ARC - 60/69 - 56

STREAM SEDIMENTATION AND TROUT POPULATIONS IN BLUEWATER CREEK, MONTANA[1,2]

By

John C. Peters
Fish & Game Building, Montana State College
Bozeman, Montana

ABSTRACT

The effects of sedimentation rates, stream discharge, and water temperature were studied in Bluewater Creek. Trout of all ages were abundant where sediment concentrations or loads were low and stream discharge stable. Few trout were found in those areas of the stream where sediment concentrations or loads were high and discharge erratic. Water temperatures were higher than desirable for trout in areas of the stream influenced by irrigation surface return flow. Survival of trout eggs was found only where stable stream discharge and low sediment concentrations were measured.

INTRODUCTION

The influences of inorganic sediment on aquatic life of streams were summarized recently by Cordone and Kelley (1961). They pointed out that there is abundant qualitative evidence that sediment is detrimental to aquatic life in salmon and trout streams. Historical changes in aquatic populations in warm-water streams resulting from sedimentation have been reported by Ellis (1931), Trautman (1957), and Larimore and Smith (1963). The question, "How much sediment is harmful?" has not been answered for either trout or warm-water streams, since most workers have failed to measure the amounts of sediment.

A sediment-fish population study in Bluewater Creek, Montana was initiated in 1960 by the Department in cooperation with the U. S. Geological Survey. The goals of the study were to determine: (1) the amount of sediment detrimental to a trout population and (2) at what stage in the life history of trout was sediment most harmful. This paper considers the quantity of sediment detrimental to a trout population.

DESCRIPTION OF THE STUDY STREAM

Bluewater Creek is a spring-fed stream, approximately 15 miles long, flowing in a northwesterly direction to its confluence with the Clarks Fork of the Yellowstone River near Fromberg, Montana. Within the upper 4 miles, a series of artesian springs supply 29 of the 30 cubic feet per second of water normally in the remaining 11 miles of stream. Except for infrequent

[1] This study was partly financed and administered through Federal Aid, Dingell-Johnson Act. (Project F-20-R, Montana)

[2] Presented at the American Fisheries Society Meeting in Minneapolis, Minnesota, September 12, 1963.

runoff in the watershed, caused by rain showers or rapid melting of snow pack, historically, the creek could be characterized as one with an extremely stable year-round flow.

Presently, the Bluewater Creek valley is intensely developed for agriculture with pasture land and cultivated crop land abundant. Because of a low annual precipitation (about 11 inches per year, over three-fourths of which occurs in the winter), water from the stream is diverted for irrigation in the valley from April to October. During the irrigation season, return surface flow changes the quality, quantity, and temperature of the water in the lower 9 miles of the study stream. Under present water use practices, the stream flows are variable in the lower 9 miles and stable in the upper part of the stream during the irrigation season. Water flows are stable in the winter months in the creek.

The native salmonid fish in Bluewater Creek was the cutthroat trout, _Salmo clarki_, but this species has been replaced by introduced forms; rainbow trout, _Salmo gairdneri_ and brown trout, _Salmo trutta_. Brown trout are self-sustaining; the few rainbow trout are escapement from the State's Bluewater Creek hatchery.

The geology of the area is described in Knappen and Moulton (1930). Numerous faults are found within a 10 mile radius of Blue Springs which gives Bluewater Creek its name. Two northeastward-trending faults are bisected by the creek.

The stream meanders through eight distinct geological formations. The upper part of the creek is flanked by the typically bright to dark red sandy shale and sandstone of the Chugwater formation. The brilliant red contrasts sharply with the browns and grays of the associate shales and is complimented by yellows of the sandstones downstream.

Woody stream bank vegetation is abundant in the upper half of the stream, with willows, _Salix spp._ and water birch, _Betula occidentalis_ predominant. Downstream, woody vegetation is scarce; it has been removed to facilitate agricultural activities.

METHODS AND TECHNIQUES

Sediment sampling stations in the study stream were chosen so that biological comparisons could be made between areas of the stream with small amounts of sediment and areas influenced by various degrees of sedimentation. Five permanent sediment stations were located in Bluewater Creek about 3 miles apart and numbered consecutively I through V; with I denoted as the upstream station, V the downstream station (FIGURE 1). To eliminate the chance of error due to variability in habitat, 3 units of equal area (4,000 square feet) were censused for fish population statistics within 1 stream mile of each sediment sampling station. In addition to measuring suspended sediment (hereafter referred to as sediment), stream flow and water temperature were measured instantaneously at each sediment station.

Sediment concentrations and discharge were measured by standard methods used by the Geological Survey. A depth-integration sampler (designated by the USGS as the DH-48 hand, suspended-sediment sampler) holding a 1-pint bottle was used to sample the water-sediment mixture. The bottle sampler fills at a rate equal to the stream velocity and does not disturb either the flow lines or velocity ahead of its intake. The depth-integration sampler's

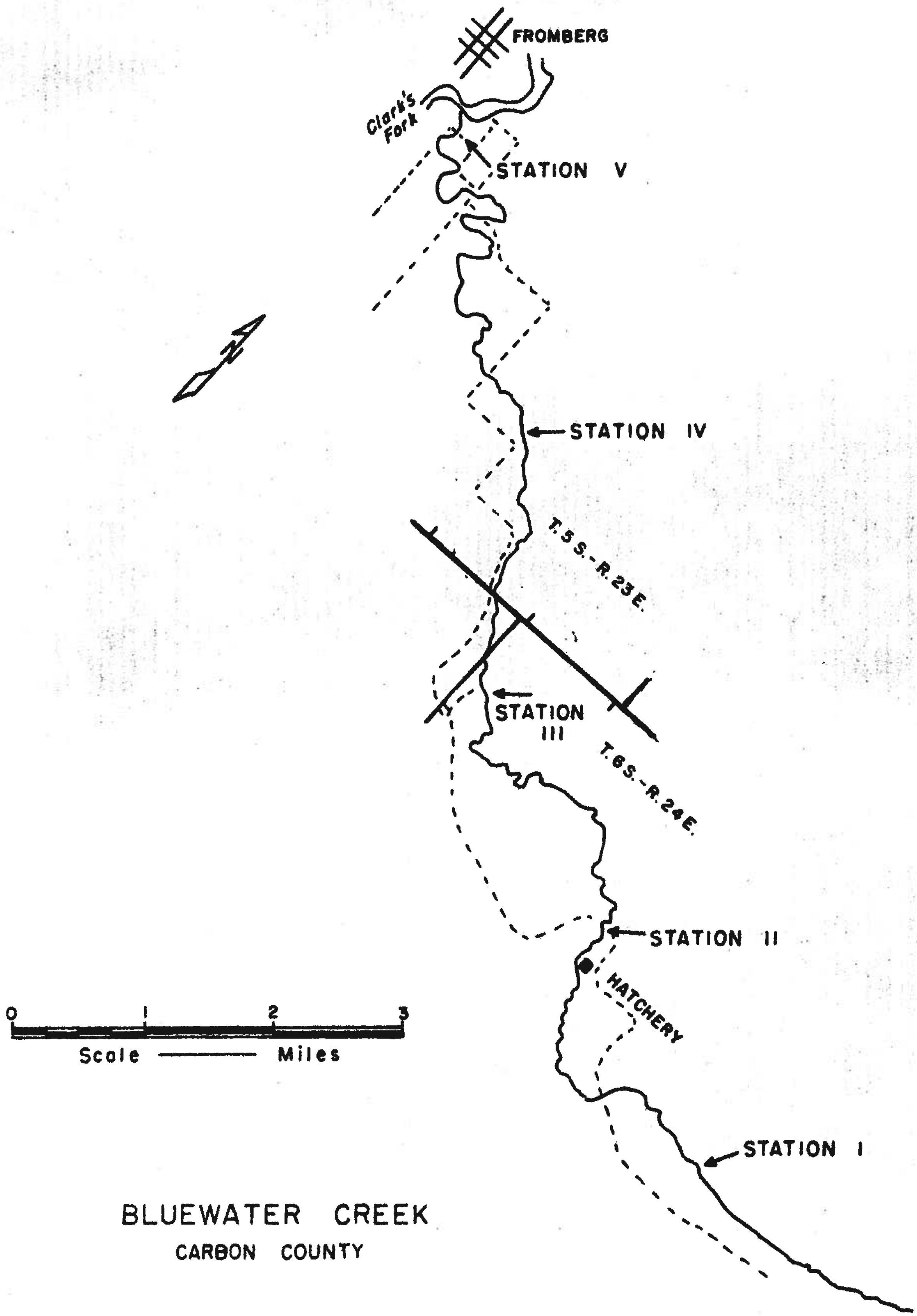

FIGURE 1. Map of Bluewater Creek showing locations of sediment stations.

design and operation is summarized in a report by the Inter-Agency Committee on Water Resources (1959). The depth-integration method of sampling secures and increment of sample from every portion of a vertical. A vertical is an imaginary vertical line at any point in a stream, extending from the surface to the bottom. A water-sediment mixture is sampled at a series of verticals, approximately 1 foot apart, across the width of a stream.

The basic method of determining the concentration of suspended-sediment samples is that of weighing the water-sediment mixture, allowing the sediment to settle to the bottom of a container, decanting the supernatant liquid, washing the sediment into an evaporating dish, and drying it in an oven. Special techniques, such as adding flocculating agents to reduce settling time, may be used. The sediment fraction is weighed with a gramatic balance. Sediment concentration is the ratio of the sediment weight in a water-sediment mixture to the total weight of the mixture and is ordinarily expressed in parts per million.

Sediment samples were collected from the test stream at all sampling areas at least twice a week. The stream was sampled for sediment as often as 12 times per day when the drainage received precipitation.

Stream gauging procedure used to measure stream discharge, is summarized in Corbett (1943). The tools used in stream gauging are (1) a current meter, (2) a staff gauge, and (3) a water level recorder. The current meter (Price Pattern) calibrated by the U. S. Bureau of Standards was used to determine the volume of water per unit time (discharge) in the vicinity of a staff gauge at each station. A staff gauge is a graduated scale on a plank, metal plate, or wall by which the stage or water level of the stream may be read. A graph, the rating curve, showing the relation between stage and discharge, was constructed after discharges at different water levels were measured.

Stevens Water Level Recorders (Type E) were used to measure continuous fluctuations in water levels. The recorder consists essentially of a height element to register the elevation of the water surface to a uniform scale, and a time element mechanism to move a pen which traverses a chart at a uniform speed. In operation, the chart drum moves horizontallv in direct proportion to changes in water levels, while a pen moves vertically at a rate controlled by the clock movement producing a graphic record of water levels against time. A float line, attached to a float resting on the water surface, passes over the float pulley and is counter-weighted to maintain the proper tension. The float pulley is thereby turned during change in water levels and this motion is imparted to the chart drum through gearing so as to record proportional increases and decreases in stage.

The water level recorders were contained in gauge-houses, constructed with 10-foot sections of 16 gauge, 2-foot diameter culvert. The gauge-houses were used to minimize the effects of weather on the water-level recorders and the recording thermometers.

Water temperature measurements were obtained from Dickson "Minicorder" recording thermometers or from Taylor Etched-Stem pocket thermometers. The braided armored copper connecting tube and the sensitive bulb of the thermographs were inserted in a 2-inch diameter galvanized pipe. The pipe not only protects the temperature-sensitive bulb but also anchors the system firmly in the stream bed. The thermograph's recording mechanism was housed either in a gauge-house or a waterproof electrical box.

Fish population estimates were obtained by electrofishing with a 230-volt smooth current generator. Blocknets were used at both the upstream and downstream boundaries and two passes were made through the sampling section. Three

4,000 square foot sections were electrofished in the vicinity of each sediment station. However, mark and recapture was done only in one of three sections.

In the mark and recapture experiments, fish captured were marked and returned to the sampling section and re-sampled again with the same amount of effort. The ratio of the marked fish recaptured to the total number of fish captured (during the subsequent effort) was used to estimate the fish population. The theory and applications of this method is summarized in Ricker (1958).

In the vicinity of the sediment stations, man-made redds were constructed by excavating a hole in the stream bed approximately 3 feet long, 2 feet wide, and 1 foot deep. The excavations were filled with 3/8 sorted gravel chips and allowed to stabilize for four days before eggs were introduced.

Eyed rainbow trout eggs were poured into Vibert boxes (Anon., 1959), partially filled with gravel chips, and placed in the redds. At each sampling station, three Vibert boxes, with an estimated 476 eggs per box, were placed 7 inches deep within the redd. The developing eggs were allowed to remain in the stream until one week after calculated hatching time.

RESULTS

Sediment

Sediment load in tons per day at the sampling stations for 2 years is summarized in FIGURES 2-6, using sediment-duration curves. The daily sediment load is calculated using the following formula: average daily discharge (cfs) x average daily sediment concentration (ppm) x 0.0027. The sediment load in the upper 6 miles of stream is relatively stable. At Station I, 90 per cent of the time the load ranged between 0.4 and 1.2 tons per day. The sediment load ranged between 2.5 and 14 tons per day 90 per cent of the time at Station II.

The lower 9 miles of the stream showed great variability in sediment loads with progressive downstream deterioration in water quality. The sediment loads, 90 per cent of the time, ranged between: 1.8 and 25 tons per day (III); 0.5 and 32 tons per day (IV); and 5.0 and 160 tons per day (V).

The time of the year that the greatest average monthly concentrations of sediment are found in the stream is during the irrigation season, April to October (TABLE 1). However, high average monthly sediment concentrations occur at the three downstream stations after the irrigation season. This occurs because sediment is deposited in the channel during the periods of low flows resulting from irrigation demands (Strahler, 1956).

An irrigation ditching system receiving water from artesian sources washed out, accounting for the high average monthly concentrations at Station II in the winter of 1962. The relatively high sediment load observed in FIGURES 3-6 occurred for 3 days in September of 1962, resulting from a heavy downpour in the watershed. Nearly 3,000 tons per day were passing by the lower station at this time.

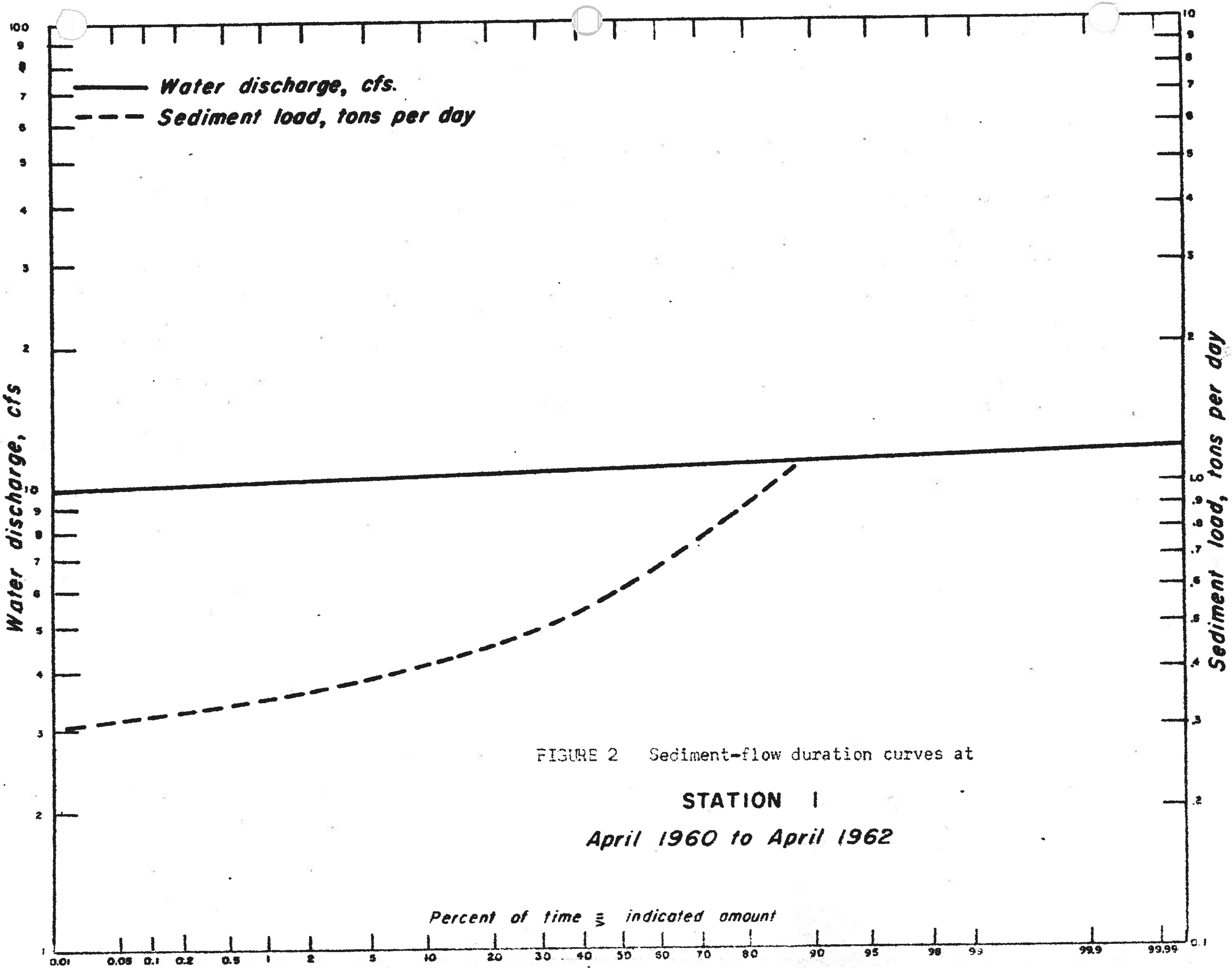

FIGURE 2 Sediment-flow duration curves at

STATION 1

April 1960 to April 1962

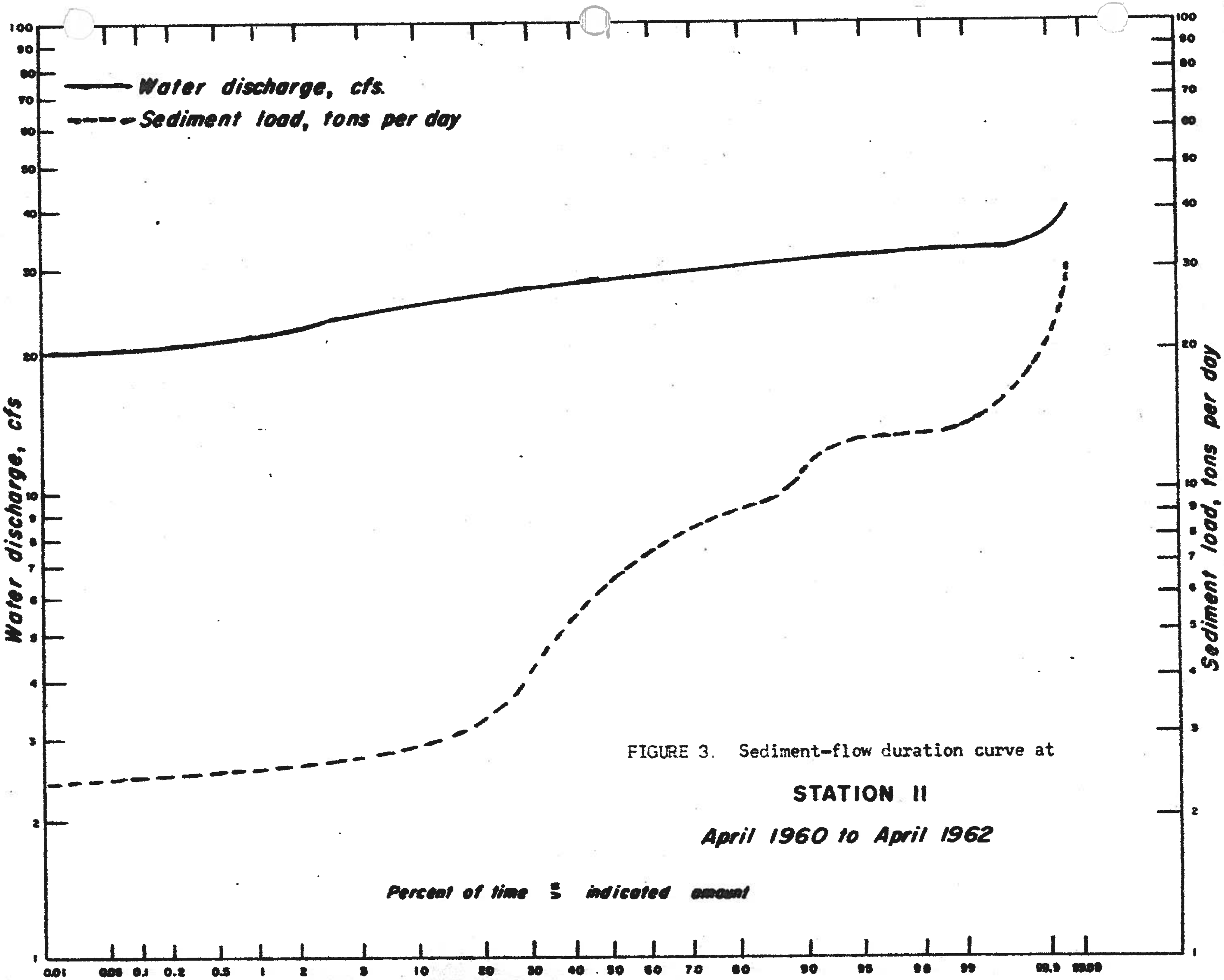

FIGURE 3. Sediment-flow duration curve at

STATION II

April 1960 to April 1962

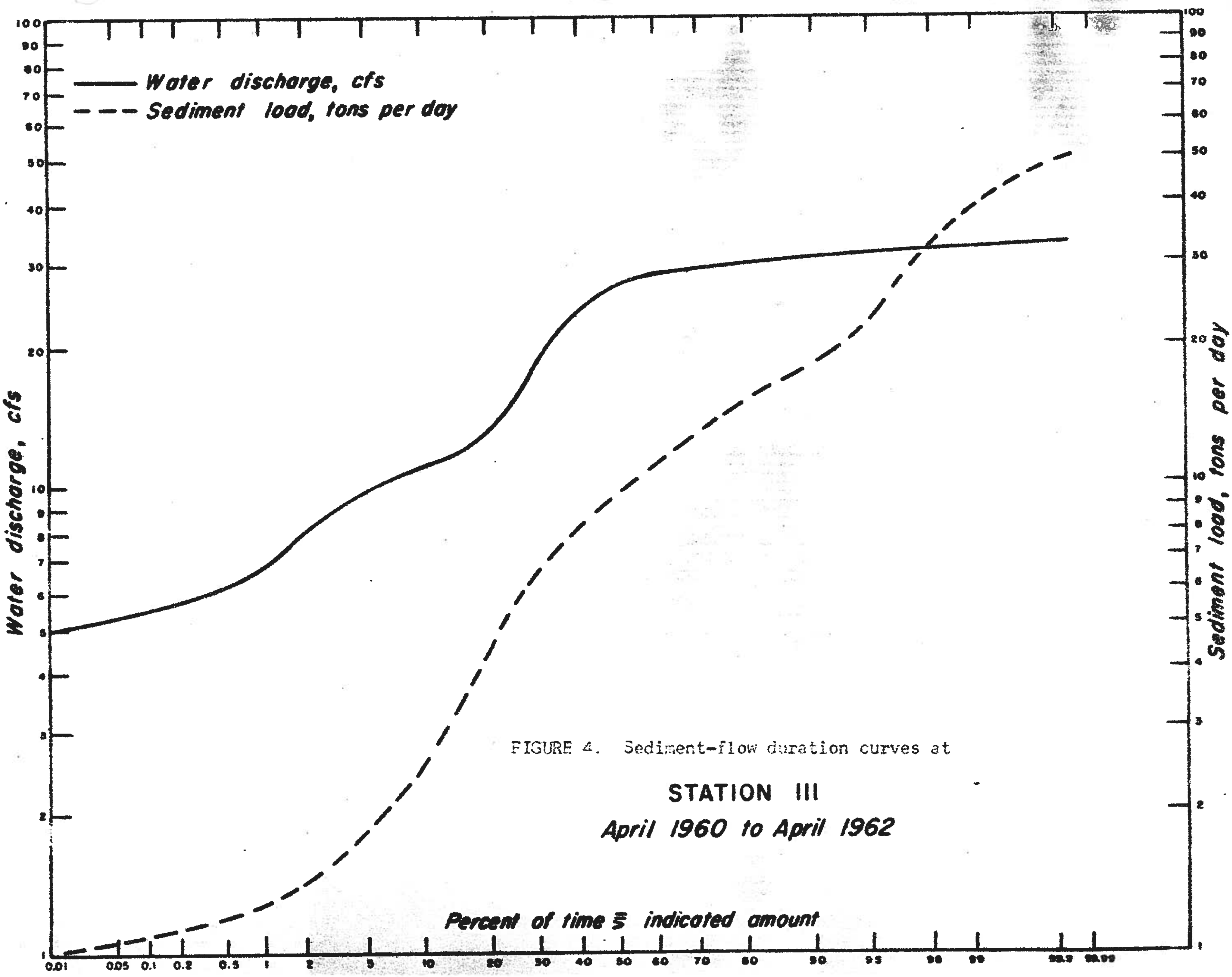

FIGURE 4. Sediment-flow duration curves at

STATION III

April 1960 to April 1962

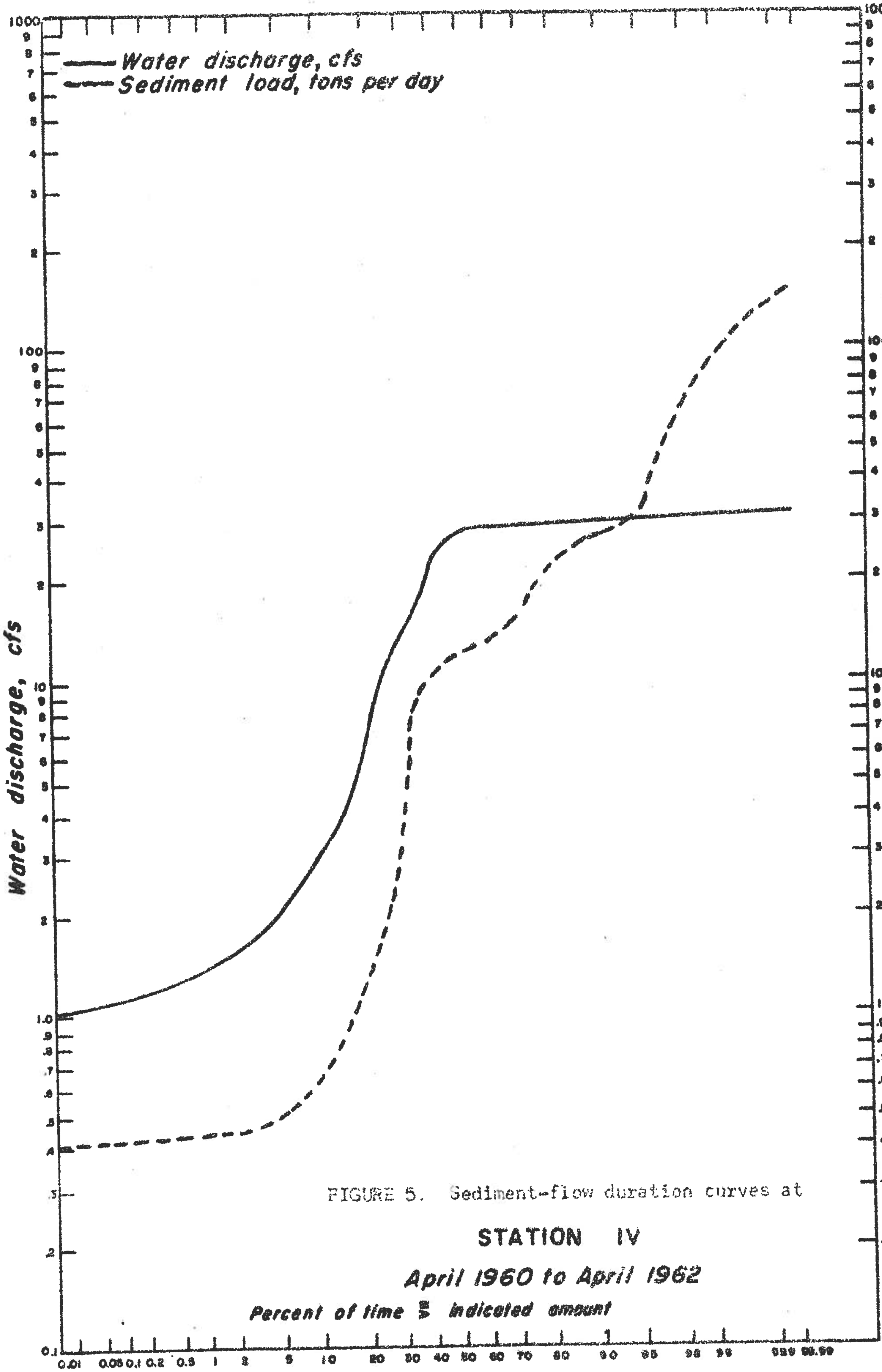

FIGURE 5. Sediment-flow duration curves at

STATION IV

April 1960 to April 1962

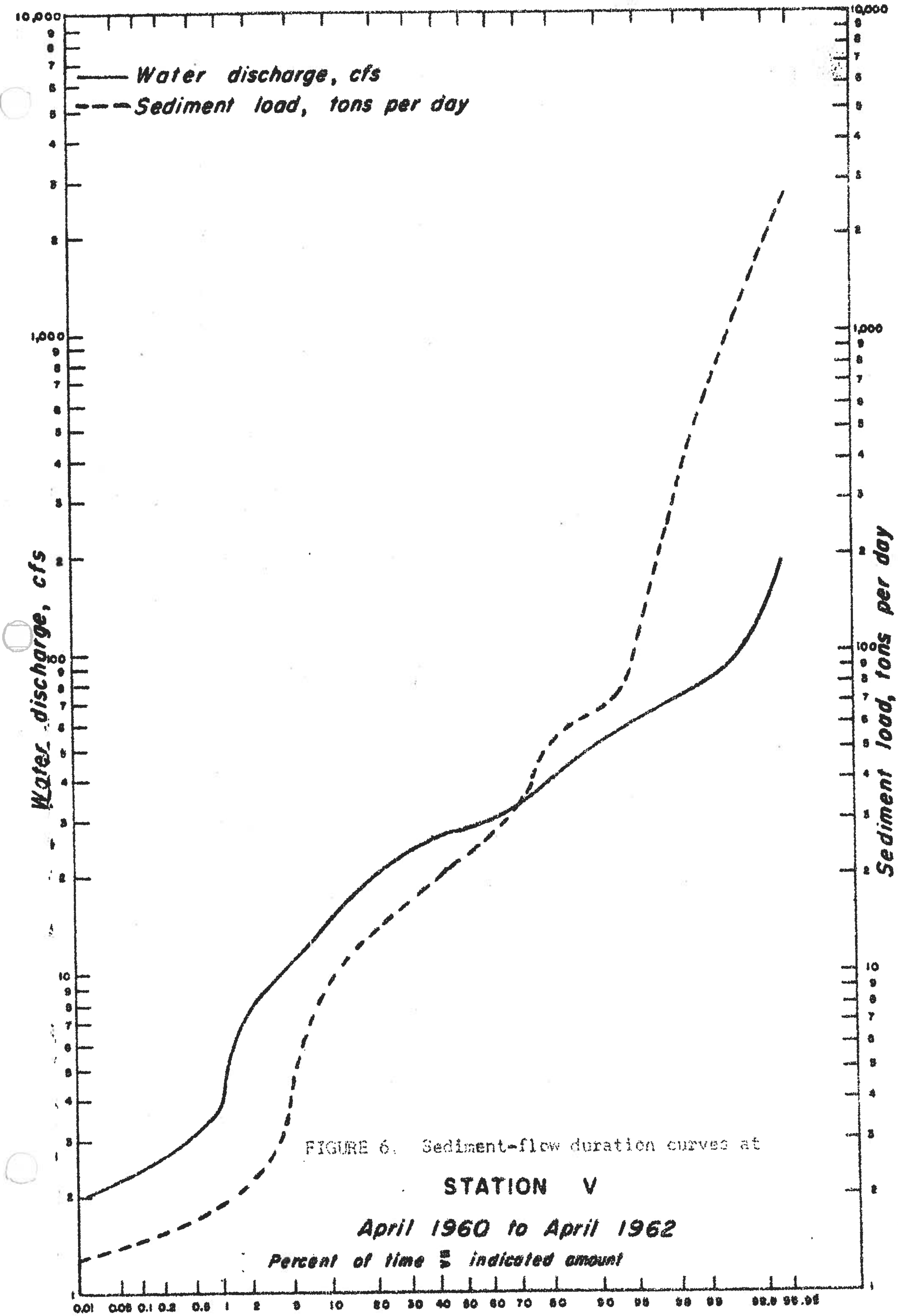

FIGURE 6. Sediment-flow duration curves at

STATION V

April 1960 to April 1962

TABLE 1. - Average monthly sediment concentration in parts per million from April 1960 to April 1962 at 5 sampling stations in Bluewater Creek.

	1960 - 1961 Average Conc. (ppm) /a Station					1961 - 1962 Average Conc. (ppm) /a Station				
	I	II	III	IV	V	I	II	III	IV	V
April	35	126	211	139	415	16	113	178	118	185
May	35	120	139	126	258	35	86	241	280	2280
June	27	59	105	80	357	52	58	120	197	319
July	17	89	104	133	226	37	42	201	210	428
August	12	55	220	275	537	13	34	204	199	355
September	16	34	90	69	227	39	79	357	754	2027
October	18	32	83	175	414	75	75	189	284	353
November	14	36	68	186	244	20	97	174	328	254
December	14	41	122	186	266	13	118	142	282	246
January	22	69	194	291	273	16	147	276	343	386
February	14	55	167	137	159	28	160	382	574	556
March	16	96	119	105	114	25	131	158	323	368

/a Partly estimated

Discharge

Discharge in cubic feet per second at the sampling stations for 2 years is summarized in FIGURES 2-6, using flow-duration curves. Stream flow or discharge in the upper 6 miles of stream was stable, ranging between 11 cfs. and 12 cfs. at I and between 25 cfs. and 31 cfs. at II, 90 per cent of the time.

Downstream, flows were unstable at the sampling stations, ranging between 1.8 cfs. and 29 cfs. at III; 0.5 cfs. and 30 cfs. at IV; and 5 cfs. and 160 cfs. at V. Station V, during the summer months, received a large amount of irrigation surface return water from the Clark Fork valley.

TABLE 2 points out that the unstable flows occurred during the irrigation season at the three downstream sampling stations. The large average monthly flows at Station V resulted from surface irrigation return flow from the Clark Fork valley.

Temperature

Measurements taken throughout the year with a pocket thermometer at the various springs supplying the water to the stream varied between 51°F and 56°F. Ice cover was observed for 10 days in January 1962 only at Station V. There is a progressive downstream loss in temperature in the winter and a progressive downstream increase in the temperature in the summer (TABLE 3). Part of the summer increase in water temperature in the lower part of the stream is attributed to dewatering and irrigation return flow. There were 7 days in July 1961 that the maximum hourly temperature was above 80° F at Station IV for more than 3 hours.

Fish Statistics

The following fish species were sampled from Bluewater Creek: brown trout, *Salmo trutta*; rainbow trout *Salmo gairdneri*; flathead chub, *Hybopsis gracilis*; longnose dace, *Rhinichthys cataractae*; white sucker, *Catostomus commersoni*; longnose sucker, *Catostomus catostomus*; and mountain sucker, *Pantosteus plebeius*. All species but the trout were classified in this paper as rough fish.

Brown trout were abundant in the vicinity of Stations I and II (TABLE 4). (Only 3 rainbow trout were censused in the entire stream.) A marginal population of brown trout was censused near Station III and trout were incidental to the population in the remaining downstream stations.

The average total length of brown trout at the end of each year was: I - 3.8 inches; II - 6.6 inches; III - 9.7 inches; IV - 14.2 inches; V - 15.7 inches; and VI - 17.3 inches. The age composition of the trout population in the vicinity of Stations I and II was:

Age Group	Per Cent of Total
0 - 1	42%
I - II	30%
II - III	14%
III - IV	9%
IV or greater	5%

TABLE 2. - Average discharge in cubic feet per second from April 1960 to April 1962 at 5 sampling stations in Bluewater Creek.

	1960 - 1961 Average Discharge (cfs) Station					1961 - 1962 Average Discharge (cfs) Station				
	I	II	III	IV	V	I	II	III	IV	V
April	11	29	29	29	45	11	29	21	18	26
May	12	27	17	13	27	11	29	16	17	29
June	8.0	24	10	2.4	33	11	26	14	4.0	20
July	12	18	9.3	3.2	15	11	26	14	5.0	23
August	12	26	17	13	33	10	26	16	6.0	20
September	12	26	19	12	22	10	29	23	13	60
October	12	28	27	23	52	10	29	26	27	43
November	12	29	27	28	38	11	30	30	29	32
December	12	30	28	28	30	11	29	30	29	29
January	11	27	27	28	28	11	30	29	28	28
February	12	27	28	28	26	11	32	29	27	29
March	11	29	27	28	28	11	30	29	27	29

TABLE 3. - Mean monthly maximum and minimum temperature (°F) at 2 stations in Bluewater Creek from January 1961 through December 1961.

Month	Station II Mean Monthly Maximum	Station II Mean Monthly Minimum	Station IV Mean Monthly Maximum	Station IV Mean Monthly Minimum
January	49°F	40°F	44°F	37°F
February	51°F	40°F	46°F	38°F
March	54°F	40°F	50°F	29°F
April	57°F	42°F	55°F	42°F
May	63°F	45°F	64°F	48°F
June	65°F(1)	44°F(1)	73°F	60°F
July	67°F	47°F	75°F	63°F
August	65°F	44°F	71°F	60°F
September	56°F	43°F	56°F	49°F
October	53°F	42°F	52°F	42°F
November	50°F	40°F	46°F	40°F
December	50°F	44°F	42°F	37°F

(1) Mean based on 27 days in June

TABLE 4. - Number of trout and rough fish collected by electrofishing in 4,000 square foot areas during August and September 1961 in Bluewater Creek.

	Station									
	I		II		III		IV		V	
Section	Trout	Rough fish	Trout	Rough fish	Trout	Rough fish	Trout	Rough fish	Trout	Rough fish
1	177	9	209	0	87	238	10	1446	4	425
2	230	6	281	19	36	141	7	1515	9*	471*
3	241	4	164	30	40	296	7	641	4*	236*
Average	216	7	218	17	55	225	8	1201	6	378

* Sampled in May 1962

TABLE 5. - Population estimate of trout by tag and recapture in Bluewater Creek.

No.	Actual number of trout caught by electrofishing	Estimate total number of trout without separation by size classes	Estimate total number of trout with separation by size classes
I	230	266 (86)*	269 (86)*
II	164	197 (83)*	198 (83)*
III	87	102 (85)*	102 (85)*
IV	7	8 (88)*	8 (88)*
V	4	6 (67)*	6 (67)*

* Ratio of the actual to the estimate of the number of trout.

There were few brown trout in the 0 - I age class at Station III (6 per cent of the total number of trout censused in the area). This indicates that trout egg survival might be poor in this area of the stream. In the lower part of the stream, the trout ranged in size from 7.0 to 12.5 inches; none in age class I or II. It is thought that there is a tendency for brown trout in the upper part of the stream to move downstream to the lower areas. This downstream movement of brown trout has been reported by Stefanich (1951).

TABLE 5 illustrates the effectiveness of the fish census for trout. The ratio of the actual number of trout to the estimate of the trout numbers with and without separation by size classes on the average was 0.85, pointing out almost no bias by electrofishing for any size group. The trout were grouped into 2-inch size classes and population estimates were calculated and totaled for the comparison.

Egg Mortality

The mortality of eyed rainbow trout eggs placed in the stream bed is enumerated in TABLE 6. There was an average progressive downstream increase in mortality from Stations I - IV. The relatively low mortality of eggs at Station V is attributed to high flows that carried out the sediment rather than depositing it in the stream bed gravels. More detailed studies on trout egg mortality in the stream are found in Peters (In Press).

TABLE 6. - Mortality of eyed rainbow eggs incubated in 5 areas in Bluewater Creek. An estimated 476 eggs were placed in the stream bed in each Vibert box on May 24, 1961; Pulled out on June 2, 1961.

Station	Mortality in Vibert Box Number			Average Mortality
	I	2	3	
I	2%	4%	4%	3%
II	35%	22%	8%	22%
III	81%	38%	42%	54%
IV	51%	83%	75%	70%
V	19%	37%	83%	47%

DISCUSSION

The Bluewater Creek valley was developed for agriculture less than 60 years

TARZWELL, C. M., and A. R. GAUFIN. 1953. Some important biological effects of pollution often disregarded in stream surveys. Proc. 8th Industrial Conference Purdue Univ., 295-316.

TRAUTMAN, MILTON B. 1957. The fishes of Ohio with illustrated keys. Ohio St. Univ. Press, Ohio Div. Wildl., 683 pp.

WALLEN, I. U. 1951. The direct effect of turbidity on fishes. Bull. Okla. Agric. Mech. Coll., 48:1-27.

WICKETT, W. P. 1954. The oxygen supply to almon eggs in spawning beds. J. Fish. Res. Bd. Can., 11:933-953.