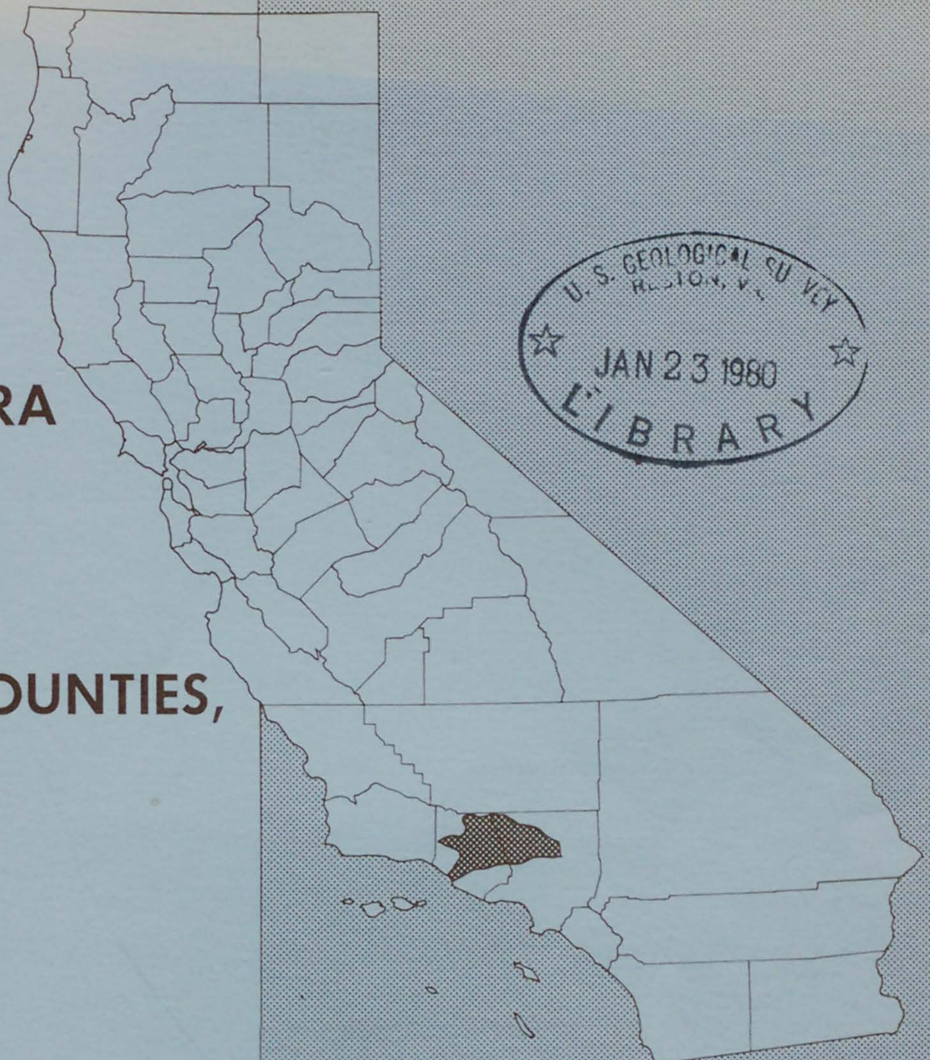

SEDIMENT DISCHARGE IN THE SANTA CLARA RIVER BASIN, VENTURA AND LOS ANGELES COUNTIES, CALIFORNIA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-78

Prepared in cooperation with
Ventura County Flood Control District,
United Water Conservation District, and
California Department of Boating
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16. Abstract (Limit: 200 words) Sediment data collected in the Santa Clara River basin during the 1967-75 water years were analyzed to determine the particle size and quantity of sediment transported past three gaging stations. The total sediment discharge of the basin, computed from records of Santa Clara River at Montalvo for water years 1968-75, was 63.5 million tons, of which 59.5 million tons was carried in suspension and an estimated 4 million tons was transported as unsampled sediment discharge. About 17.7 million tons, or 28 percent of the total sediment discharge, was coarse sediment. Most of the sediment was transported during only a few days of floodflow each year. During the 1968-75 water years, approximately 55 percent of the total sediment was transported in 2 days and 92 percent was transported in 53 days. The long-term (1928-75) average annual sediment discharge of the Santa Clara River at Montalvo is estimated at 3.67 million tons. Of that quantity, 2.58 million tons consisted of fine sediment and 1.09 million tons consisted of coarse sediment. A sediment budget for the Santa Clara River basin was estimated for sediment discharges under both natural and actual conditions. The major difference between natural and actual sediment discharges of the Santa Clara River basin is the sediment intercepted upstream from Lake Piru. The combined trap efficiency of Lake Piru and Pyramid Lake approaches 100 percent. Sediment deposited in these reservoirs resulted in about a 6-percent reduction of sediment to the Santa Clara River basin during the historical period (1928-75) and a 12-percent reduction during the period most affected by dams (1953-75). Sediment losses to the basin by gravel mining, diversion of flows, and interception of sediment in the Castaic Creek basin resulted in additional reductions of 2 percent during the period 1928-75 and 4 percent during the period 1953-75.

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c. COSATI Field/Group

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

The inch-pound system is used in this report. For readers who prefer metric units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
acre-ft (acre-foot)	0.001233	hm^3 (cubic hectometer)
ft (foot)	0.3048	m (meter)
ft/s (foot per second)	0.3048	m/s (meter per second)
ft^2 (square foot)	0.09290	m^2 (square meter)
ft^3/s (cubic foot per second)	0.02832	m^3/s (cubic meter per second)
inch	25.4	mm (millimeter)
lb/ft^3 (pound per cubic foot)	16.01	kg/m^3 (kilogram per cubic meter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)
ton (short ton)	0.9072	metric ton
ton/d (ton per day)	0.9072	metric ton per day
ton/yr (ton per year)	0.9072	metric ton per year
yd^3 (cubic yard)	0.7646	m^3 (cubic meter)

Abbreviations used:
- mg/L (milligram per liter)
- °C (degree Celsius)

SEDIMENT DISCHARGE IN THE SANTA CLARA RIVER BASIN,

VENTURA AND LOS ANGELES COUNTIES, CALIFORNIA

By Rhea P. Williams

ABSTRACT

Sediment data collected in the Santa Clara River basin during the 1967-75 water years were analyzed to determine the particle size and quantity of sediment transported past three gaging stations. The total sediment discharge of the basin, computed from records of Santa Clara River at Montalvo for water years 1968-75, was 63.5 million tons, of which 59.5 million tons was carried in suspension and an estimated 4 million tons was transported as unsampled sediment discharge. About 17.7 million tons, or 28 percent of the total sediment discharge, was coarse sediment (particles larger than 0.062 millimeter).

Most of the sediment was transported during only a few days of floodflow each year. During the 1968-75 water years, approximately 55 percent of the total sediment was transported in 2 days and 92 percent was transported in 53 days.

The long-term (1928-75) average annual sediment discharge of the Santa Clara River at Montalvo is estimated at 3.67 million tons. Of that quantity, 2.58 million tons consisted of fine sediment and 1.09 million tons consisted of coarse sediment.

A sediment budget for the Santa Clara River basin was estimated for sediment discharges under both natural and actual conditions. The major difference between natural and actual sediment discharges of the Santa Clara River basin is the sediment intercepted upstream from Lake Piru. The combined trap efficiency of Lake Piru and Pyramid Lake approaches 100 percent. Sediment deposited in these reservoirs resulted in about a 6-percent reduction of sediment to the Santa Clara River basin during the historical period (1928-75) and a 12-percent reduction during the period most affected by dams (1953-75). Sediment losses to the basin by gravel mining, diversion of flows, and interception of sediment in the Castaic Creek basin resulted in additional reductions of 2 percent during the period 1928-75 and 4 percent during the period 1953-75.

INTRODUCTION

This report was prepared in cooperation with the Ventura County Flood Control District, the United Water Conservation District, and the California Department of Boating and Waterways. The purpose of the investigation was to collect, analyze, and interpret data on the quantity and particle size of sediment transported in the Santa Clara River basin. Sediment-transport information is needed to properly design and manage flood- and erosion-control activities in the basin. These, in turn, influence water supply, land development, and the quantity of sediment available for maintaining ocean beaches. Basin accounting of sediment transport is expected to continue as new sites are brought into the gaging network.

Sediment data collected for 7 to 9 water years (1967-75)[1] at three sites--Santa Clara River at Los Angeles-Ventura County line (11108500), Sespe Creek near Fillmore (11113000), and Santa Clara River at Montalvo (11114000)--were analyzed to determine fine- and coarse-sediment discharge. Estimates of long-term sediment discharge were made by establishing relations between sediment and water discharge in the period 1967-75 and applying these short-term relations to long-term records of water discharge (1928-75). Most of the data for this analysis were reported by the U.S. Geological Survey (1967-75).

PREVIOUS INVESTIGATIONS

Sediment yields for parts of the Santa Clara River basin were estimated by Scott, Ritter, and Knott (1968) and Scott and Williams (1974) through indirect techniques involving correlation of sediment yields in nearby small-watershed debris basins with a variety of parameters based on land use, climate, soil erodibility, and geomorphological factors. These indirect methods provided a useful estimate of sediment amounts that might be delivered to major channels. Sediment surveys of Lake Piru were made in 1965 by Scott, Ritter, and Knott (1968) and in 1975 by the United Water Conservation District (written commun., 1978). A comprehensive long-term research effort is under way by the California Institute of Technology and the Scripps Institute of Oceanography to examine sediment management for southern California coastal drainage basins. Early results from that effort are in the streamflow section of this report, and they also were addressed by Taylor, Brown, and Brownlie (1977) and Brownlie and Brown (1978).

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[1]A water year is a 12-month period beginning October 1 and ending September 30 of the specified year. All periods indicated refer to water years.

ENVIRONMENT

The Santa Clara River basin is in the western part of the Transverse Ranges of southern California (fig. 1). Contained in the basin are intensely folded and faulted sedimentary rocks of the Topatopa and Santa Susanna Mountains, highly fractured schist of the Sierra Pelona, and heavily fractured granite of the San Gabriel Mountains and headwaters of Piru Creek. The main stem of the Santa Clara River follows the axis of a massive sedimentary syncline that extends from the Sierra Pelona vicinity westward beyond Ventura into the Pacific Ocean.

Mountainous parts of the basin are extremely rugged, exhibiting the effects of rapid orogeny and attendant rapid erosion that began generally in the mid-Pleistocene and has continued to the present. The maximum basin relief is about 8,800 ft (crest of Mount Pinos at the northern basin boundary to sea level near Ventura).

The climate of the basin varies from a moist, Mediterranean type near the Pacific Coast to a near-desert type at the extreme eastern boundary. Annual precipitation is about 8 inches in the easternmost part of the basin and more than 35 inches near the headwaters of Piru Creek (Rantz, 1969). About 90 percent of the annual precipitation occurs between November and April, and snow falls occasionally above elevations of 4,000 ft during these months.

The mountainous parts of the basin are mantled predominantly with chaparral, a highly flammable brush composed of many species of shrubs that have the ability to regrow after burning. Pockets of conifer and broadleaf evergreen forests grow in sheltered canyons and at higher elevations, and grass and low shrubs constitute the sparse vegetation of the eastern Sierra Pelona. Citrus orchards and various crops cover the flood plain and hills adjoining the main Santa Clara River channel, and a dense riparian growth that includes willow and cottonwood trees borders many parts of the channel.

The principal tributaries to the Santa Clara River are mountain streams that enter from the north. Southern tributaries constitute minor inflow to the Santa Clara River and drain only a small area of the basin. Northern tributaries flow in narrow, bedrock-confined channels having steep gradients. Along the mountain front that parallels California Highway 126 (fig. 1), these channels change abruptly into alluvial channels of lesser gradient before merging with the Santa Clara River channel. The latter is a broad, braided alluvial channel for most of its length, in contrast to the confined channels that feed it.

Major structural controls on channels in the basin include Santa Felicia Dam (1955) and Pyramid Dam (1971) on Piru Creek, Castaic Dam (1972) on Castaic Creek, and Bouquet Canyon Dam (1934) on Bouquet Creek (fig. 1). Lake Piru was designed to impound runoff from the basin. Bouquet Reservoir and Pyramid Lake receive water imported by canal and pipeline from northern California. Water from Pyramid Lake is then transported through a tunnel to Castaic Lake, from which releases are made to supply water for the Los Angeles metropolitan area. Releases into Piru Creek from Pyramid Lake are also made to augment flow into Lake Piru. The drainage-basin area, controlled by major dams (since 1972), is about 590 mi^2, or 36 percent of the total basin area of 1,640 mi^2. Several smaller dams, constructed specifically for the retention of sediment, control about 6 mi^2 of mountain-front drainage between Ventura and Piru (Scott and Williams, 1974, p. 9).

STREAMFLOW

Measured Streamflow

Station 11108500, Santa Clara River at Los Angeles-Ventura County line, was established in October 1952 and is currently in operation (1978). Runoff from the drainage area of 644 mi^2 has been partly regulated by Bouquet Reservoir (drainage area 13.6 mi^2) since 1934 and Castaic Reservoir (drainage area 154 mi^2) since January 1972. Overflow from Lake Hughes (drainage area 17.1 mi^2, fig. 1) occurs only during high-runoff years. Average daily discharge for 23 water years of record (1953-75) was 36.7 ft^3/s. Maximum flow was 68,800 ft^3/s (January 25, 1969).

Daily-discharge records for the Santa Clara River at Montalvo (station 11114000) for the current continuous period began October 1949. Prior to October 1969 the record was published as station 11113920, Santa Clara River at Saticoy, 3.9 mi upstream. Runoff from the 1,612-mi^2 drainage area is partially controlled (425 mi^2) by Santa Felicia Dam, which has impounded Lake Piru since May 1955, and in recent years by Pyramid Dam, which was established upstream from Piru Dam in December 1971, and also by Castaic Reservoir (fig. 1). Natural flows are affected by ground-water withdrawals and a diversion (not in operation at floodflows) 6 mi upstream from the Montalvo station. The average daily discharge at the Montalvo station represents flow to the ocean. Average daily discharge for 26 years (1950-75) was 116 ft^3/s. The maximum instantaneous flow was 165,000 ft^3/s January 25, 1969.

Station 11113000, Sespe Creek near Fillmore, began operation for the current continuous period in October 1927. Runoff from the 251-mi^2 drainage area is unregulated. The Fillmore Irrigation Co. has diverted water at a point 1 mi upstream since September 1911. The average daily discharge for 48 years of continuous record (1928-75) was 105 ft^3/s. This figure does not include the diversion. The maximum instantaneous flow was 60,000 ft^3/s on January 25, 1969.

Flow-duration curves of daily mean discharge for concurrent short- and long-term periods are shown in figures 2-4. Differences in curve shape for the various periods usually reflect changes in site location, climate, geology, or man's influence (Searcy, 1959). However, if the curves of each site remain parallel and the station was not moved, the change is assumed to be due only to magnitude variations in precipitation. These curves show that high discharge occurred more frequently during the short-term period 1969-75 than during the base period 1953-69 of the three stations. This difference can be attributed to the record-breaking runoff during January and February of 1969 in southern California. Although the high mean-flow period of a short-term record may not appear to be representative of a long-term period, the records are assumed to be comparable as long as they remain parallel. The recurrence intervals of discharge and sediment yield will rarely coincide; however, when water-discharge records are available, the relation of water discharge to sediment discharge is a valid physical index in determining probable sediment yields of previous unsampled years. Although some fluctuation occurs for the low-flow curve (1969-75) of figure 2 (assumed to be caused by upstream reservoir operations beginning in 1972), the 1953-75 curve does not significantly vary from the base period. Thus, no adjustments to flow durations were made.

Estimated Streamflow, 1928-75

In order to determine the impacts of dams and diversions on streamflow and sediment discharge at the mouth of the Santa Clara River, W. R. Brownlie developed a method for computing the streamflows of the drainage basin as they would occur in the absence of human controls (Taylor and others, 1977, p. 47-70). The method applies for the 1928-75 period and examines flows at the stations of concern in this report. Therefore, it is pertinent to discuss Brownlie's results in the context of estimating long-term streamflow and sediment discharge in the basin. Basically, Brownlie used the streamflow data that were continuous at some stations for the 1928-75 period and developed correlations to estimate flows at other stations for periods when data were not available (table 1).

The estimated natural flow (absence of control structures) was calculated from the following equation:

Natural flow at Santa Clara River near Montalvo =
measured flow at Santa Clara River near Montalvo
+ diverted flow at the lower river diversion dam (Saticoy diversion)
+ adjusted stored inflow to Lake Piru
- Lake Piru releases diverted at Saticoy diversion dam
+ adjusted stored inflow to Castaic reservoir
- release flows from Castaic reservoir.

TABLE 1. - Periods of streamflow record for the Santa Clara River basin, 1928-75

[Modified from Taylor and others, 1977, p. 53. Sources of record: USGS, U.S. Geological Survey; UWCD, United Water Conservation District, Santa Paula, Calif.; DWR, California Department of Water Resources, Los Angeles, Calif.]

Station name and number	1928 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975
Santa Clara River at Montalvo, 11114000	1928-32: USGS data; 1933-49: No data collected; 1950-75: USGS Data
Saticoy diversion, 11113900	1929-75: UWCD records; diversion began in 1929
Santa Paula Creek near Santa Paula, 11113500	1928-75: USGS data; records of diversions to Santa Paula Water Works not available for all years
Sespe Creek near Fillmore, 11113000	1928-75: USGS data; records include diversions to Fillmore Irrigation Company
Piru Creek near Piru, 11110000	1928-55: USGS data; 1956-71: UWCD data, Santa Felicia dam; 1972-75: USGS data
Castaic Creek near Saugus, 11108145	1928-44: No data collected; 1945-71: USGS Data; 1972-75: DWR data, Castaic Reservoir

The individual components of the equation, where not complete for the 1928-75 period, were extended to the full period on the basis of correlations with streamflow records, reservoir-operation data, and allowances for percolation losses. Thus, the ultimate solution of the equation required a tabulation of actual and computed annual streamflows for several stations for a common base period. These streamflows are listed in table 2 and may be applied to appropriate sediment-transport relations for an estimate of historical sediment discharge. The sediment-transport relations and qualifications on their use are discussed in the following section.

SEDIMENT TRANSPORT

The total sediment discharge of a stream can be divided into two parts: (1) fine-sediment discharge, which usually comes from land-surface erosion and consists of particles finer than those found in appreciable quantity in the streambed; and (2) coarse-sediment discharge, which consists of particle sizes found in appreciable quantity at the surface of the streambed. The dividing size between fine and coarse sediment is considered to be 0.062 mm, the dividing line between silt and very fine sand.

All the fine sediment and generally the major part of the coarse sediment are transported in suspension and are usually sampled through the depth of flow to within 0.3 ft of the bed. This sampled part of the total sediment discharge is referred to as the suspended-sediment discharge and is published in the annual data reports for California (U.S. Geological Survey, 1967-77).

The remaining coarse sediment is transported as bedload (sliding, skipping, and rolling along or very close to the bed) or in suspension within 0.3 ft of the bed. This part of the total sediment discharge is referred to as the unsampled discharge. The total sediment discharge is the sum of the suspended-sediment discharge plus the unsampled discharge.

Most coarse sediment transported by the Santa Clara River is derived from the erosion of its channel during periods of high runoff. In turn, the sediment that is transported downstream is replaced by material transported to the main channel by the major tributaries, such as Sespe and Santa Paula Creeks. This material is supplied to the tributaries from eroded hillsides, landslides, slumps, and debris flows and is deposited in the Santa Clara River channel during periods of medium flow. Thus, the sediment continuously feeds the main channel of the Santa Clara River, and average streambed elevations of the sandbed stream remain somewhat constant. However, human activities, such as gravel mining or placement of structures within the stream system, generally create local regime controls on the stream's capability to transport coarse sediment. These activities will be discussed further in a later section of this report.

The quantity of coarse sediment transported depends primarily on source availability, particle size of the sediment, and the channel hydraulics of streamflow at the measuring section. No adjustments were made to distinguish between the long-term effects of a dam on coarse-sediment transport and source availability, as these effects were not readily apparent (at moderate to high flows during 1969-75) on yearly comparison of the sediment-discharge relations.

TABLE 2. - Annual streamflow for 12 components of the Santa Clara River drainage system for 1928-75, in acre-feet

[Taylor and others, 1977, p. 67-70]

Water year	Natural flow, Santa Clara River near Montalvo	Measured flow, Santa Clara River near Montalvo[1]	Diverted flow, lower river diversion dam (Saticoy diversion)	Adjusted stored inflow to Lake Piru[2]	Lake Piru releases diverted at Saticoy diversion dam[3]	Adjusted stored inflow to Castaic Reservoir[2]	Release flows from Castaic Reservoir[2]	Natural flow, Santa Clara River at Los Angeles-Ventura County line[4]	Lake Piru inflows	Natural flow Piru Creek	Sespe Creek
1928	15,700	15,700	0	0	0	0	0	8,204	0	10,454	19,500
1929	34,080	29,400	4,680	0	0	0	0	8,169	0	9,637	18,900
1930	22,920	15,500	7,420	0	0	0	0	8,138	0	9,180	18,000
1931	22,970	15,800	7,170	0	0	0	0	8,187	0	12,351	16,900
1932	142,596	133,000	9,596	0	0	0	0	16,311	0	51,542	83,000
1933	34,278	24,248	10,030	0	0	0	0	8,596	0	10,308	32,200
1934	62,891	54,931	7,960	0	0	0	0	9,891	0	16,435	52,000
1935	121,662	102,849	18,813	0	0	0	0	14,104	0	32,929	83,600
1936	60,778	47,870	12,908	0	0	0	0	9,777	0	13,868	52,730
1937	291,609	271,472	20,137	0	0	0	0	36,082	0	67,754	171,000
1938	485,841	472,189	13,652	0	0	0	0	76,370	0	125,161	239,000
1939	80,269	66,724	13,545	0	0	0	0	10,930	0	37,159	46,050
1940	43,764	26,974	16,790	0	0	0	0	8,965	0	18,886	32,500
1941	879,202	878,806	396	0	0	0	0	200,449	0	220,077	375,600
1942	68,823	68,823	0	0	0	0	0	10,225	0	31,305	42,240
1943	340,188	340,188	0	0	0	0	0	44,732	0	100,654	170,500
1944	330,651	328,695	1,956	0	0	0	0	42,956	0	121,757	143,100
1945	85,916	81,178	4,738	0	0	0	0	11,306	0	33,435	54,460
1946	95,693	78,451	17,242	0	0	0	0	12,001	0	31,441	64,450
1947	68,116	45,358	22,758	0	0	0	0	10,184	0	27,600	45,340

1948	7,805	0	7,805	0	0	0	0	7,921	0	6,448	7,960
1949	7,725	2,191	5,534	0	0	0	0	7,927	0	5,854	9,070
1950	15,146	5,450	9,696	0	0	0	0	8,069	0	7,070	16,900
1951	0	0	0	0	0	0	0	7,855	0	2,344	3,520
1952	217,367	192,000	25,367	0	0	0	0	33,225	0	76,730	150,200
1953	25,160	3,310	21,850	0	0	0	0	7,308	0	13,401	22,330
1954	32,296	12,370	19,926	0	0	0	0	7,488	0	15,229	33,090
1955	12,996	945	12,051	0	0	0	0	5,039	0	11,553	17,060
1956	33,959	14,190	17,159	2,610	0	0	0	5,508	10,850	11,060	29,600
1957	19,196	5,620	13,076	500	0	0	0	3,283	9,610	11,050	23,780
1958	418,359	278,500	74,589	78,780	13,510	0	0	40,178	92,590	93,980	226,200
1959	59,530	19,320	36,180	7,130	3,100	0	0	3,395	15,670	18,700	31,880
1960	14,038	331	14,267	0	560	0	0	668	5,380	7,520	12,890
1961	5,954	459	5,495	0	0	0	0	561	4,100	6,270	8,940
1962	333,781	224,500	48,571	68,120	7,410	0	0	28,805	82,980	90,760	179,000
1963	25,594	6,220	22,374	1,040	4,040	0	0	1,861	7,580	9,530	16,530
1964	14,906	4,720	10,846	560	1,220	0	0	1,100	5,880	8,260	13,660
1965	25,049	7,590	16,229	1,230	0	0	0	1,951	9,420	10,930	26,440
1966	246,557	154,100	53,747	43,590	4,880	0	0	39,558	69,060	69,690	157,700
1967	238,392	114,200	90,272	45,090	11,170	0	0	39,761	62,550	74,770	157,100
1968	58,049	9,780	45,669	2,600	0	0	0	11,722	14,740	16,700	24,290
1969	1,033,121	889,500	95,411	71,990	23,780	0	0	253,382	212,800	200,140	465,300
1970	112,345	52,140	78,745	9,660	28,200	0	0	23,979	23,300	26,790	56,150
1971	147,091	66,690	64,498	16,730	4,540	3,713	0	26,368	37,080	39,010	66,780
1972	68,194	29,710	30,004	12,051	3,591	20	0	15,762	20,970	23,958	29,920
1973	283,541	200,800	63,627	28,297	8,433	3,430	4,180	60,168	49,240	56,257	161,500
1974	133,885	62,610	60,586	14,781	4,405	596	283	24,531	25,720	29,385	54,380
1975	121,537	52,300	58,071	15,820	4,714	60	0	16,124	27,530	31,453	65,340

[1]Flow for 1933-50 estimated from regression analysis.
[2]Flow that would have passed through reservoir site without dam, adjusted for downstream percolation.
[3]Portion of Lake Piru inflow routed to and diverted at Saticoy, adjusted for percolation.
[4]Flow for 1928-52 estimated from regression analysis. Flow for 1971-75 adjusted for Castaic Reservoir storage.

Data Collection

Sediment-discharge data were collected at three stations (fig. 1) during water years 1967-75. The length of the records ranged from 7 to 9 years. The data used to compute total sediment discharge consisted of suspended-sediment and bed-material samples, analyzed for concentration and particle-size distribution, and of streamflow measurements.

Samples were collected at selected verticals in the stream cross section to determine average suspended-sediment concentration and particle-size distribution of sediment in the water-sediment mixture. Suspended sediment was sampled between the water surface and a point 0.3 ft above the bed of the stream, using standard depth-integrating samplers (U.S. Inter-Agency Committee on Water Resources, 1963).

Sediment transported within 0.25 ft of the streambed was sampled at the Santa Clara River at the Montalvo station, using a bedload sampler (Helley and Smith, 1971) designed for collecting coarse sediment. Sampling time, number of sampling points, stream width, gage height, and dry weight of the sediment were recorded for each sample to determine the rate of transport of coarse sediment near the streambed. Because the bedload sampler was not yet calibrated, a trap-efficiency coefficient of 1.0 was assumed.

At all three sites the unsampled sediment discharge was computed by use of the MODEIN version (Burkham and others, 1977) of the modified Einstein procedure (Colby and Hembree, 1955). Data required for these computations are:

1. Stream width, average depth, and mean velocity either from a streamflow measurement or from a relation of hydraulic parameters.
2. Average depth at the vertical where the suspended-sediment samples were collected.
3. Average concentration of suspended sediment.
4. Particle-size analysis of the suspended sediment.
5. Particle-size analysis of the bed material.
6. Water temperature.

Analyses of particle-size distribution were made on selected suspended-sediment samples. Table 3 lists the results of these analyses and the hydraulic properties used.

Several particle-size analyses of the streambed material were made at each site (figs. 5-7). At the Los Angeles-Ventura County line station, discharges at low to medium stages were generally confined to an established channel with well-sorted bed material, whereas at flood stages the full channel width had a wider range of particle sizes in the bed. The streambed is composed of 75 percent sand and 25 percent gravel. Particle-size data in figure 5 indicate that the main channel of the Santa Clara River at the Los Angeles-Ventura County line is predominantly sand, with 99 percent of the bed finer than 4 mm. The flood channel is considerably coarser, with particles larger than 70 mm in diameter available for transport. Because the particle-size distribution of bed material in the main channel was distinctly different from that in the flood channel, total sediment discharge was computed for both particle-size distributions.

Particle-size distributions of bed-material samples collected at Montalvo showed a small variation. Total sediment discharge was computed for a single composite particle-size distribution (fig. 6).

Particle-size distribution of the coarse material in the streambed of Sespe Creek was determined by examination of photographs, by particle counts, and by sieve analyses. Figure 7 indicates the variability of particle-size distribution during the data-collection period. The average particle-size distribution of bed material used for computation of coarse sediment discharge for each stream is shown in table 4.

In addition to using the modified Einstein bedload method for Sespe Creek, bedload was also computed by using the Meyer-Peter and Muller (MPM) bedload formula (converted by the U.S. Bureau of Reclamation, 1960).

This method of bedload determination is commonly preferred over the modified Einstein method for coarse-bed streams (gravel and cobbles). However, as shown in figure 8, there is good agreement between the two methods. Thus, for determining the entire unsampled sediment discharge (which the MPM method does not compute), the modified Einstein method was selected.

TABLE 3. - Particle-size distribution of suspended sediment and hydraulic

Date	Time	Water temperature (°C)	Discharge (ft^3/s)	Sediment concentration (mg/L)	Sediment discharge (tons per day)	Particle: Percentage of particles finer				
						0.002	0.004	0.008	0.016	0.031
						Clay		Silt		
Santa Clara River at Los Angeles-Ventura County line (11108500)										
Nov. 5, 1968	1420	22	1.9	94	0.48	35	49	66	73	77
Jan. 19, 1969	1220	14	10	309	8.3	41	57	66	69	71
Jan. 20, 1969	0100	11	466	22,300	28,100	33	46	60	76	84
Mar. 12, 1969	1045	11	504	5,050	6,870	19	28	33	43	53
Mar. 1, 1970	1335	13	600	25,800	41,800	26	28	37	50	65
Nov. 29, 1970	1210	13	9,000	42,100	1,020,000	20	27	36	54	69
Nov. 29, 1970	1430	12	4,820	47,500	618,000	21	29	41	54	67
Dec. 21, 1970	0740	7	2,220	34,600	207,000	23	31	39	52	64
Dec. 21, 1970	1655	10	870	10,300	24,200	27	35	45	59	72
Dec. 22, 1971	0715	10	61	10,600	1,750	39	51	69	90	93
Dec. 22, 1971	1640	13	201	2,870	1,560	45	60	76	86	92
Dec. 27, 1971	0810	7	963	24,300	63,200	35	39	52	74	94
Dec. 27, 1971	1120	6	3,190	20,700	178,000	31	38	44	65	81
Dec. 27, 1971	1240	7	1,470	21,900	86,900	24	33	44	58	72
Feb. 15, 1972	1705	18	46	215	27					
Mar. 17, 1972	1030	18	14	467	18	31	41	47	55	60
Nov. 14, 1972	1230	13	86	2,310	536	50	68	84	91	94
Nov. 14, 1972	1630	14	512	4,490	6,210	44	56	74	83	91
Dec. 4, 1972	1300	13	93	1,700	427	32	51	74	87	89
Feb. 6, 1973	0720	11	318	4,630	3,980	31	41	57	71	80
Feb. 10, 1973	1700	13	942	11,300	28,700	22	26	31	45	60
Feb. 11, 1973	0640	11	10,600	27,300	781,000	29	31	44	62	78
Feb. 11, 1973	1215	11	4,680	27,700	350,000	16	19	27	38	52
Mar. 21, 1973	1325	12	421	1,960	2,230	14	18	25	33	46
Nov. 23, 1973	0720	8	21	503	29	36	49	57	62	64
Dec. 1, 1973	1540	15	32	248	21					
Dec. 10, 1973	0800	9	21	181	10					
Jan. 4, 1974	1345	15	373	3,560	3,590	37	49	62	68	70
Jan. 6, 1974	0835	5	189	3,110	1,590	33	50	66	77	81
Jan. 7, 1974	1125	8	2,160	8,670	50,600	28	33	47	62	74
Jan. 28, 1974	1730	16	46	56	7.0					
Oct. 7, 1974	0915	17	21	593	34	44	54	67	78	82
Dec. 4, 1974	0720	12	2,210	10,000	59,700	34	44	61	76	86
Dec. 4, 1974	1135	13	152	3,730	1,530	37	49	64	73	79
Mar. 8, 1975	0715	12	1,160	8,780	27,500	29	43	58	75	88
Mar. 22, 1975	0720	12	25	2,530	171	29	38	54	72	85
Apr. 9, 1975	0705	9	116	4,730	1,480	33	43	57	72	83

properties at time of suspended-sediment sampling

size than size (millimeters) indicated 0.062						Hydraulic properties of channel Area (ft^2)			
0.062	0.125	0.250	0.500	1.000	2.000	Area (ft^2)	Width (ft)	Depth (ft)	Velocity (ft/s)
Sand									
Santa Clara River at Los Angeles-Ventura County line (11108500)--Continued									
83	90	98	100			1.0	3.4	0.29	1.90
79	81	94	100			4.86	6.0	.81	2.06
90	93	97	99	100		90	82	1.10	5.18
65	89	100				102	132	.77	4.92
78	91	98	100			100	97	1.03	6.00
79	83	95	100			750	64	11.8	12.0
74	77	84	99	100		460	75	6.1	10.5
74	87	97	99	100		225	75	3.0	9.87
84	93	98	99	100		110	74	1.49	7.91
95	96	98	100			20	42	.48	3.05
94	96	100				48	73	.66	4.19
97	98	100				148	106	1.40	6.51
88	91	96	97	100		350	86	4.05	4.11
79	86	96	99	100		205	102	2.00	7.17
59	63	97	100			16	36	.45	2.88
65	68	75	87	95	100	4.0	11	.36	3.50
95	96	99	100			26	49	.53	3.31
94	97	99	100			105	111	.95	4.88
91	92	96	99	100		27	50	.54	3.44
86	92	98	100			75	73	1.03	4.24
70	81	92	99	100		158	105	1.50	5.96
90	97	99	100			850	61	13.9	12.5
67	86	96	99	100		460	77	5.95	10.2
64	89	99	100			72	67	1.07	5.85
65	68	89	100			9.1	17	.54	2.31
44	49	72	96	100		12	22	.58	3.56
8	8	26	75	100		9.1	17	.54	2.31
72	72	80	99	100		75	73	1.03	4.97
82	83	90	98	100		45	54	.84	4.20
81	86	94	100			270	96	280	8.00
68	82	91	100			16	40	.38	2.97
84	87	94	98	100		9.0	22	.40	2.33
90	93	98	100			275	96	2.85	8.04
82	84	89	98	100		43	41	1.05	3.53
94	98	100				175	97	1.80	6.63
89	91	96	100			11	26	.43	2.27
87	92	98	100			34	41	.83	3.41

TABLE 3. - Particle-size distribution of suspended sediment and hydraulic

Date	Time	Water temperature (°C)	Discharge (ft^3/s)	Sediment concentration (mg/L)	Sediment discharge (tons per day)	Particle Percentage of particles finer 0.002	0.004	0.008	0.016	0.031
						Clay		Silt		
Santa Clara River at Montalvo (11114000)										
Jan. 19, 1969	1100	11	42	2,050	232	67	73	83	93	100
Jan. 20, 1969	0305	13	14,500	18,800	736,000	21	26	31	47	60
Jan. 25, 1969	1015	14	163,000	91,400	40,200,000	26	34	40	60	77
Jan. 25, 1969	1725	13	56,100	71,200	10,800,000	22	26	32	50	66
Jan. 26, 1969	1540	13	28,700	21,100	1,640,000	17	19	25	34	44
Feb. 6, 1969	0900	10	16,400	53,400	2,360,000	22	23	32	44	71
Feb. 19, 1969	1000	11	970	3,420	8,960	26	37	53	71	82
Dec. 21, 1970	0700	15	6,100	45,900	756,000	22	30	36	50	63
Dec. 21, 1970	1200	15	5,400	36,600	534,000	26	33	40	60	74
Jan. 4, 1971	0700	14	3.5	1,150	11	9	13	17	20	22
Dec. 23, 1971	1000	8	336	1,440	1,310	41	57	76	89	95
Dec. 24, 1971	1700	9	5,300	16,700	239,000	32	34	42	60	72
Dec. 25, 1971	1700	9	961	3,830	9,940	23	34	43	52	61
Dec. 26, 1971	1200	8	1,580	9,840	42,000	26	29	39	49	55
Dec. 27, 1971	1200	8	6,000	22,900	321,000	30	36	42	58	71
Dec. 27, 1971	1700	8	3,030	11,300	92,400	31	35	43	60	72
Jan. 26, 1972	0800	6	.69	15,300	29	60	84	96	98	98
Jan. 27, 1972	0700	5	.92	9,480	24	59	75	96	99	99
Oct. 5, 1972	1030	20	.35	8,570	8.1	66	83	95	96	99
Nov. 15, 1972	0830	14	133	900	323	50	72	87	96	99
Nov. 15, 1972	1330	16	70	597	113	50	70	87	95	99
Nov. 18, 1972	1015	12	9.4	282	7.2	50	65	76	87	94
Jan. 16, 1973	1300	13	1.4	7,790	29	32	40	49	63	77
Jan. 18, 1973	1600	12	3,300	14,100	126,000	36	37	46	61	79
Feb. 6, 1973	1230	12	2,860	13,400	103,000	27	33	44	58	74
Feb. 10, 1973	1300	13	1,150	33,300	103,000	21	26	35	48	64
Feb. 11, 1973	1330	12	20,500	35,400	1,196,000	19	23	33	45	60
Mar. 8, 1973	1630	13	1,000	996	2,690	70	84	89	92	93
Mar. 11, 1973	1230	12	900	2,020	4,910	34	47	62	80	94
Apr. 12, 1973	1430	15	.50	314	0.4	65	85	93	98	99
Jan. 4, 1974	1015	7	51	1,250	172	42	57	74	89	97
Jan. 8, 1974	1000	7	4,440	9,990	120,000	31	37	50	65	77
Dec. 4, 1974	0930	14	6,500	14,400	253,000	45	55	73	88	96
Dec. 6, 1974	1145	15	3.0	323	2.6	41	58	62	74	85
Dec. 28, 1974	1030	9	150	1,140	462	72	87	97	97	99
Dec. 28, 1974	1530	10	200	1,240	670	70	84	90	93	96
Feb. 4, 1975	0900	10	400	253	273	50	68	79	89	94
Feb. 9, 1975	1030	12	1,000	566	1,530	67	84	92	98	99
Mar. 6, 1975	0900	12	3,790	16,400	168,000	24	25	38	51	66
Mar. 7, 1975	0845	12	3,420	6,770	62,500	18	22	28	37	47
Mar. 8, 1975	1315	12	10,500	18,100	513,000	19	25	32	45	59
Apr. 5, 1975	1730	14	1,150	45,400	47,800	37	49	71	90	97

properties at time of suspended-sediment sampling--Continued

size						Hydraulic properties of channel			
than size (millimeters) indicated						Area	Width	Depth	Velocity
0.062	0.125	0.250	0.500	1.000	2.000	(ft^2)	(ft)	(ft)	(ft/s)
Sand									
Santa Clara River at Montalvo (11114000)--Continued									
						23	45	0.51	1.83
73	90	97	100			2,050	512	4.00	7.07
91	100					16,730	1,560	10.7	9.86
78	95	99	100			5,800	892	6.5	4.67
54	71	89	97	100		3,450	683	5.05	8.32
73	94	99	100			2,250	542	4.15	7.29
89	97	100				255	163	1.56	3.80
74	82	92	98	100		1,050	342	3.07	5.81
83	90	96	98	100		950	322	2.95	5.68
24	28	55	96	100		3.3	12	.27	1.06
96	97	98	99	100		114	114	1.00	2.95
79	87	97	99	100		940	319	2.95	5.64
66	68	81	94	100		253	162	1.56	3.80
59	62	83	96	100		370	194	1.91	4.27
80	85	94	99	100		1,050	343	3.06	5.71
78	83	91	99	100		610	249	2.45	4.97
100						.36	2.0	.18	1.92
100						.60	3.0	.20	1.53
99	100					.28	1.9	.15	1.90
100						56	79	.71	2.38
100						34	58	.59	2.06
97	99	100				7.1	21	.34	1.32
93	99	100				1.6	7.3	.22	.88
94	97	98	100			660	263	2.51	5.00
86	93	97	100			590	246	2.40	4.85
75	90	96	99	100		292	172	1.70	3.94
71	87	94	99	100		2,700	600	4.50	7.59
95	98	100				265	168	1.58	3.77
99	100					242	160	1.51	3.72
99	99	100				.34	2.0	.17	1.47
99	99	100				26	41	.64	1.92
87	95	99	100			840	300	2.80	5.29
100						1,120	358	3.13	5.80
91	95	96	98	100		3.0	12	.26	1.00
100						61	65	.94	2.46
96	96	99	100			76	72	1.06	2.63
95	97	98	100			130	89	1.46	3.08
99	100					265	169	1.57	3.77
79	86	92	100			730	273	2.67	5.19
56	63	78	97	100		680	267	2.55	5.03
72	82	92	99	100		1,600	446	3.59	6.56
100						290	173	1.68	3.97

TABLE 3. - Particle-size distribution of suspended sediment and hydraulic

Date	Time	Water temperature (°C)	Discharge (ft^3/s)	Sediment concentration (mg/L)	Sediment discharge (tons per day)	Particle: Percentage of particles finer: Clay 0.002	0.004	Silt 0.008	0.016	0.031
Sespe Creek near Fillmore (11113000)										
Jan. 14, 1969	1355	12	62	196	33	51	72	84	92	96
Jan. 19, 1969	1450	15	2,000	3,400	18,400	30	35	47	63	83
Jan. 21, 1969	0800	11	28,000	25,500	1,930,000	17	20	28	42	56
Jan. 22, 1969	1825	13	8,000	9,230	199,000	17	23	32	43	58
Jan. 22, 1969	1055	13	3,190	1,920	16,500	20	30	41	54	65
Jan. 24, 1969	1820	12	4,360	2,790	32,800	11	15	21	28	38
Jan. 26, 1969	1530	12	21,900	20,600	1,220,000	12	14	20	32	45
Feb. 8, 1969	1210	12	1,200	1,510	4,890	26	33	46	60	75
Feb. 23, 1969	1715	7	8,570	17,100	396,000	8	11	14	19	27
Feb. 25, 1969	1220	10	13,700	21,300	788,000	13	20	26	37	50
Feb. 28, 1970	1600	11	6,500	8,280	145,000	20	22	28	40	52
Mar. 3, 1970	0725	9	1,000	1,360	3,670	11	16	22	30	36
Nov. 29, 1970	0810	13	8,000	17,600	380,000	13	17	23	36	47
Dec. 22, 1970	1230	7	350	275	260	33	50	63	75	84
Dec. 24, 1971	0900	10	3,650	6,340	62,500	21	27	31	50	66
Dec. 24, 1971	1630	11	3,250	4,060	35,600	23	29	36	56	69
Dec. 27, 1971	1400	8	1,470	2,790	11,100	14	16	22	29	38
Dec. 28, 1971	1220	7	545	634	933	35	43	52	62	70
Feb. 11, 1973	1430	10	11,200	18,900	584,000	13	14	21	29	42
Feb. 12, 1973	1230	10	2,800	4,060	30,700	15	22	30	39	51
Feb. 15, 1973	1700	11	680	143	263					
Jan. 7, 1974	1205	9	6,500	10,400	183,000	23	28	43	58	74
Jan. 8, 1974	1215	8	1,090	1,290	3,800					
Jan. 17, 1974	1220	10	644	302	525					
Mar. 8, 1974	1805	9	495	169	226					
Dec. 4, 1974	0935	12	2,380	5,200	33,400	18	25	35	47	59
Dec. 4, 1974	1600	12	1,720	4,890	22,700	34	46	64	79	88
Mar. 6, 1975	1355	10	2,850	3,120	24,000	23	32	46	59	70
Mar. 8, 1975	1700	12	3,750	2,820	28,600	19	27	38	51	65

properties at time of suspended-sediment sampling--Continued

size						Hydraulic properties of channel			
than size (millimeters) indicated						Area	Width	Depth	Velocity
0.062	0.125	0.250	0.500	1.000	2.000	(ft^2)	(ft)	(ft)	(ft/s)
Sand									
Sespe Creek near Fillmore (11113000)--Continued									
99	99	100				30	40	0.73	2.09
94	100					328	110	2.98	6.10
72	89	98	100			3,400	200	17.0	8.24
74	87	95	98	99	100	650	126	5.15	12.3
73	80	86	91	95	100	325	111	2.92	9.82
48	62	81	98	100		420	131	3.20	10.4
61	79	91	98	100		1,380	2.03	6.80	15.9
88	99	100				153	85	1.80	7.84
33	41	56	80	96	99	645	172	3.75	13.3
60	76	90	97	100		1,030	212	4.85	13.4
65	80	93	99	100		575	181	3.18	11.3
45	52	74	100			142	56	2.55	7.04
57	72	88	98	100		612	170	3.60	13.1
91	92	100				92.8	78	1.19	3.77
80	87	96	98	99	100	336	70	4.80	10.9
76	77	84	90	91	96	315	70	4.50	10.3
46	50	65	92	98	100	165	54	3.05	8.91
78	81	89	96	100		100	50	2.00	5.45
56	76	90	99	100		912	212	4.30	12.3
68	81	91	98	100		300	71	4.20	9.33
81	87	94	100			150	47	3.19	4.53
90	98	100				520	75	6.93	12.5
83	91	99	100			174	65	2.68	6.26
51	56	66	79	92	100	109	50	2.18	5.91
						132	58	2.30	3.75
71	86	96	99	100		273	70	3.90	8.72
93	96	99	100			214	67	3.19	8.04
78	85	90	97	100		294	70	4.20	9.69
78	87	94	100			343	70	4.90	10.9

TABLE 4. - Average particle-size distribution of surface bed material used

[Methods of analysis: sieve, optical, particle count]

Stream	Number of samples	Particle size: Percentage finer than size (millimeters) indicated												
		0.062	0.125	0.250	0.500	1.00	2.00	4.00	8.00	16.0	32.0	64.0	128	256
		Sand						Gravel				Cobble		
Santa Clara River at Los Angeles-Ventura County line (flood channel)	3	4	8	20	45	64	76	82	87	92	97	100		
Santa Clara River at Los Angeles-Ventura County line (main channel)	3	-	-	5	35	74	94	99	100					
Santa Clara River at Montalvo	4	-	1	5	28	56	74	86	93	97	99	100		
Sespe Creek near Fillmore	3	1	3	7	14	23	35	49	64	77	89	97	99	100

Sediment-Discharge Relations

Sediment-transport relations are generally expressed as a logarithmic plot of sediment discharge versus water discharge. The relations between daily values of suspended-sediment and water discharge for the period studied are shown in figures 9-11. The curve drawn represents the average value of suspended-sediment discharge for individual ranges of water-discharge values listed in table 5. Large variations in sediment transported at similar streamflows for different years might be expected as the basin becomes altered by nature and man's activity. However, the plots of suspended-sediment data for the periods studied indicate no discernible change in relation for any of the stations. The large variation in suspended-sediment discharge at the Montalvo site (fig. 10) for water discharges less than 6 ft^3/s resulted partly from temporary sluicing at gravel-mining areas during 1972 and 1973. Sediment-transport curves defining the relation between water discharge and suspended-, unsampled- , and total sediment discharges are illustrated in figures 12-14. The relations between coarse-sediment discharge and water discharge at each station are shown in figures 15-17.

The computed total sediment discharge (based on the sediment transport curves shown in figures 12-14) versus the daily total sediment discharge loads (including measured quantities) differed by 1.3 percent for the Santa Clara River at the Los Angeles-Ventura County line, 0 percent for the Santa Clara River at Montalvo, and 0.8 percent for Sespe Creek near Fillmore (table 6). Table 6 indicates that suspended-sediment discharge is extremely variable from year to year. This variability occurs because annual sediment discharge is dependent on the number, intensity, and duration of the few storms that occur each year and which result in most sediment being transported in a few days each year. At the Montalvo station (1968-75 water years), approximately 55 percent of the total sediment was transported in two days and 92 percent was transported in 53 days.

Streambed Changes

Because of streambed fluctuations during the extreme high flows of the 1969 water year, further qualification of data selection was helpful at two of the study sites.

Significant deposition occurred at the Sespe Creek station during 1969 (fig. 18). Gradual downcutting and a general coarsening of the low-to-medium flow channel bed has since resumed. The bed-material size distribution for November 22, 1967, and September 30, 1975, as determined by optical, sieve, and particle count, varied somewhat with the composite distribution used. However, if 1928-75 sediment-discharge estimates were based on either the November 1967 or September 1975 size distribution, less than a 2-percent difference would result in the total coarse-sediment discharge. The deposition of sediment caused a transitional shift in channel hydraulics (below 10,000 ft^3/s) for the period 1969-75. If hydraulic properties representative of pre-1969 conditions were applied over the long-term period, the quantity of coarse-sediment transport would be reduced by an estimated 10 percent of the total sediment discharge. However, because streambed changes are somewhat cyclic (fig. 18) and are a continuing process, the given sediment-discharge values are assumed to be representative of the long-term period.

Evaluation of the coarse-sediment discharge of the lower Santa Clara River was particularly complex because bedload rates were different at the two sites on which the 1969 water-year records are based. Hydraulic evaluation of the Saticoy site indicates higher mean velocities and shallower depth (at equal water-discharge values) than at the Montalvo site. Hydraulic characteristics at Montalvo were determined from high-water measurements taken during February 1969 when the Saticoy bridge was out. Discharge of fine sediment (finer than 0.062 mm) was assumed to be similar at the two sites.

Bed-material particle-size distribution (fig. 19) indicates a wide deviation between sieve and optical size analyses of the samples taken during the 1969 water year at Saticoy. Agreement is fair for sieve-analysis comparison at the two sites, however. The deviation is easily explained as the difference in the method of bed-material analysis. Optical size analysis by photographs considers only the particle volume of the surface layer. Once threshold velocities are reached for particle movement on this armored layer, the remaining bed material becomes similar to the bed material at Montalvo.

The competency of discharge to transport bed material at these two sites is inferred by the bedload-transport relations of figure 20. Moderate discharges in the Saticoy reach dislodge little bed material, allowing the stream to exercise its sediment-carrying capability elsewhere in the channel reach. The natural process of sorting and subsequent armoring may lower the streambed if upstream material fails to replenish a site. Such was apparently the case as degradation continued at a rate of 1 ft/yr during the period 1944-76 at the Southern California Gas Co. pipeline crossing 1 mi upstream from the Saticoy station, according to Leeds, Hill, and Jewett, Inc. (1976). This detailed report directly attributed local channel scour (and erosion of the northwest bank) to upstream and downstream sand- and gravel-mining operations.

If it is assumed that local channel change was caused by gravel and sand extraction, several rates can be estimated. The net reduction in streambed volumes was computed by using the longitudinal and cross-sectional data of the above report for surveys made in 1951, 1967, and 1976. Conversion of the volume of coarse sediment to weight units indicated an average sediment removal of 75,000 ton/yr during the 1951-67 water years and 400,000 ton/yr during the 1968-73 water years. The conversion was based on an assumed unit weight of 90 lb/ft^3 for coarse sediment (Gottschalk, 1964, p. 17-18). During the 1974-76 water years, deposition of coarse sediment in the gravel-mining areas exceeded the quantity of sediment removed by mining. The average net deposition for 1974-76 was estimated to have been 110,000 ton/yr.

The average rates of gravel mining during the periods 1953-75 and 1928-75 were estimated to have been 144,000 and 72,000 ton/yr.

Long-Term Sediment Discharge

A short-term sediment record can be extended to represent long-term sediment discharge, based on long-term streamflow data, if an adequate relation between sediment discharge and water discharge can be established.

Long-term mean sediment discharges at the three sites were estimated (table 7) by applying the previously developed short-term relations between water and sediment discharges to the long-term streamflow at each site.

From the estimated mean annual sediment discharges shown in table 7, the estimated mean daily sediment discharge during the period 1953-75 for the Santa Clara River at the Los Angeles-Ventura County line was 1,840 tons; the coarse-sediment discharge was 950 tons. The estimated mean daily total sediment discharge during the period 1950-75 for the Santa Clara River at Montalvo was 9,720 tons; the coarse-sediment discharge was 2,960 tons. The estimated mean daily total sediment discharge for 1928-75 for Sespe Creek near Fillmore was 2,900 tons; the coarse-sediment discharge was 1,540 tons.

The quantity of sediment transported by the Santa Clara River at Montalvo is reduced a small amount by flows diverted at Saticoy. These flows are generally diverted during periods of low flow and low sediment concentration for irrigation and ground-water recharge. It is estimated that diverted sediment averaged about 15,000 ton/yr during the period 1953-75 and 8,600 ton/yr during the period 1928-75. The composition of this sediment is assumed to have been largely silt- and clay-sized material.

The average discharge and sediment relations used (figs. 9-17) are probably representative of existing and past sediment yields; however, as continued physical changes occur (urbanization, road building, reservoir construction, gravel mining, major fires, or increased agriculture), these developed sediment relations may also significantly change.

TABLE 5. - Relation and frequency of occurrence of water and suspended-sediment discharge

Range in water discharge (ft^3/s)	Number of daily occurrences	Average water discharge (ft^3/s)	Average suspended-sediment discharge (tons)
Santa Clara River at Los Angeles-Ventura County line, 1969-75			
<0.01	0	0	0
0.01- .10	0	0	0
.10- 1.0	14	.72	.09
1.0 - 10	377	6.79	5.30
10 - 40	1,697	19.9	29.5
40 - 100	254	56.6	161
100 - 300	152	166	1,140
300 - 700	34	428	7,700
700 - 1,000	9	838	16,700
1,000 - 4,000	13	1,900	72,000
4,000 - 7,000	3	4,660	255,000
7,000 - 10,000	0	--	--
10,000 - 30,000	3	23,700	2,610,000
Santa Clara River at Montalvo, 1968-75			
<0.01	1,049	0	0
0.01- 1.0	891	.22	[1].24
1.0 - 3.3	309	2.07	[1]5.54
3.3 - 6.0	75	4.27	[1]16.7
6.0 - 10	125	8.41	1.63
10 - 40	133	16.14	6.38
40 - 100	57	63.19	53.4
100 - 400	90	210	544
400 - 1,000	85	675	2,720
1,000 - 1,300	27	1,130	9,710
1,300 - 2,000	28	1,610	20,800
2,000 - 4,000	24	2,940	82,300
4,000 - 8,000	15	5,890	200,000
8,000 - 20,000	8	11,900	806,000
20,000 - 40,000	4	26,800	3,050,000
40,000 - 70,000	0	--	--
70,000 -100,000	2	83,300	17,400,000

[1]Average suspended-sediment discharge includes data obtained during temporary sluicing at gravel-mining areas in 1972 and 1973.

TABLE 5. - Relation and frequency of occurrence of water and suspended-sediment discharge--Continued

Range in water discharge (ft^3/s)	Number of daily occurrences	Average water discharge (ft^3/s)	Average suspended-sediment discharge (tons)
Sespe Creek near Fillmore, 1967-75			
<0.01	0	0	0
0.01- 3.8	942	1.17	.03
3.8 - 7.0	256	5.42	.18
7.0 - 10	150	8.43	.33
10 - 15	179	12.4	.46
15 - 30	469	21.1	1.20
30 - 70	553	46.5	4.69
70 - 100	147	82.0	37.0
100 - 150	145	121	42.3
150 - 300	179	206	118
300 - 600	141	405	598
600 - 1,000	51	794	1,390
1,000 - 3,000	43	1,660	17,700
3,000 - 6,000	21	4,150	92,200
6,000 - 10,000	4	7,520	308,000
10,000 - 20,000	4	16,400	1,040,000
20,000 - 30,000	3	24,100	2,040,000

TABLE 6. - Annual water and sediment discharge in the Santa Clara River basin

Year	Water discharge (cfs-days)	Sediment discharge, in tons: Suspended sediment	Unsampled sediment	Fine sediment	Coarse sediment	Total sediment
	11108500--Santa Clara River at Los Angeles-Ventura County line					
1969	128,000	9,180,000	1,620,000	5,300,000	5,500,000	10,800,000
1970	12,100	74,000	51,000	56,800	68,200	125,000
1971	11,400	334,000	63,000	272,000	125,000	397,000
1972	7,930	59,600	30,400	47,200	42,800	90,000
1973	28,600	454,000	201,000	237,000	418,000	655,000
1974	12,100	65,600	65,400	10,000	121,000	131,000
1975	8,080	27,600	30,000	16,500	41,100	57,600
1969-75	208,210	10,194,800	2,060,800	5,939,500	6,316,100	12,255,600
	11114000--Santa Clara River at Montalvo					
1968	4,930	75,700	16,800	69,600	22,900	92,500
1969	448,000	50,500,000	2,800,000	39,100,000	4,200,000	53,300,000
1970	26,300	664,000	115,000	527,000	252,000	779,000
1971	33,600	2,410,000	170,000	2,016,000	564,000	2,580,000
1972	15,000	476,000	70,000	416,000	130,000	546,000
1973	101,000	4,310,000	550,000	3,020,000	1,840,000	4,860,000
1974	31,600	493,000	128,000	281,000	340,000	621,000
1975	26,400	536,000	152,000	364,000	324,000	688,000
1968-75	686,830	59,464,700	4,001,800	45,793,600	17,672,900	63,466,500
	11113000--Sespe Creek near Fillmore					
1967	77,500	677,000	423,000	426,000	674,000	1,100,000
1968	10,500	20,600	6,300	18,400	8,500	26,900
1969	234,000	9,510,000	5,190,000	6,000,000	8,700,000	14,700,000
1970	26,600	304,000	136,000	216,000	224,000	440,000
1971	32,300	553,000	194,000	440,000	307,000	747,000
1972	13,700	77,700	31,300	57,800	51,300	109,000
1973	80,100	2,850,000	980,000	2,230,000	1,600,000	3,830,000
1974	26,100	137,000	70,000	99,000	108,000	207,000
1975	31,600	258,000	146,000	166,000	238,000	404,000
1967-75	532,400	14,387,300	7,176,600	9,653,200	11,910,700	21,563,900

TABLE 7. - Estimated long-term coarse-sediment discharge of the Santa Clara River basin, various periods

Station	Period	Estimated sediment discharge, in tons per year				
		Suspended sediment	Unsampled sediment	Fine sediment	Coarse sediment	Total sediment
Santa Clara River at Los Angeles-Ventura County line	1953-75	542,000	131,000	325,000	348,000	673,000
Santa Clara River at Montalvo	1950-75	3,400,000	150,000	2,470,000	1,080,000	3,550,000
	1953-75	3,600,000	250,000	2,700,000	1,150,000	3,850,000
Sespe Creek near Fillmore	1928-75	729,000	331,000	496,000	564,000	1,060,000
	1953-75	1,000,000	430,000	656,000	774,000	1,430,000

ESTIMATED SEDIMENT BUDGET FOR THE SANTA CLARA RIVER BASIN

An attempt was made to estimate the annual sediment budget for the Santa Clara River basin for two periods, 1953-75 and 1928-75 (table 8).

The period 1953-75 is representative of basin conditions when the Santa Clara River was affected by dams, diversions, and gravel mining. Sediment discharges were estimated on the basis of records of daily streamflow and relations of daily water discharge versus daily sediment discharge.

The period 1928-75 is representative of historical basin conditions. Sediment discharges for 1928-52 were estimated by applying annual sediment-transport relations for periods of available sediment record (1967-75) to annual values of natural flow given in table 2 (Taylor and others, 1977, p. 47-70). Estimated sediment discharge for 1928-52 (natural flow) and 1953-75 (controlled flow) were combined to obtain the long-term historical sediment discharge.

The sediment budget for both periods is generally based on the following assumptions:

1. Sediment discharge for the 292-mi^2 ungaged area was equivalent to the difference between sediment discharge at Montalvo and the sum of sediment discharges for upstream stations and sediment losses;
2. Adjustment of downstream flows due to the operation of Castaic Reservoir was insignificant for the base periods (1953-75, 1928-75);
3. Any increase in downstream sediment concentration owing to clear-water releases from Lake Piru was small for the base periods;
4. Annual sediment yield for the basin upstream from Lake Piru was directly proportional to that for the Sespe Creek basin.

An evaluation of the validity of these assumptions is beyond the scope of this report. Inconsistencies in individual budget values can be verified or substantiated only by a more comprehensive study of the basin and by the collection of additional data. Nevertheless, the estimated sediment discharges given in table 8 allow some useful observations on the nature of sediment transport in the basin and put into perspective the availablility of sediment at different sites and the net loss of sediment to reservoirs and gravel mining.

Estimated data in table 8 indicate that the natural sediment discharge of the Santa Clara River basin (1928-75) was 4.03 million ton/yr, excluding sediment lost to dams, gravel mining, and flow diversion. Estimated sediment losses were prorated over the historical periods 1953-75 and 1928-75. These losses included 12.6 million tons of sediment trapped by dams in the Piru Creek basin (1955-75) and 700,000 tons of sediment trapped in the Castaic Creek basin (1970-75).

Sediment yields are extremely variable in different parts of the Santa Clara River basin, ranging from 900 ton/mi^2 in the eastern part to 6,100 ton/mi^2 in the western part. The large variability in sediment yield appears reasonable because of significantly higher rainfall and runoff in the western part of the basin. During the period 1928-75, annual runoff per square mile of drainage area was about eight times larger for Sespe Creek than for the upper Santa Clara River.

The major difference between natural and actual sediment discharges of the Santa Clara River basin is the sediment intercepted upstream from Santa Felicia Dam. The combined trap efficiency of Lake Piru and Pyramid Lake approaches 100 percent. Sediment deposited in these reservoirs resulted in a reduction of sediment to the Santa Clara River basin of about 6 percent during the historical period (1928-75) and 12 percent during the period most affected by dams (1953-75). Sediment losses to the basin by gravel mining, flow diversion at Saticoy, and interception of sediment in the Castaic Creek basin resulted in additonal reductions of 2 percent during 1928-75 and 4 percent during 1953-75.

TABLE 8. - Annual sediment budget for the Santa Clara River basin, 1928-75

Station name and number, or part of basin	Drainage area		Natural sediment discharge, in millions of tons						Actual sediment discharge in millions of tons					
	Square miles	Percentage of basin	1953-75			1928-75			1953-75			1928-75		
			Fine	Coarse	Total	Fine	Coarse	Total	Fine	Coarse	Total	Fine	Coarse	Total
Santa Clara River at Los Angeles-Ventura County line, 11085000	644	40	0.34	0.36	0.70	0.27	0.29	0.56	0.32	0.35	0.67	0.26	0.28	0.54
Area upstream from Santa Felicia Dam	425	26	.42	.13	.55	.48	.14	.62	.008	.002	.01	.28	.08	.36
Sespe Creek near Fillmore, 11113000	251	16	.66	.77	1.43	.50	.56	1.06	.66	.77	1.43	.50	.56	1.06
[1]Ungaged area upstream from station 11114000	292	18	1.04	.86	1.90	1.04	.75	1.79	1.04	.86	1.90	1.04	.75	1.79
Sediment loss by diversion or gravel mining	-	-	--	--	--	--	--	--	-.015	-.14	-.16	-.009	-.072	-.08
Total area upstream from Montalvo, 11114000	1612	100	3.15	1.43	4.58	2.79	1.24	4.03	2.70	1.15	3.85	2.58	1.09	3.67

[1]Fine and coarse sediment discharge based on particle-size relations for area upstream from Santa Felicia Dam and for station 11114000.

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ILLUSTRATIONS

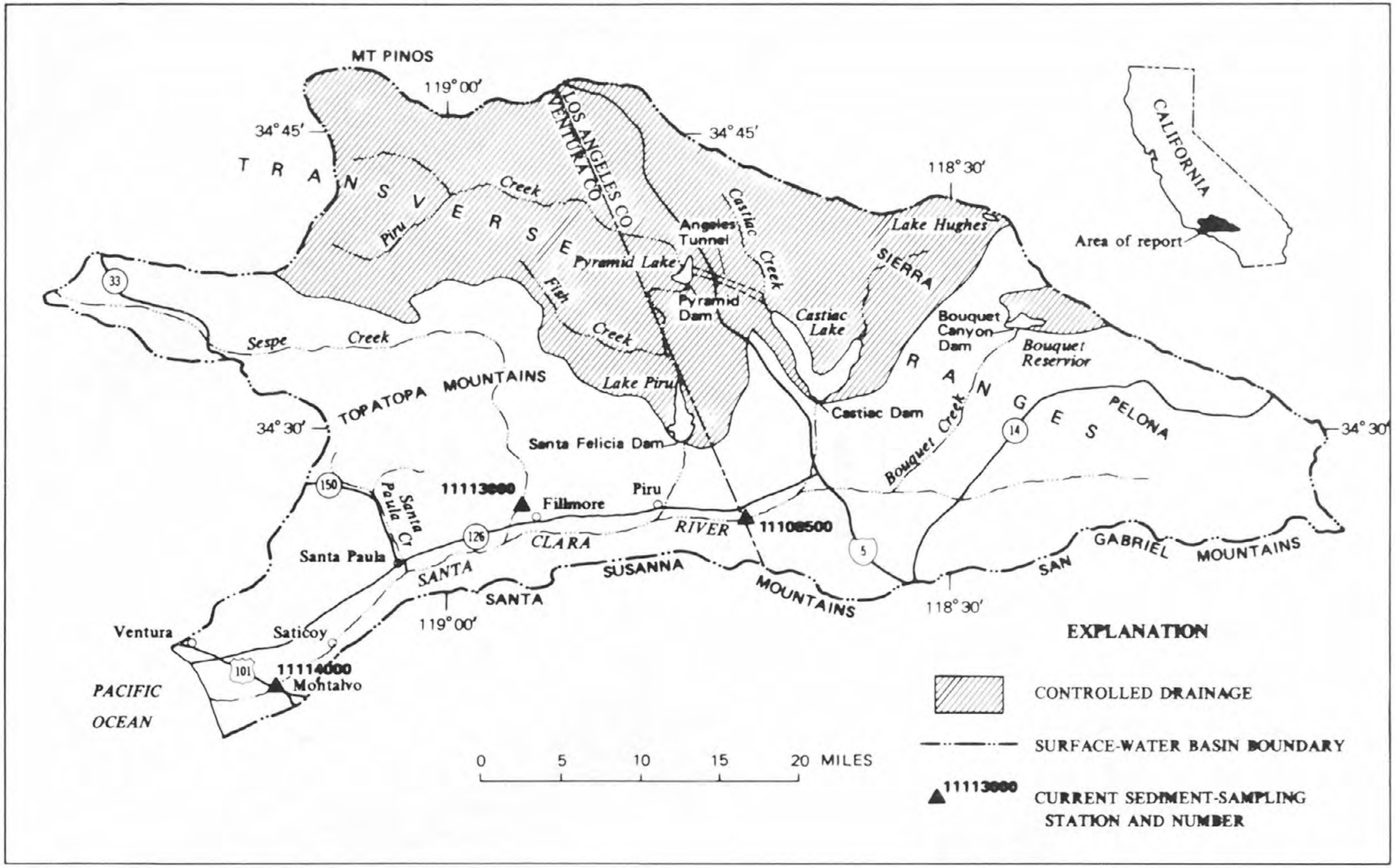

FIGURE 1.--Location of sediment-sampling stations.

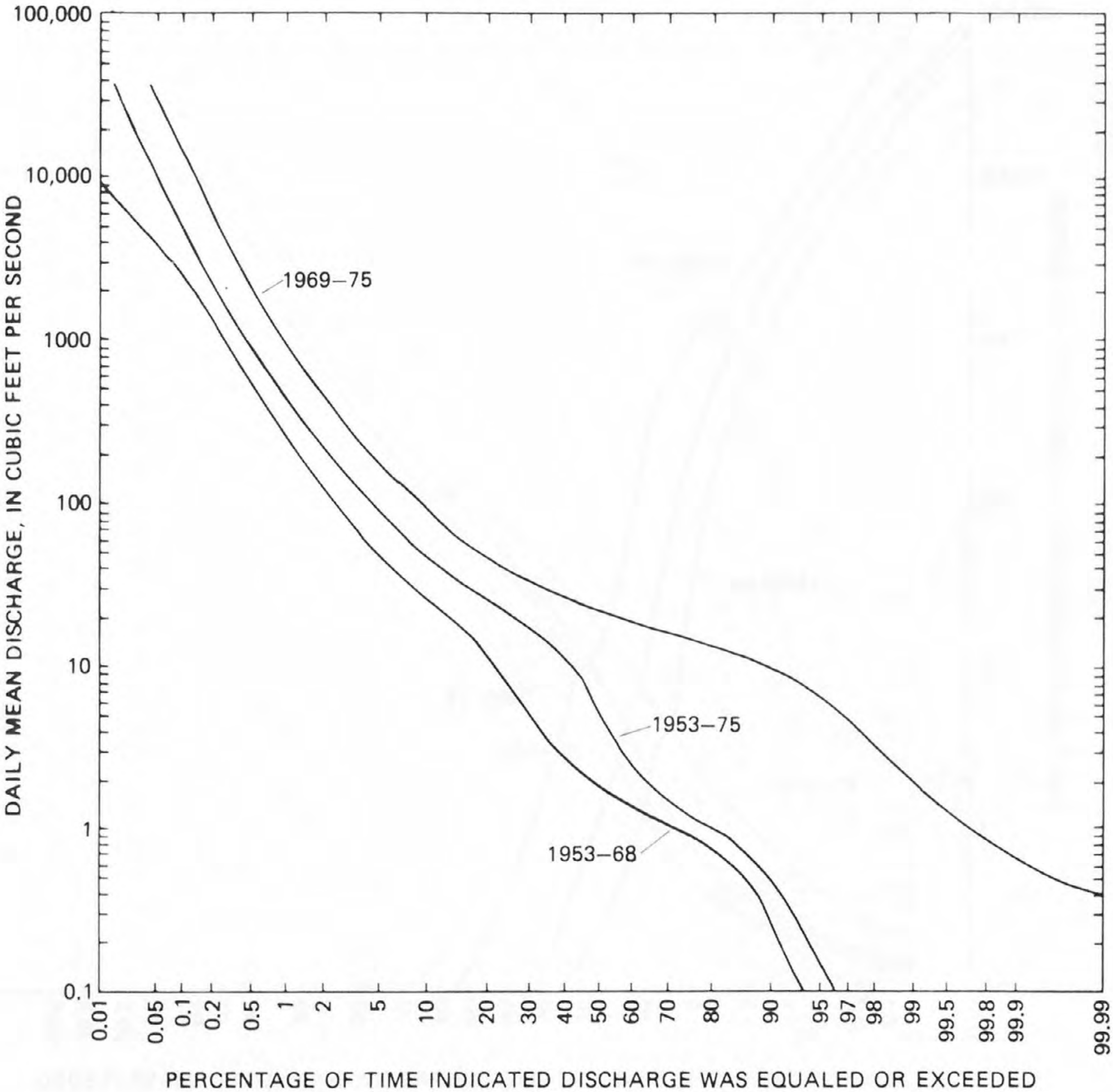

FIGURE 2.--Flow-duration curves, Santa Clara River at Los Angeles-Ventura County line (11108500).

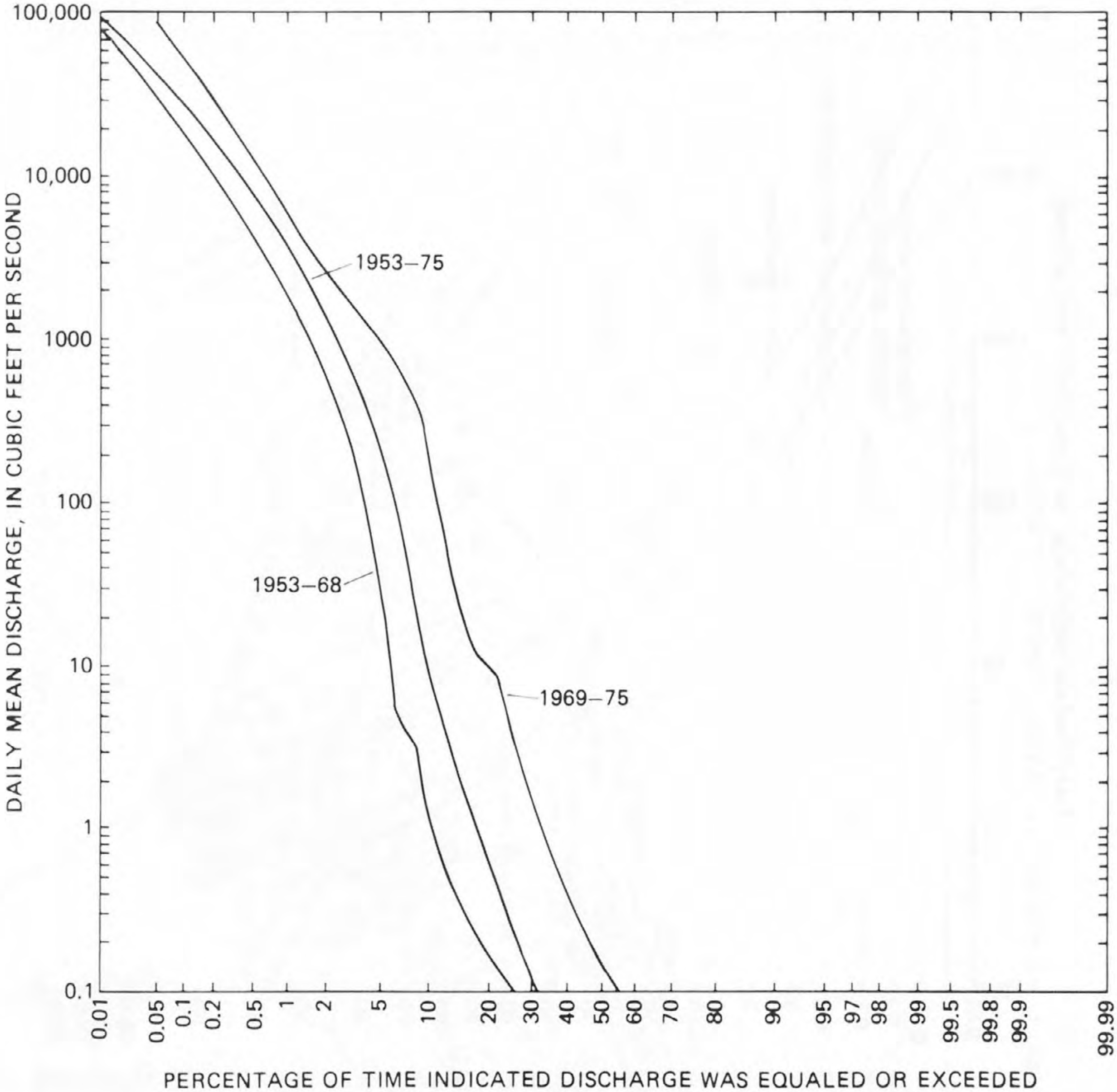

FIGURE 3.--Flow-duration curves, Santa Clara River at Montalvo (11114000).

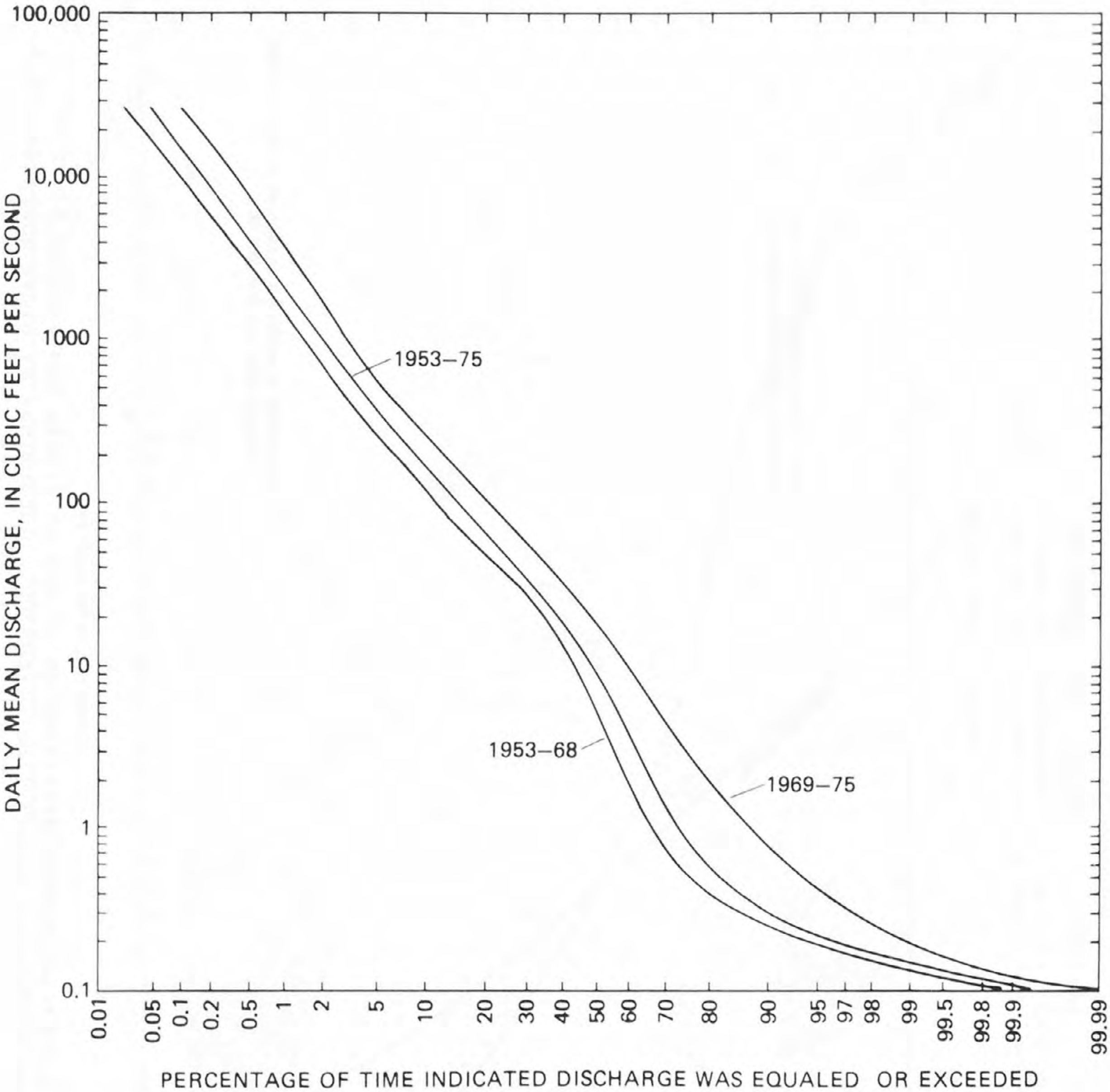

FIGURE 4.--Flow-duration curves, Sespe Creek near Fillmore (11113000).

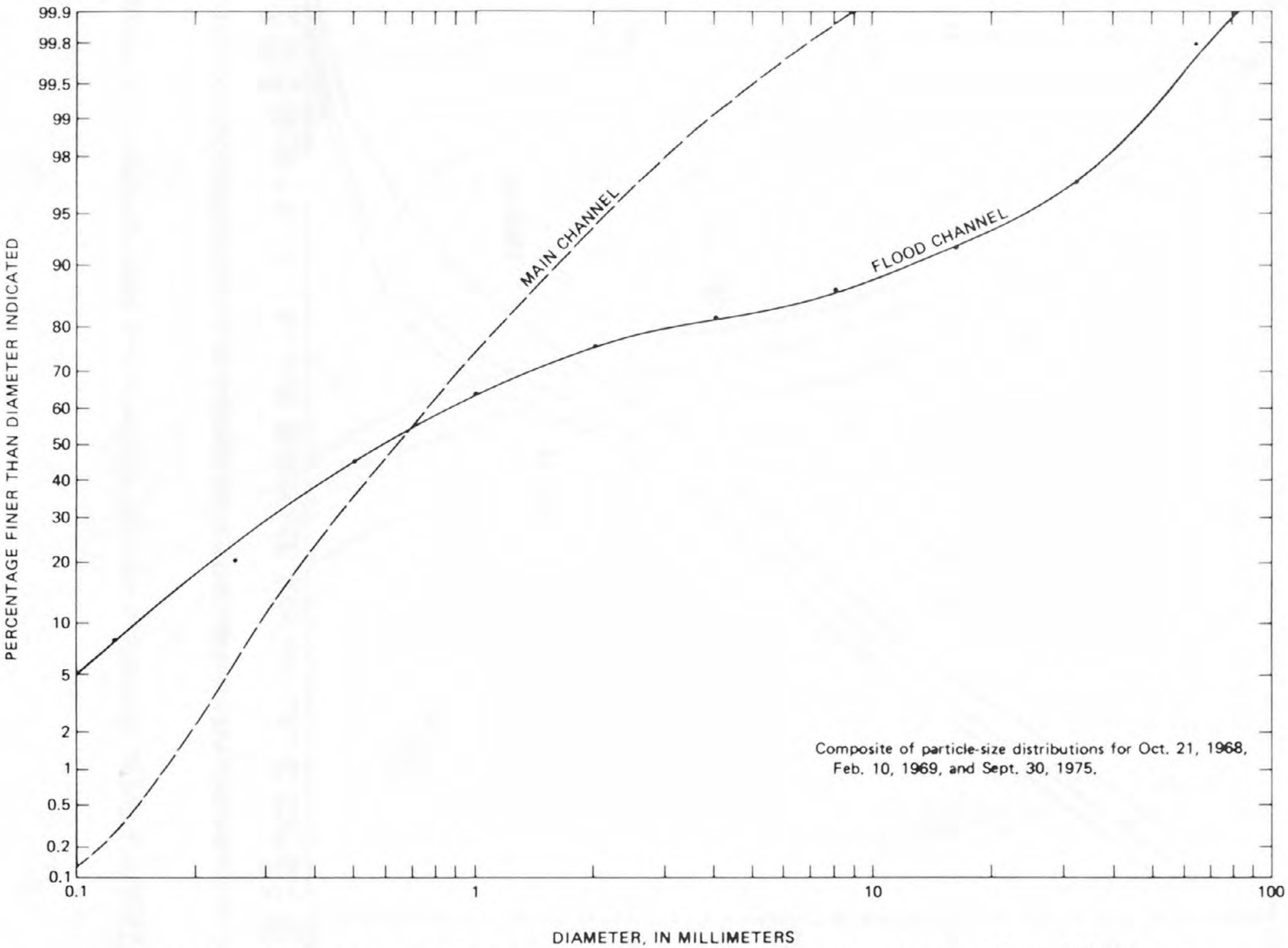

FIGURE 5.--Particle-size distribution of bed material, Santa Clara River at Los Angeles-Ventura County line (11108500), determined by sieve analysis.

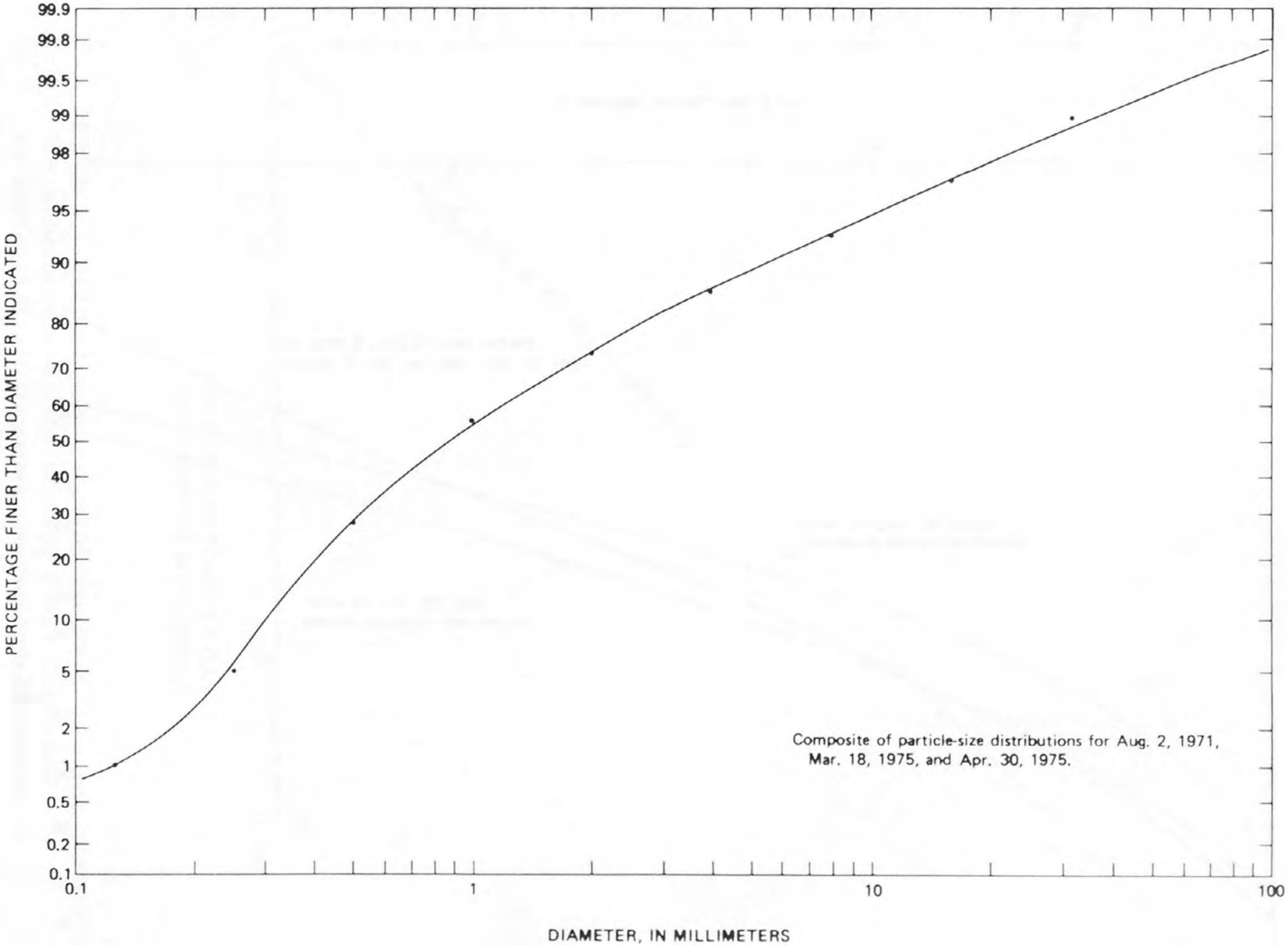

FIGURE 6.--Particle-size distribution of bed material, Santa Clara River at Montalvo (11114000), determined by sieve analysis.

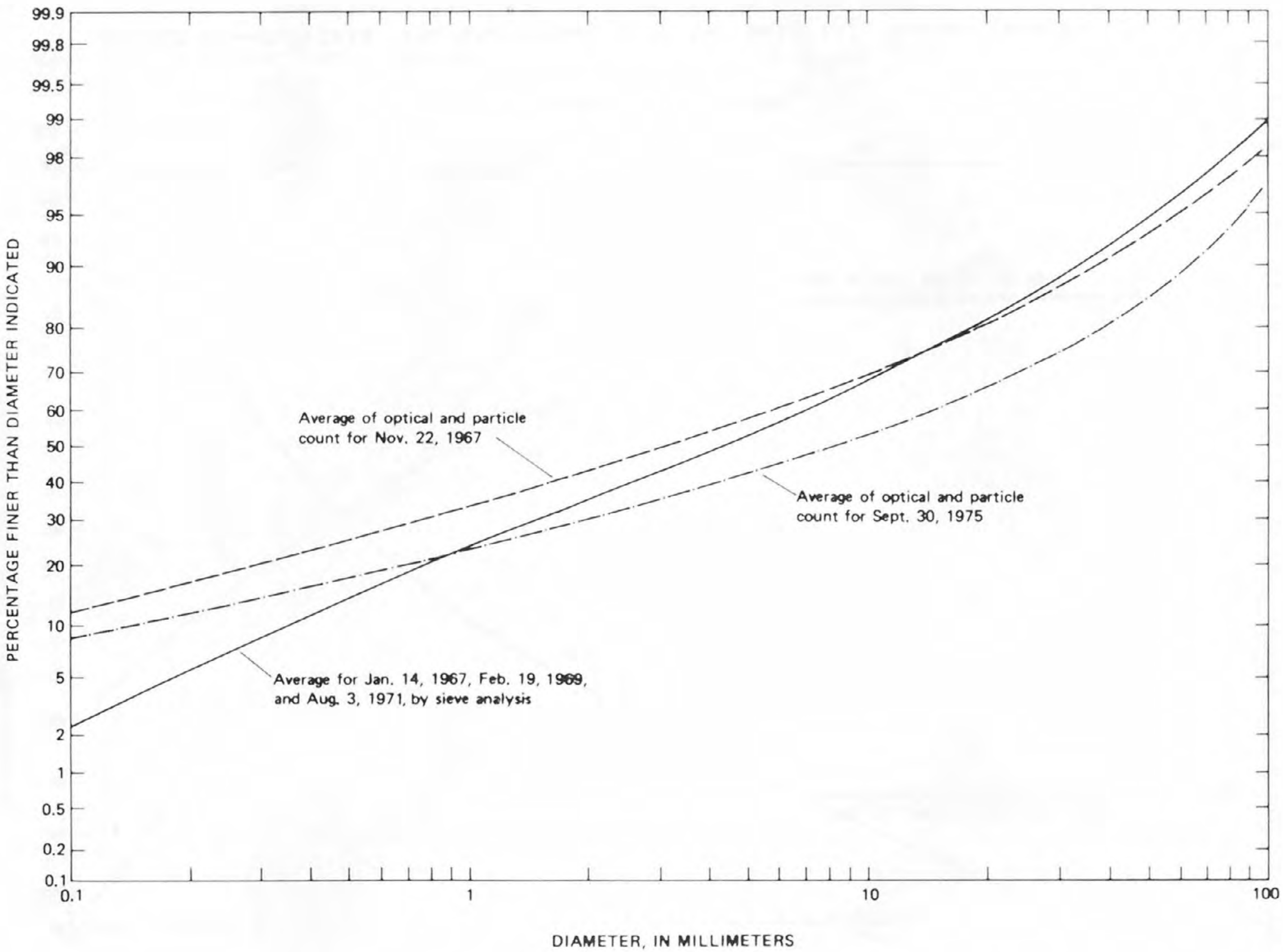

FIGURE 7.--Particle-size distribution of bed material, Sespe Creek near Fillmore (11113000), determined by optical, particle-count, and sieve analyses.

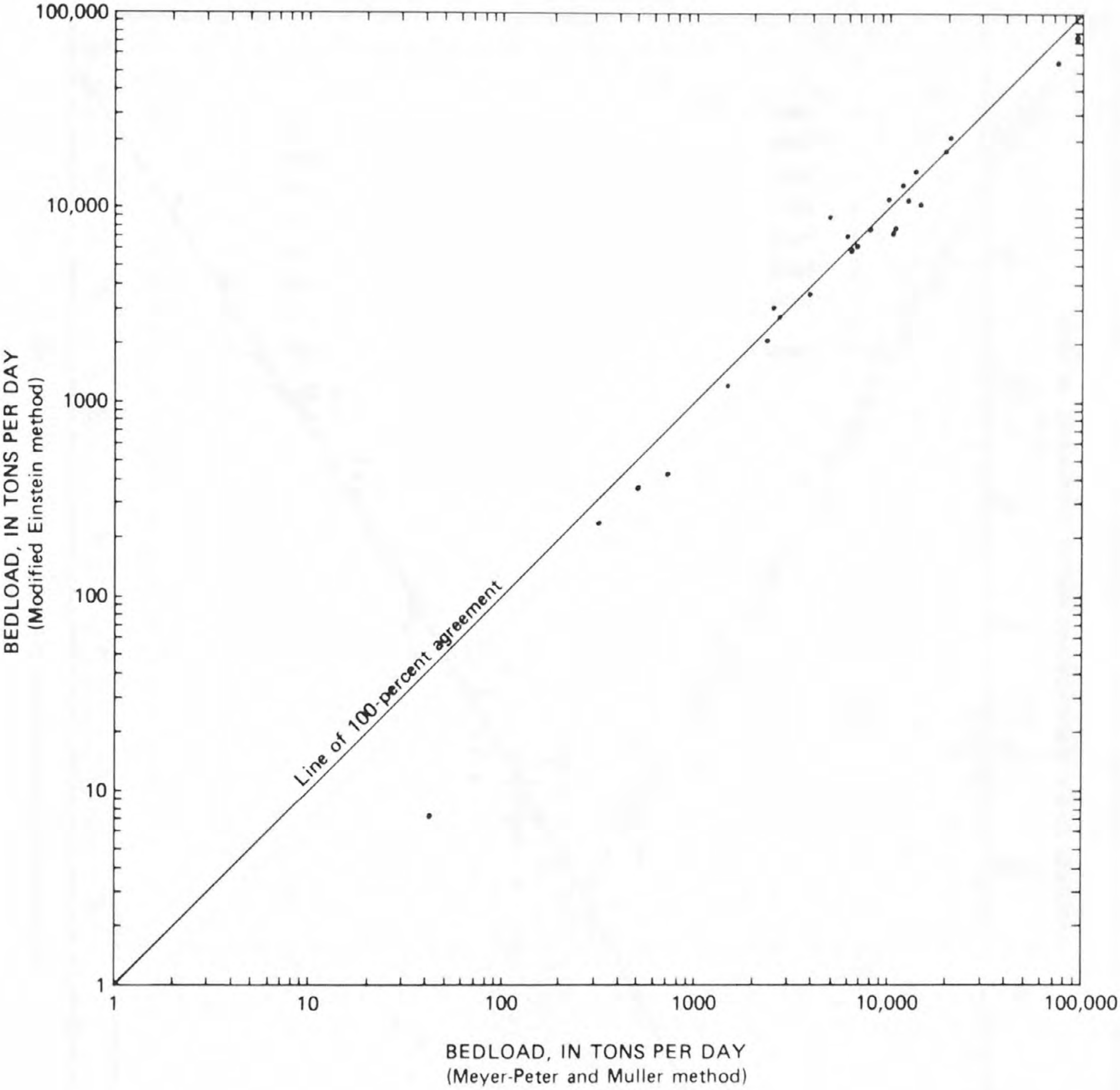

FIGURE 8.--Bedload comparison of modified Einstein method to Meyer-Peter and Muller method, Sespe Creek near Fillmore (11113000), water years 1967-75.

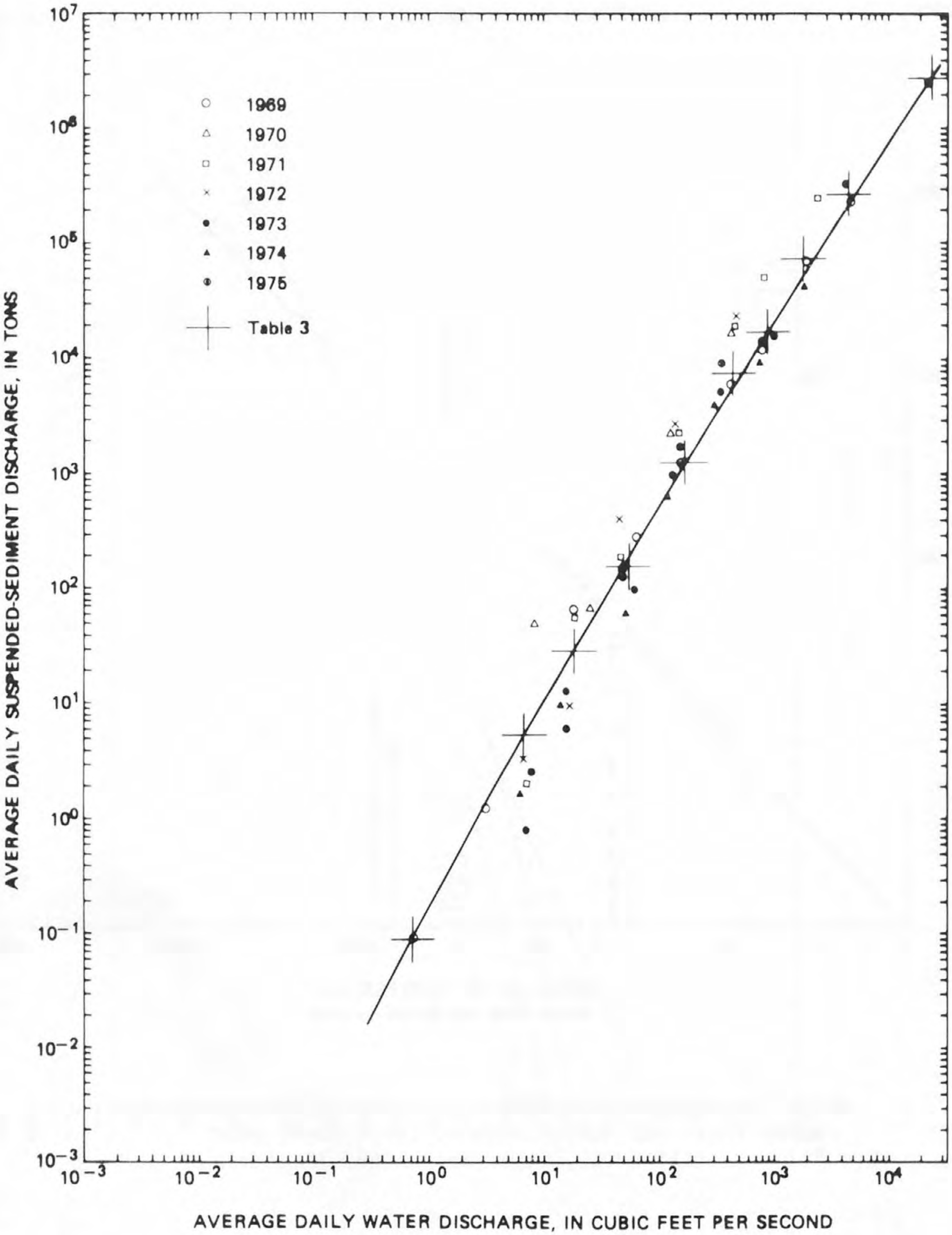

FIGURE 9.--Relation of suspended-sediment discharge to water discharge, Santa Clara River at Los Angeles-Ventura County line (11108500), water years 1969-75.

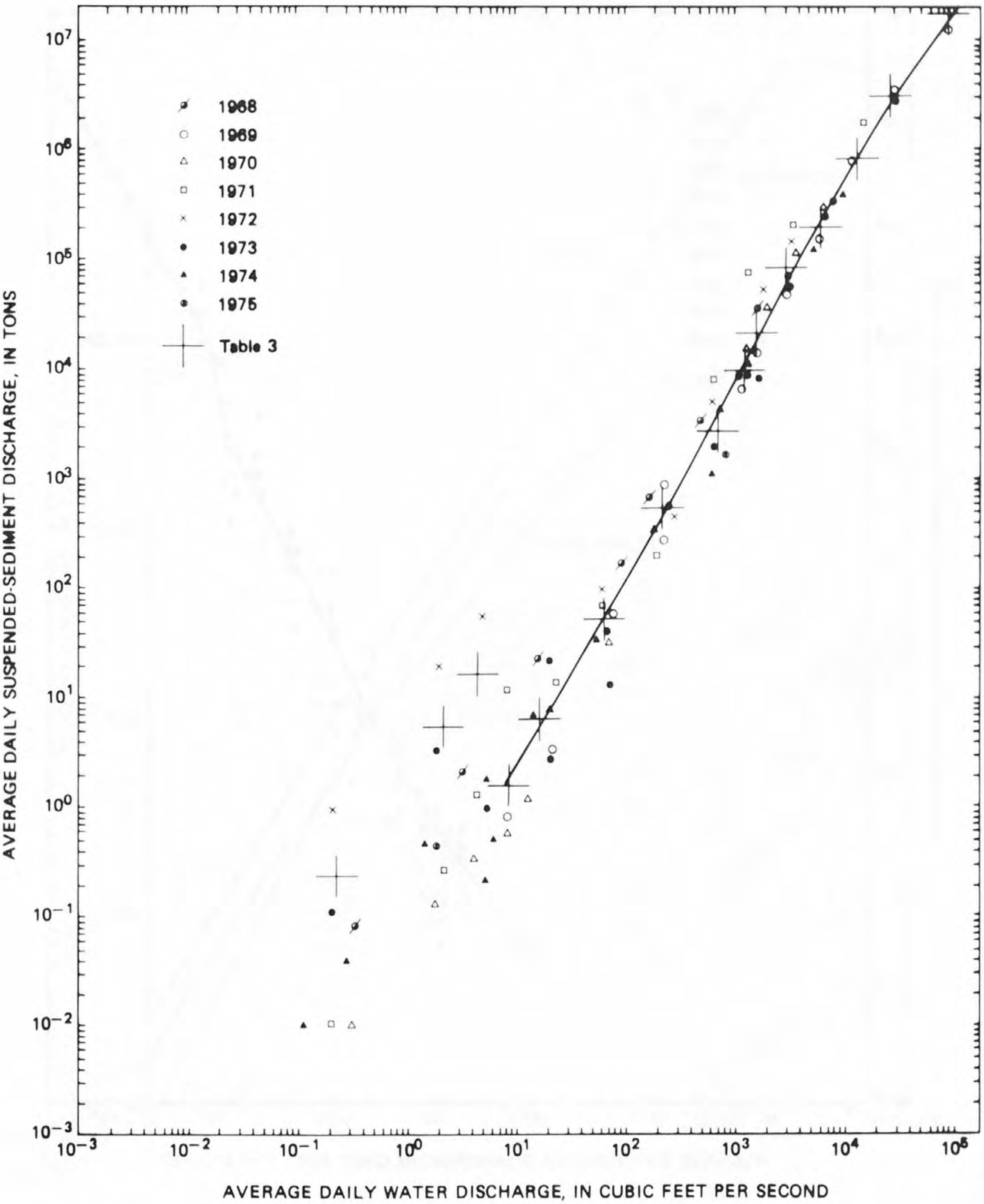

FIGURE 10.--Relation of suspended-sediment discharge to water discharge, Santa Clara River at Montalvo (11114000), water years 1968-75.

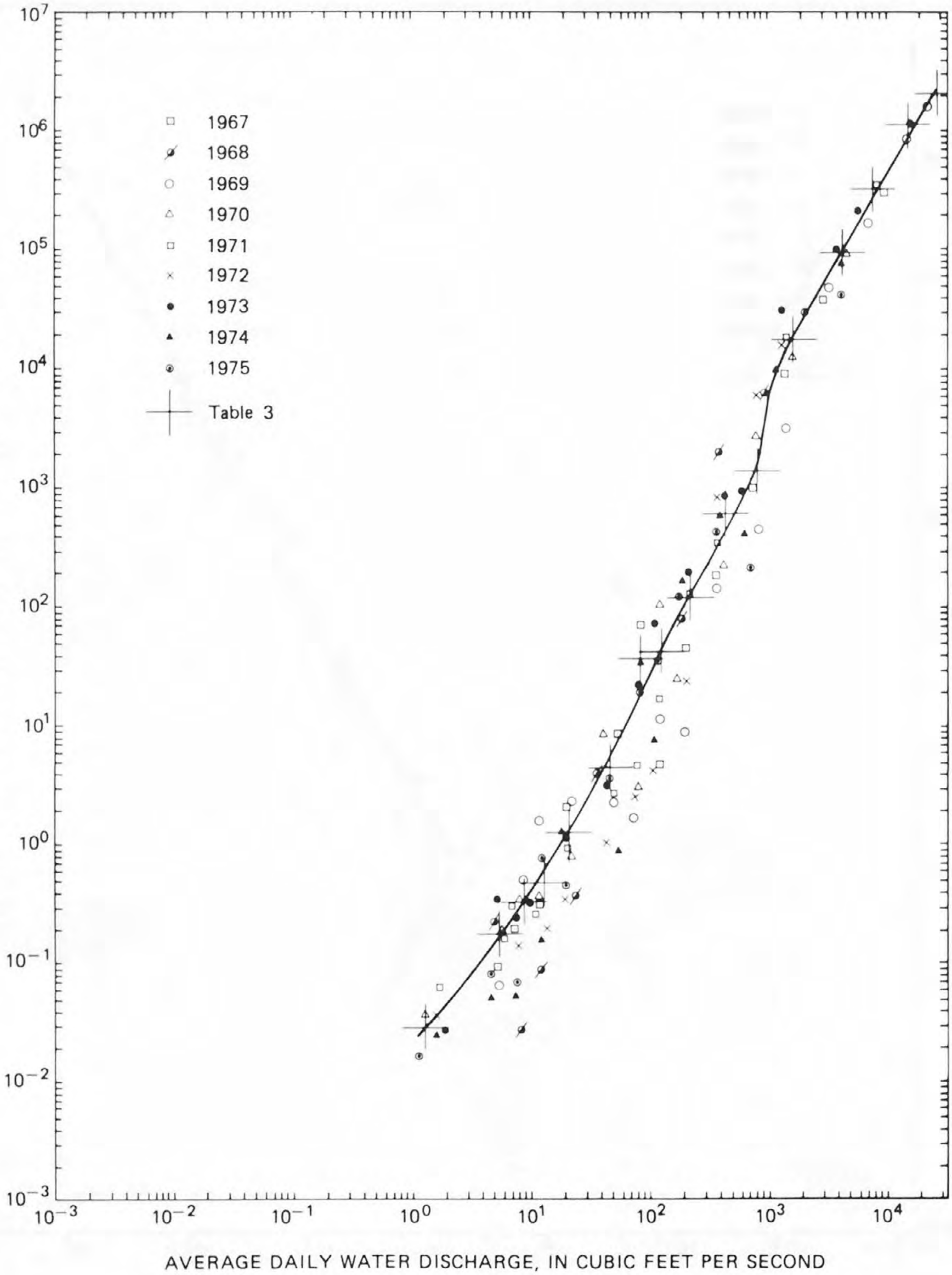

FIGURE 11.--Relation of suspended-sediment discharge to water discharge, Sespe Creek near Fillmore (11113000), water years 1967-75.

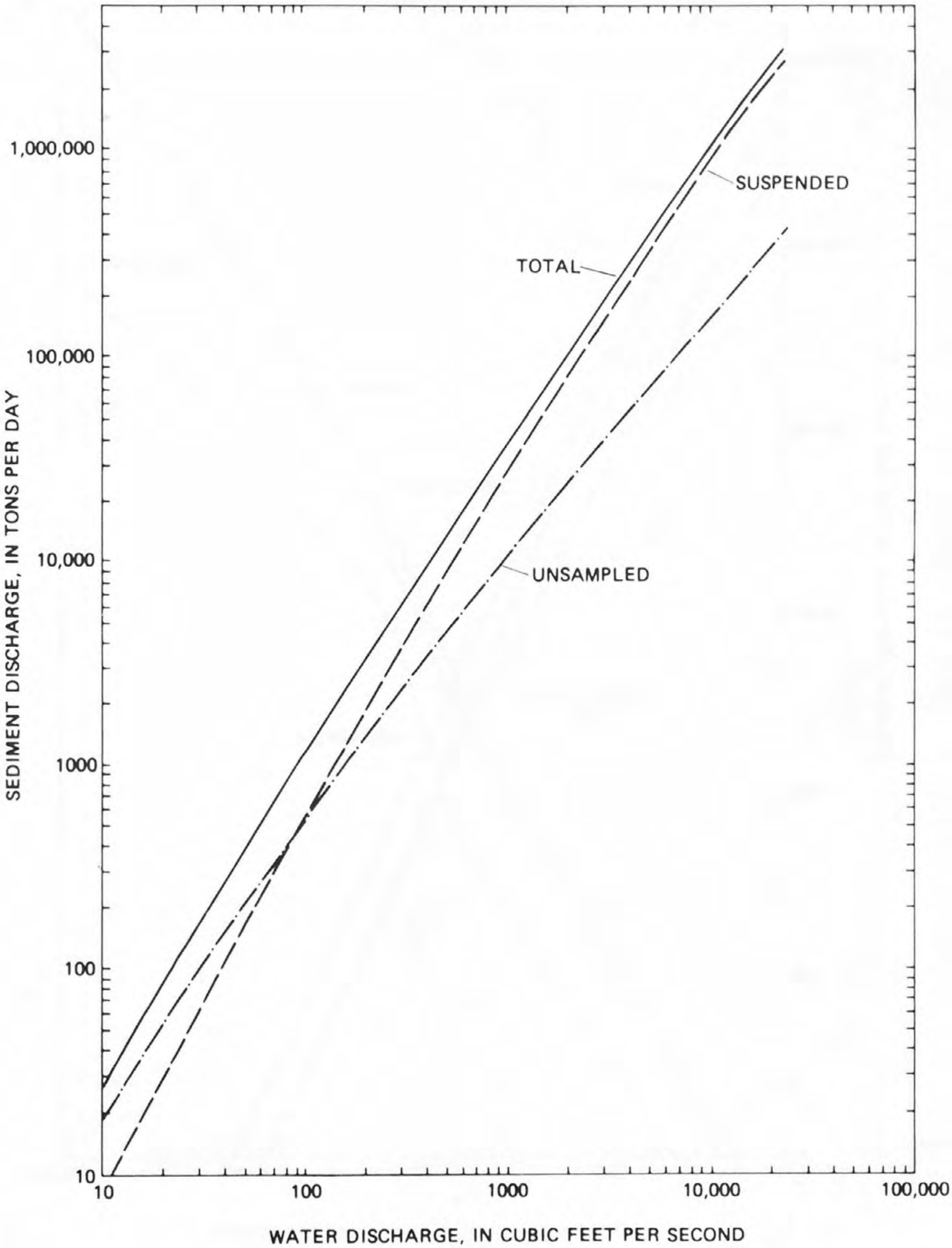

FIGURE 12.--Relation of water discharge to suspended-, unsampled, and total sediment discharges, Santa Clara River at Los Angeles-Ventura County line (11108500), water years 1969-75.

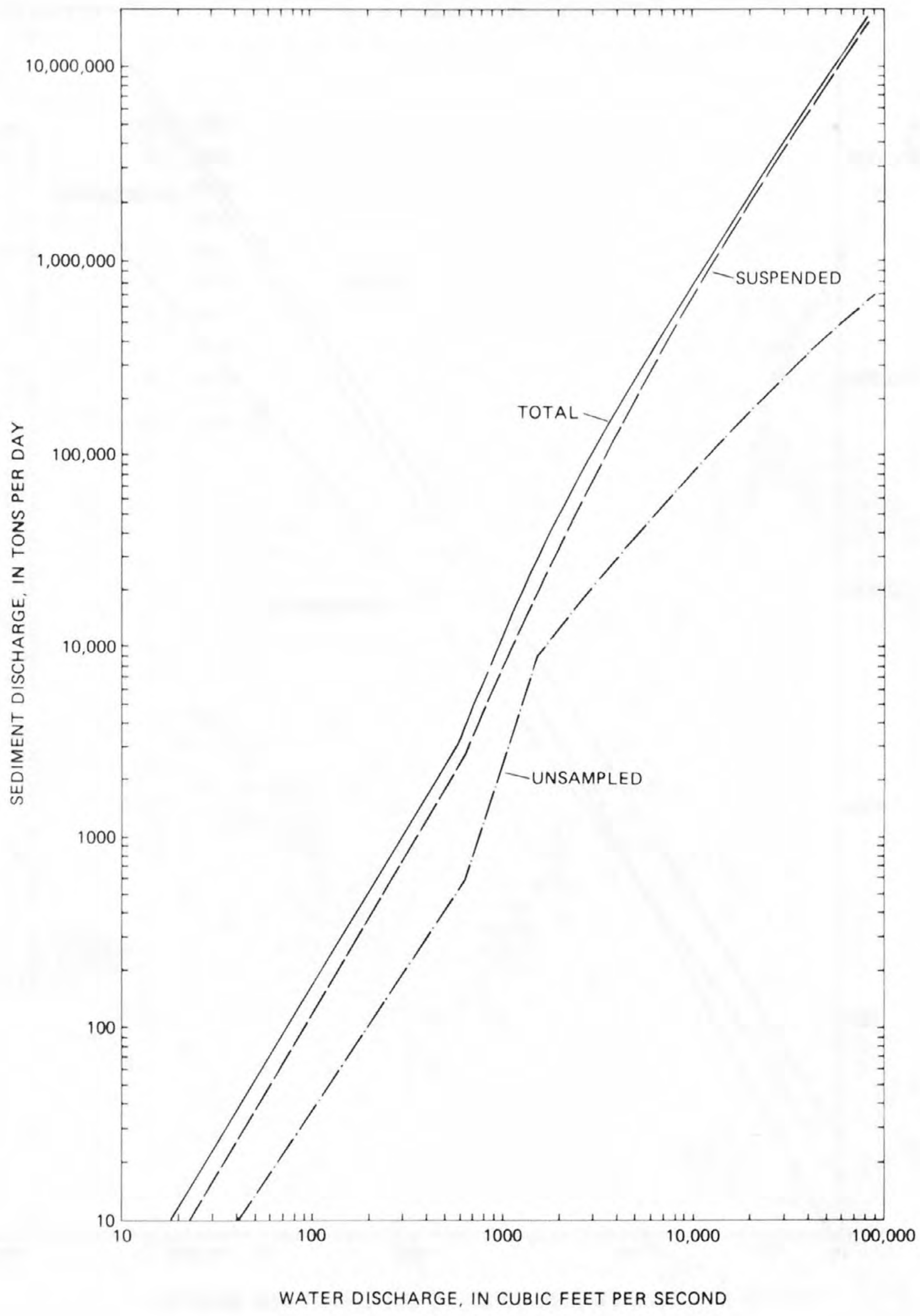

FIGURE 13.--Relation of water discharge to suspended-, unsampled, and total sediment discharges, Santa Clara River at Montalvo (11114000), water years 1968-75.

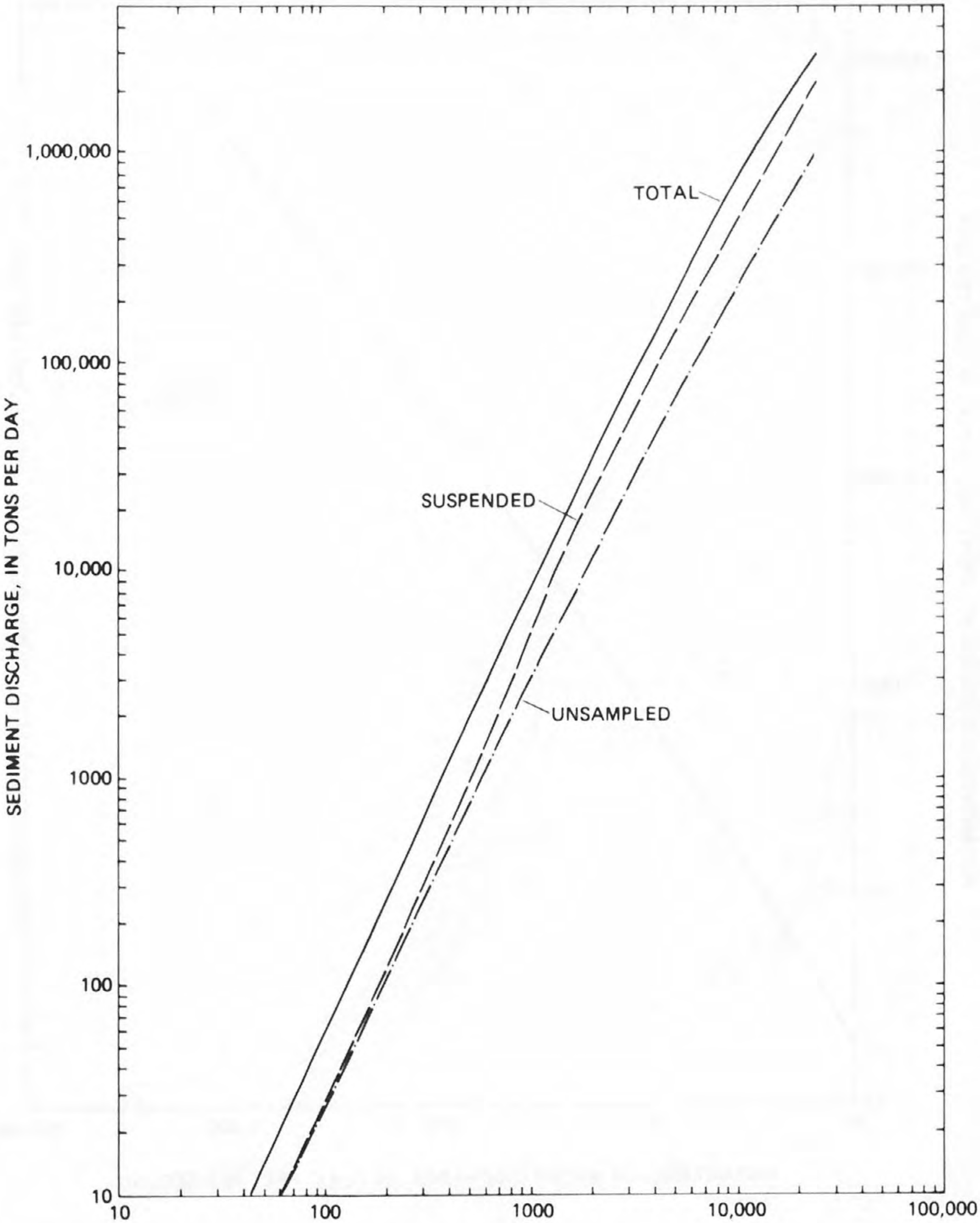

FIGURE 14.--Relation of water discharge to suspended-, unsampled, and total sediment discharges, Sespe Creek near Fillmore (11113000), water years 1967-75.

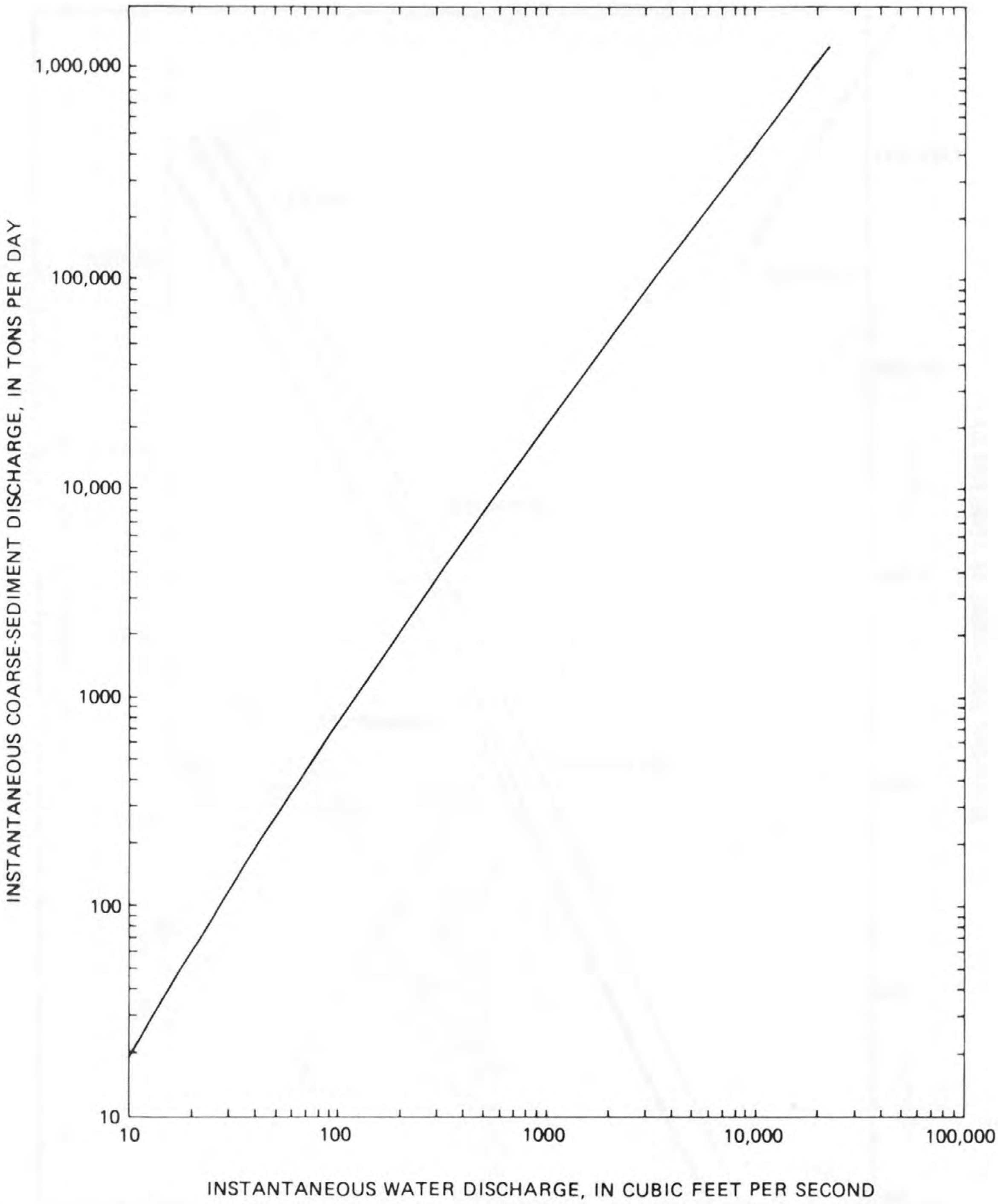

FIGURE 15.--Relation of water discharge to coarse-sediment discharge, Santa Clara River at Los Angeles-Ventura County line (11108500), water years 1969-75.

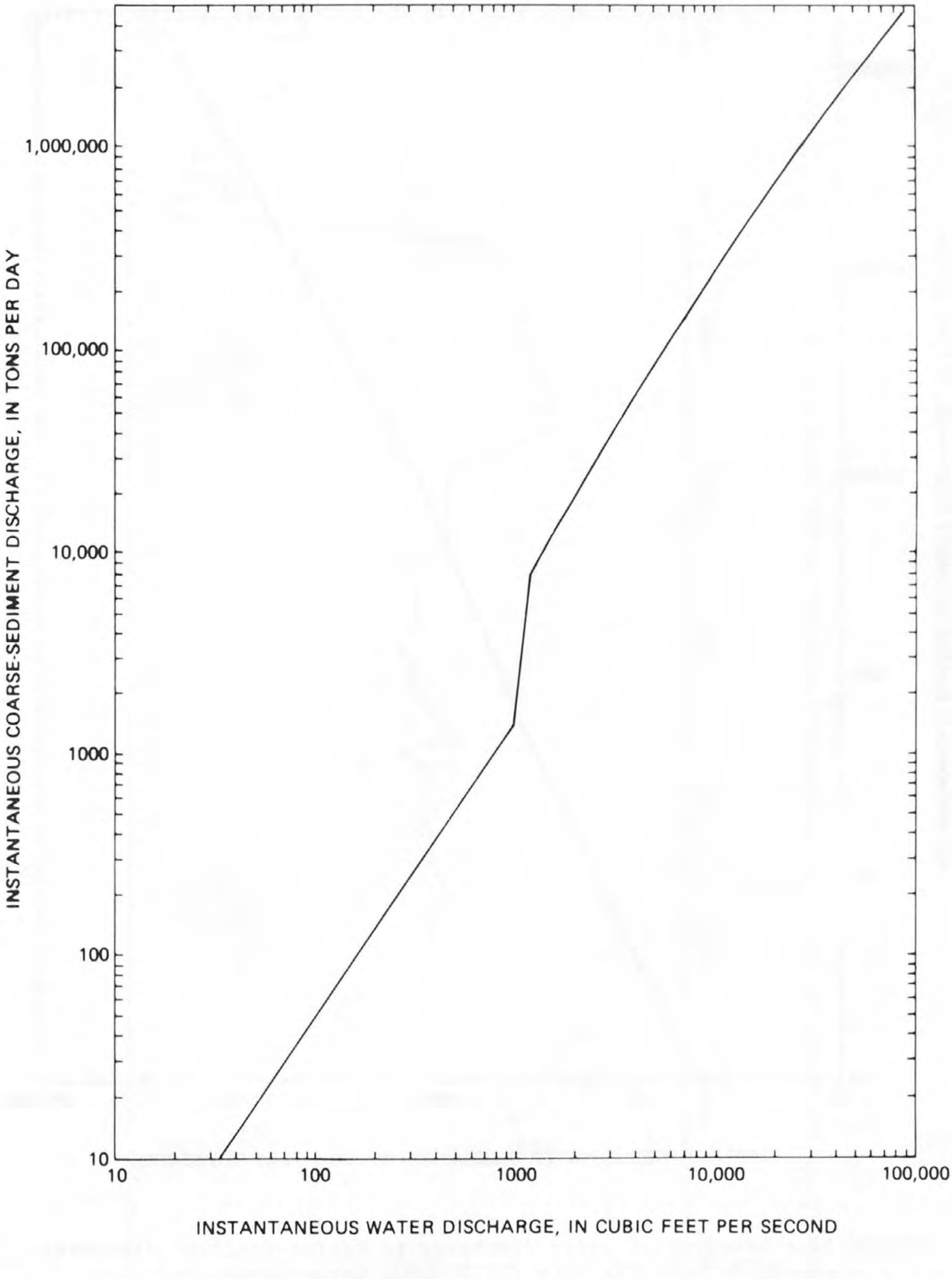

FIGURE 16.--Relation of water discharge to coarse-sediment discharge, Santa Clara River at Montalvo (11114000), water years 1968-75.

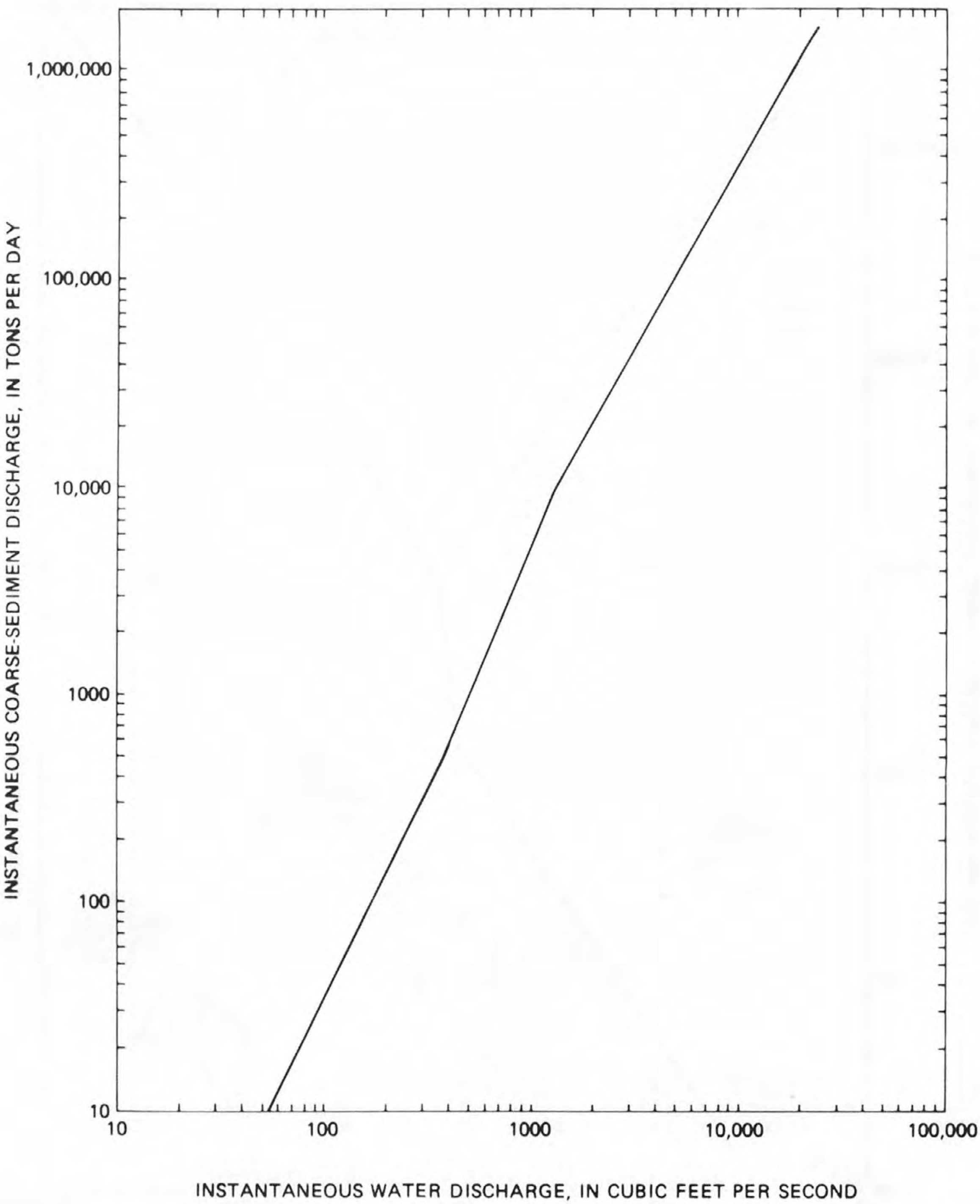

FIGURE 17.--Relation of water discharge to coarse-sediment discharge, Sespe Creek near Fillmore (11113000), water years 1967-75.

FIGURE 18.--Variation in low-water streambed elevation, Sespe Creek near Fillmore (11113000).

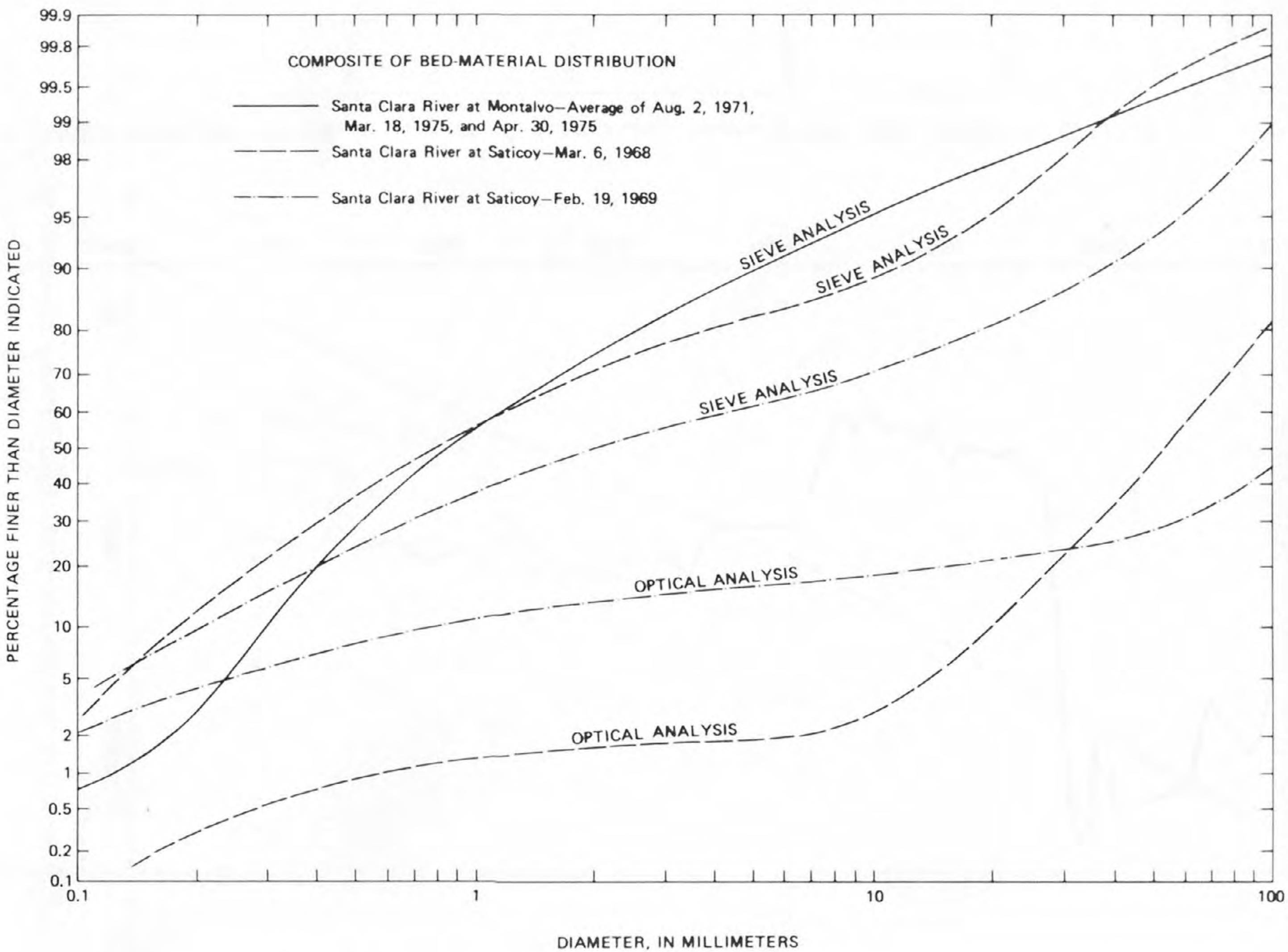

FIGURE 19.--Particle-size distribution of bed material, Santa Clara River at Montalvo (11114000), and at Saticoy (11113920).

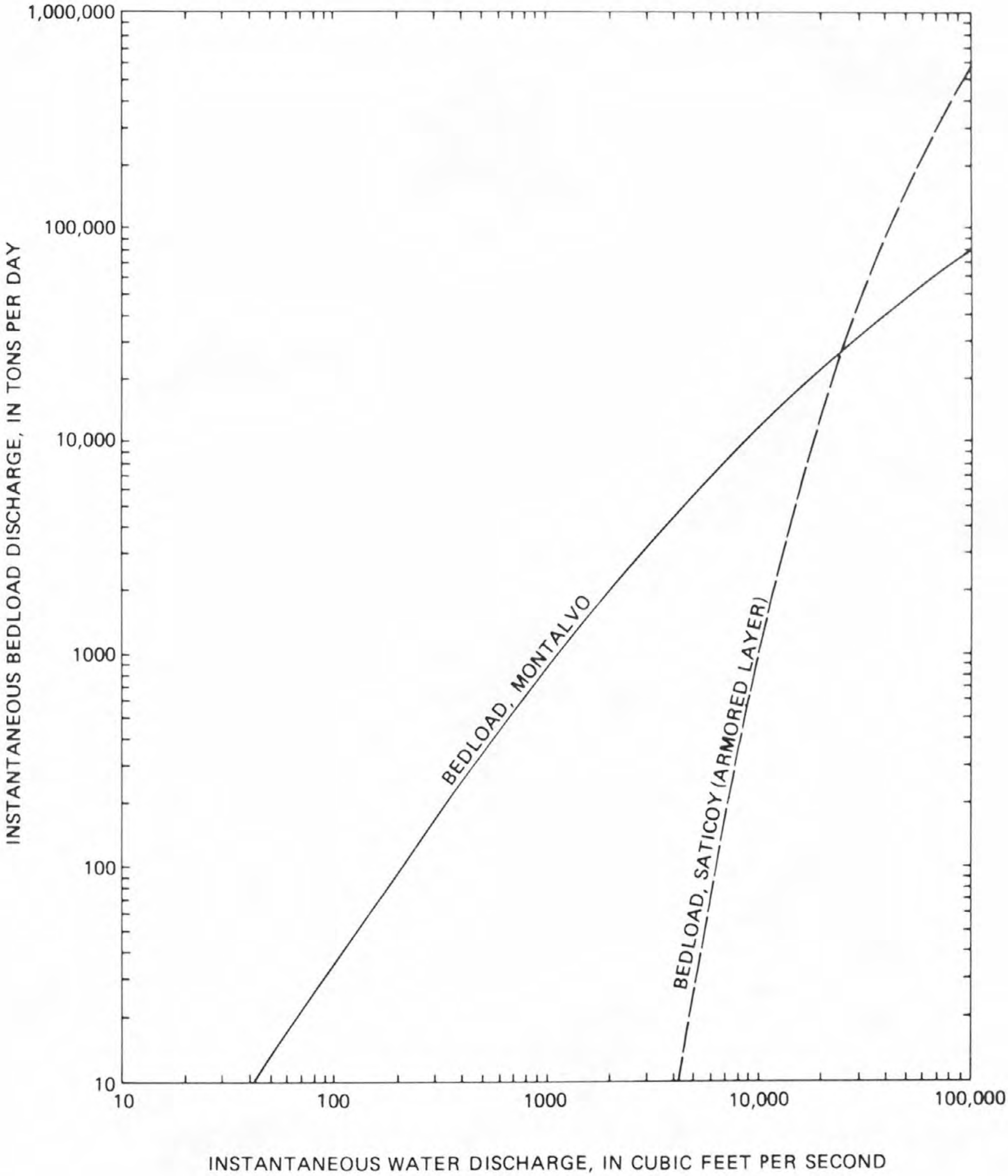

FIGURE 20.--Relation of water discharge to bedload-sediment discharge, Santa Clara River at Montalvo (11114000), and at Saticoy (11113920), water year 1969.

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