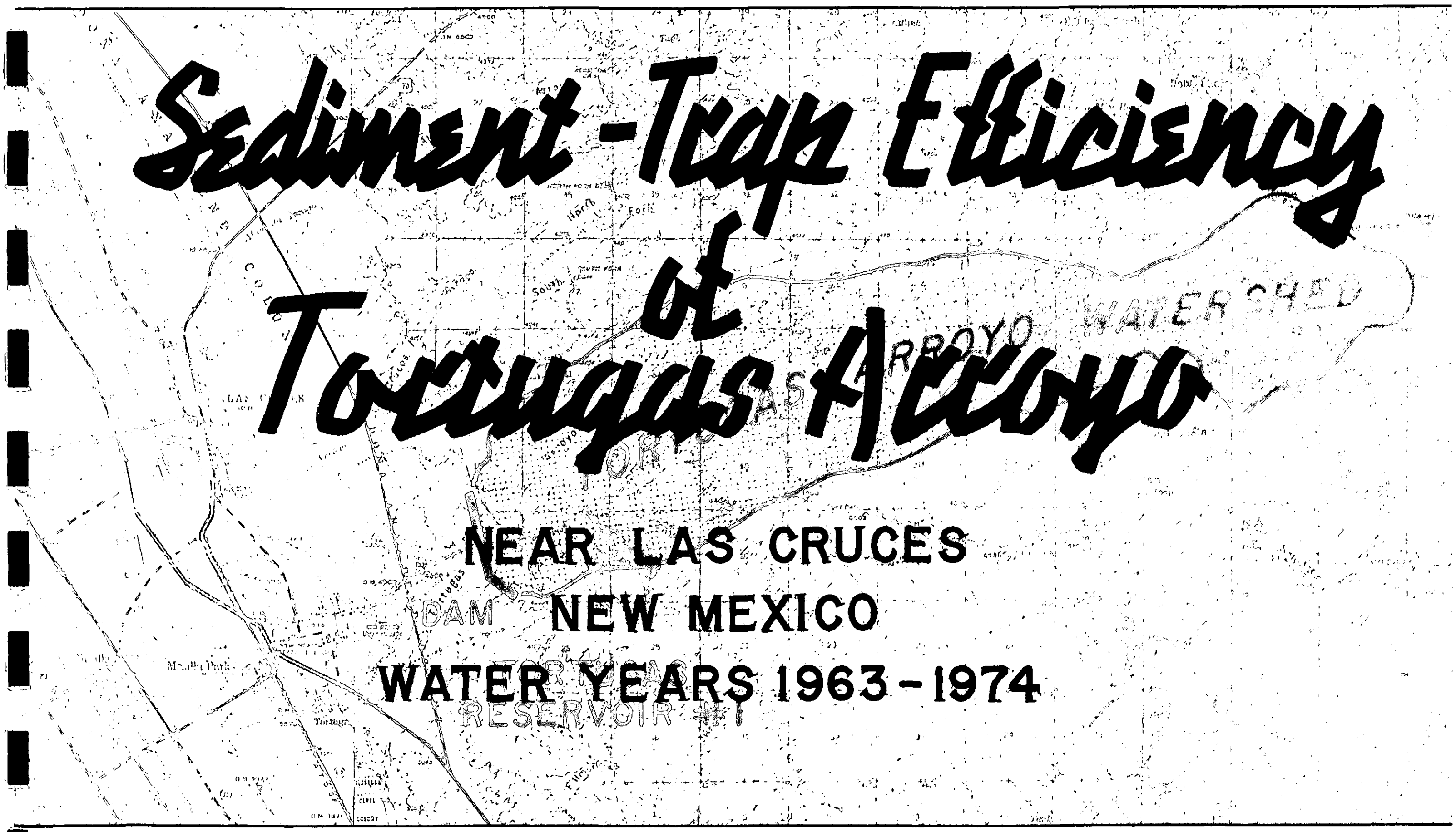
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Open-File Report USGS 77-586



Sediment-Trap Efficiency of Tortugas Arroyo

NEAR LAS CRUCES NEW MEXICO

WATER YEARS 1963-1974

Prepared in cooperation with U.S. Department
of Agriculture, Soil Conservation Service

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By D. E. Funderburg and F. E. Roybal

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Albuquerque, New Mexico

July 1977

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Contents

Illustrations

Illustrations - Concluded

Tables

Conversion chart

In this report some measurements are given in English units followed by metric units in parentheses. The conversion factors used are:

English Unit	Multiply by		Metric unit
acre-feet (acre-ft)	1233	=	cubic meters (m^3)
acre-feet (acre-ft)	0.0012335	=	cubic hectometers (hm^3)
foot (ft)	0.3048	=	meter (m)
mile (mi)	1.609	=	kilometer (km)
square mile (mi^2)	2.59	=	square kilometer (km^2)
inch (in)	25.4	=	millimeter (mm)
cubic feet per second (ft^3/s)	0.02832	=	cubic meters per second (m^3/s)
ton (short)	0.9072	=	metric ton (t)

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SEDIMENT-TRAP EFFICIENCY OF TORTUGAS ARROYO

NEAR LAS CRUCES, NEW MEXICO, WATER YEARS 1963-1974

By D. E. Funderburg and F. E. Roybal

Abstract

The U.S. Geological Survey, in cooperation with the U.S. Soil Conservation Service, began an investigation of sedimentation of Tortugas Floodwater Retarding Reservoir No. 1 on Tortugas Arroyo near Las Cruces, New Mexico, in 1963. This investigation was part of a nationwide investigation of the trap efficiency of detention reservoirs. Reservoir No. 1 is normally a dry reservoir and runoff from the 20.7 mi^2 (53.6 km^2) drainage area generally occurs from high-intensity summer thundershowers. The total outflow recorded for the period of record (July 3, 1963 to June 30, 1974) was 1,743 acre-feet (2.1 hm^3), yielding 6,055 tons (5,493 metric tons) of sediment. Over 99 percent of the coarse sediments and a high percentage of the silts and clays were deposited in the reservoir before reaching the outflow pipe. The determined trap efficiency of Reservoir No. 1 was 96 percent for the period of record.

Introduction

The Geological Survey, in cooperation with the Soil Conservation Service, began a joint investigation to measure the trap efficiency of Tortugas Floodwater Retarding Reservoir No. 1 on Tortugas Arroyo near Las Cruces, N. Mex., in April 1963. The investigation was part of a nationwide program to evaluate the trap efficiency of sediment detention reservoirs. The program was initiated at the request of the Soil Conservation Service under authorization of Public Law 566 and conducted by the Geological Survey with funds transferred by the Soil Conservation Service under letter of agreement dated December 10, 1962.

Through appraisal and evaluation of hydrologic principles, this program was intended to (a) provide planning data for the design of small detention reservoirs; (b) distinguish the principal factors that influence trap efficiency; and (c) study sediment yield as related to the physical characteristics of small drainage basins.

Summaries of water discharge and sediment data for water years 1963 through 1974 were published in the annual report "Water Resources for New Mexico - Part 2," U.S. Geological Sruvey.

This summary report, for water years 1963 through 1974, includes revised sediment-load computations for the period.

Description of drainage basin

Tortugas Arroyo near Las Cruces, N. Mex. is located in Dona Ana County, in Dona Ana Bend Colony Grant. The outflow gage (Lat 32°17'15"N., Long 106°43'43"E.) is 30 ft (9 m) downstream from Tortugas flood detention dam, 1.2 mi (1.9 km) northeast of New Mexico State University, and 3.3 mi (5.3 km) southeast of Las Cruces (fig. 1).

Runoff flows generally west into the reservoir. The drainage area is 20.7 mi2 (53.6 km2), about 0.8 to 2.7 mi (1.3 to 4.3 km) wide, and 10.5 mi (16.9 km) long. The drainage basin extends from the top of the Organ Mountains [9,012 ft (2,747 m) above mean sea level] down steep slopes for 5 mi (8 km) [4,945 ft (1,507 m) above mean sea level] and then flattens out to a gently sloping terrain (mostly mesa land) for the lower 5.5 mi (8.8 km), as shown in figure 2.

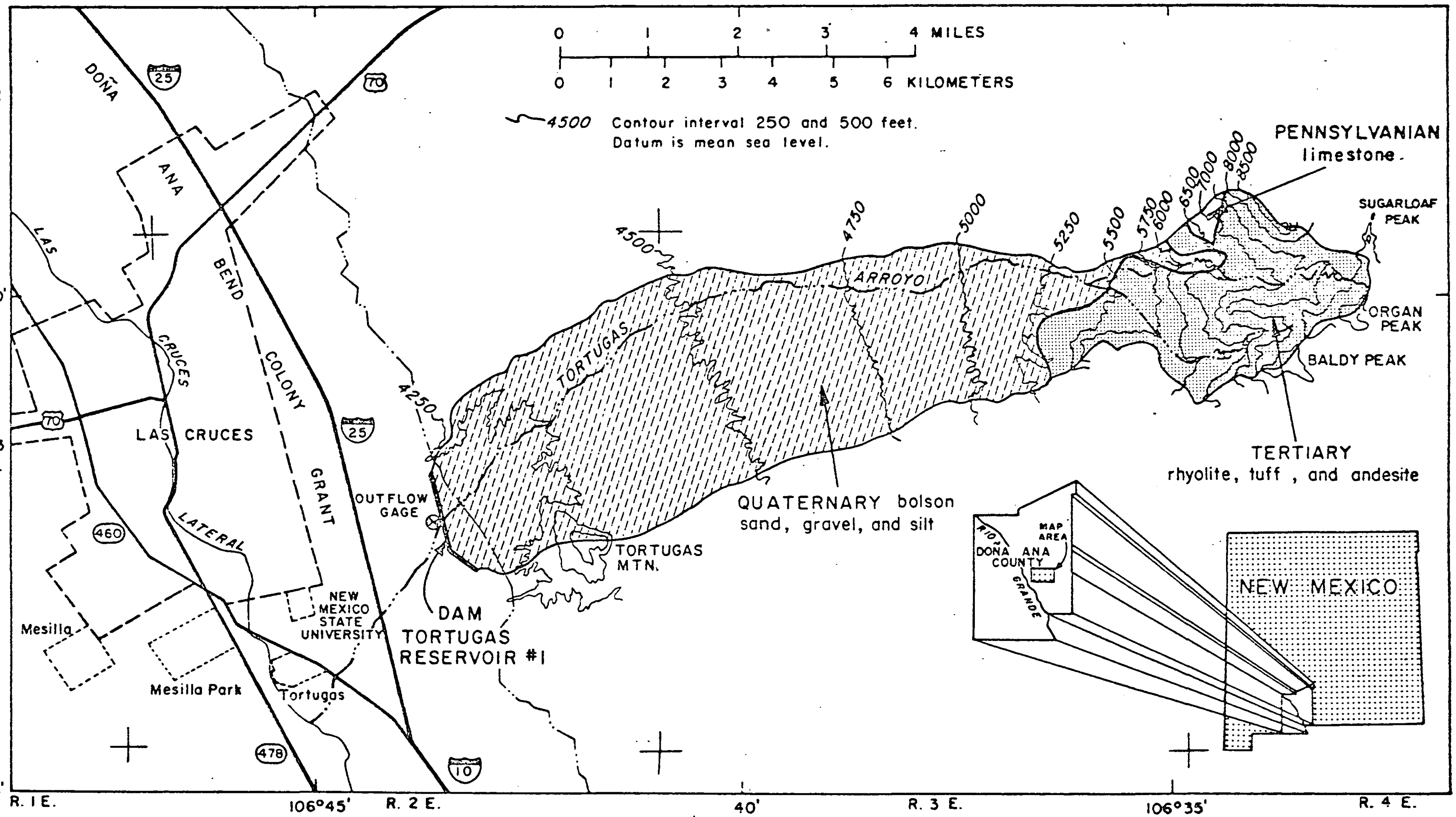

Figure 1.--Tortugas Arroyo watershed.

Figure 2.--General view of lower part of drainage basin.

The mountainous upper one third of the drainage basin is composed of Tertiary volcanic rocks; primarily rhyolite, tuff, and andesite. Along the upper end of the basin, between Organ and Sugarloaf peaks, the rock exposed is primarily Tertiary quartz monzonite while Pennsylvanian limestone is exposed in a thin zone along the northern edge. Quaternary bolson and alluvial gravels dominate the lower two thirds of the drainage basin.

The Tertiary volcanic rocks and quartz monzonite in the upper part of the drainage basin would be resistant and subject to very little erosion. The lower two thirds would be bolson and alluvial gravels which would be more easily eroded.

Description of reservoir

The reservoir is formed by an earth filled "L" shaped structure (fig. 3), about 3,400 ft (1,036 m) in length and 44 ft (13 m) maximum height. The top of the dam is at elevation 4,116.8 ft (1,254.8 m), the crest of the emergency spillway at 4,109.5 ft (1,252.6 m), and the crest of the principal spillway at 4,093.5 ft (1,247.7 m).

The reservoir is designed for floodwater and sediment storage. The original capacity of the reservoir below the emergency spillway elevation was 1,324 acre-ft (1.63 hm^3). This storage represents approximately 1.2 inches (30 mm) of runoff from the drainage basin.

The outlet structure in the reservoir (fig. 4), consists of a concrete tower with port openings leading to a 2.5 ft (0.8 m) diameter concrete pipe through the base of the dam (fig. 5). The tower has 9.2 ft (2.8 m) x 4.2 ft (1.3 m) outside dimensions, with 10 inches (254 mm) thick walls, and is 18.5 ft (5.6 m) high. There are 13 port openings in the concrete tower. Each port is 17 inches (432 mm) wide and 8 inches (203 mm) high. There are two ports on each side of the tower with sills at 4,093.50 ft (1,247.70 m) elevation, nine ports along the upstream side and none on the downstream side. The upstream ports are on 2.0 ft (0.6 m) centers. The sill of the lowest port is at 4,077.50 ft (1,242.82 m) above mean sea level. The upstream three lower ports and the top one were left open, the other ports were closed with cover plates. A trash rack extends along the full length of the upstream face of the outlet tower (fig. 6).

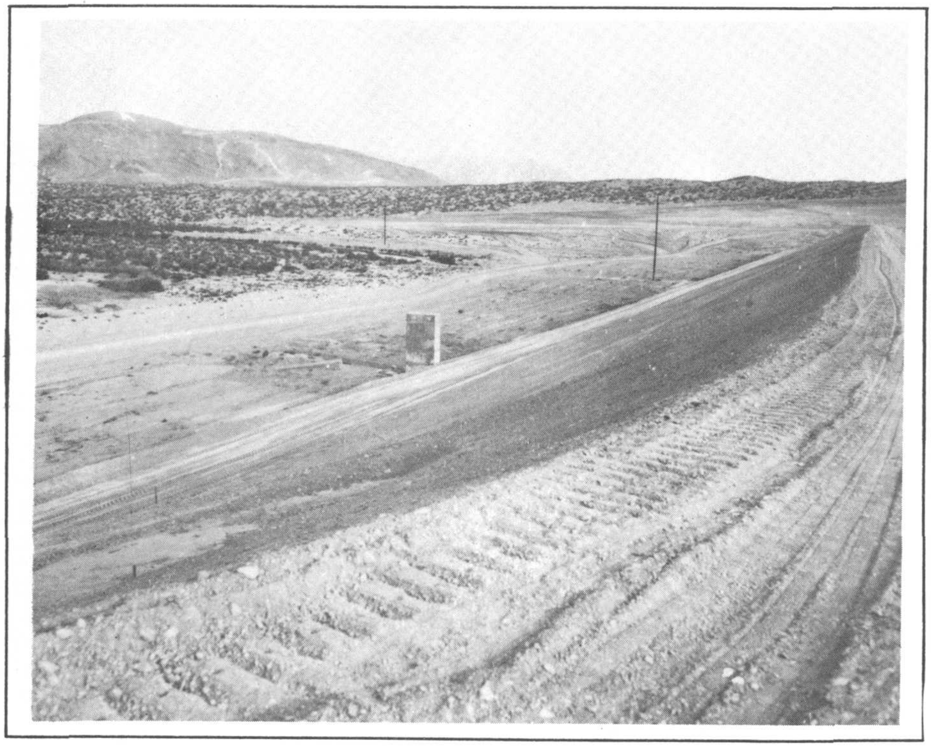

Figure 3.--General view of dam and detention reservoir.

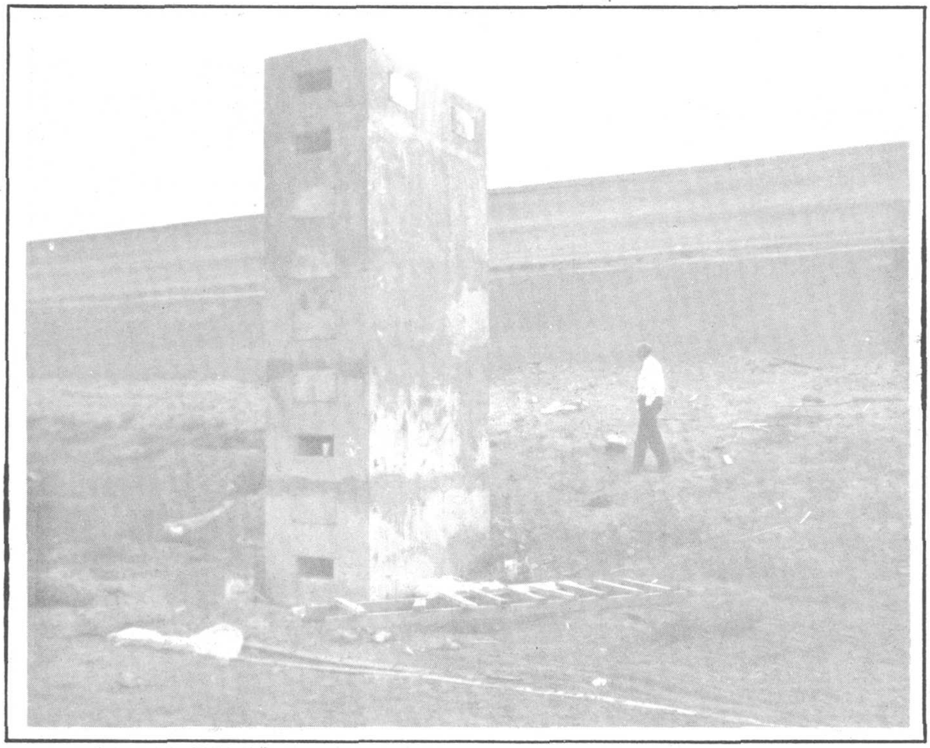

Figure 4.--Outlet tower in reservoir

Figure 5.--Reservoir outflow pipe.

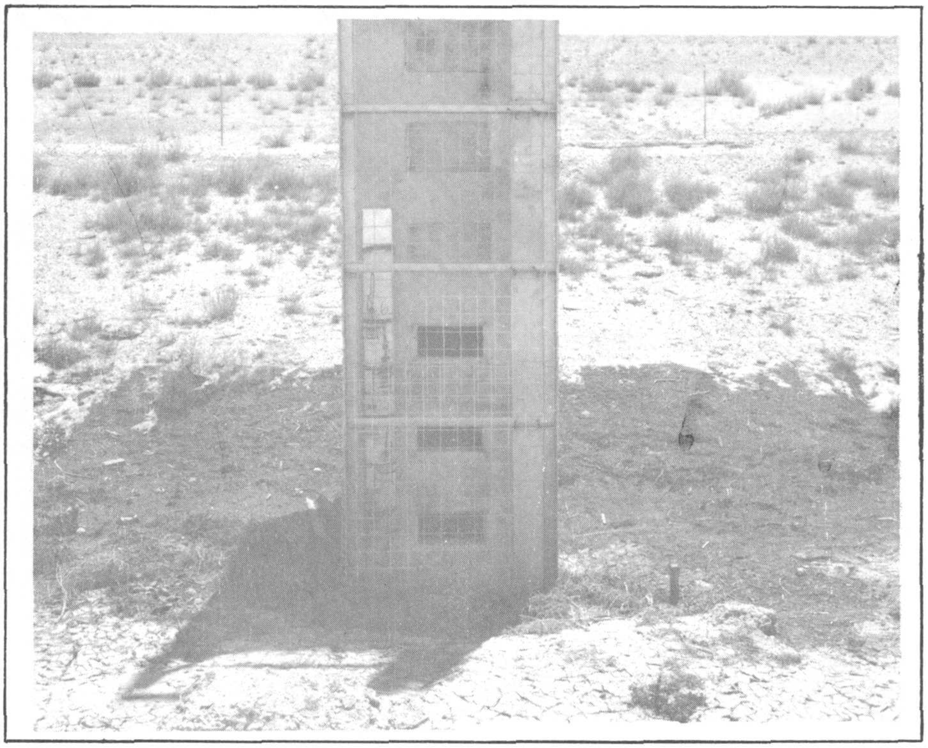

Figure 6.--Outlet tower portholes, single-stage sampler,

and trash rack.

A staff gage, faced with enameled sections from 0.0 to 20.34 ft was attached to the left side of the tower. The zero of this gage is at 4,076.51 ft (1,242.52 m) above mean sea level.

Hydrologic measurements

A water-stage recorder and Parshall flume at the downstream end of the reservoir outlet pipe were used to measure the outflow water-discharge from the reservoir (fig. 7).

The water-stage recorder is a continuous Stevens, Type A-35, analog recorder, in a 3.5 ft (1.1 m) square metal shelter over a 3.5 ft (1.1 m) diameter corrugated metal conduit well about 6 ft (1.8 m) in length. The well is adjacent to a Parshall flume. The intake consists of a single short pipe, 3 inches (76 mm) diameter, with invert flush with floor of flume. Enamel staff gage sections are mounted on the inside of the well and opposite the flume wall. Datum of gage is at 4,071.62 ft (1,241.03 m) above mean sea level (from datum established by Soil Conservation Service).

The Parshall flume is of steel, standard in design, with a 5 ft (1.5 m) throat width, a 2.5 ft (0.8 m) throat depth, and a capacity of 86 ft^3/s (2.44 m^3/s). It rests on a concrete slab and merges with the concrete stilling basin upstream.

The channel is manmade with earth banks. Discharge from the reservoir passes through port openings of outlet tower to a smooth concrete pipe through the base of the dam into a concrete stilling basin, 10 ft (3 m) wide, and 20 ft (6.1 m) long and 3.5 ft (1.1 m) high, at the head of the Parshall flume (fig. 8). The bottom of the sloping floor in the stilling basin is about 1 foot lower than the floor of the flume with a gradual rise into the flume. The purpose of the stilling basin was to decrease velocity of approach to the Parshall flume.

Sediment-sampling operations

Outflow-sediment samples were collected from the sampling platform at the downstream end of the outlet pipe (fig. 8). The samples were collected with a USDH-48 suspended-sediment sampler, using a standard 1/4-inch (6.35 mm) nozzle.

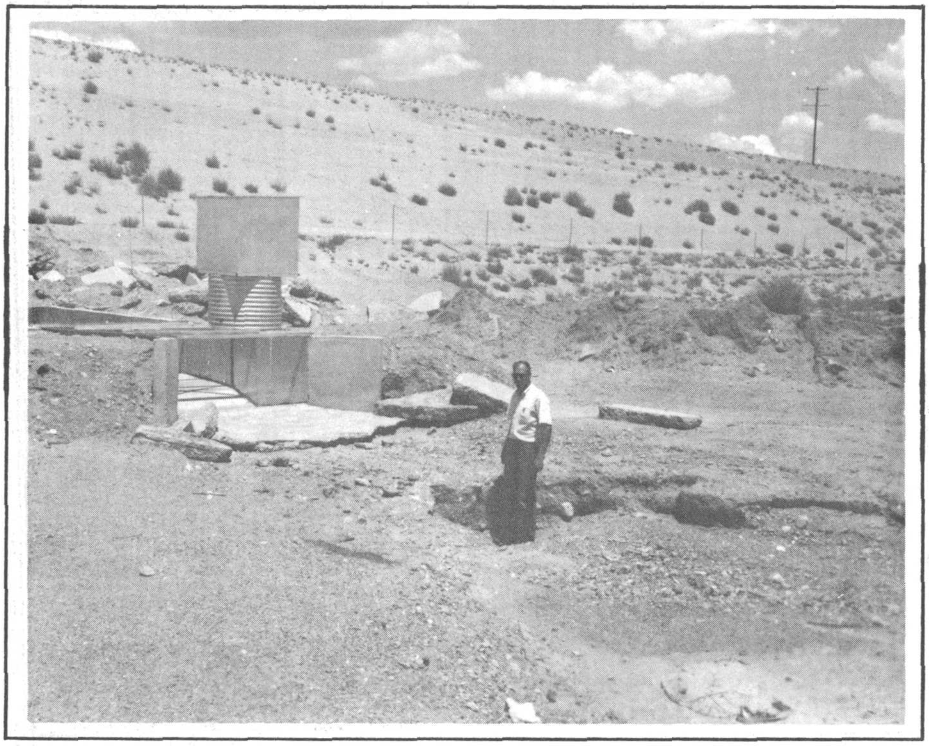

Figure 7.--Parshall flume and water-stage recorder downstream from outlet pipe.

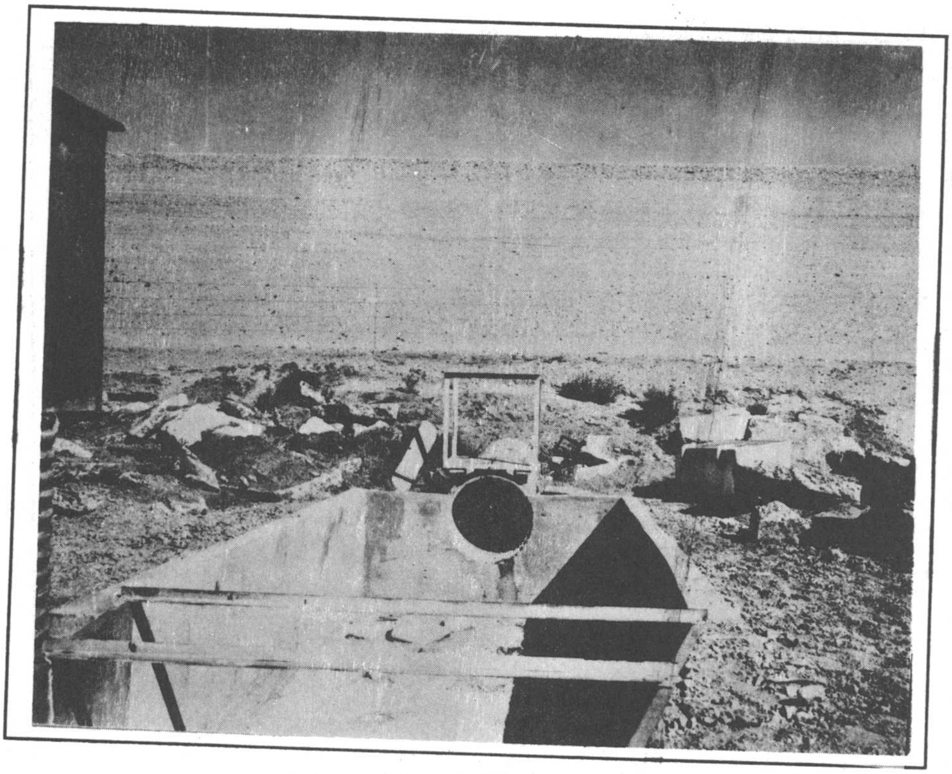

Figure 8.--Sampling platform and stilling basin below dam.

Whenever possible, outflow sampling started with the beginning of flow and was continued at frequent intervals to define the sediment concentration throughout the flow period.

It was most difficult to arrange the presence of personnel at the infrequent flows and especially for the initial peak outflows. Single-stage samplers were installed on the outlet tower to supplement the manual sampling program, as shown in figure 6. However, the fixed-sampler failed to collect any representative samples and was disregarded.

Discussion of flow periods

Outflow-sediment load as well as outflow volume and average concentration of outflow sediment for all 55 outflow periods covered by this report are presented in table 1, all particle-size analyses are presented in table 2, and all chemical analyses of the native water from these size analyses are presented in table 3. Particle-size and chemical analyses of native water were discontinued after 1971.

1963 Water Year.--Flow nos. 1, 2, and 3 occurred during this water year. The total outflow was 22.6 acre-ft (0.028 hm^3), yielding 125 tons (113 t) of sediment.

Hydrographs and curves showing outflow discharge and outflow concentration for flows 1, 2, and 3 are presented in figures 9 through 11. None of the outflow samples taken during this water year contained material in the sand range (>0.062 mm); apparently, there was sufficient ponding of the inflow to allow all the sand particles to settle out in the reservoir.

1964 Water Year.--There were three flows (nos. 4, 5, and 6); the two smallest were not sampled.

Numerous samples were taken during flow no. 6, thus the outflow concentration was well defined. The 4:00 p.m. outflow sample collected on September 11, 1964, contained 13 percent sand, probably due to the high velocity flow reaching the outlet tower before ponding. There were two outflow-discharge peaks and two outflow-concentration peaks during this 72-hour period of flow. Outflow-discharge hydrograph and concentration curve for flow no. 6 are presented in figure 12.

The outflow-sediment load for flow nos. 4 and 5 was estimated from a sediment-transport curve based on instantaneous data collected during this water year. An estimate was made for each subdivision in the computation, then totaled. The estimates appear reasonable as indicated by figure 28, a plot of outflow volume (acre-feet) per flow period against outflow-sediment load (tons). Outflow-sediment loads for other flow periods were estimated in the same manner.

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1963 to June 1974

Water year	Flow no.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow-sediment load (tons)
1963	1	July 3- 4, 1963	18	6.4	4.3	3,100	45
	2	July 29-30, 1963	31	9.3	3.6	1,300	42
	3	Aug. 10-11, 1963	35	6.9	2.4	2,000	38
1964	4	June 24-25, 1964	20	6.5	3.3	-	e 40
	5	Sept. 10, 1964	15	3.6	2.9	-	e 30
	6	Sept. 11-14, 1964	72	52.2	8.7	2,100	260
1965	7	Aug. 21-26, 1965	118	249	25.5	1,640	754
	8	Sept. 7, 1965	12	.2	.2	310	.6
	9	Sept. 7- 8, 1965	25	17	8.2	-	e 30
1966	10	June 29, 1966	6	1.4	2.6	-	e 8
	11	Aug. 3- 4, 1966	11	2.8	3.0	3,200	18
	12	Aug. 5- 6, 1966	12	.6	.6	590	.8
	13	Aug. 16, 1966	5	.2	.6	2,800	1.0
	14	Aug. 19-20, 1966	23	10	5.5	2,200	73
	15	Sept. 4- 5, 1966	29	32	13	3,500	220
	16	Sept. 6- 7, 1966	16	.2	.2	-	e 1.0
	17	Sept. 7- 8, 1966	18	1.6	1.1	1,800	10
	18	Sept. 20-21, 1966	30	24	9.8	1,500	91

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1963 to June 1974 - Continued

Water year	Flow no.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow-sediment load (tons)
1967	19	June 5- 6, 1967	9.5	2.1	2.65	5,480	27
	20	June 17-18, 1967	9.5	.1	.13	3,590	.6
	21	June 19-20, 1967	25.5	19	9.04	3,240	109
	22	June 29-July 1, 1967	31.5	28	10.9	3,940	215
	23	July 13-14, 1967	22.5	7.1	3.82	2,410	43
	24	Aug. 4- 5, 1967	26.25	8.1	3.72	2,250	43
	25	Aug. 5-10, 1967	114.25	347	36.7	1,630	913
	26	Aug. 11, 1967	11.75	2.5	2.57	2,680	15
	27	Aug. 15-16, 1967	18.75	6.2	3.98	2,470	36
	28	Aug. 16-17, 1967	29.75	23	9.29	3,550	148
	29	Sept. 4- 5, 1967	24.2	13	6.41	3,260	94
	30	Sept. 25, 1967	6.33	.5	.92	1,650	2.1
1968	31	July 25-26, 1968	15.5	12	9.74	3,410	75
	32	July 31-Aug. 1, 1968	13.5	3.7	3.36	3,150	26
1969	33	June 2, 1969	6.0	.3	.52	4,870	2.4
	34	June 15-16, 1969	12	3.8	3.79	6,370	43
	35	July 9, 1969	11	3.8	4.23	3,320	28
	36	July 9-11, 1969	33	37	13.5	3,780	267
	37	July 17-18, 1969	19	7.6	4.84	3,340	56
	38	July 19-20, 1969	19	1.5	.93	1,980	9
	39	July 20-21, 1969	24	12	5.72	2,530	63
	40	Aug. 6, 1969	7.0	.3	.57	1,640	1.5
	41	Aug. 31-Sept. 1, 1969	27.25	44	19.5	2,870	203
	42	Sept. 1- 3, 1969	44.25	66	18.1	2,170	249

Table 1.--Outflow-sediment load, outflow volume, and average outflow-sediment concentrations, July 1963 to June 1974 - Concluded

Water year	Flow no.	Date	Outflow duration (hours)	Total outflow (acre-ft)	Average outflow for period (ft^3/s)	Average outflow-sediment concentration (mg/L)	Outflow-sediment load (tons)
1970	43	Oct. 8-10, 1969	28.25	13	5.69	1,260	43
	44	Oct. 21-24, 1969	72.5	176	29.4	1,910	620
1971	45	July 26, 1971	1.25	.06	.5	10,000	.7
	46	Aug. 18, 1971	5.5	2.2	4.59	4,070	18
	47	Aug. 25-26, 1971	25	13	6.35	2,490	98
1972	48	June 11-13, 1972	46	88	23.2	1,090	148
	49	Aug. 18, 1972	2	.03	.25	-	e .14
	50	Aug. 27-28, 1972	21.5	24	13.5	2,880	111
	51	Sept. 1-4, 1972	71.5	303	51.2	610	307
1973	52	Oct. 18-21, 1972	57.5	22	4.53	-	e186
	53	Oct. 26, 1972	23	29	15.2	-	e191
	54	July 14-15, 1973	11	.2	.2	-	e .48
	55	July 25, 1973	5	.3	.72	-	e 1.0

Table 2.--Particle-size analyses

[Methods of analysis: P, pipet; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed; V, visual accumulation tube]

Summary of particle-size analyses of suspended sediment, period July 1963 to June 1974

Date	Time	Dis- charge (ft³/s)	Sediment conc. of sample (mg/L)	Percent finer than indicated size, in millimeters												Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	4.00	
July 3, 1963	1930	12.9	15,300	36	48	-	87	-	100	-	-	-	-	-	-	PWC
July 3	1945	12.9	10,300	43	60	81	94	100	-	-	-	-	-	-	-	PWC
July 3	1945	12.9	10,300	3	10	37	94	100	-	-	-	-	-	-	-	PN
July 4	0200	5.0	3,090	79	93	-	100	-	-	-	-	-	-	-	-	PWC
July 29	1630	14.2	7,450	58	78	92	97	100	-	-	-	-	-	-	-	PWC
July 29	1630	14.2	7,450	6	26	91	96	100	-	-	-	-	-	-	-	PN
Aug. 10	1400	11.4	11,800	41	51	72	88	100	-	-	-	-	-	-	-	PWC
Aug. 10	1400	11.4	11,800	6	28	66	89	98	100	-	-	-	-	-	-	PN
Aug. 10	1530	11.7	5,140	57	78	-	99	-	100	-	-	-	-	-	-	PWC
Sept. 11,1964	1600	23.3	15,800	33	41	49	66	79	87	88	90	94	95	98	100	SPWC
Sept. 11	1600	23.3	15,800	2	11	37	50	80	87	88	90	94	95	98	100	SPN
Sept. 12	0030	14.2	3,670	73	96	-	100	-	-	-	-	-	-	-	-	PWC
Sept. 12	0230	10.6	2,630	83	95	-	99	-	100	-	-	-	-	-	-	PWC
Sept. 12	1030	19.1	2,720	72	94	-	100	-	-	-	-	-	-	-	-	PWC
Sept. 12	1230	16.3	2,280	81	98	-	100	-	-	-	-	-	-	-	-	PWC
Sept. 13	0430	6.2	675	97	98	-	99	-	100	-	-	-	-	-	-	PWC
Aug. 21, 1965	1930	7.0	2,500	82	97	-	98	-	100	-	-	-	-	-	-	PWC
Aug. 22	2130	58	18,600	34	43	-	73	-	100	-	-	-	-	-	-	PWC
Aug. 23	1000	61	906	95	99	99	99	100	-	-	-	-	-	-	-	PWC
Aug. 23	1000	61	906	14	33	97	98	98	100	-	-	-	-	-	-	PN
Aug. 24	1930	32	309	88	95	-	99	-	100	-	-	-	-	-	-	PWC
Aug. 25	2230	6.4	236	92	96	-	99	-	100	-	-	-	-	-	-	PWC

Table 2.--Particle-size analyses - Continued

Date	Time	Dis- charge (ft³/s)	Sediment conc. of sample (mg/L)	Percent finer than indicated size, in millimeters												Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	4.00	
Aug. 3, 1966	1830	3.0	3,880	68	85	90	92	92	96	98	100	-	-	-	-	VPWC
Aug. 3	1830	3.0	3,880	6	24	88	91	93	96	98	100	-	-	-	-	VPN
Aug. 5	1900	1.5	3,580	62	80	88	88	89	92	98	100	-	-	-	-	VPWC
Aug. 5	1900	1.5	3,580	4	16	70	87	87	92	98	100	-	-	-	-	VPN
Aug. 19	1800	.4	1,450	88	94	95	95	95	98	98	99	100	-	-	-	VPWC
Aug. 19	1800	.4	1,450	9	21	95	96	97	98	98	99	100	-	-	-	VPN
Aug. 19	2230	17	3,130	76	92	-	98	-	100	-	-	-	-	-	-	PWC
Sept. 4	1530	34	23,100	28	38	49	63	84	100	-	-	-	-	-	-	PWC
Sept. 4	1530	34	23,100	4	16	42	62	85	100	-	-	-	-	-	-	PN
Sept. 7	1830	1.9	2,940	67	86	97	98	98	98	99	100	-	-	-	-	SPWC
Sept. 7	1830	1.9	2,940	5	20	90	91	94	98	99	100	-	-	-	-	SPN
Sept. 20	1700	30	3,670	75	91	92	95	95	100	-	-	-	-	-	-	PWC
Sept. 20	1700	30	3,670	5	11	63	98	98	100	-	-	-	-	-	-	PN
Sept. 21	0100	14	900	96	97	-	98	-	100	-	-	-	-	-	-	PWC
June 5, 1967	1730	9.2	35,200	-	6	32	65	83	95	97	99	100	-	-	-	VPN
June 5	1730	9.2	35,200	27	34	49	66	80	95	97	99	100	-	-	-	VPWC
June 6	0330	.02	2,720	84	98	-	99	-	100	-	-	-	-	-	-	PWC
June 19	2230	22.7	3,770	-	6	43	99	99	100	-	-	-	-	-	-	PWC
June 19	2230	22.7	3,770	58	84	96	99	99	100	-	-	-	-	-	-	PWC
June 29	1850	16.8	18,800	1	13	27	61	36	99	100	-	-	-	-	-	VPN
June 29	1850	16.8	18,800	25	42	50	70	82	99	100	-	-	-	-	-	VPWC
July 13	1745	13.7	6,300	3	19	84	97	97	100	-	-	-	-	-	-	PN
July 13	1745	13.7	6,300	55	77	93	98	98	100	-	-	-	-	-	-	PWC
Aug. 4	1320	3.9	30,300	2	13	30	62	92	100	-	-	-	-	-	-	PN
Aug. 4	1320	3.9	30,300	26	42	56	75	93	100	-	-	-	-	-	-	PWC
Aug. 5	1910	85.0	8,890	3	20	56	78	95	100	-	-	-	-	-	-	PN

Table 2.--Particle-size analyses - Continued

Date	Time	Dis-charge (ft³/s)	Sediment conc. of sample (mg/L)	Percent finer than indicated size, in millimeters												Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	4.00	
Aug. 5, 1967	1910	85.0	8,890	36	54	66	85	96	100	-	-	-	-	-	-	PWC
Aug. 6	1045	71.2	1,470	87	98	-	99	-	100	-	-	-	-	-	-	PWC
Aug. 7	1355	43.5	442	13	57	98	99	100	-	-	-	-	-	-	-	PN
Aug. 7	1355	43.5	442	96	97	98	99	100	-	-	-	-	-	-	-	PWC
Aug. 11	1245	9.5	8,260	3	7	44	96	99	100	-	-	-	-	-	-	PN
Aug. 11	1245	9.5	8,260	54	66	88	97	99	100	-	-	-	-	-	-	PWC
Aug. 15	1015	13.1	3,670	2	12	65	99	100	-	-	-	-	-	-	-	PN
Aug. 15	1015	13.1	3,670	71	85	95	99	100	-	-	-	-	-	-	-	PWC
Aug. 16	1825	10.8	16,900	3	11	54	95	99	100	-	-	-	-	-	-	PN
Aug. 16	1825	10.8	16,900	53	71	82	94	99	100	-	-	-	-	-	-	PWC
Sept. 4	1400	12.2	49,800	1	7	13	26	43	81	96	97	99	100	-	-	VPN
Sept. 4	1400	12.2	49,800	12	19	23	33	46	81	96	97	99	100	-	-	VPWC
July 25, 1968	1830	18.7	5,260	52	72	90	99	99	100	-	-	-	-	-	-	PWC
July 25	1830	18.7	5,260	11	17	48	98	100	-	-	-	-	-	-	-	PN
July 26	0130	8.72	1,970	82	99	-	100	-	-	-	-	-	-	-	-	PWC
July 31	2130	10.8	5,030	55	77	96	99	100	-	-	-	-	-	-	-	PWC
July 31	2130	10.8	5,030	10	23	76	99	100	-	-	-	-	-	-	-	PN
June 2, 1969	1830	1.0	6,380	57	83	96	98	98	100	-	-	-	-	-	-	PWC
June 2	1830	1.0	6,380	0	10	63	97	100	-	-	-	-	-	-	-	PN
July 17	1630	16.8	7,510	43	60	82	96	99	100	-	-	-	-	-	-	PWC
July 17	1630	16.8	7,510	6	24	61	90	97	100	-	-	-	-	-	-	PN
July 19	1530	8.0	5,770	40	61	86	96	99	100	-	-	-	-	-	-	PWC
July 19	1530	8.0	5,770	6	23	66	94	98	100	-	-	-	-	-	-	PN
July 20	1430	19.0	6,970	34	48	63	77	88	96	98	100	-	-	-	-	VPWC
July 20	1430	19.0	6,970	5	20	37	68	88	96	98	100	-	-	-	-	VPN
Sept. 1	1700	43.0	3,110	58	77	86	90	92	94	95	96	99	99	100	-	SPWC
Sept. 1	1700	43.0	3,110	2	14	66	92	93	94	95	96	99	99	100	-	SPN

Table 2.--Particle-size analyses - Concluded

Date	Time	Discharge (ft³/s)	Sediment conc. of sample (mg/L)	Percent finer than indicated size, in millimeters												Method
				0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.00	2.00	4.00	
Oct. 22,1969	0830	55	2,680	75	95	99	100	-	-	-	-	-	-	-	-	PWC
Oct. 22	0830	55	2,680	7	24	95	100	-	-	-	-	-	-	-	-	PN
July 26,1971	1400	.60	53,300	0	2	10	30	33	51	93	100	-	-	-	-	VPN
July 26	1400	.60	53,300	5	19	28	31	33	51	93	100	-	-	-	-	VPWC
Aug. 18	1830	.50	3,480	2	8	34	99	99	99	99	99	99	99	100	-	SPN
Aug. 18	1830	.50	3,480	74	95	96	97	98	99	99	99	99	99	100	-	SPWC
Aug. 25	1800	24.0	12,300	2	9	32	85	96	97	97	98	99	100	-	-	VPN
Aug. 25	1800	24.0	12,300	33	44	71	87	96	97	97	98	99	100	-	-	VPWC
Aug. 25	2400	18.0	2,410	69	77	-	78	-	80	81	83	89	94	97	100	SPWC
June 12,1972	1100	33.3	982	98	98	-	99	-	100	-	-	-	-	-	-	SPWC
Aug. 27	1000	28.9	3,320	65	87	-	100	-	-	-	-	-	-	-	-	SPWC
Sept. 2	0900	71.2	613	94	99	-	99	-	99	99	100	-	-	-	-	SPWC

Table 3.--Chemical analyses

[mg/L]

Date of collection	8-3-66	8-5-66	8-19-66	8-23-66	9-4-66	9-20-66	6-5-67	6-19-67
Time of collection	-	-	-	-	-	-	-	-
Calcium (Ca)	33	48	41	44	37	35	94	56
Magnesium (Mg)	3.3	4.4	3.3	2.2	3.3	2.1	11	4.0
Sodium (Na)	.9	2.8	2.2	4.4	1.5	2.6	6.7	2.0
Dissolved solids residue on evaporation	130	208	164	176	146	136	348	200
Hardness as $CaCO_3$	96	138	116	119	106	96	278	156
Specific conductance (micromhos per cm at 25°C)	207	325	245	269	221	213	554	313
pH		7.7	7.7	7.9	7.5	7.7	7.2	7.3
Percent sodium	2	4	4	7	3	6	5	3
Sodium absorption ratio[1/]	0	.1	.1	.2	.1	.1	.2	.1
Dissolved solids (tons per acre-foot)	.18	.28	.22	.24	.20	.18	.47	.27

1/ Water-Supply Paper 1473, second ed., p. 228, Hem, 1970.

Table 3.--Chemical analyses - Continued

Date of collection	6-29-67	7-13-67	8-4-67	8-5-67	8-7-67	8-11-67	8-15-67	8-16-67
Time of collection	1930	1900	1400	2000	1455	1330	2330	1930
Calcium (Ca)	60	36	58	30	23	43	49	44
Magnesium (Mg)	6.4	3.4	4.7	2.7	1.1	3.8	3.5	4.6
Sodium (Na)	2.0	1.1	3.0	3.0	3.3	3.1	3.2	2.9
Dissolved solids residue on evaporation	220	137	244	122	95	160	172	166
Hardness as $CaCO_3$	176	104	164	86	62	123	137	129
Specific conductance (micromhos per cm at 25°C)	350	214	343	191	150	255	276	260
pH	6.8	7.0	7.3	7.1	6.9	7.4	7.1	7.5
Percent sodium	2	2	4	7	10	5	5	5
Sodium absorption ratio	.1	0	.1	.1	.2	.1	.1	.1
Dissolved solids (tons per acre-foot)	.30	.19	.33	.17	.13	.22	.23	.23

Table 3.--Chemical analyses - Continued

Date of collection	9-4-67	7-25-68	7-31-68	6-2-69	7-17-69	7-19-69	7-20-69	9-1-69
Time of collection	1500	1830	2130	1830	1630	1530	1430	1700
Calcium (Ca)	56	51	40	51	35	43	62	38
Magnesium (Mg)	6.4	3.4	1.9	5.4	6.0	10	9.1	2.2
Sodium (Na)	1.8	1.6	1.6	4.8	1.4	2.4	2.2	1.5
Dissolved solids residue on evaporation	202	170	148	198	123	155	211	126
Hardness as $CaCO_3$	166	141	108	149	112	149	192	104
Specific conductance (micromhos per cm at 25°C)	323	287	231	332	210	270	353	215
pH	7.4	7.5	7.4	7.9	7.5	7.7	7.7	7.7
Percent sodium	2	2	3	7	3	3	2	3
Sodium absorption ratio	.1	.1	.1	.2	.1	.1	.1	.1
Dissolved solids (tons per acre-foot)	.27	.23	.20	.27	.17	.21	.29	.17

Table 3.--Chemical analyses - Concluded

Date of collection	10-22-70	7-26-71	8-18-71	8-25-71
Time of collection	0830	1400	1830	1800
Calcium (Ca)	36	67	48	58
Magnesium (Mg)	1.5	10	3.3	5.5
Sodium (Na)	2.0	5.1	5.4	3.1
Dissolved solids residue on evaporation	112	306	216	202
Hardness as $CaCO_3$	96	210	130	170
Specific conductance (micromhos per cm at 25°C)	201	461	301	329
pH	7.4	7.4	7.3	7.4
Percent sodium	4	5	8	4
Sodium absorption ratio	.1	.2	.2	.1
Dissolved solids (tons per acre-foot)	.15	.42	.29	.27

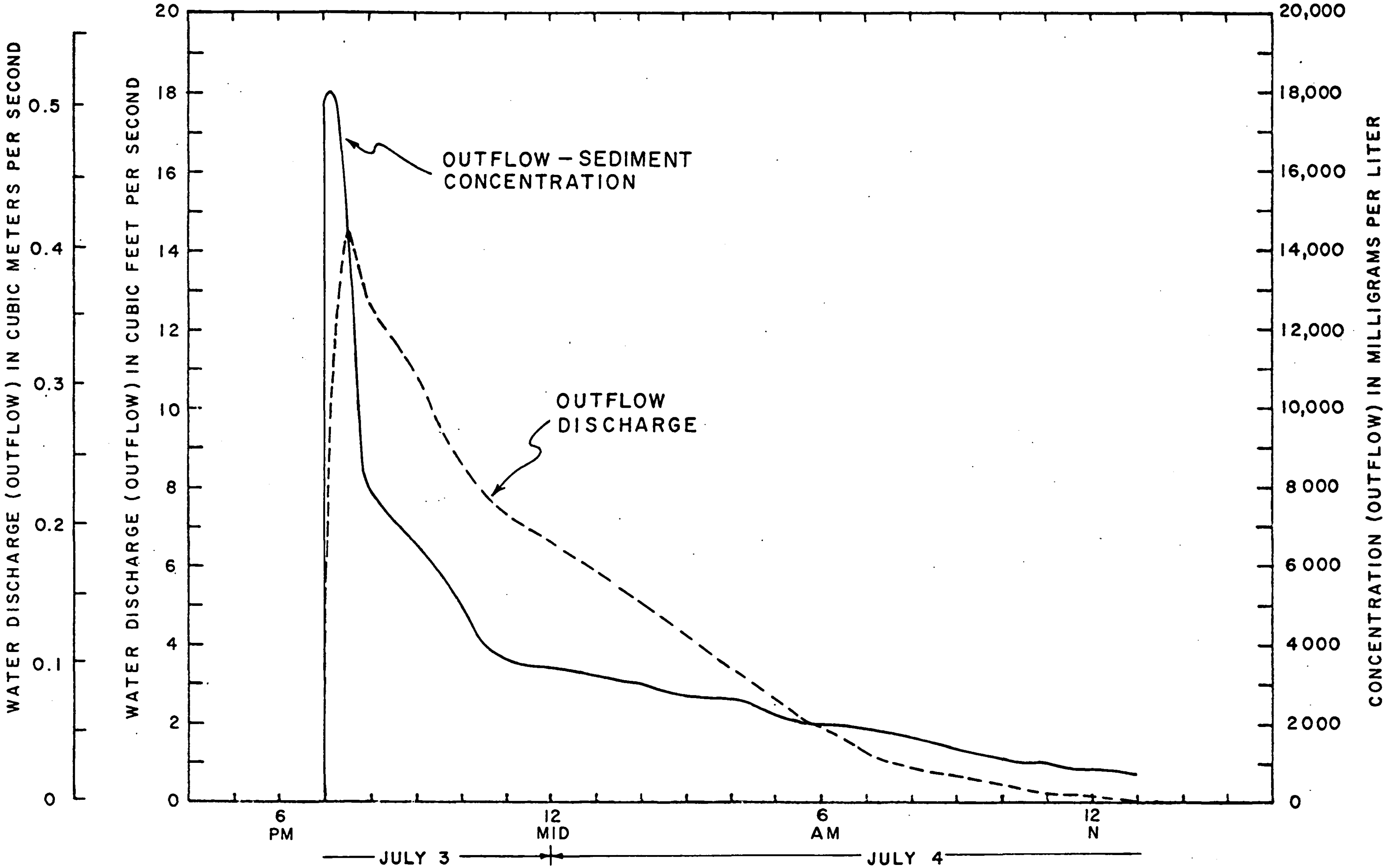

Figure 9.--Outflow discharge and outflow-sediment concentration for flow 1, July 3-4, 1963.

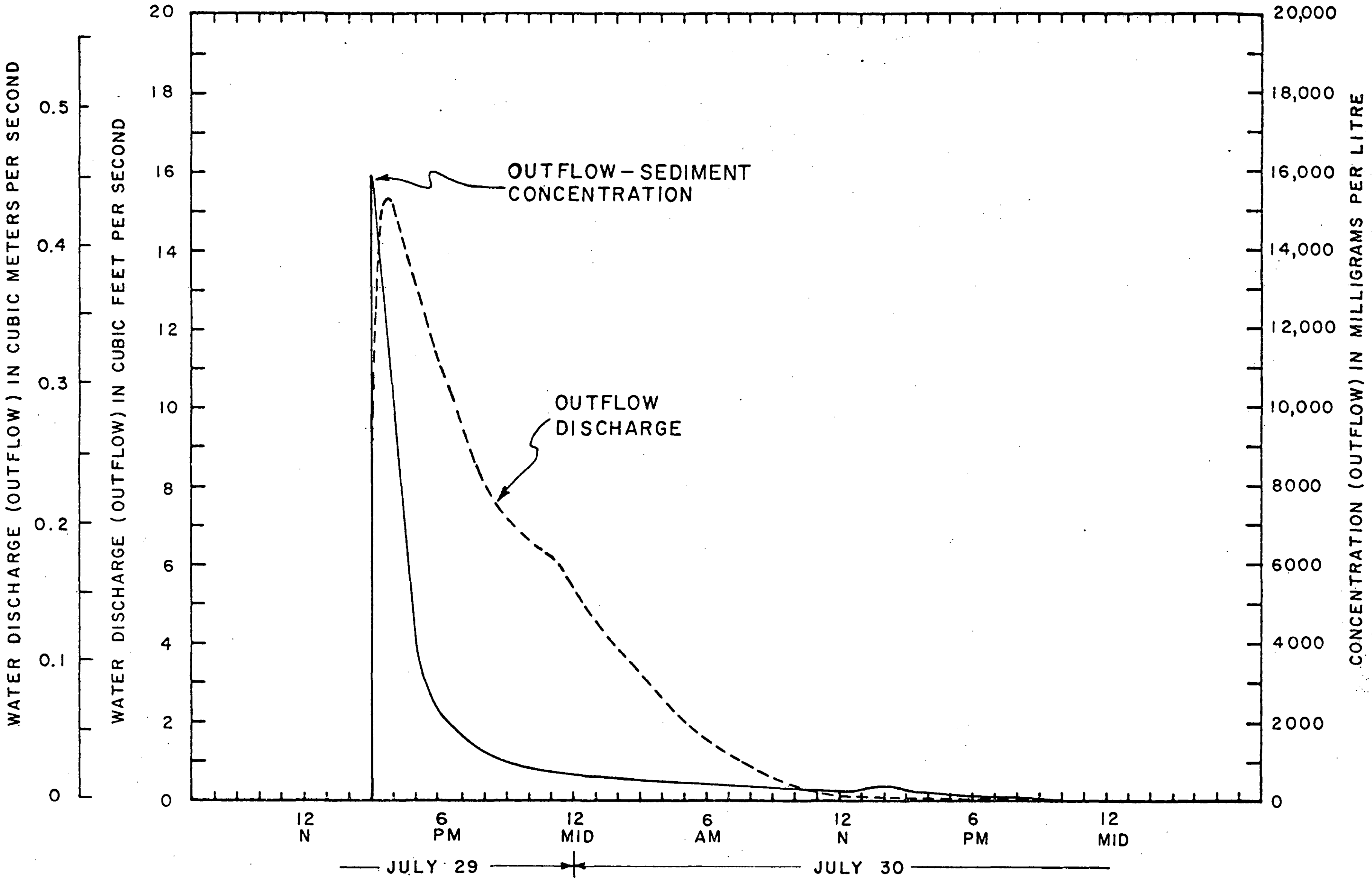

Figure 10.--Outflow discharge and outflow-sediment concentration for flow 2, July 29-30, 1963.

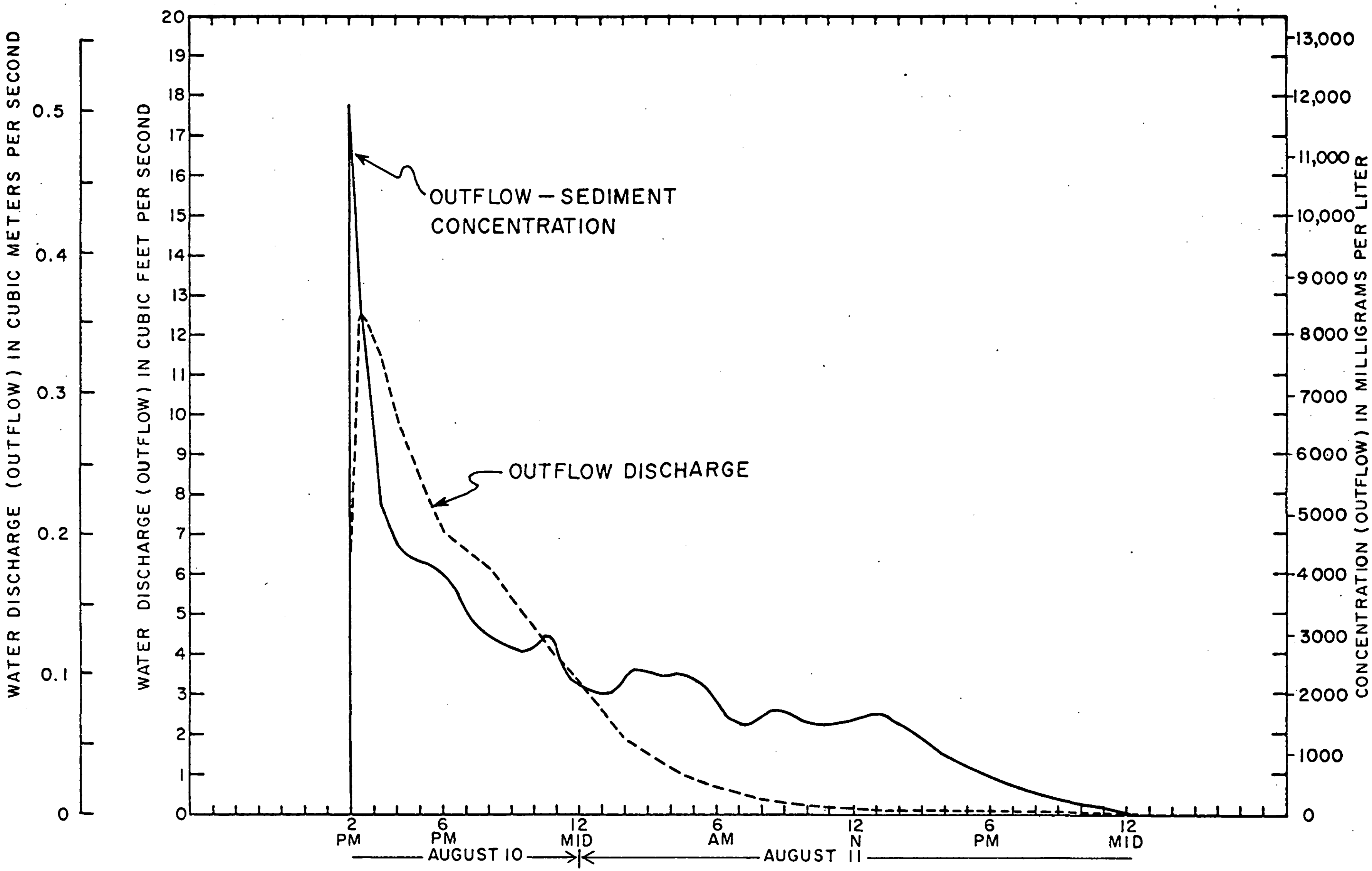

Figure 11.--Outflow discharge and outflow-sediment concentration for flow 3, August 10-11, 1963.

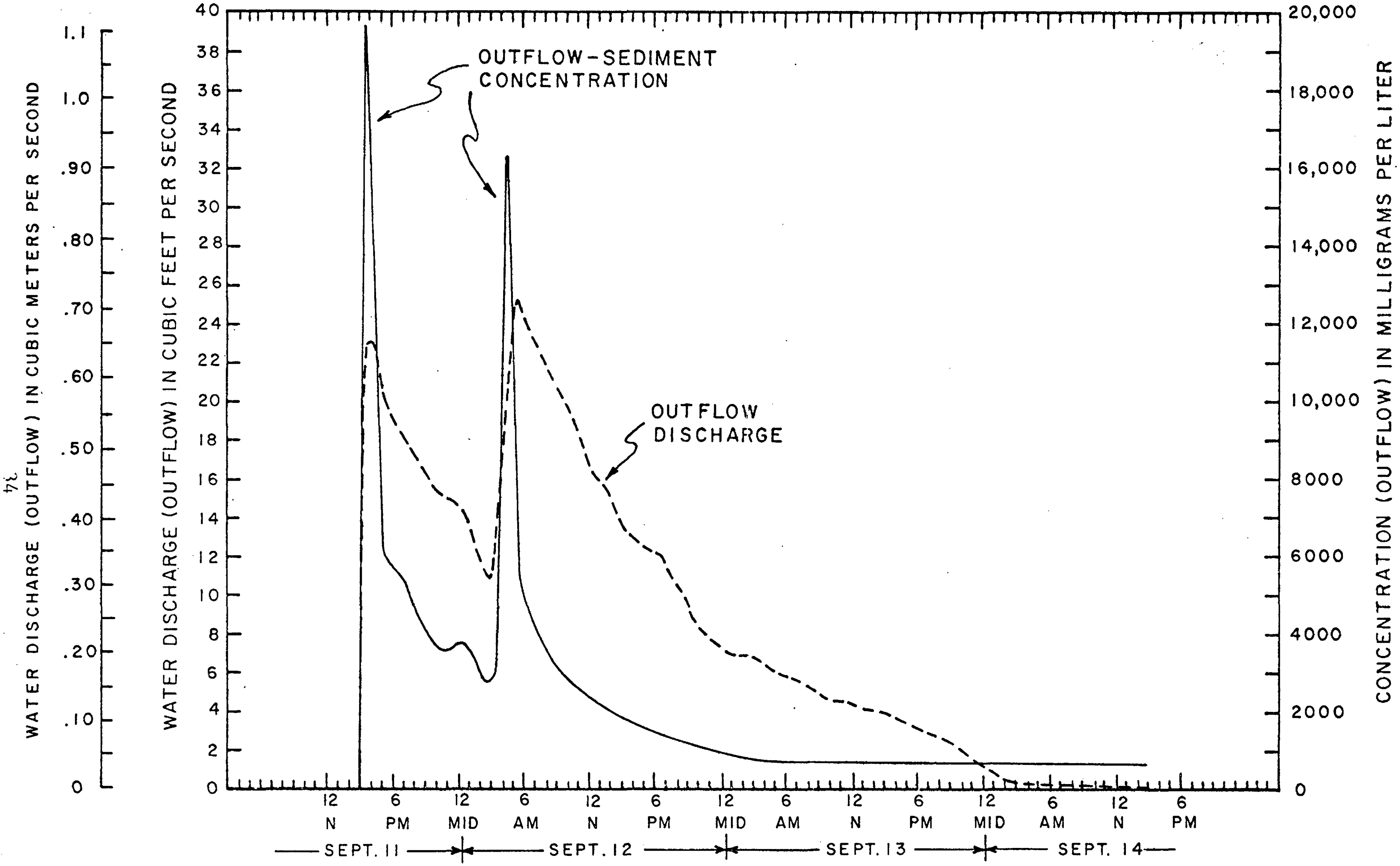

Figure 12.--Outflow discharge and outflow-sediment concentration for flow 6, September 11-14, 1964.

1965 Water Year.--There were three flows (nos. 7, 8, and 9). Number 7 was the third largest flow that occurred during the period covered by this report, yielding an outflow-sediment load of 754 tons (684 t). The period of flow, which lasted 118 hours, consisted of three separate outflow-discharge and concentration peaks. Numerous samples were taken and 14 outflow-discharge measurements were made. Particle-size analyses indicated that all outflow sediment was finer than sand size. Outflow-discharge hydrograph and outflow-concentration curve for flow 7 are presented in figure 13.

Number 8 was a minor flow of 0.2 ft^3/s (0.01 m^3/s) lasting 12 hours.

There were no samples collected on flow 9 and the outflow-sediment load was estimated as before.

1966 Water Year.--Nine flows (nos. 10 to 18) occurred during this water year. Number 15 was the largest flow, moving 220 tons (200 t) of sediment in 32 acre-ft (39,456 m^3) of outflow. Hydrographs and curves showing outflow discharge and outflow concentration for flows 11, 12, 13, 14, 15, and 18 are presented in figures 14 through 19.

Several of the outflow samples collected during the water year contained some sand. The samples were from small flows; apparently, there was insufficient ponding of the inflow to trap all the sand material.

Flows 10 and 16 were not sampled; the outflow-sediment load was estimated as in previous cases.

The second sediment-concentration peak observed on flow 18 was probably caused from agitation of the previously deposited sediments near the outlet structure as the water level in the reservoir diminished. The occurrence of the second concentration peak may by explained as follows: During the time the water is ponded, the flow velocity through the reservoir is very low. Then, as the ponding effect diminishes, a narrow channel forms through the deposited material. The higher velocity in the narrow channel would permit the flow to pick up previously deposited material and transport it through the outlet pipe. This "second-peak" phenomenon occurred on other flows shown in this report.

1967 Water Year.--There were 12 flows (nos. 19 through 30). Number 25 was the largest flow that occurred during the period covered by this report. The total outflow was 347 acre-ft (0.428 hm^3), yielding an outflow-sediment load of 913 tons (828 t). Particle-size analyses of several outflow samples taken during this period of flow indicated that all sands were trapped in the reservoir.

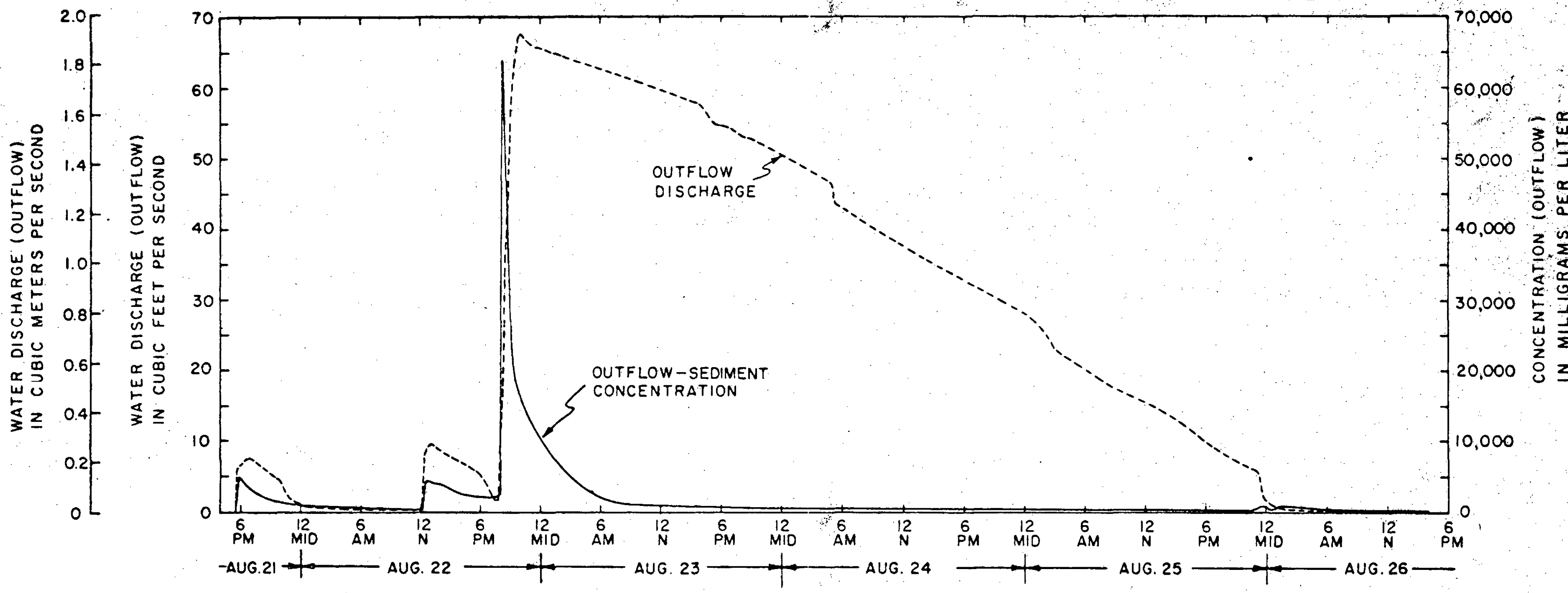

Figure 13.--Outflow discharge and outflow-sediment concentration for flow 7, August 21-26, 1965.

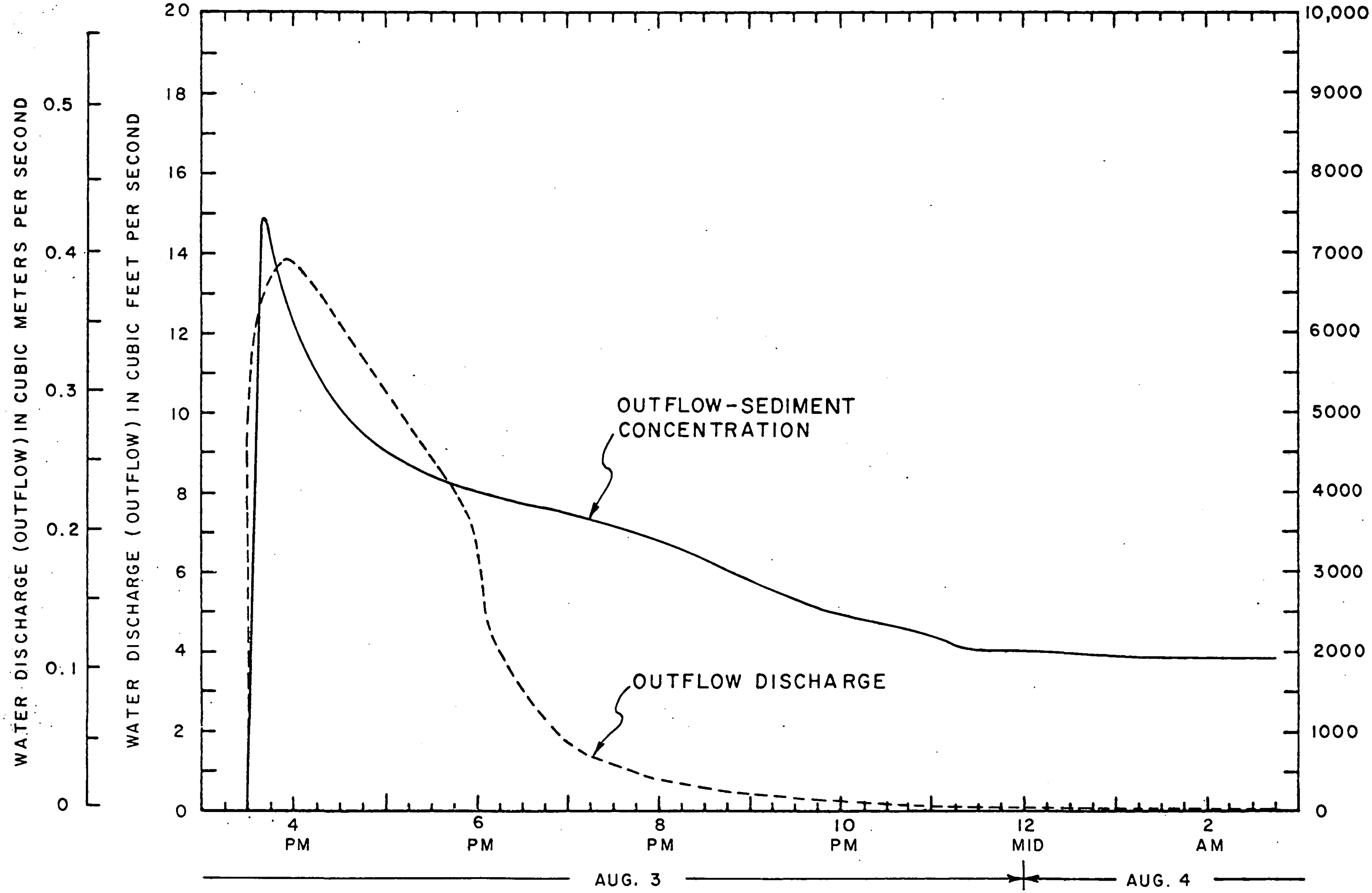

Figure 14.--Outflow discharge and outflow-sediment concentration for flow 11, August 3-4, 1966.

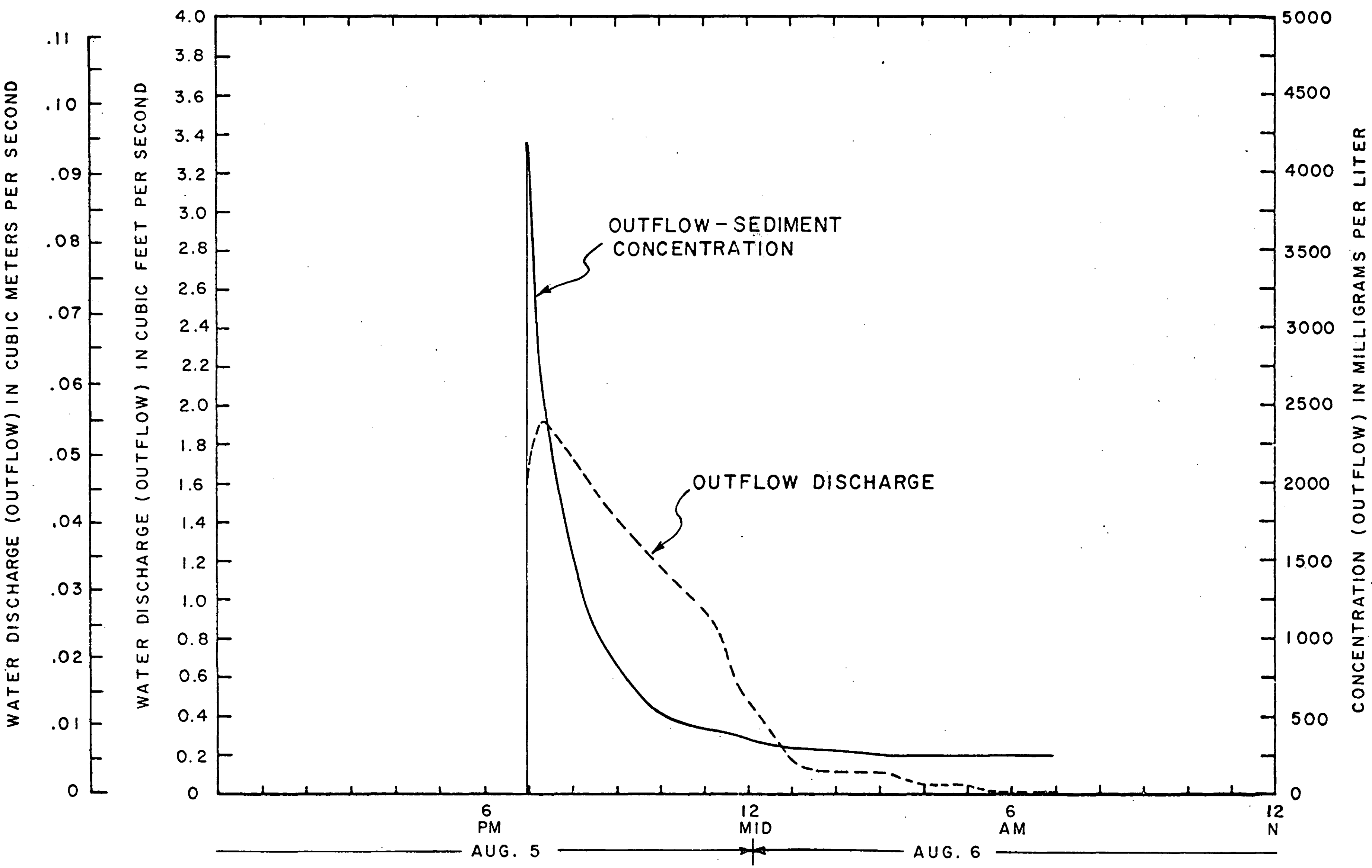

Figure 15.--Outflow discharge and outflow-sediment concentration for flow 12, August 5-6, 1966.

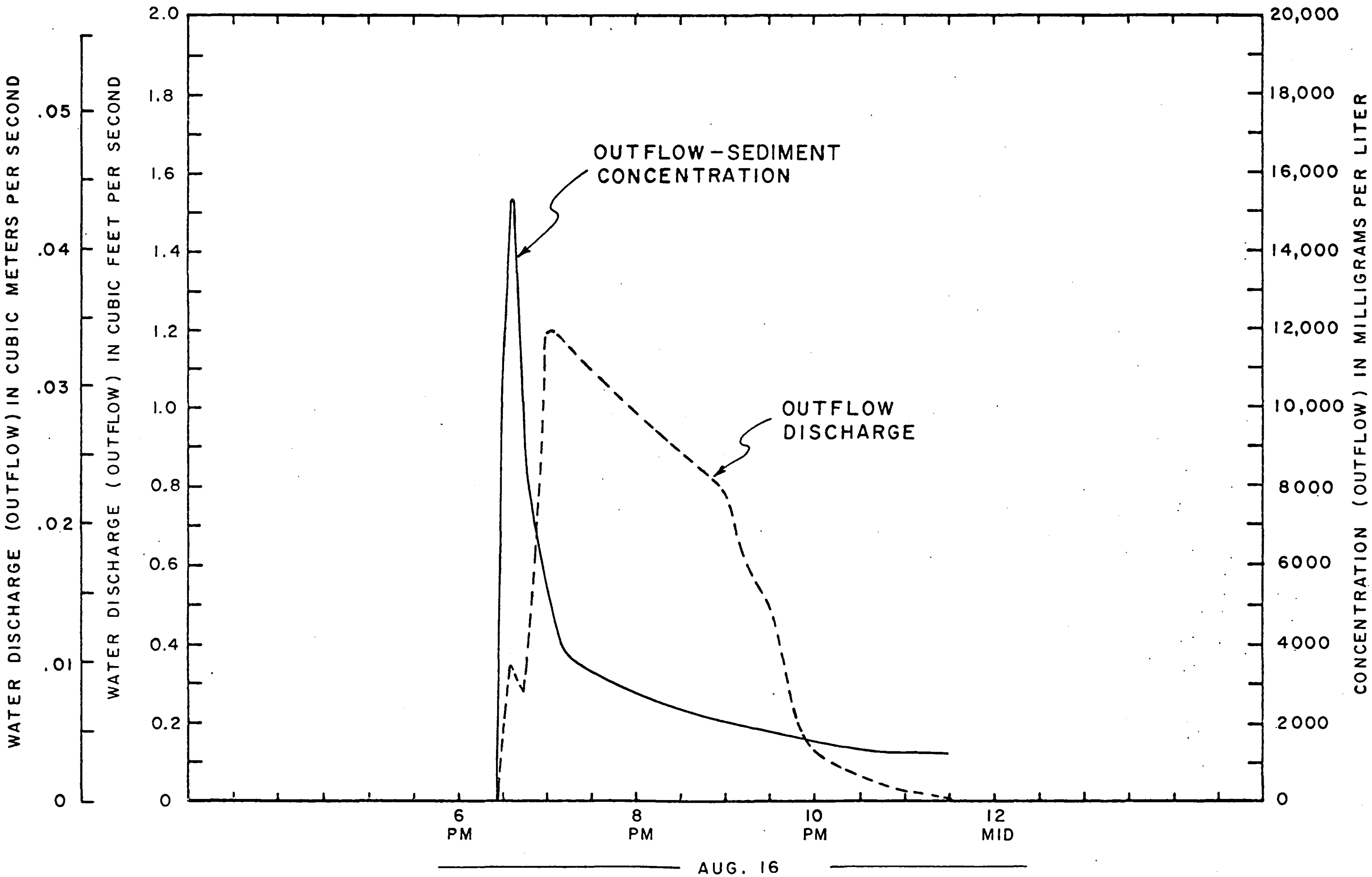

Figure 16.--Outflow discharge and outflow-sediment concentration for flow 13, August 16, 1966.

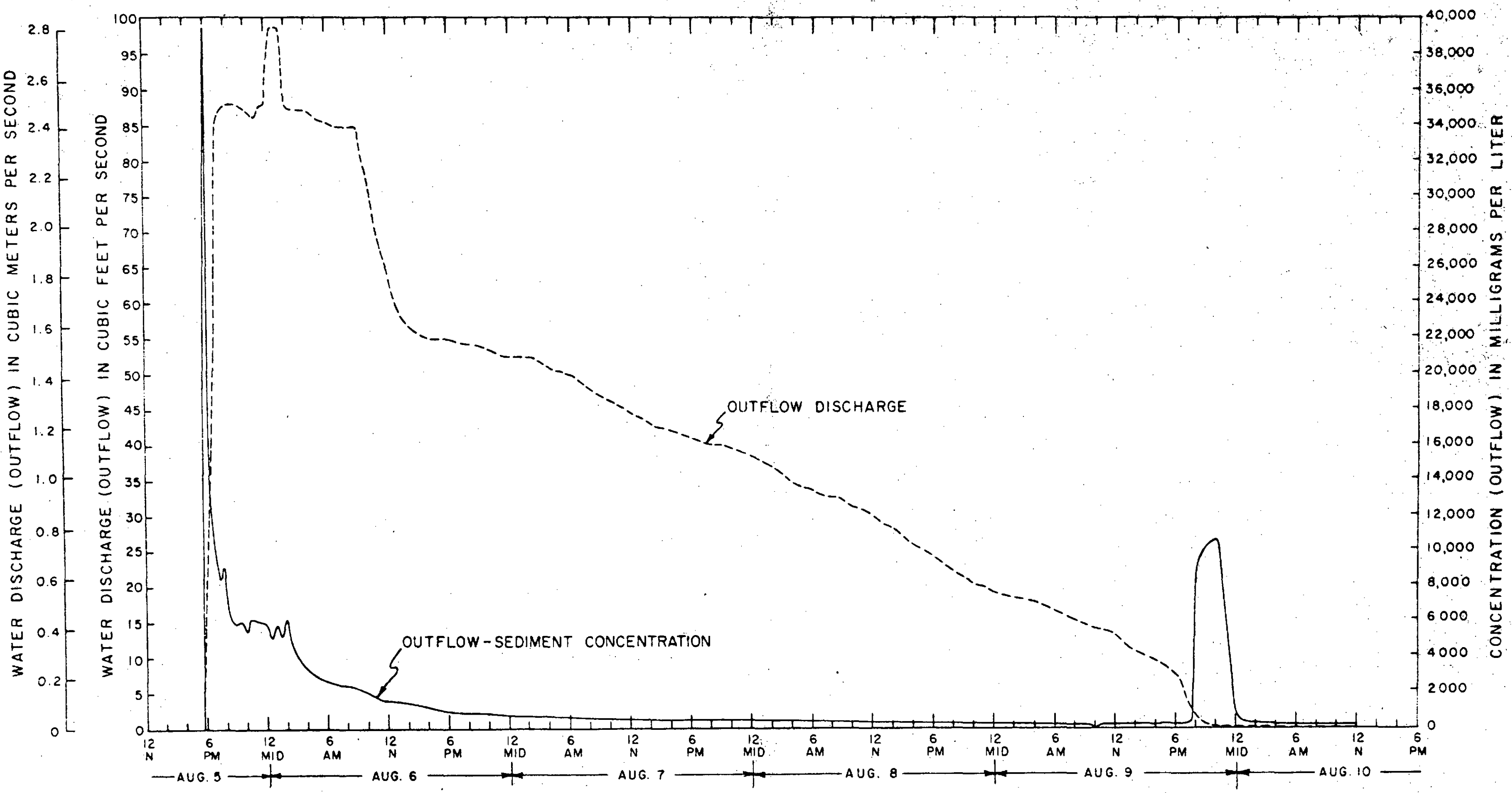

Figure 17.--Outflow discharge and outflow-sediment concentration for flow 14, August 19-20, 1966.

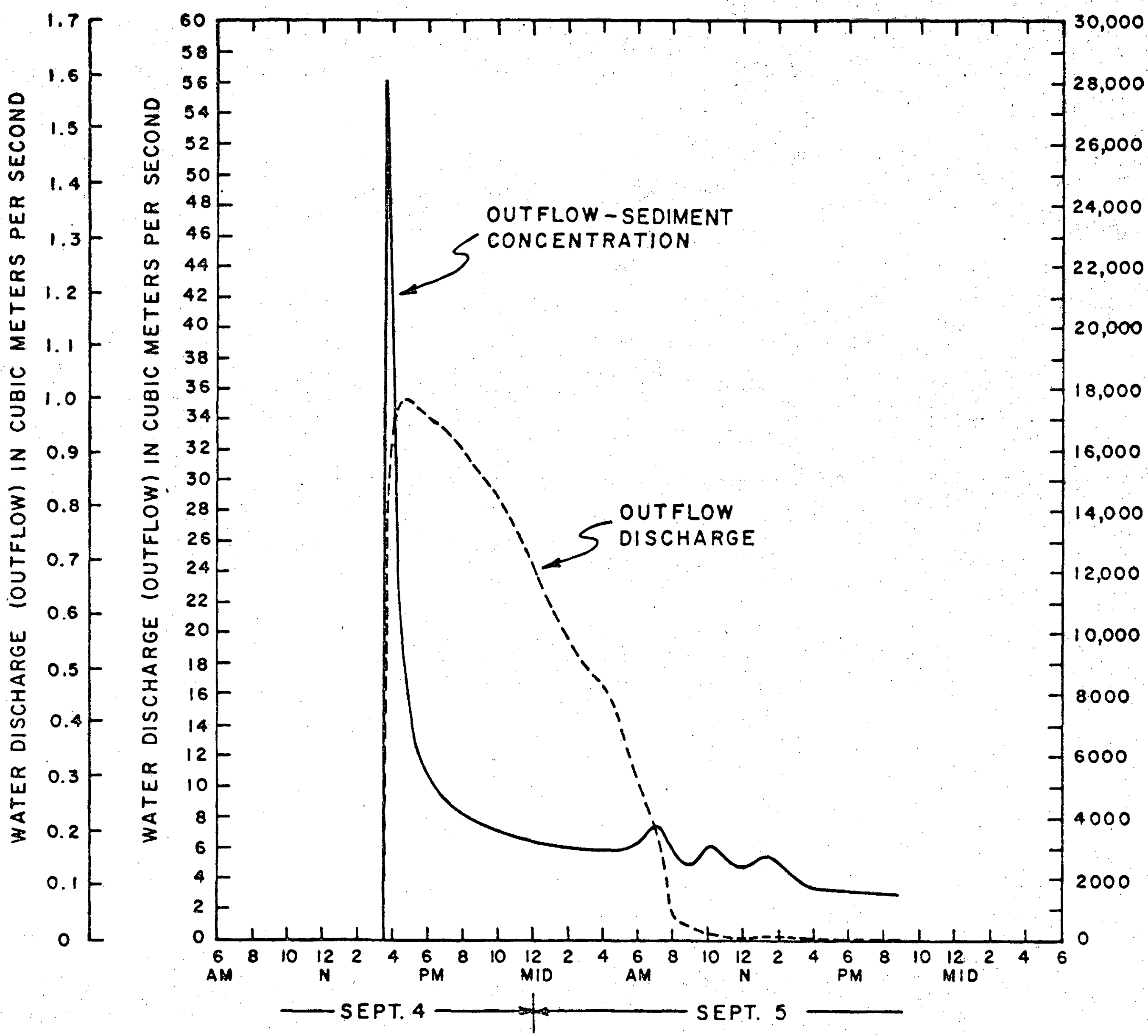

Figure 18.--Outflow discharge and outflow-sediment concentration for flow 15, September 4-5, 1966.

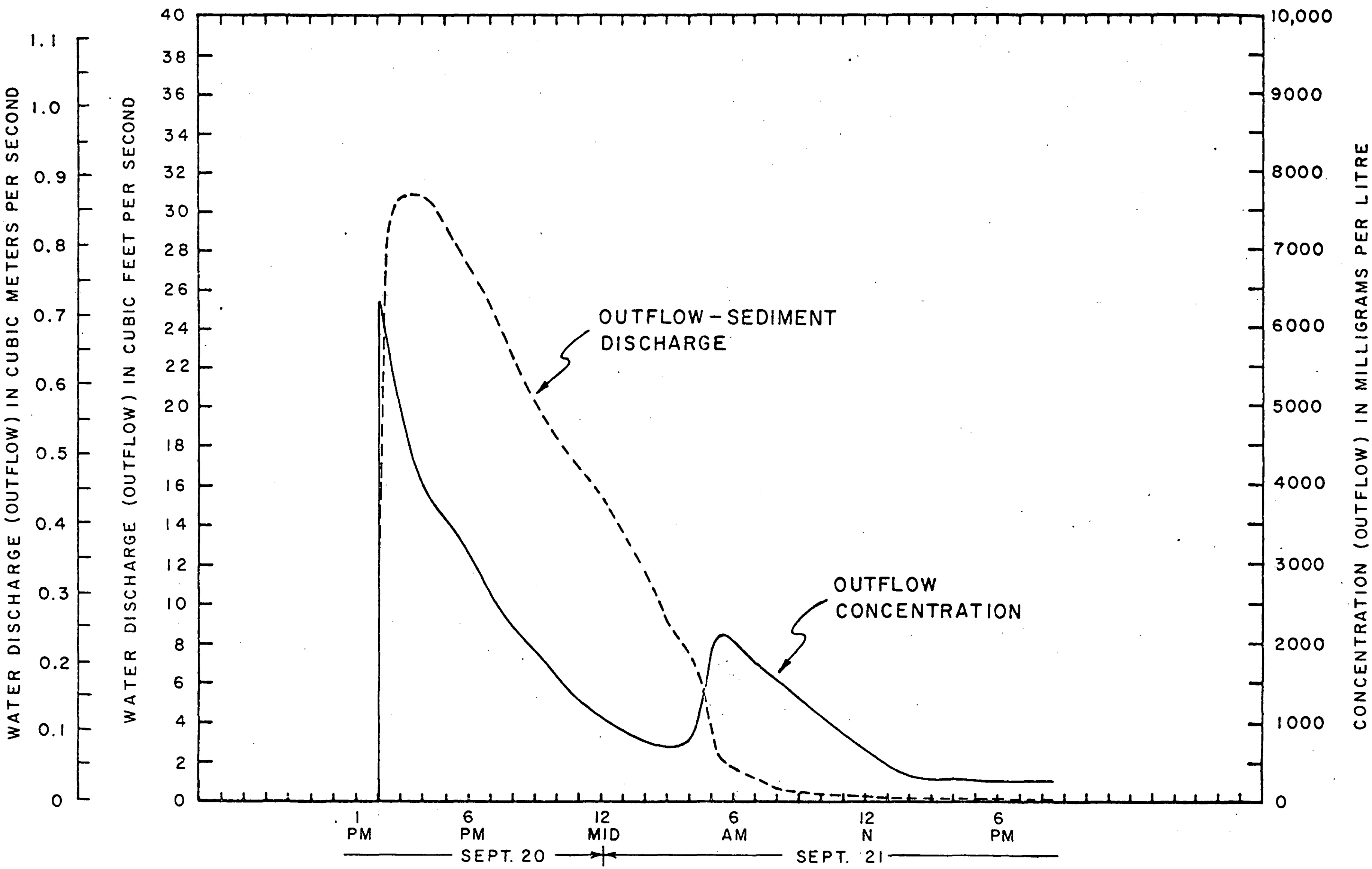

Figure 19.--Outflow discharge and outflow-sediment concentration for flow 18, September 20-21, 1966.

All flows this water year were sampled. Three of the 13 outflow samples analyzed for particle size contained sand; one sample contained 19 percent sand, one had 5 percent, and one had 1 percent.

Hydrographs and curves showing outflow discharge and concentration for flows 22, 25, and 28 are presented in figures 20 through 22.

1968 Water Year.--Two flows (nos. 31 and 32) occurred during the water year. The total outflow was 15.7 acre-ft (19,358 m^3), yielding 101 tons (92 t) of sediment. Outflow-discharge hydrograph and concentration curve for flow 31 are presented in figure 23.

1969 Water Year.--There were 10 flows (nos. 33 through 42), and all were sampled. The three largest flows (nos. 36, 41, and 42) combined, produced 78 percent of the outflow-sediment load for the water year. The average outflow-sediment concentration for flow 34 was 6,370 mg/L; this was the second highest average concentration observed for the period of this report.

1970 Water Year.--Flow nos. 43 and 44 occurred during this water year. The outflow-sediment load for flow 44 was the third largest for the period of record, moving 620 tons (562 t) of sediment in 176 acre-ft (0.217 hm^3) of outflow. Outflow-discharge hydrograph and concentration curve for flow 44 are presented in figure 24.

1971 Water Year.--There were three flows (nos. 45, 46, and 47) during this water year. The average concentration of 10,000 mg/L for flow 45 was the highest observed for the period of this report. The only sample, collected during the 1.25 hour period of flow, contained 49 percent sand; apparently, there was no ponding of the inflow during the entire flow period. Outflow samples taken during floww 46 and 47 also contained some sand. Outflow-discharge hydrograph and concentration curve for flow 47 are presented in figure 25.

1972 Water Year.--There were four flows (nos. 48 through 51) during the water year; the smallest of these flows was not sampled. Hydrographs and curves showing outflow discharge and concentration for flows 48 and 51 are presented in figures 26 and 27. The outflow-sediment load for flow 49 was estimated.

1973 Water Year.--There were four flows (nos. 52 through 55). No samples were taken and the outflow-sediment load was estimated for each period of flow. The estimates appear reasonable as indicated by figure 28.

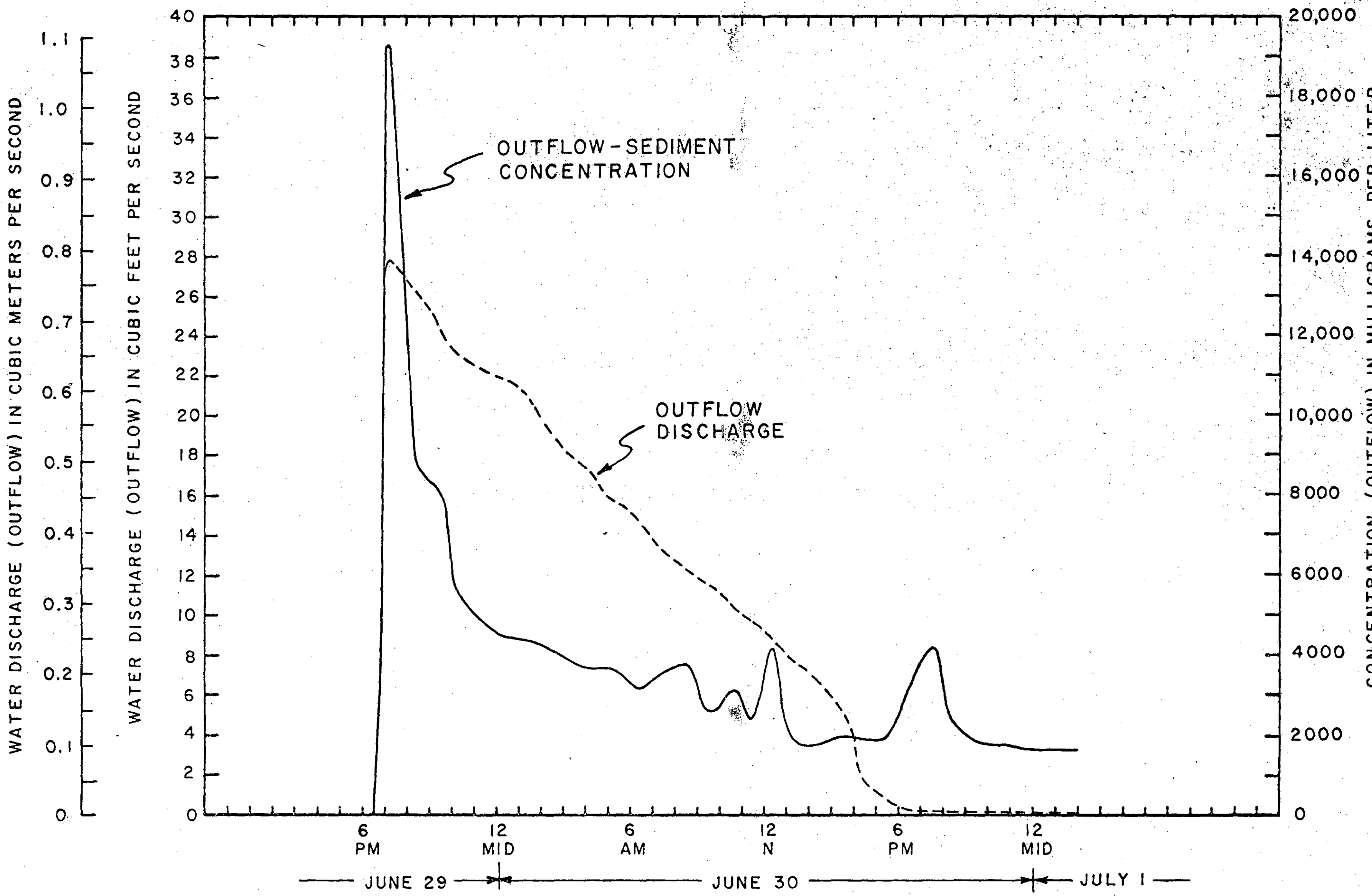

Figure 20.--Outflow discharge and outflow-sediment concentration for flow 22, June 29-July 1, 1967.

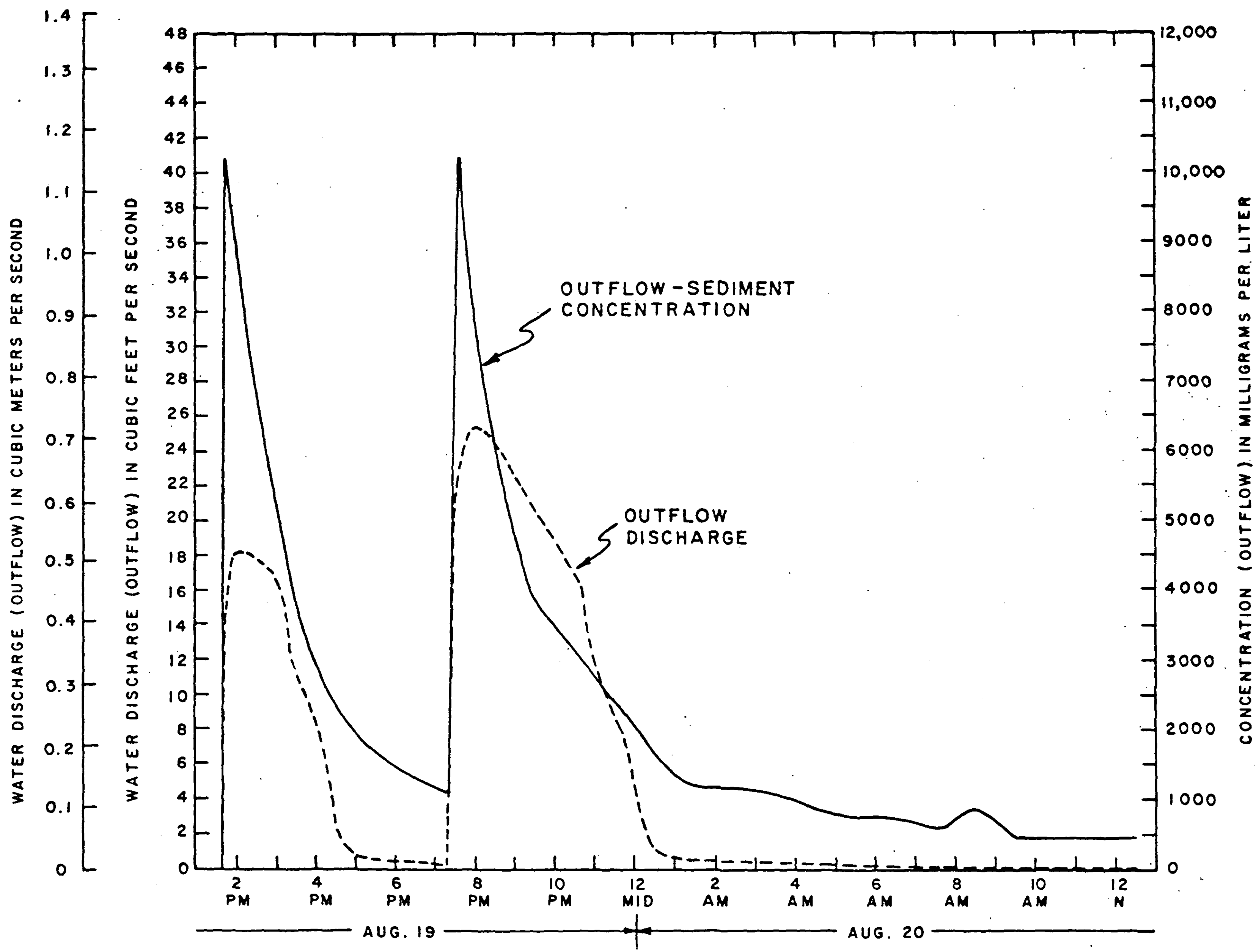

Figure 21.--Outflow discharge and outflow-sediment concentration for flow 25, August 5-10, 1967.

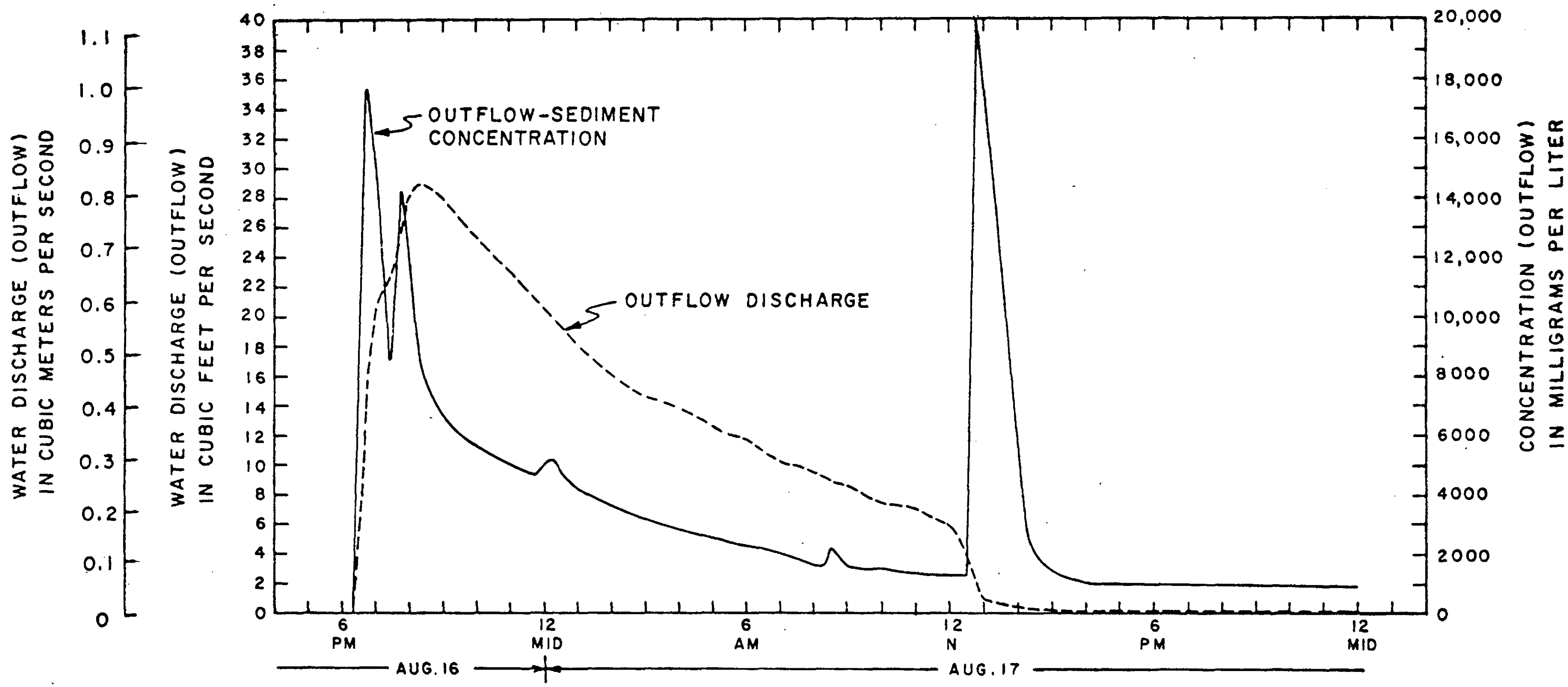

Figure 22.--Outflow discharge and outflow-sediment concentration for flow 28, August 16-17, 1967.

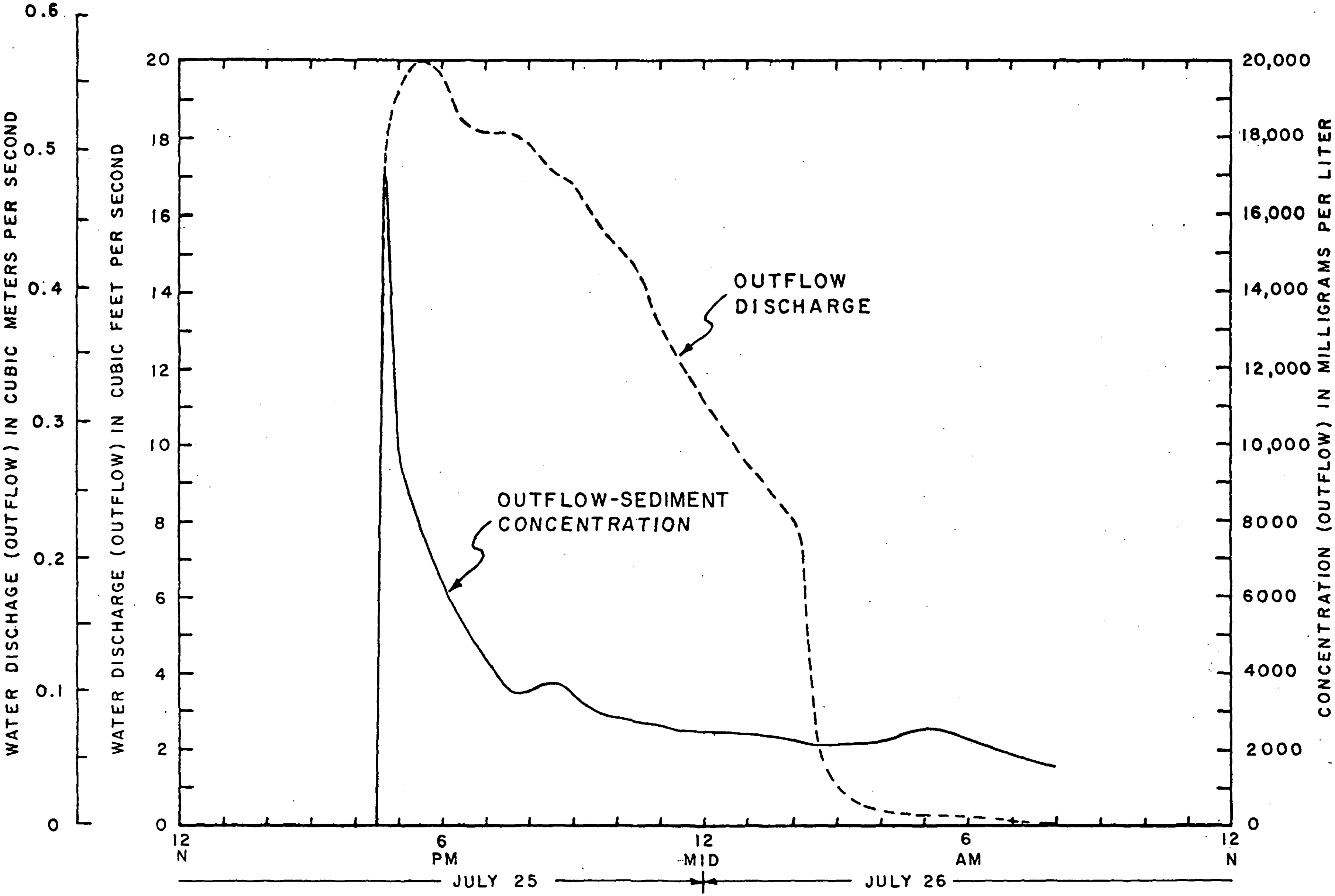

Figure 23.--Outflow discharge and outflow-sediment concentration for flow 31, July 25-26, 1968.

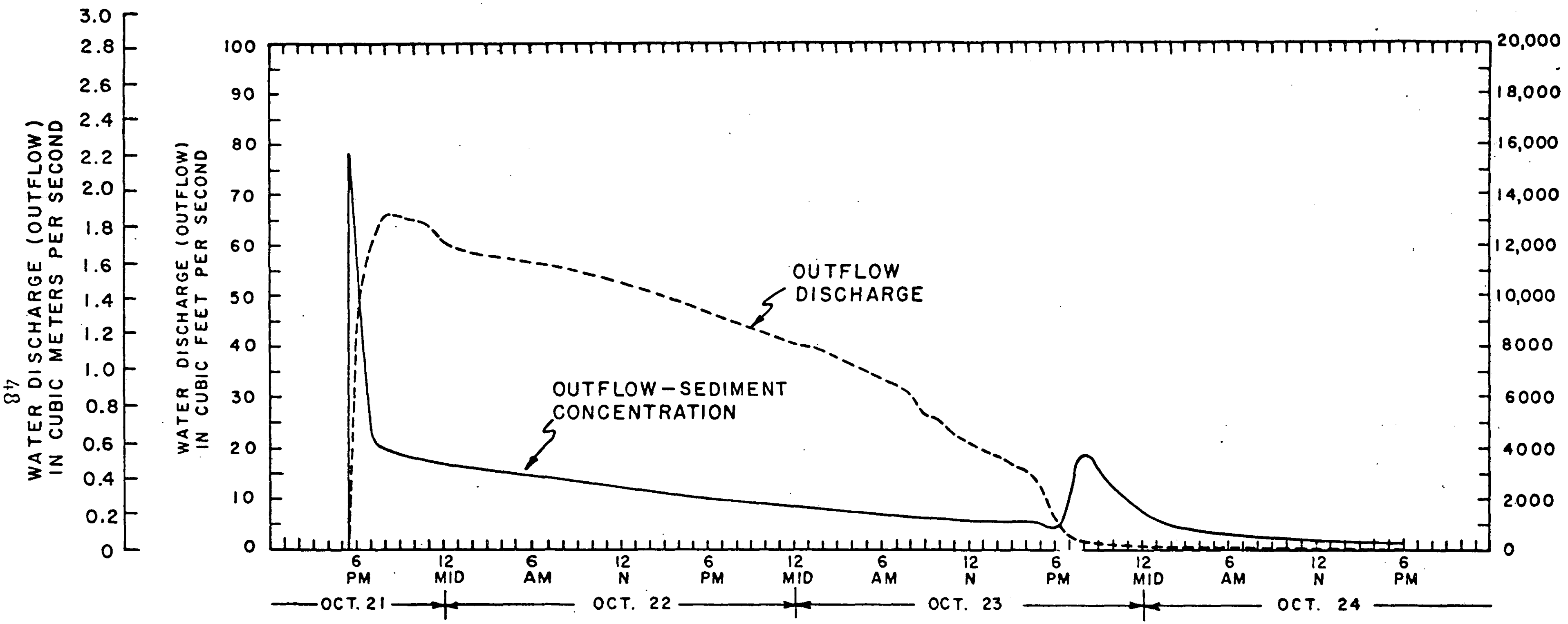

Figure 24.--Outflow discharge and outflow-sediment concentration for flow 44, October 21-24, 1969.

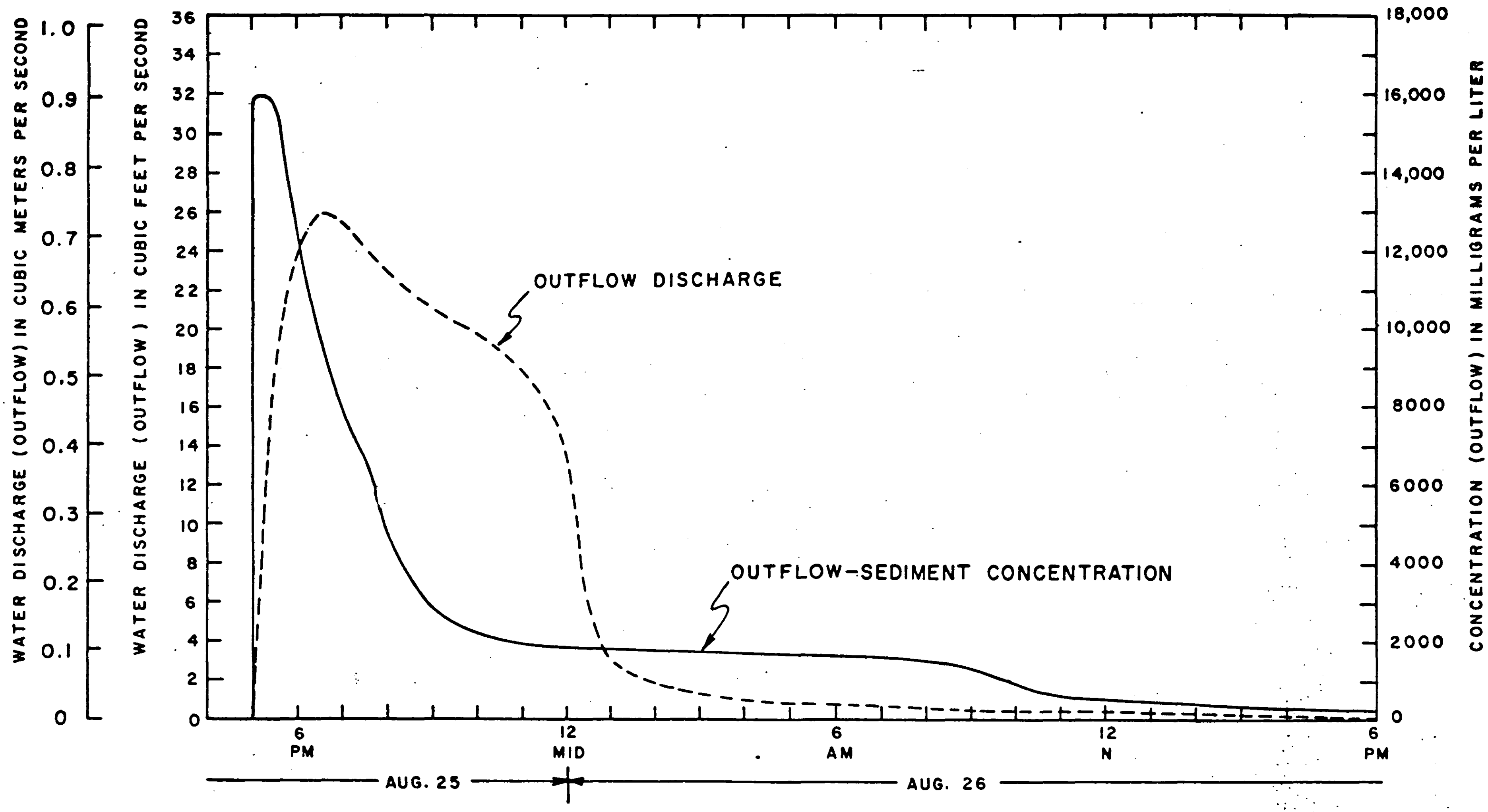

Figure 25.--Outflow discharge and outflow-sediment concentration for flow 47, August 25-26, 1971.

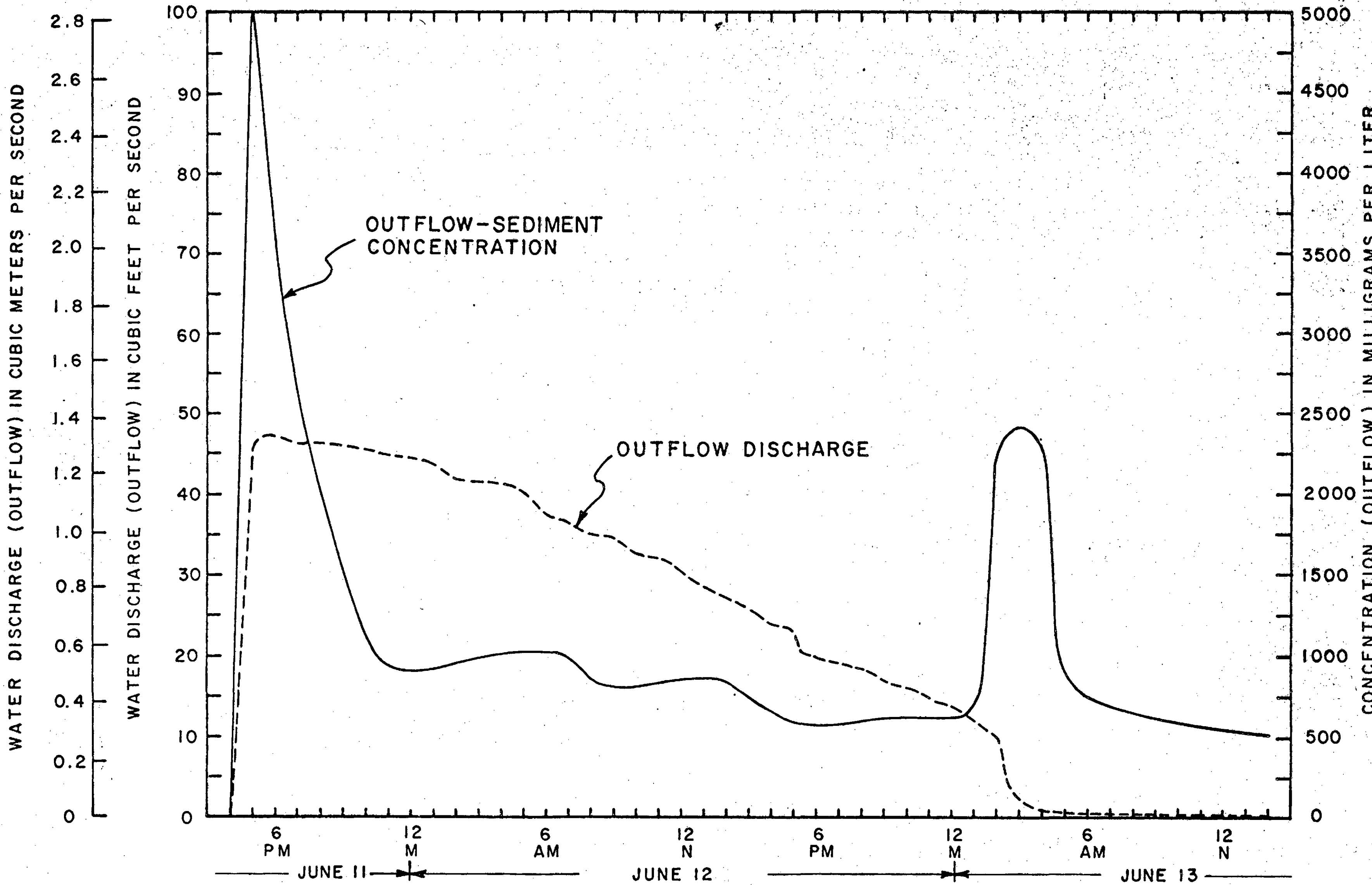

Figure 26.--Outflow discharge and outflow-sediment concentration for flow 48, June 11-13, 1972.

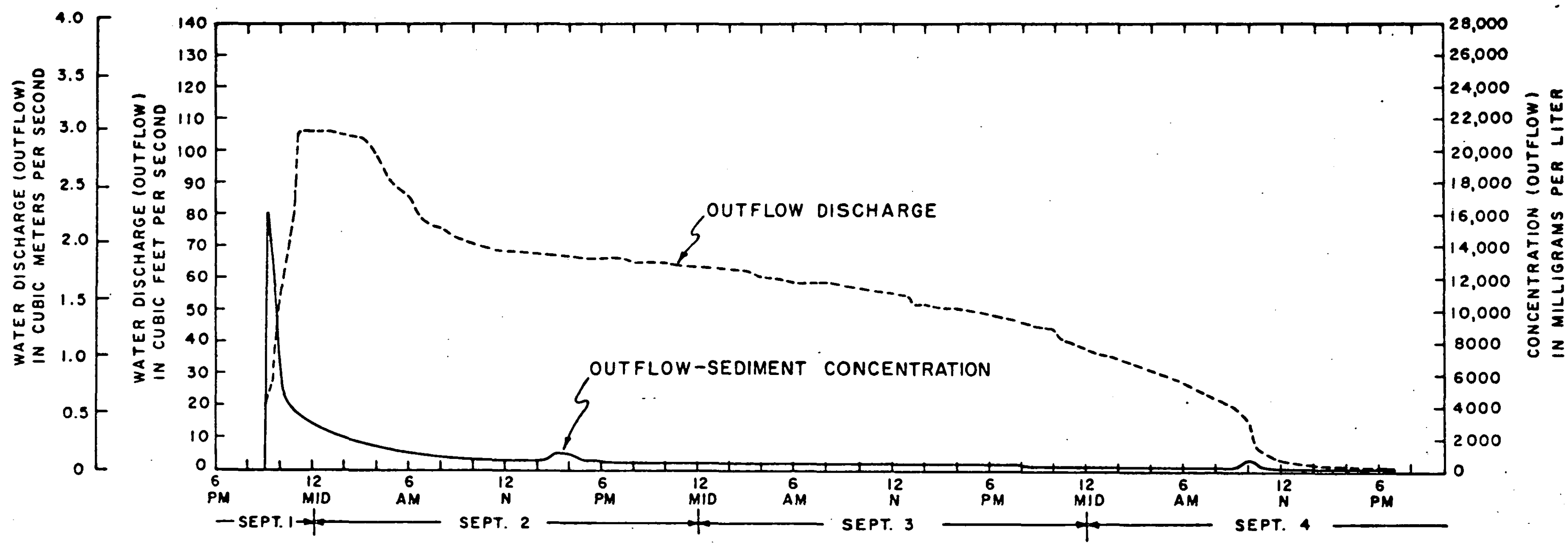

Figure 27.--Outflow discharge and outflow-sediment concentration for flow 51, September 1-4, 1972.

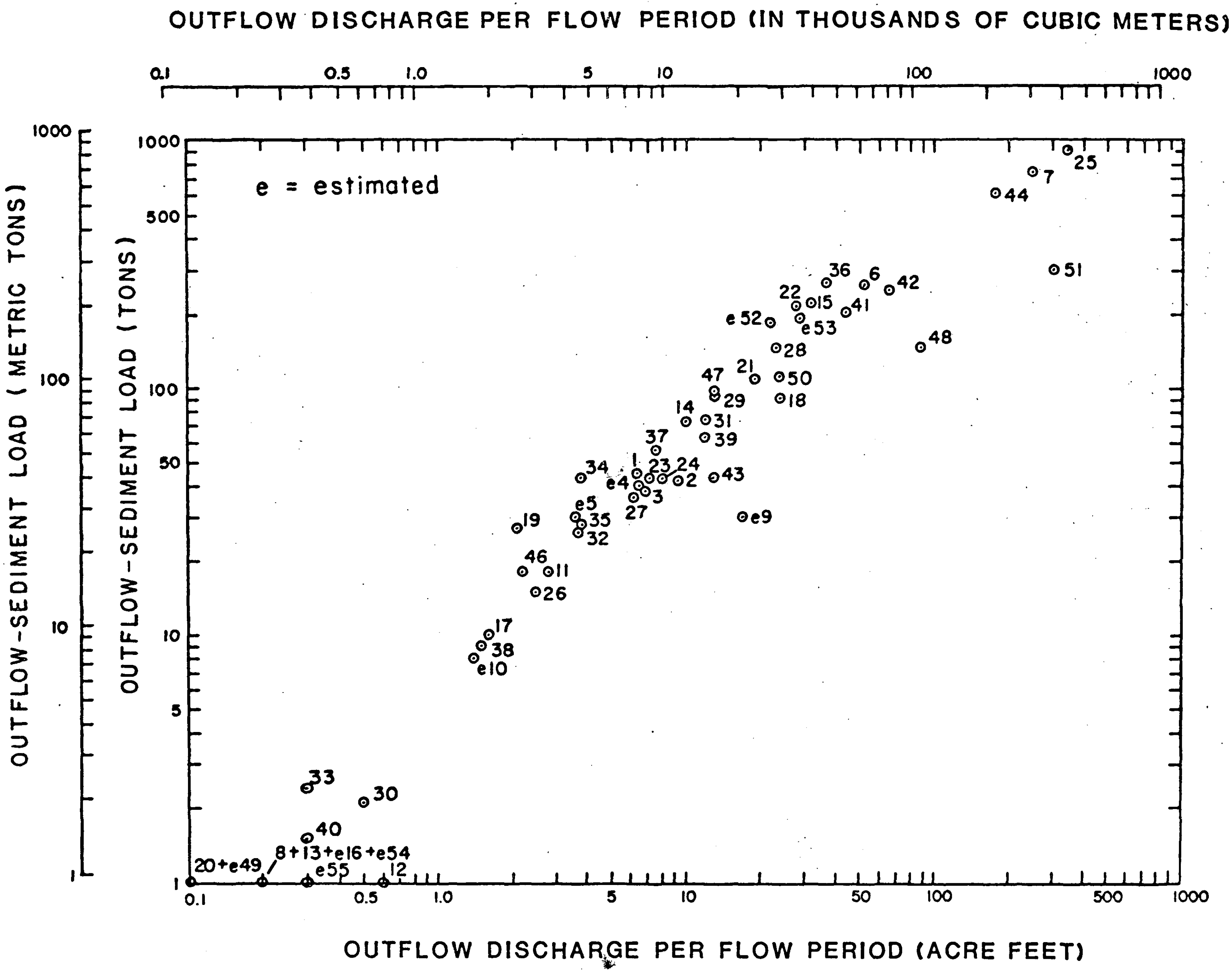

Figure 28.--Relationship of outflow discharge in acre-feet per flow period to [redacted]utf[redacted]sed[redacted]nt [redacted].

1974 Water Year.--The station operation was discontinued on June 30, 1974. There was no flow during the period to June 30.

Computation of trap efficiency

Particle-size analyses of outflow samples were made by standard sedimentation methods. Eighty-seven outflow samples were analyzed for particle-size. The sediment concentration ranged from 236 to 53,300 mg/L. The results, as shown in table 2, indicate that most of the sand-size particles (>0.062 mm) were trapped in the reservoir. Some outflow samples collected when there was no ponding of the flow in the reservoir contained quantities of sand. Of the 87 particle-size analyses, 55 were analyzed in a distilled-water settling medium. The remaining 32 were analyzed in a native-water settling medium. The distilled water, with a chemical dispersing agent added for deflocculation of the fine particles (>0.062 mm), was used to determine the particle-size distribution and thus represent "standardized" conditions. Analyses of samples in the native-water medium was intended to represent the particle-size characteristics of the sediment as they might occur in the natural setting. Flocculation occurred in the native-water settling medium in the laboratory. Analyses in native water indicated an average difference of 48 percent less in the clay (>0.002 mm) size compared to the same analyses made with distilled water having a dispersing agent added. The high calcium-sodium ratio in water will cause flocculation of soil colloids, and water with a low calcium-sodium ratio will tend to disperse soil colloids (Rainwater and Thatcher, 1969, p. 127-265). It can be assumed that flocculation occurred in the reservoir, but the degree to which it occurred is unknown.

The reservoir was surveyed in 1967 and again in 1975 by the U.S. Soil Conservation Service to determine the extent of sediment deposition. The reservoir capacity loss for the period between the initial survey in 1963 and the survey in 1975 was 73.3 acre-ft (90.379 m^3), as shown in table 4. This represents a 5.55 percent storage loss in 12 years.

Table 4.--Summary of reservoir-sedimentation surveys

Date of survey	Period years	Capacity (acre-ft)	Total sediment deposits to date (acre-ft)	Average specific mass (lb per ft^3)
April, 1963	-	1,324	-	-
May, 1967	4	1,298	26	84
December, 1975	12	1,251	73	-

The trap efficiency of the reservoir was computed using data from the reservoir surveys. Trap efficiency is a ratio, expressed as a percentage, of the weight of sediment retained in a reservoir to the weight of sediment entering the reservoir. As shown by Anttila (1970), the equation used for the calibration of the trap efficiency of the reservoir is

$$TE = 100 \frac{A}{A + B}$$

where

TE = trap efficiency of the reservoir, in percent,

A = weight of sediment deposited in reservoir (tons),

B = weight of sediment discharged from reservoir (tons).

The measured trap efficiency of Tortugas Floodwater Retarding Reservoir No. 1 was 96 percent during the period April 1963 to June 1974. During the first 4 years of the study, the trap efficiency of the reservoir was 97 percent.

The trap efficiency of a reservoir depends upon various factors. Some of these factors that Brune (1953, p. 407-417) and others have studied in attempts to correlate trap efficiency include: ratio between storage capacity and drainage area; ratio between storage capacity and inflow; age of the reservoir; shape of the reservoir basin; the type of outlets and method of operation; the particle-size characteristics of the sediment; and the behavior of the finer sediment fractions under various conditions. Most of the correlations shown by Brune were for normal ponded reservoirs ("normal" meaning "conventional reservoirs as distinguished from desilting basins and dry reservoirs") (p. 411).

Tortugas Floodwater Retarding Reservoir No. 1 is normally dry except for summer-storm runoff. The inflow from these storms are usually small and of short duration. The reservoir was designed so that it would contain no dead storage of water, and the total outflow for any one flow did not exceed 26 percent of the reservoir storage capacity during the period covered by this report. Over 99 percent of the coarse sediments (>0.062 mm) and a high percentage of the silts and clays are deposited in the reservoir before reaching the outflow pipe. The 96 percent trap-efficiency value appears to be reasonable for this type of reservoir and the quantity of inflow.

Summary

All periods of flow during the investigation occurred from early June to late October. Many rain showers were observed over the drainage basin, and apparently the arid terrain of the basin was able to absorb most of the low volume and low intensity rainfalls. Therefore, high volume and high intensity summer thundershowers appear necessary to load the drainage basin and cause runoff. At times, summer thundershowers tend to soak one or more separate portions of the drainage area causing runoff in only parts of the basin.

The total outflow recorded for the period of record (July 1963 to June 1974) was 1,743 acre-ft (2.1 hm^3), yielding 6,055 tons (5,493 t) of sediment.

The trap efficiency of reservoir 1 was 96 percent for the period of record.

Selected references

Anttila, P. W., 1970, Sedimentation in Plum Creek Subwatershed No. 4, Shelby County, North-Central Kentucky: U.S. Geol. Survey Water-Supply Paper 1798-G, 54 p.

Brune, G. M., 1953, Trap efficiency of reservoirs: Am. Geophys. Union Trans., v. 34, no. 3, p. 407-418.

Flint, R. F., 1972, Fluvial Sediment in Hocking River Subwatershed 1 (North Branch), Hunters Run, Ohio: U.S. Geol. Survey Water-Supply Paper 1798-I, 22 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, second ed., 363 p.

Mundorff, J. C., 1966, Sedimentation in Brownell Creek Subwatershed No. 1, Nebraska: U.S. Geol. Survey Water-Supply Paper 1798-C, 49 p.

Rainwater, F. H., and Thatcher, L. L., 1960, Methods for collection and analysis of water samples: U.S. Geol. Survey Water-Supply Paper 1454, 301 p.

U.S. Geological Survey, annual reports 1964-1974, Water Resources Data for New Mexico, Part 2, Water Quality Records.