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AUTOMATIC SEDIMENT VOLUME RECORDER TESTS ON LABORATORY CREEK, OXFORD, MISSISSIPPI

by

William C. Harmon and Robert F. Piest

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AUTOMATIC SEDIMENT VOLUME RECORDER
TESTS ON LABORATORY CREEK, OXFORD, MISSISSIPPI[1]

By

William C. Harmon and Robert F. Piest[2]

PREFACE

The tests reported in this paper were made as part of the program of the Federal Inter-Agency Sedimentation Work Group located at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota. The program is sponsored by the Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources. The sediment volume recorder was on loan to the Sedimentation Laboratory as part of the test phase of the project for developing improved sediment-sampling equipment. The recorder was developed by B. C. Colby, deceased, formerly Project Supervisor, and H. H. Stevens, Jr., Hydraulic Engineer.

INTRODUCTION

Need for Development

During the past few decades, much has been added to the knowledge of the origin of sediment and its movement in streams. These

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[1] Contribution from the USDA Sedimentation Laboratory, Soil and Water Conservation Research Division, Agricultural Research Service, United States Department of Agriculture in cooperation with the University of Mississippi and the Mississippi Agricultural Experiment Station.

[2] Mechanical Engineer, USDA Sedimentation Laboratory, Oxford, Mississippi and Hydraulic Engineer, North Central Watershed Research Center, Columbia, Missouri, formerly of the USDA Sedimentation Laboratory.

advances in the state of art were due to an increased recognition of erosion problems, which in turn led to the development of improved techniques for sampling sediments, and for analyzing and interpreting sediment movement.

One of the most serious obstacles to further progress in this field is the limitation of present-day sediment-sampling equipment. Although automated systems are performing complex tasks in virtually every field of endeavor, no one has yet built a satisfactory sediment sampler or discovered a reliable method for monitoring sediment discharge.

There are several reasons for the lack of automation in sediment sampling. Sediments are not uniformly dispersed throughout the stream cross section, either in the vertical or horizontal direction. All present-day samplers must be immersed in the stream; since they offer resistance to flow, many difficulties ensue. Also, an exceedingly difficult problem exists in trying to sample sediments moving adjacent to the stream bed.

Because limited resources have heretofore been available for sampler improvement, we have been forced to coexist with elemental sampling procedures. During recent years, the problem has been approached by utilizing electronic-, sonic-, and nuclear-detection equipment. Several of these methods show promise but it will take years to develop them into field research tools. Recognizing this, the Federal Inter-Agency Subcommittee on Sedimentation directed the research unit at the St. Anthony Falls Hydraulic Laboratory to design, build, and test a series of automatic pumping samplers.

Three types of pumping samplers were built. The prime objective in the design of each was to permit the collection of pumped-streamflow samples that did not require attendance during runoff periods. Aside from the basic pumping system that was common to each type of sampler, three alternate "handling" systems were built. These involved:

1. The weighing and automatic weight-recording of each pumped sample. (The sediment concentrations are then obtained from the weight recorder.)
2. The automatic collection of pint samples for later laboratory analysis. (This operation could properly be called semi-automatic.)
3. Obtaining a photographic record of the sediment and runoff volumes for each pumped sample. (The volumes are then converted to sediment concentrations on the basis of volume-weight relationships of the sediment column. The volume-weight relation is calibrated by laboratory analyses of single pint samples that are collected at each complete revolution of the entire group of sedimentation tubes.)

This last sampler, which is called the sediment volume recorder, is the subject of this report. It was field tested on the North Loup River near St. Paul, Nebraska prior to its installation on Laboratory Creek at Oxford, Mississippi. The North Loup River is a perennial stream with relatively steady discharges of runoff and sediment; Laboratory Creek is an ephemeral stream characterized by rapid fluctuations in water level and in the quantity and substance of its sediment load. Sand comprises a large fraction of the sediment load of both streams.

The Sediment Volume Recorder

The principal elements of the sediment volume recorder (Figure 1) are the 72-unit bottle rack and the 12-unit sedimentation tube rack. These racks are mounted on motor-driven shafts that are made to rotate into sampling position at the proper time. A brief explanation of sampler operation, on a perennial stream, follows.

An electric timer starts the cycle at 30-minute intervals by opening a solenoid pinch-valve which allows water from a flush tank to purge the sampler intake system of debris. The pump then starts, and river water is pumped into the system for about 90 seconds. The water is wasted, for the first minute, into a flush tank which overflows back to the stream. After about a minute, when a water-sediment equilibrium has been established throughout the intake system, a splitter solenoid diverts the flow into a sedimentation tube. About 1500 ml of water-sediment mixture is sampled in 3 to 4 seconds. This tube is photographed five and one half hours later so that the volumes of settled sediment and the sediment-water mixture can be obtained by reading the sediment volume indicator level and sediment level. After 6 hours have elapsed, the tube has dumped its sample and is again in sampling position.

With each complete revolution of the sedimentation tube wheel (12 tubes), one split sample is automatically collected in a pint bottle for sediment concentration analysis in the laboratory.

A tapper operates at the "sample" position to ensure that the sediments do not deposit unevenly in the sedimentation tube; another tapper aids in dislodging sediment from the tube during the "dump" cycle.

For more detailed descriptions of the devices listed above, one may refer to a report by H. H. Stevens, Jr., entitled Report Q.[3/]

The Laboratory Creek Setup

The objectives of the tests were to determine the operational reliability of the component parts of the unit, both individually and collectively, to determine the sampling efficiency of the unit, and to adapt the unit to a small ephemeral stream. A site on the small ephemeral stream behind the USDA Sedimentation Laboratory, and about 120 feet above a stream gage-sampling station, was selected for the test (Figure 2). The drainage area above the site is about 1½ square miles.

The stream has a trapezoidal-shaped alluvial channel composed of bed material with a median diameter of about 400 microns. Average channel depth is about 6 feet; channel width is about 20 feet. A 25-degree bend at the site of the installation causes the flow to concentrate slightly on the sampler side of the stream; therefore, the velocities along the wingwall of the sampler intake are somewhat higher than would normally be expected at the water's edge. Flow velocities at midstream sometimes exceed 8 feet per second.

Sediment concentrations vary widely with watershed and meteorologic conditions although they do not usually exceed about 30,000 ppm.

3/ St. Anthony Falls Hydraulic Laboratory, "Investigation of a Pumping Sampler with Alternate Suspended-Sediment Handling Systems," Report Q, Progress Report, June 1962. Prepared by H. H. Stevens, Jr., Hydraulic Engineer, Federal Inter-Agency Sedimentation Project.

About 1/3 of the total sediment load is sand; a significant portion (up to 4 percent) of the sediment is colloidal material which does not readily settle.

MODIFICATIONS

To adapt the sediment volume recorder for operation on an ephemeral stream a mercury switch was mounted on a common water-closet float and was placed in the well of the water stage recorder. The float was set to activate the timing motor whenever the water rose above the sampler intake.

A 1/10 rpm timing motor was substituted for the 1/30 rpm motor used on perennial streams. This motor is the primary control for all sampler activities, which take six minutes; the ten-minute sampling cycle was chosen so that sediment concentration graphs could be defined adequately during short, high-intensity storms. Also, some time was needed between cycles to adjust sampler components.

The pump intake was so placed that sampling could start when the water reached a depth of 6 inches, and the float was positioned in the gage well to start the unit when the water reached this depth. To correlate stages with sampling times, a 6-volt relay-operated recording pen was installed in the housing for the A-35 water stage recorder. The pen was wired into the splitter solenoid circuit so that a mark was made on the lower edge of the chart each time a tube sample was taken.

After these necessary modifications to adapt the sampler to a small ephemeral stream were completed, a number of attempts were made to collect automatic samples without further alteration of the component parts. These attempts were unsuccessful, however, as the original impeller pump did not pull water from the stream. The check valve did not hold a prime because of sand particles lodging in the valve seat, and the brass pump parts were scored beyond use by the sand particles with a frequency which made repairs impractical.

The addition of a solenoid pinch valve to insure a prime did not solve the problem, so the impeller pump was finally replaced by a rotary screw pump which was more resistant to wear and also provided a higher vacuum lift. The unit was now ready for testing.

Cycle of Operation for Tests on Laboratory Creek

During runoff events, a tube sample was taken every ten minutes. Below is a list of cycle events in the order of occurrence.

1. The cycle was started when the float in the gage well activated the 1/10-rpm timing motor, which in turn started the 1/3-rpm and 1/6-rpm timing motors.
2. The 1/3-rpm timing motor activated the solenoid pinch valve, which allowed flushing water to flow back to the stream through the intake.
3. The 1/6-rpm timing motor activated the solenoid on the 16 mm movie camera so that a single-frame photograph could record the sediment accumulation and water height in the sedimentation tube which had previously filled 11 cycles before.
4. After the photograph was taken, the wheel motor was started and the tube wheel was rotated by the 1/6-rpm timing motor.

The wheel motor was stopped by a limit switch when the next tube was in position.

5. The 1/3-rpm timing motor activated the pump for 100 seconds. For the first 50 seconds of this time, the splitter was in the waste position to allow the sediment concentration to become constant and to replenish the flush water.
6. The 1/6-rpm timing motor activated the dump solenoid and dump tapper motor. The dump solenoid drained the tube, which was photographed at the beginning of the cycle, and the dump tapper helped to loosen the sediment.
7. At the end of the waste time, the 1/3-rpm timing motor activated the splitter solenoid, which moved the supply line to the sample position for about 5 seconds. This circuit also activated the marking pen in the A-35 recorder housing.
8. The sampler tapper motor was in operation during the 6 minutes that the 1/6-rpm motor was in operation, to assure a more even compaction of settled materials.
9. If no sample was brought in by the silt pump, the normal cycle of operation was discontinued and the normal cycle was started.

The safety cycle was not altered for the Laboratory Creek installation, so it is not covered in this report. A full description may be found in Report Q, previously referenced in this report.

TEST PROCEDURES

Test Period

The sediment volume recorder was operated through 17 storms during the period April 1962 through July 1963. The pumped samples were compared with concurrent samples collected by ARS personnel with a USDH-48 hand sampler. These last samples were either point-integrated at the intake, depth-integrated at the intake vertical, or depth-integrated through the entire channel cross section at the pump intake. In addition, most of these runoff events were sampled at the normal cross section near the gaging station.

Calibration and Sample Analyses

Shortly after the unit was placed in operation, each sedimentation tube was volumetrically calibrated, and procedures were set up for collecting and analyzing the pumped samples. For each storm sampled thereafter, personnel were present to record the fill time for each tube, the height of the sediment column, and the float reading. The volume of the sampled water sediment mixture determined the float reading.

In addition to the single picture, which was taken automatically, several others were usually taken manually. The extra pictures showed a pointer indicating the sediment-water interface, and a card giving each tube number, date, and time of fill. This procedure was followed because location of the interface was sometimes obscured by the formation of foccules. Many of the samples were then caught in bottles and carried into the laboratory for analysis.

Standard analyses by laboratory personnel involved the separation of sand from the silt-clay fractions by wet sieving on a No. 230 (.062 mm) U. S. Standard sieve; the concentration of each sediment component was expressed in parts per million. The total concentration was determined by summing the concentrations of the fines, sands, and organic matter.

Component Evaluation

The mechanical operation of all parts of the sampler was closely observed throughout the tests to determine causes of any component malfunction. In some instances the cause of failure was difficult to ascertain because many of the component functions were mutually dependent. Thus, a malfunction of one component would cause an apparent failure of another.

The components are evaluated as follows:

1. Remote recording unit. The remote marking pen and accompanying wiring to the power supply and sampler splitter circuits gave excellent performance. The only failure occurred on March 5, 1963, when a section of fill at the bridge washed out. This caused a short in the pen circuit.

2. Remote float apparatus. This simple arrangement gave trouble-free operation throughout the tests. No study was made to determine the exact stage of sampler activation or deactivation, but the float was adjusted so that it approximated the elevation of the top of the pump intake.

3. Intake system. Only the physical system is considered here, an evaluation of intake characteristics is discussed elsewhere.

   The intake system gave much trouble during initial sampler development. Part of this difficulty must be ascribed to a faulty pump which was later replaced. Because it was suspected that the intake system was not maintaining a prime, an extra pinch valve solenoid was also installed in the line. Thereafter, only one intake malfunction occurred during the 17-storm test period. This happened when a sweetgum ball was drawn into the system during the March 5, 1963 storm. The intake-flush system is considered reliable.

4. Pump. The impeller pump was not suitable for operation, probably due to the large amount of sand in suspension in Laboratory Creek. A rotary screw pump which gave a higher vacuum lift was installed in April 1962. The new pump performed satisfactorily.

5. Drive-motor, center shafts, and gear-drive mechanisms. The gears, gear shafting, and bearings caused many of the unit malfunctions. Some of the failures which were associated with these units are listed below:

   a. Slack in the gears and gear shafting allowed misalignment of component parts of the unit, causing improper filling of tubes and bottles.

   b. Loose gears and shafts caused instability of the tube wheel. This frequently permitted the tube wheel to rotate enough to release the microswitch which, in turn, started the wheel motor out of phase with other cycle events.

c. Slack between the shafts and bearings caused excessive stress and wear on gear teeth from improper engagement.

6. Sedimentation tubes. The sedimentation tubes were made of glass and were easily broken. Replacements were expensive and difficult to acquire. Plastic substitutes were found to be unacceptable, however. The alignment of the tubes in the tube rack is somewhat critical. Some difficulty was experienced with the sediment smearing the glass; this made it difficult to read the level of sediment accumulation. Leakage at the gasket seats of the sedimentation tubes sometimes occurred. This resulted in a loss of part of the sample.

7. The tube wheel (tube-mounting rack). This is the assembly into which the 12 tubes are placed, and includes float assemblies and staff gages for determining the height of the sediment and water columns. The deflection of the tube wheel under different loading conditions (as the tubes filled) seriously affected the operation of the entire unit by rendering the control microswitch ineffective. Stiffeners were added to the tube wheel to reduce this deflection.

The float pulleys which were mounted on the tube wheel near the top of each of the 12 sedimentation tubes did not rotate freely. This caused errors in reading sample volumes.

This trouble could probably be corrected by installing pulleys with better bearings.

8. Bottle wheel. Some difficulty was encountered by nonalignment of sample bottles with the splitter, with the result that some of the samples were lost by spillage. Much of this trouble was due to the gear system which drove the bottle-wheel table; some was due to the fact that the sliding plastic "splitter" assembly would "bind".

   In any event, this feature of the sediment volume recorder was not adapted to our needs on a small ephemeral stream. Only one sample can be collected with each complete 2-hour revolution of the tube wheel; therefore, it was possible to experience a major storm and still not have adequate sample coverage.

   Much thought was given to changing the unit so that more frequent bottle-wheel samples could be obtained. This could not be done without extensive modification, however, because the camera, dump, and fill positions are consecutive.

9. Sample splitter. Although minor difficulties were experienced with the splitter, sampling solenoid, and associated mechanisms, these units are fairly reliable.

10. The dump assemblies. The dump solenoid is very effective. The major difficulty was due to the brass rods soldered to the dump mechanism; they frequently broke loose and fell out. In any future use of the sampler, this undesirable feature can be corrected.

11. Tappers. The purpose of the tapper at the sampling position was to level the precipitating sediments in the neck of the sedimentation tube; the function of the dump tapper was to dislodge and help drain the sediment from the tube when at dump position.

The tappers generally did not operate satisfactorily. Malfunctions were mostly due to inadequacies of tapper design, although some trouble occurred because the tubes were not rotated into proper position.

12. Photographic record. The photographic records of the sediment and water levels of each sedimentation tube are very important. Some minor difficulties were attributed to improper lighting and subsequent film exposure; another early problem was caused by a misfit of the shutter release threads with the tapped threads of the camera housing. An occasional "misfire" was due to improper adjustment of the solenoid arm.

Although the above problems occurred during the early operation of the sampler, they were largely overcome. The remaining difficulty was the inability to locate the water-sediment interface. This problem was due to:

a. The turbidity of the water (because the colloids do not settle out.)

c. The staining of the tube glass by previous fill cycles.

Figure: 3

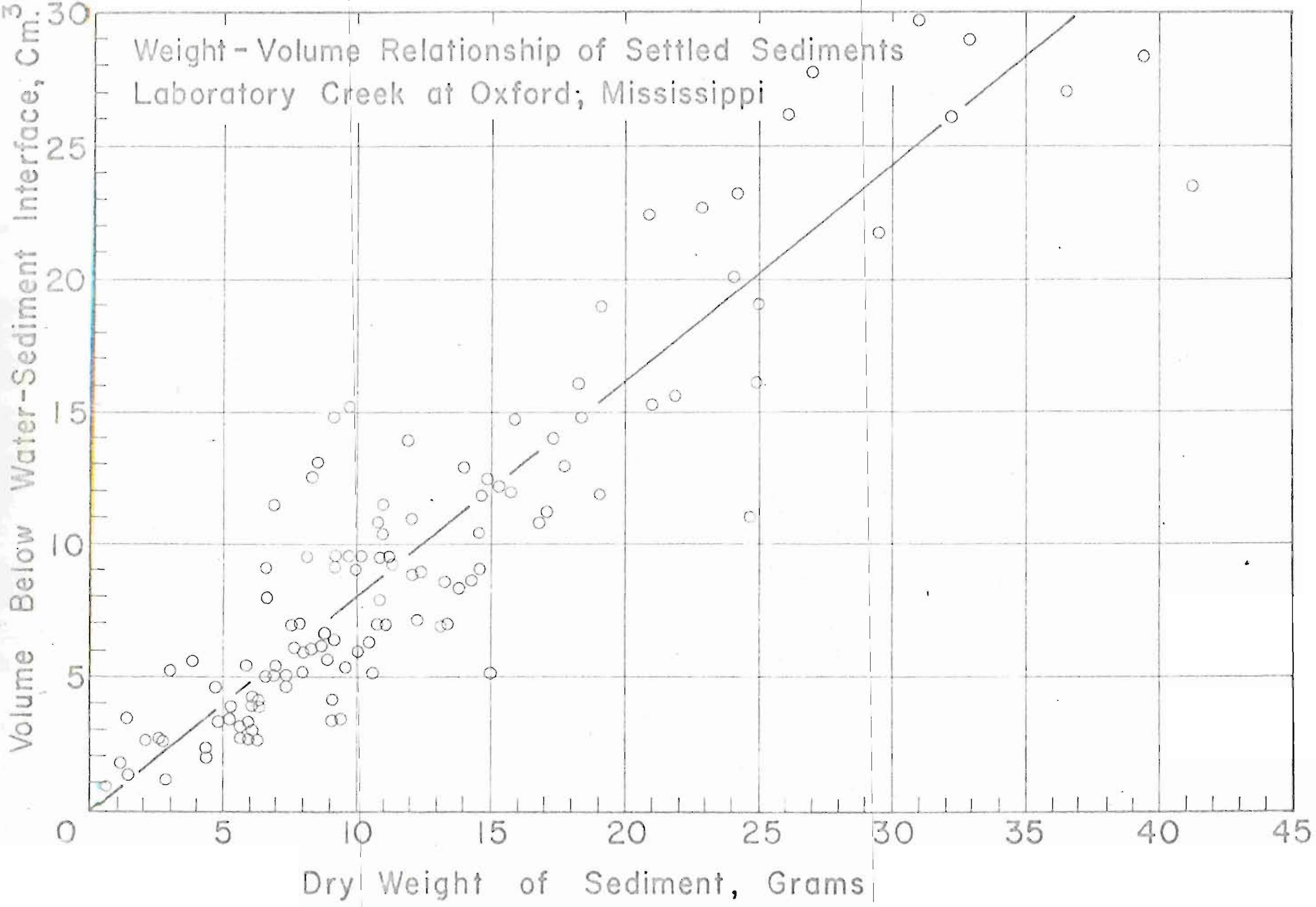
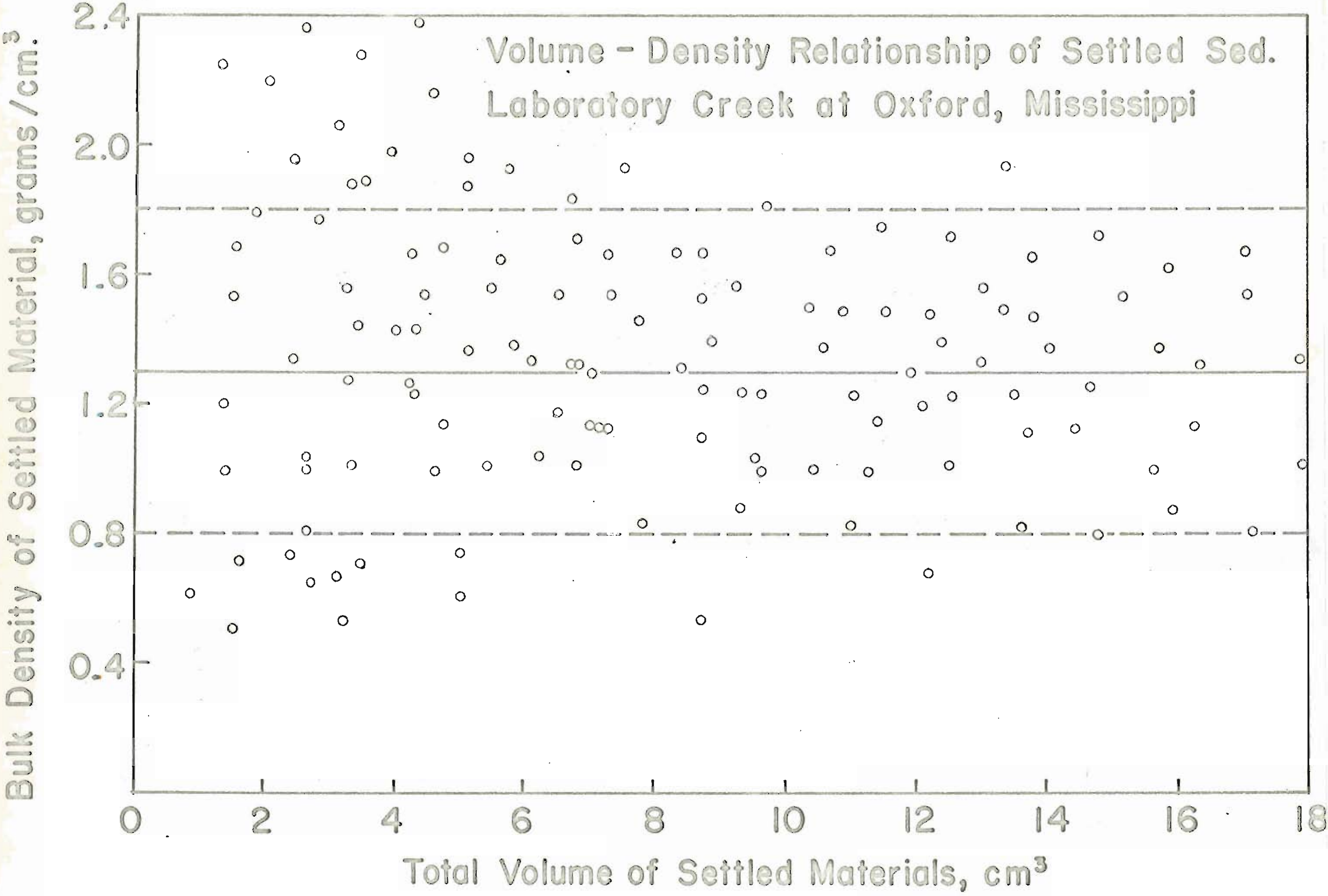

Weight - Volume Relationship of Settled Sediments
Laboratory Creek at Oxford, Mississippi
Volume Below Water-Sediment Interface, Cm.^{3}
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
45
Dry Weight of Sediment, Grams

Figure 4


Volume - Density Relationship of Settled Sed.
Laboratory Creek at Oxford, Mississippi
Bulk Density of Settled Material, grams/cm.³
2.4
2.0
1.6
1.2
0.8
0.4
0
2
4
6
8
10
12
14
16
18
Total Volume of Settled Materials, cm³

c. The formation of floccules in the neck of the sedimentation tube during certain storms. These floccules formed above the precipitated sediments, and it was difficult to discern the true water-sediment interface, even with the naked eye.

13. The safety cycle. Although the safety cycle functioned as intended for a perennial stream, it is not a desirable feature for small ephemeral streams. Except for the presence of personnel to manually interrupt it, the twelve-hour cycle would have caused the unit to remain inoperative through several runoff events.

DATA COMPARISONS

Sediment-Volume Relationship

The Laboratory Creek tests showed the sediment-volume relationship to be the greatest problem in the determination of sediment concentration for pumped samples. A plot of dry weight versus the volume of deposited sediments in the sedimentation tube, as shown in Figure 3, reveals a scatter from .5 to 2.5 grams per cubic centimeter. This range of values is obviously too great and there is strong indication that it resulted from the inability to read the volumes accurately when the total volumes were small. This is illustrated by Figure 4, in which densities of settled materials from the sedimentation tube samples are plotted against total volumes of settled materials. The greatest scatter occurs at low total volumes. Figure 5 shows that the densities of the settled materials increased with increases in gage height. This relationship between density and gage height was probably influenced considerably by the increase in sand content with increase in gage height. The fact that sand content increased with gage height is shown in Figure 6, and Figure 7 shows that this increase in sand content caused an increase in density.

Sample Comparisons

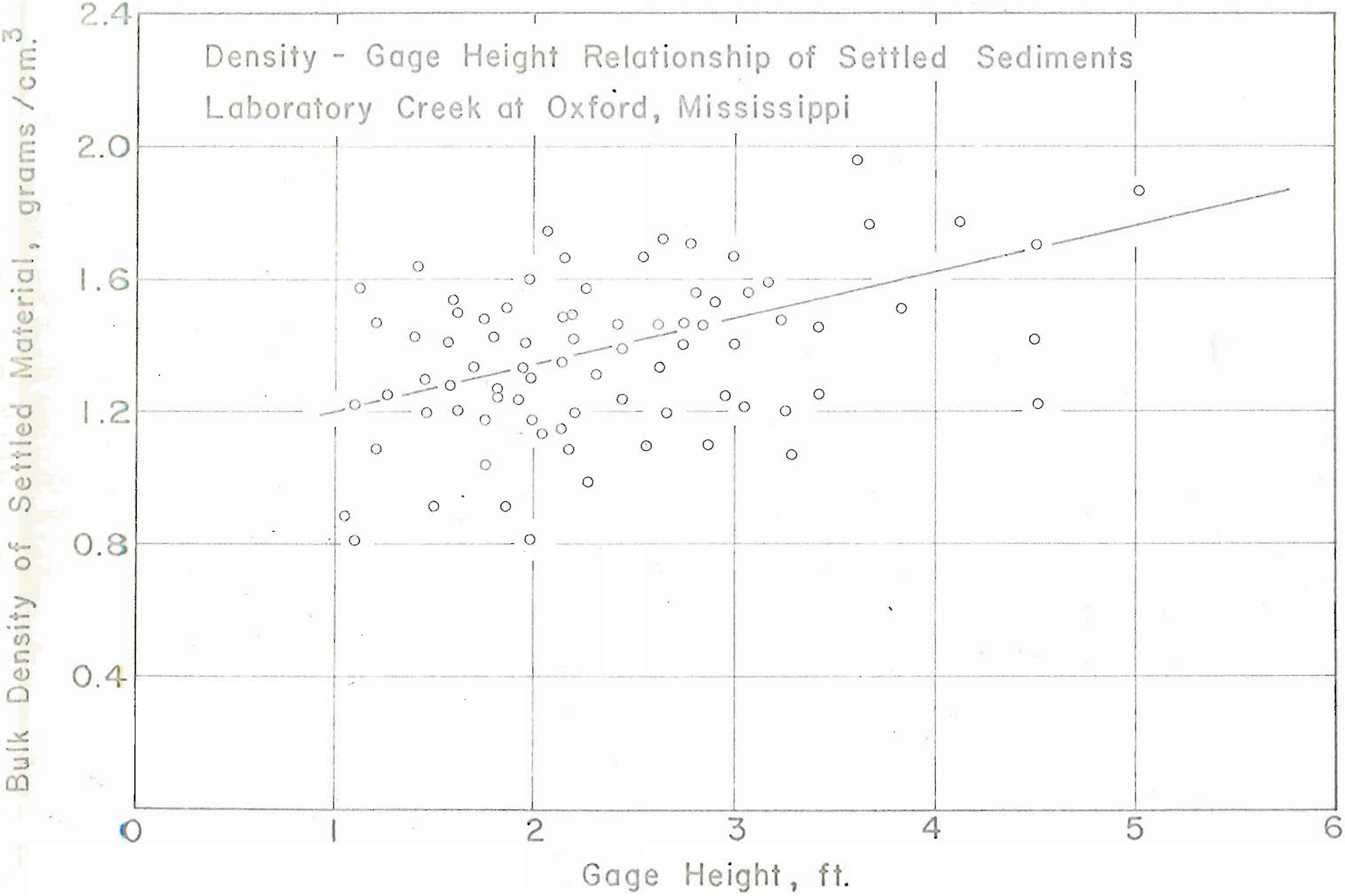
In Figures 8 to 12, the concentration curves are based upon hand samples collected by the equal transit rate procedure. These curves are considered representative of the cross section concentrations for the selected storms. The concentrations for the special samples[4/] are plotted on these graphs so that a visual comparison can be made between the concentrations of sediment in the special samples and the representative cross section sample concentrations.

It is noted from these figures and Table I that approximately 80 percent of the special samples had lower concentrations than the depth-integrated samples. Figure 13 shows this same relationship and, in addition, indicates that the deviation of pumped and pump-intake sample concentrations from the mean stream concentrations increased with increasing stage.

The samples compared in Tables I-III and plotted in Figure 13 were chosen because they were taken concurrently, thereby eliminating the chance of error which might have been induced by a time difference.

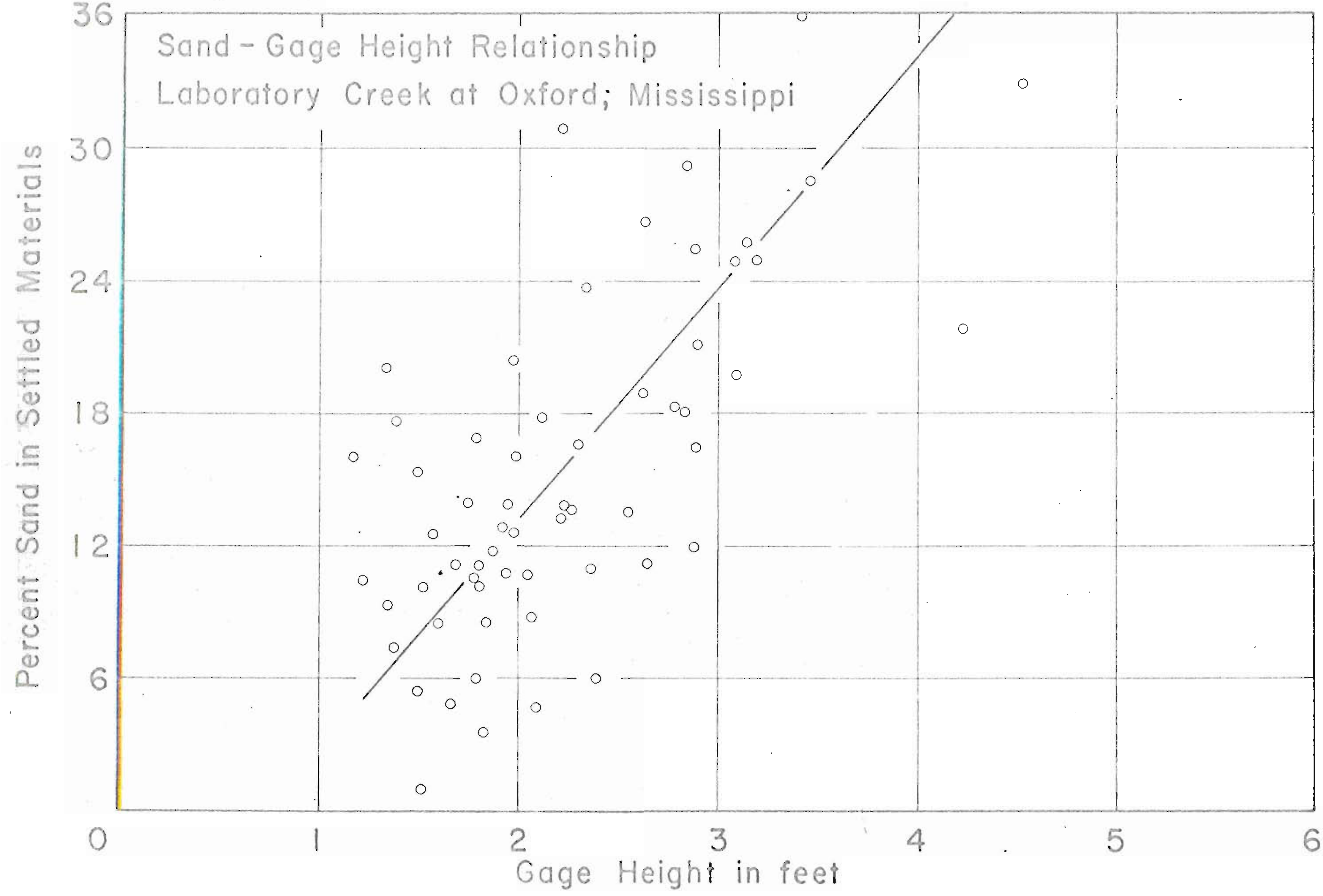
[4/] "Special samples" refers to all samples taken for comparison with cross section samples.

Figure 5



Density - Gage Height Relationship of Settled Sediments
Laboratory Creek at Oxford, Mississippi

Figure 6



Sand - Gage Height Relationship
Laboratory Creek at Oxford; Mississippi

Figure 7

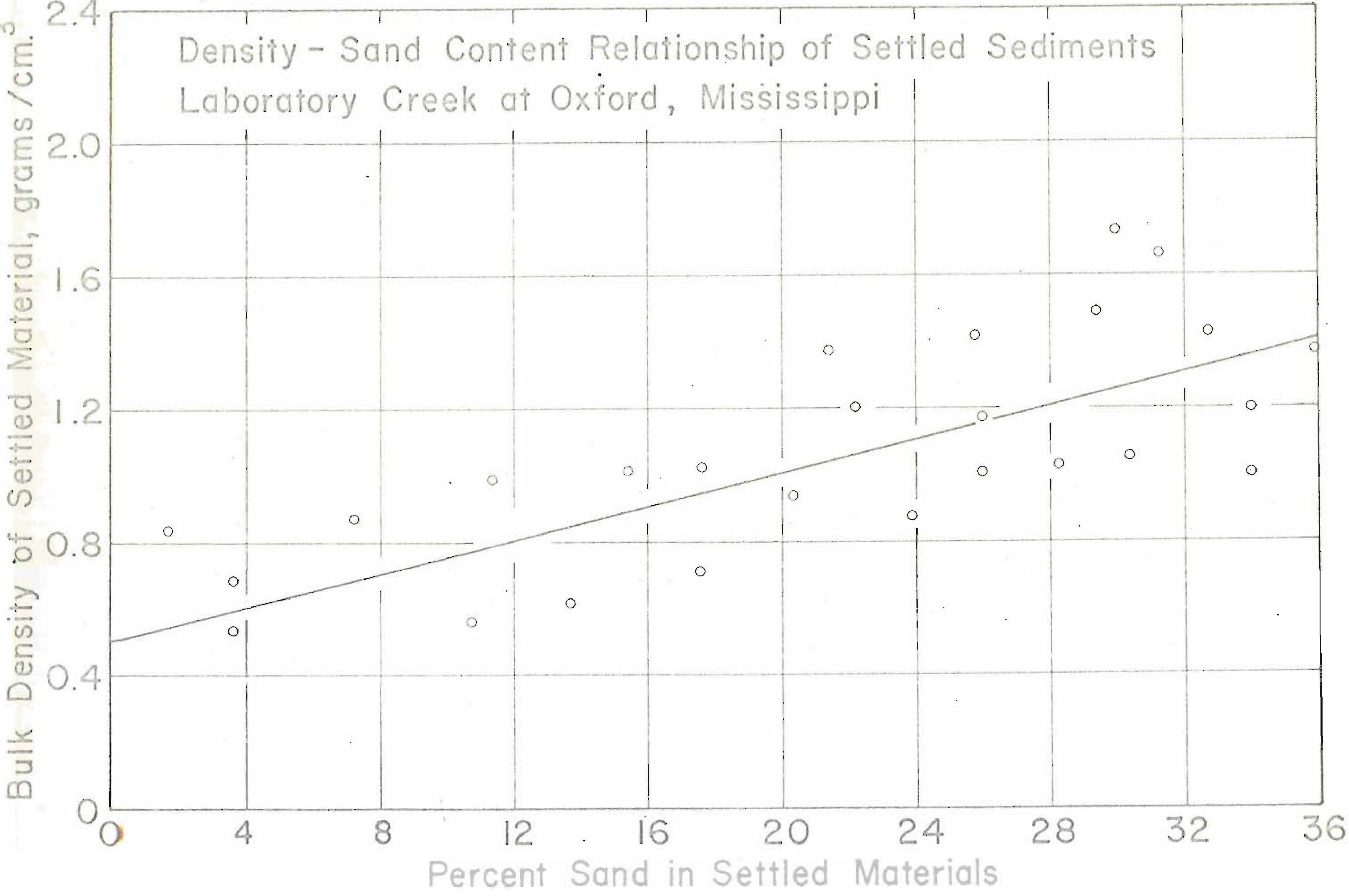
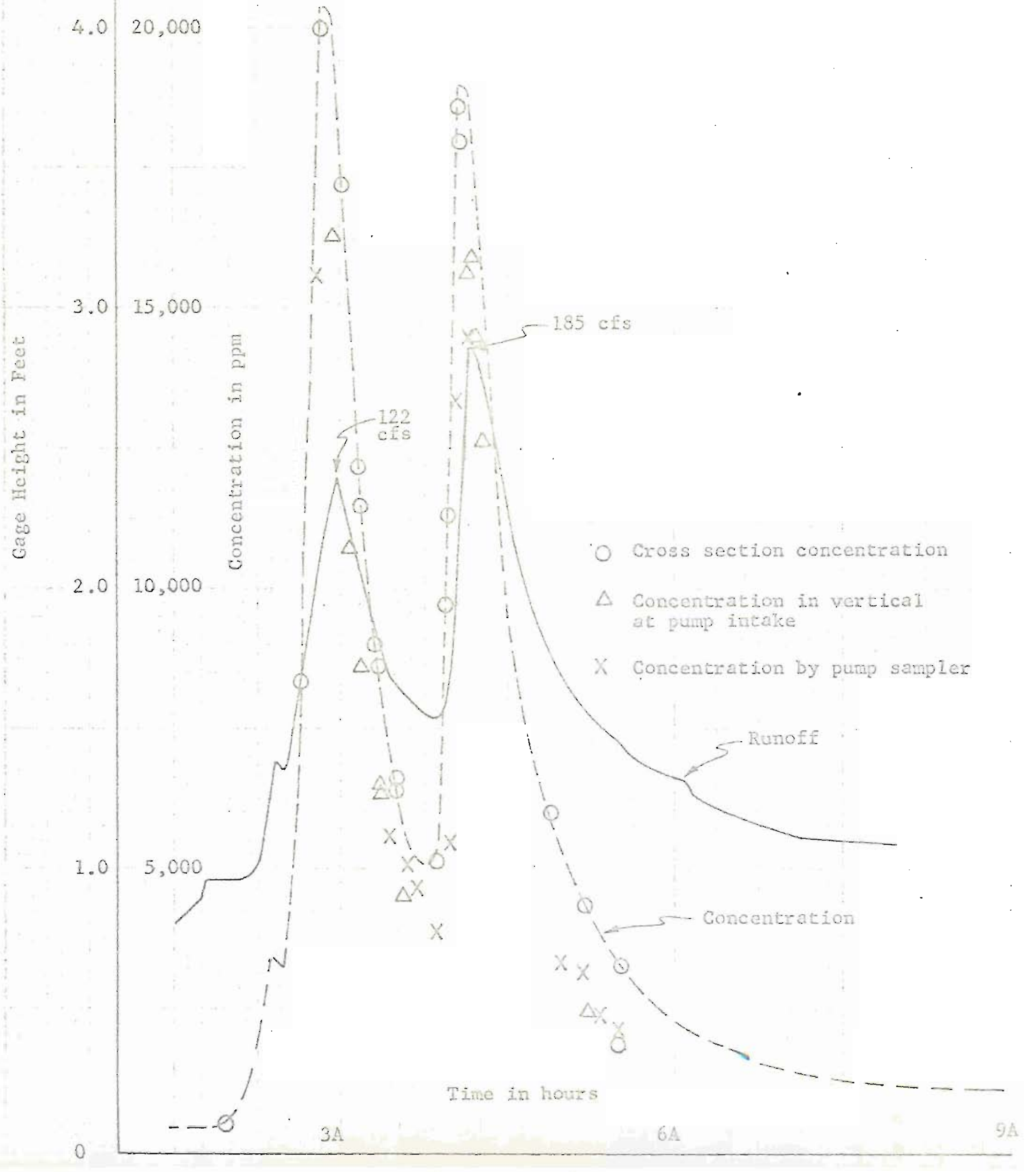

Density - Sand Content Relationship of Settled Sediments
Laboratory Creek at Oxford, Mississippi
Bulk Density of Settled Material, grams/cm.^{3}
2.4
2.0
1.6
1.2
0.8
0.4
0
0
4
8
12
16
20
24
28
32
36
Percent Sand in Settled Materials

Figure 8.--Concentrations for storm of 3-5-63.



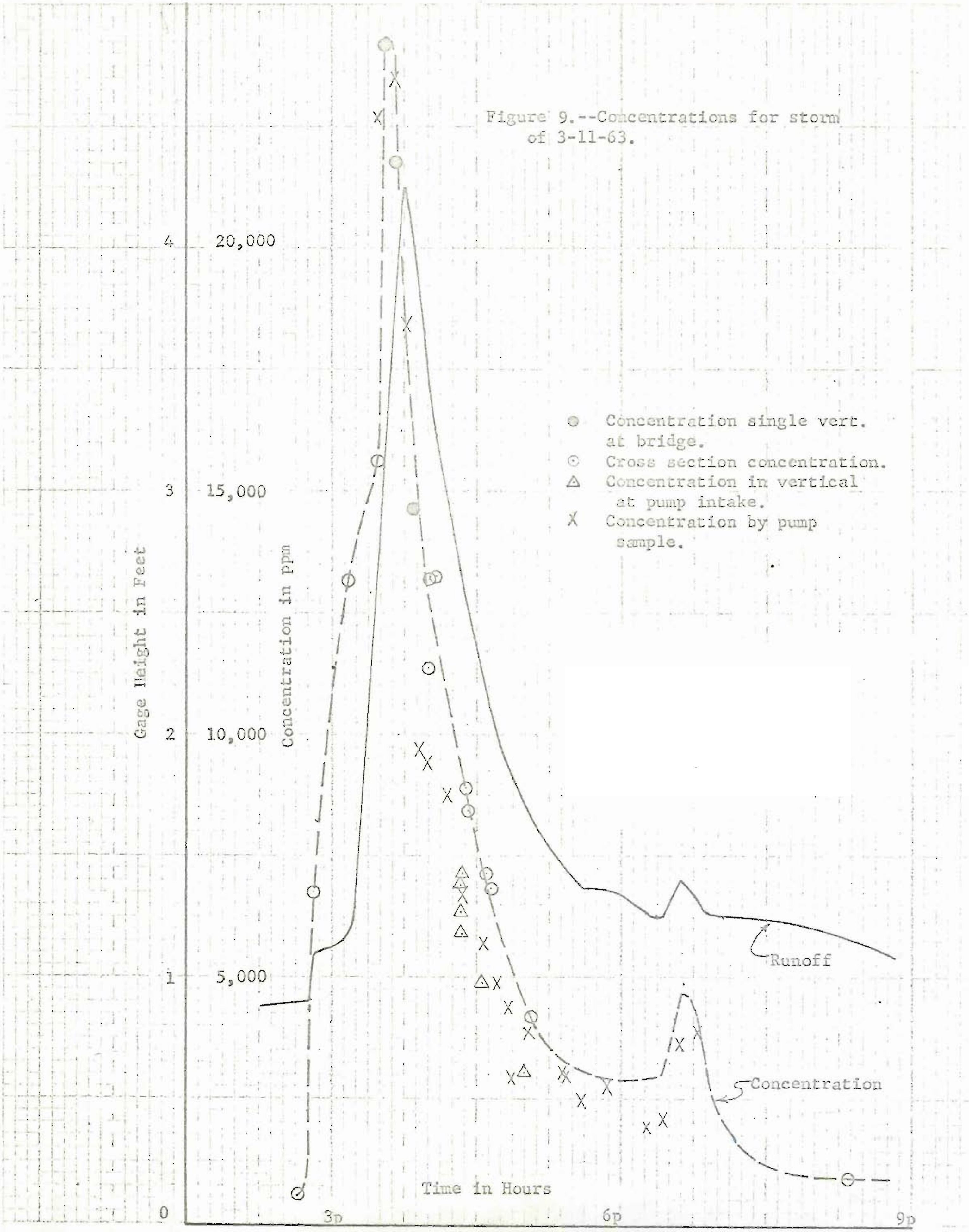


Figure 9.--Concentrations for storm of 3-11-63.

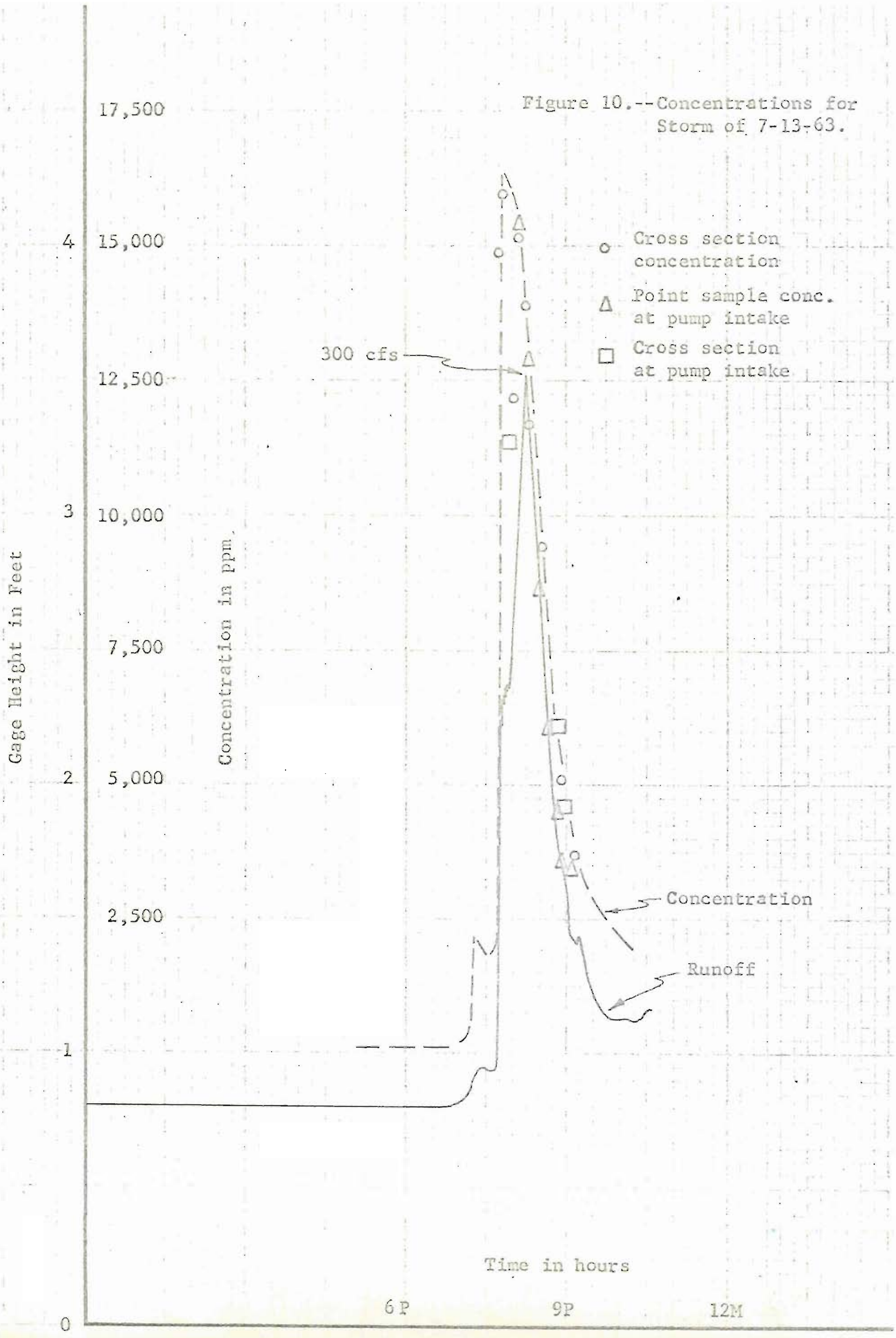
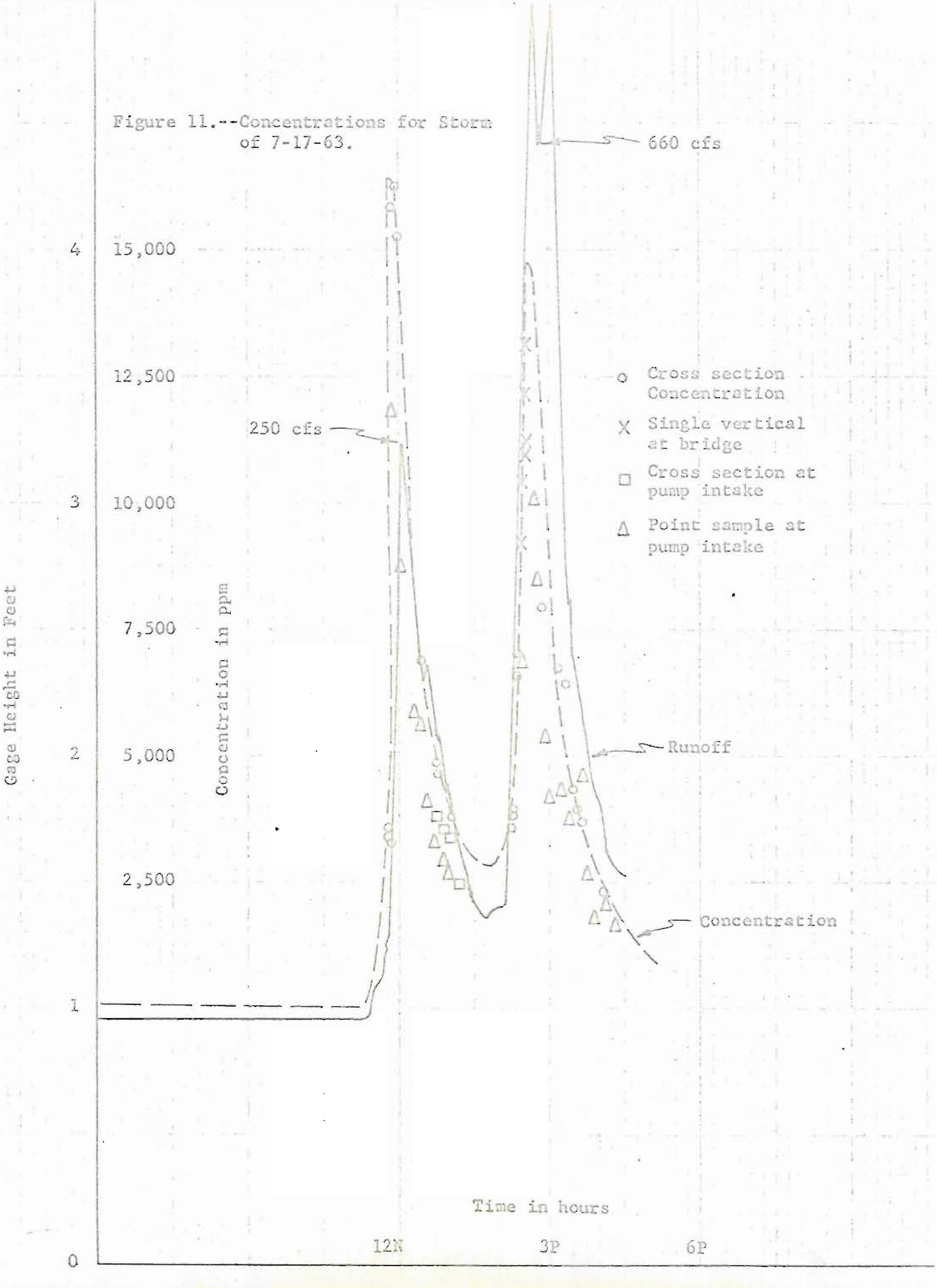


Figure 10.--Concentrations for Storm of 7-13-63.

Figure 11.--Concentrations for Storm of 7-17-63.



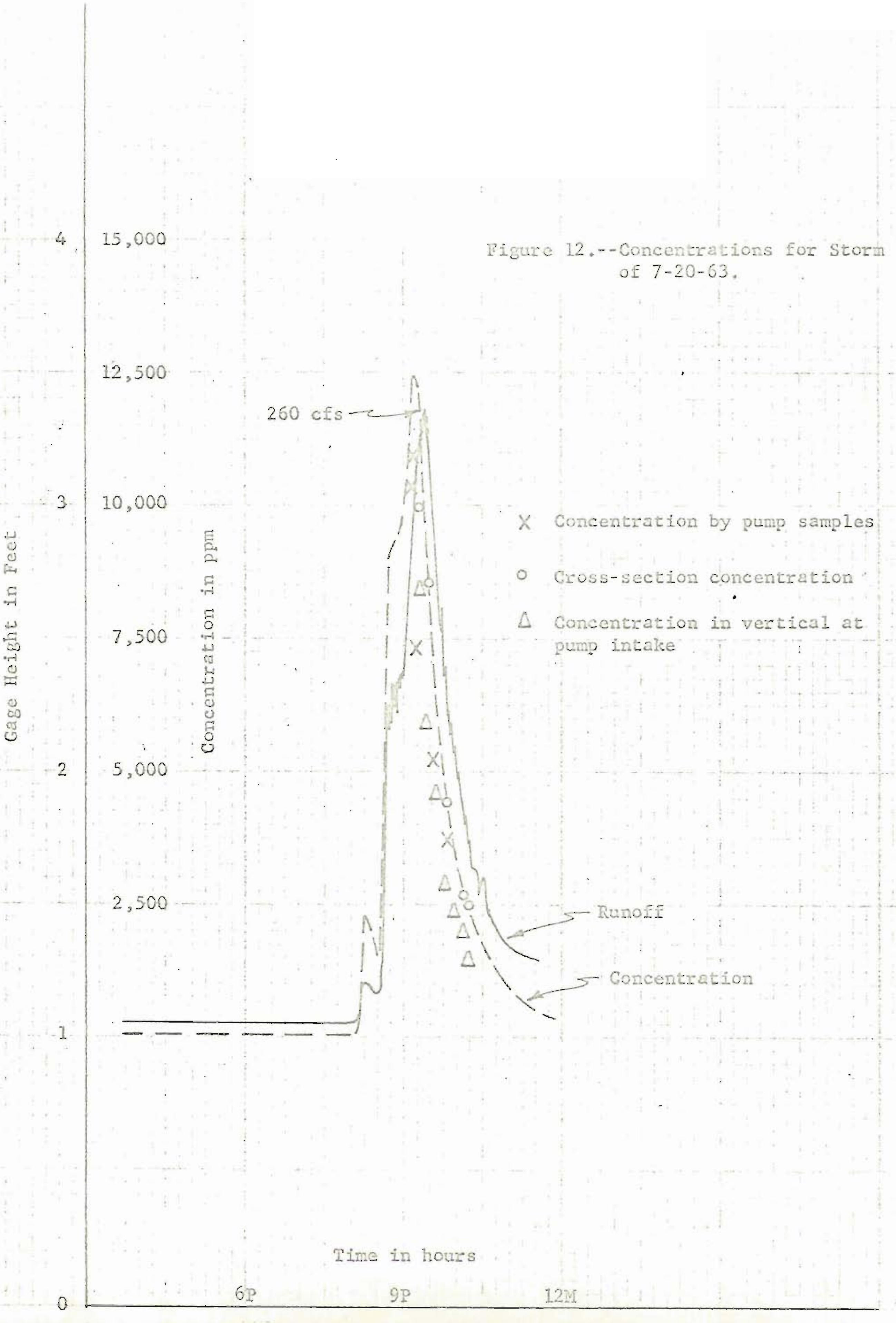


Figure 12.--Concentrations for Storm of 7-20-63.

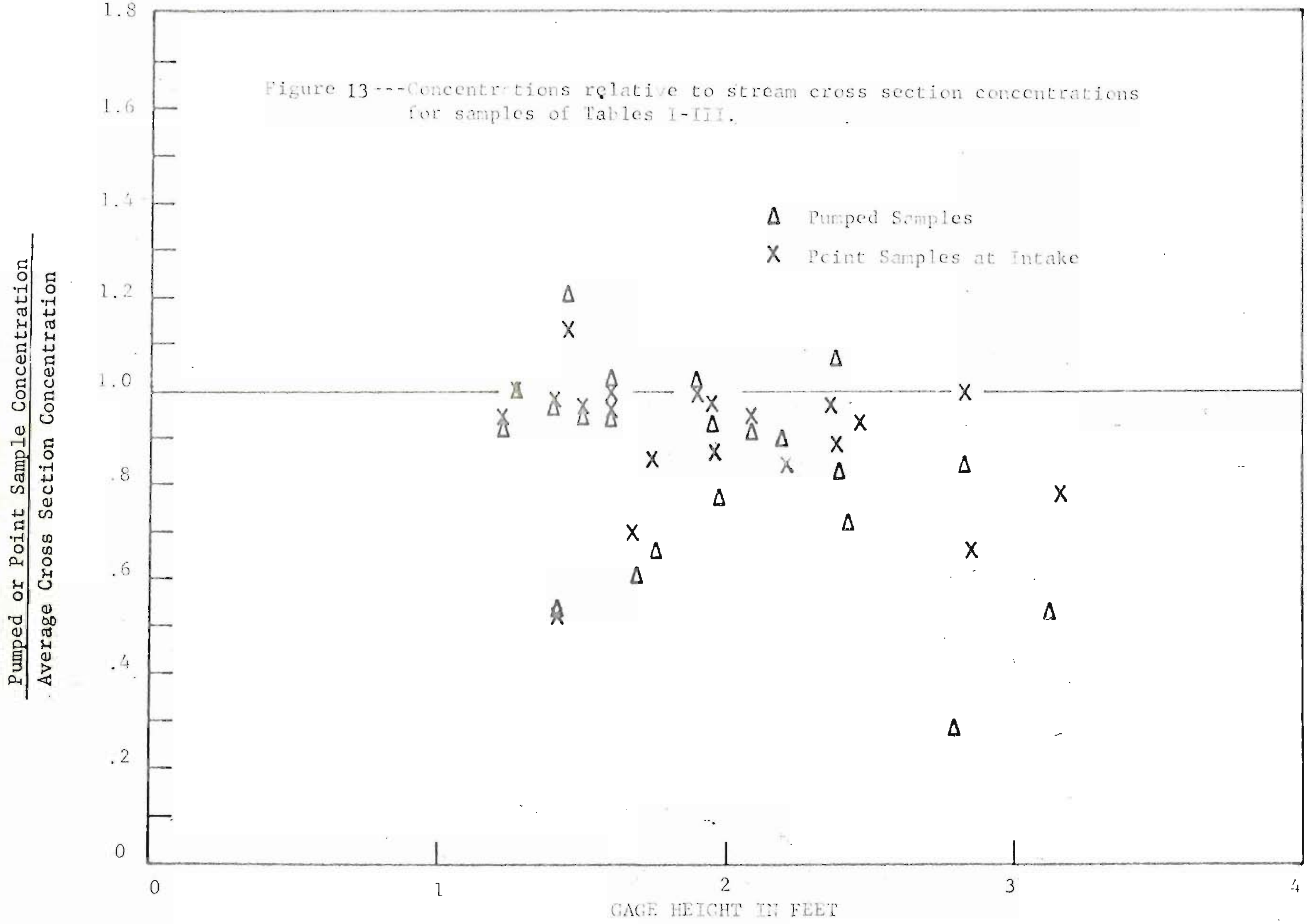


Figure 13---Concentrations relative to stream cross section concentrations for samples of Tables I-III.

TABLE I

Comparison of Concentrations of Cross Section Samples with Pump Samples

Date of Storm	Time	Gage Height	Cross Section Samples		Pump Samples		Ratio (1)	Ratio (2)
			Total Conc. (PPM)	Sand Conc. (PPM)	Total Conc. (PPM)	Sand Conc. (PPM)		
5/27/63	3:45 AM	2.06	6520	1320	6010	1330	.92	1.01
	3:55 AM	1.97	5350	1570	4180	657	.78	.42
	4:05 AM	1.72	5130	1320	3130	336	.61	.25
	4:25 AM	1.44	2480	168	2360	298	.95	1.77
	4:35 AM	1.42	2150	115	1190	250	.55	.22
6/24/63	9:05 AM	1.80	6350	1070	4070	1910	.64	1.78
	9:15 AM	1.67	5660	1040	5270	929	.93	.89
	9:25 AM	1.53	4390	513	4590	714	1.05	1.39
	9:35 AM	1.47	3530	272	4510	641	1.28	2.36
	9:45 AM	1.41	3230	308	3110	303	.96	.98
	9:55 AM	1.36	2430	141	2430	189	1.00	1.34
	10:05 AM	1.31	2450	311	2270	201	.93	.65
7/13/63	8:48 PM	2.30	6110	1350	4330	485	.71	.36
	8:58 PM	1.70	4550	554	1260	17	.28	.31
	9:08 PM	1.44	3840	415	3960	640	1.03	1.54
7/17/63	11:56 AM	1.90	16300	5340	15400	6820	.94	1.28
	12:26 PM	2.44	6910	1400	5820	1580	.84	1.13
	12:36 PM	2.32	4880	1430	6330	2940	1.30	2.05
	12:56 PM	2.00	3270	788	2980	587	.91	.74
7/20/63	9:00 PM	3.25	12800	3980	6710	2400	.52	.60
	9:20 PM	2.38	4420	1680	3680	1440	.83	.86

(1) Ratio of total concentration of pump samples to total concentration of cross section samples
(2) Ratio of sand concentration of pump samples to sand concentration of cross section samples

TABLE II

Comparison of Concentrations of Vertical Samples with Pump Samples

Date of Storm	Time	Gage Height	Single Vertical Sample Conc		Pump Sample Concentrations		Ratio (1)	Ratio (2)
			Total Conc.	Sand Conc	Total Conc	Sand Conc		
5/27/63	3:45 AM	2.06	6620	1320	6010	1330	.91	1.00
	3:55 AM	1.97	5350	1570	4180	657	.78	.42
	4:05 AM	1.72	4880	1050	3130	336	.64	.32
	4:25 AM	1.44	2420	160	2360	298	.98	1.86
	4:35 AM	1.42	2130	125	1190	250	.56	2.00
6/24/63	9:05 AM	1.80	5980	1050	4070	1910	.68	1.82
	9:15 AM	1.67	5010	538	5270	929	1.05	1.73
	9:25 AM	1.53	4010	392	4590	714	1.14	1.82
	9:35 AM	1.47	3460	207	4510	641	1.30	3.10
	9:45 AM	1.41	3060	213	3110	303	1.02	1.42
	9:55 AM	1.36	2430	141	2430	189	1.00	1.34
	10:05 AM	1.31	2240	138	2270	201	1.01	1.45
7/13/63	8:48 PM	2.30	--	--	4330	485	--	--
	8:58 PM	1.70	--	--	1260	17	--	--
	9:08 PM	1.44	--	--	3960	640	--	--
7/17/63	11:56 AM	1.90	8770	4160	15400	6820	1.76	1.63
	12:26 PM	2.44	--	--	5820	1580	--	--
	12:36 PM	2.32	4540	1000	6330	2940	1.39	2.94
	12:56 PM	2.00	--	--	2980	587	--	--
7/20/63	9:00 PM	3.25	--	--	6710	2400	--	--
	9:20 PM	2.38	--	--	3680	1440	--	--

(1) Ratio of total concentration for pump samples to total concentration of single vertical samples
(2) Ratio of sand concentrations for pump samples to sand concentration of single vertical samples

TABLE III

Comparison of Concentrations of Point Samples with Pump Samples

Date of Storm	Time	Gage Height	Point Sample Concentrations		Pump Sample Concentrations		Ratio (1)	Ratio (2)
			Total Conc. (PPM)	Sand Conc. (PPM)	Total Conc. (PPM)	Sand Conc. (PPM)		
5/27/63	3:45 AM	2.06	6520	1320	6010	1330	.92	1.01
	3:55 AM	1.97	--	--	4180	657	--	--
	4:05 AM	1.72	3080	328	3130	336	1.01	1.02
	4:25 AM	1.44	2480	168	2360	298	.95	1.77
	4:35 AM	1.42	2150	115	1190	250	.55	2.17
6/24/63	9:05 AM	1.80	5950	845	4070	1910	.68	2.26
	9:15 AM	1.67	5120	667	5270	929	1.03	1.39
	9:25 AM	1.53	4390	513	4590	714	1.04	1.39
	9:35 AM	1.47	3530	272	4510	641	1.28	2.36
	9:45 AM	1.41	3230	308	3110	303	.96	.98
	9:55 AM	1.36	2540	190	2430	189	.96	1.00
	10:05 AM	1.31	2260	180	2270	201	1.00	1.12
7/13/63	8:48 PM	2.30	4460	534	4330	485	.97	.91
	8:58 PM	1.70	3690	365	1260	17	.34	.46
	9:08 PM	1.44	3450	475	3960	140	1.15	1.35
7/17/63	11:56 AM	1.90	11800	2020	15400	1820	1.30	3.37
	12:26 PM	2.44	5640	1070	5820	1580	1.03	1.47
	12:36 PM	2.32	4030	1030	6330	2940	1.57	2.85
	12:56 PM	2.00	2920	636	2980	587	1.02	.92
7/20/63	9:00 PM	3.25	5950	1830	6710	2400	1.13	1.31
	9:20 PM	2.38	2880	995	3680	1440	1.27	1.44

(1) Ratio of total concentration of pump samples to total concentration of point samples
(2) Ratio of sand concentrations of pump samples to sand concentration of point samples

The comparisons in Table I show that the average ratio of concentrations of pumped samples to concentrations of depth-integrated samples was .85. This ratio increased during the tests, which indicates that the ratio was affected by an increase in average bed elevations of about three inches. Tables II and III show that the concentrations of pump samples, on the average, agree fairly well with the concentrations of the "point" and "single vertical" samples. The average ratio of concentrations of pumped samples to the concentrations of point and single vertical samples was 1.01. Each of the above tables shows that the sand content of the pumped samples relative to the sand content of each of the special samples was very erratic. In each case, however, the average ratio of sand concentration of all other samples was usually greater than 1. Although there were large deviations with respect to gage height, there was a definite trend toward higher sand content at higher stages of flow.

OVERALL EVALUATION

Any overall evaluation of the sampler must be based upon the adaptation of the various sampler characteristics to a given situation. It is assumed that the sampler can be made operational (mechanically reliable) and that no major modifications are necessary. For what conditions, then, is the sampler best suited? What are the limiting conditions for practical operation? Aside from mechanical difficulties attributed to various sampler components, the following factors limit the sampler operation:

1. Intake characteristics. Results of previous sediment sampler tests, as well as the present one, indicate a concentration difference between pump samples and those collected at the pump intake by conventional equipment. Comparisons, from Table III, for example, show that the ratio of point samples to pump samples varies from 0.34 to 1.57. There is well-documented evidence that the point concentration at the intake varies, within rather wide limits, from the representative cross-section concentration. The amount of variation also changes with stage, season, and with intake location. A consideration of intake characteristics then leads to the conclusion that sampler performance is best for streams where sediments are well mixed.
2. Qualitative and quantitative variability of sediments. Large changes in the size distribution and the concentration of sediments occur during a given storm runoff period. These variations are also caused by changing season, land use, etc., and they affect the operation of the sediment volume recorder in several ways:
    a. The volume-weight relationship is a function of the size distribution of deposited sediments. The variability of sediment density in the settling tubes is quite serious. The calibration curve of Figure 3 shows a plot of dry sediment weight versus volume. The scatter is readily evident.

b. This uncertainty in the volume-weight relation is also a function of the total volume of settled sediments as indicated in Figure 4. Whenever there is a large fluctuation in sediment concentrations, the diameter of the throat of the sedimentation tube must be large enough to contain the deposit. By such a design, however, low sediment concentrations accumulate to low heights in the tube, and the error in reading column heights is often as much as 25 percent.

This source of error could be eliminated by the use of sedimentation tubes with tapered necks, but inquiry indicated that the cost of making such tubes was prohibitive. The alternative is to limit sampler use to those streams that do not have widely-fluctuating concentrations.

3. Inefficient operation (inadequate bottle-wheel sampling) on ephemeral streams. The bottle-wheel feature of the sediment volume recorder is not adapted for use on small ephemeral streams, as previously discussed.

4. Operational difficulties due to power requirements, cold weather, and the general vulnerability of the complex sampler "package". Practical considerations associated with the installation of the sediment volume recorder are the proximity to power lines, the use of power units in remote locations, and provisions for operation in the several cold weather months during which significant runoff occurs.

CONCLUSIONS

The field conditions under which the sediment volume recorder, as now constituted, can most suitably operate, would be to sample "total load" from a large perennial stream. At a total load station, the sediments are nearly uniformly distributed through the river cross section, either by natural or by artificial means, so that all sediments are in suspension. Also, we would expect larger percentages of coarse material and less variation in sediment concentration at these locations. These circumstances would increase the accuracy of the volumetric calibration of the sampler.

The sediment volume recorder is least suited for operation on a small ephemeral stream, because of the many reasons cited. However, the modifications added at Oxford to adapt the sampler to this type operation--remote apparatus, etc.--worked fine. If one is satisfied with the limited accuracy of this type of operation, some benefit can be derived from it.

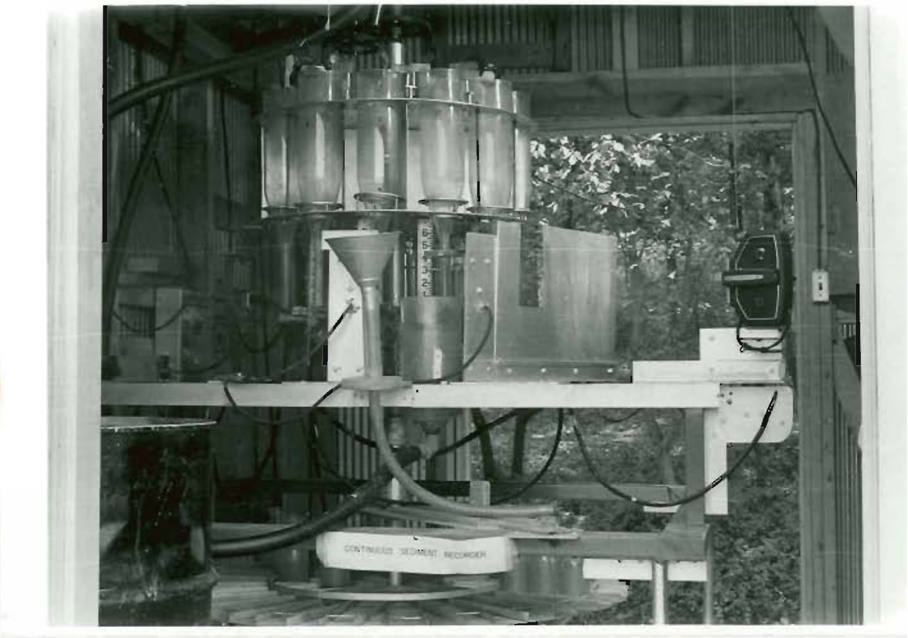


Figure 1.--Sediment volume recorder installation, with sedimentation tubes at top of photo and partially filled bottle rack at bottom.

Figure 2.--Section of stream channel with recorder shelter on right bank. Gage well and stream-gaging section are shown in background.