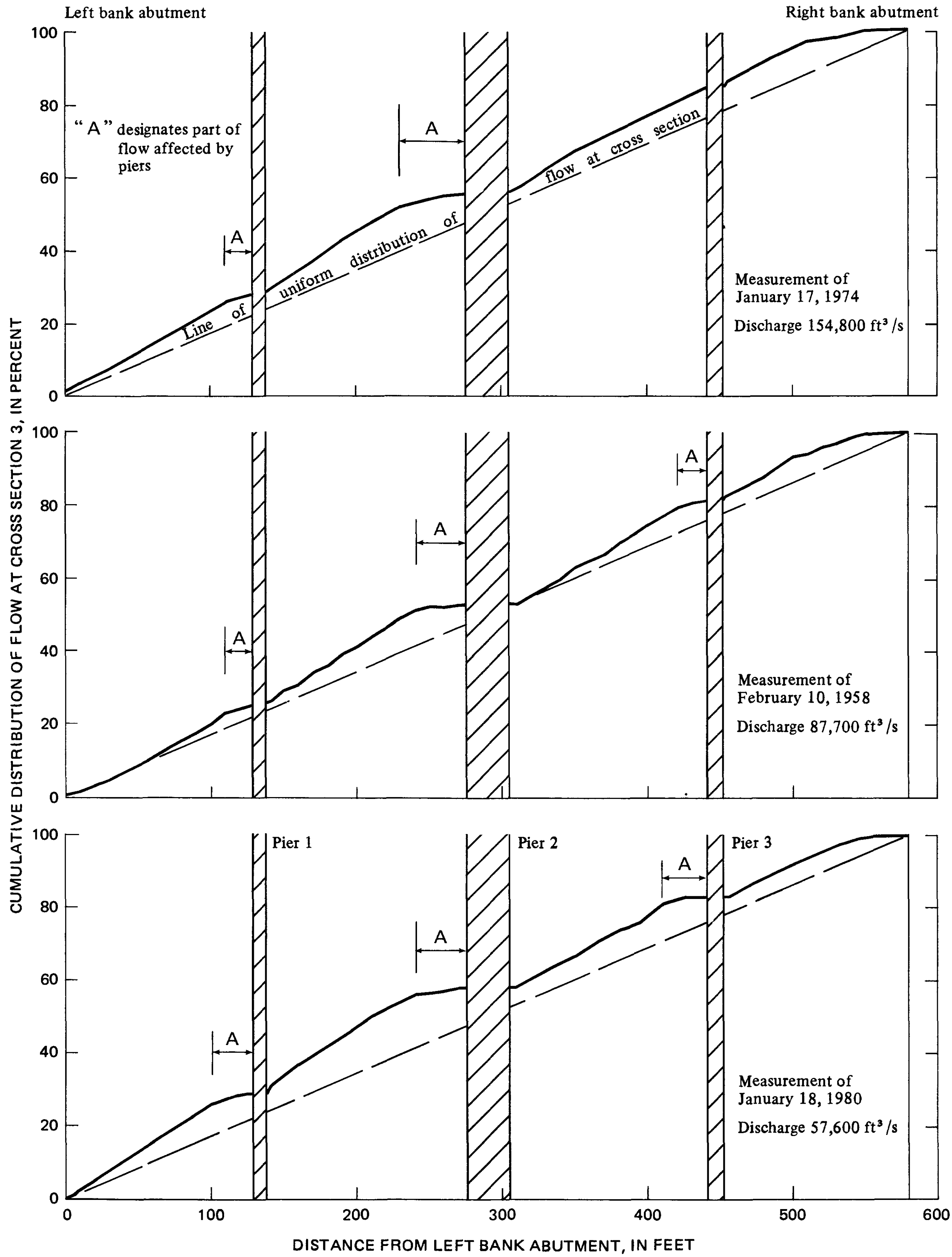


FIGURE 12.--Effect of piers on distribution of flow through openings of Gianella Bridge.

SUMMARY

The sandy-silt loam of the flood plain along the Sacramento River in the vicinity of the Gianella Bridge is easily eroded by streamflow. Levees along the banks of the river confine most flows to the main channel at the bridge site; however, discharges exceeding about 90,000 ft^3/s cause overflow to the flood plain.

The amount and distribution of overflow on the flood plain have been altered by changes in the location of the levees along the channel and in agricultural operations on the flood plain. Channel changes, measured by variations in river sinuousity, slope, and alinement, appear to be significant during 2- or 3-year intervals of time, although over longer periods the channel seems to be in equilibrium.

The average recurrence interval for overbank flow is about 2 years. Flows in the main channel during floods with a recurrence interval of 100 years are about 175,000 ft^3/s. For flows exceeding 159,000 ft^3/s in the main channel, backwater at the approach section of the bridge is about 0.6 ft and may extend more than 1.9 mi upstream from the bridge, depending on the extent of flooding. For all conditions of flow, the Giannella Bridge piers and drawrest support structure occupy 10 to 14 percent of the channel area.

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