Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter C3

COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

By George Porterfield

Book 3

APPLICATIONS OF HYDRAULICS

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

First printing 1972

Second printing 1977

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

For sale by the Branch of Distribution, U.S. Geological Survey,
1200 South Eads Street, Arlington, VA 22202

PREFACE

The series of manuals on techniques describes procedures for planning and executing specialized work in water-resources investigations. The material is grouped under major subject headings called books and further subdivided into sections and chapters; Section C of Book 3 is on sediment and erosion techniques.

The unit of publication, the chapter, is limited to a narrow field of subject matter. This format permits flexibility in revision and publication as the need arises.

Provisional drafts of chapters are distributed to field offices of the U.S. Geological Survey for their use. These drafts are subject to revision because of experience in use or because of advancement in knowledge, techniques, or equipment. After the technique described in a chapter is sufficiently developed, the chapter is published and is sold by the U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202 (authorized agent of Superintendent of Documents, Government Printing Office).

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COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

George Porterfield

Abstract

This report is one of a series concerning the concepts, measurement, laboratory procedures, and computation of fluvial-sediment discharge. Material in this report includes procedures and forms used to compile and evaluate particle-size and concentration data, to compute fluvial-sediment discharge, and to prepare sediment records for publication.

Introduction

Collection, computation, and publication of fluvial-sediment and related environmental data are part of a national program to evaluate effects of sedimentation on the life and economics of projects related to navigation, flood control, transportation, reclamation, water supply, recreation, pollution, and fisheries. Fluvial-sediment investigations may include determination of the sediment discharge of rivers, surveys of reservoirs, studies of channel morphology, research in basic processes, and interpretation of sediment data.

The purpose of this chapter is to combine into a single handbook the necessary information to evaluate sediment data, compute sediment discharge, and tabulate the data for publication. The content is based not only on the author's experience but includes information from the voluminous literature accumulated during the past two or three decades as well as the ideas of many experienced coworkers.

Although this chapter is limited to methods of compilation, computation, and editorial format, it also includes reference to sampling techniques, laboratory procedures, principles of sediment transport, and quality control, because knowledge of these is fundamental to computation of sediment records. The entire operation, from the collection of the sample in the field to the laboratory analysis and the computation and publication of the records, requires a high degree of coordination. Minor duplication of material in other chapters of the manual is necessary and intentional to allow use of the chapter as separate entities.

This manual was prepared by the California district, Water Resources Division, U.S. Geological Survey, Menlo Park, Calif., under the general supervision of R. Stanley Lord, District Chief. Technical advice and assistance were given by Geological Survey personnel in California, Texas, New Mexico, and Pennsylvania districts and by F. C. Ames, H. P. Guy, and J. K. Culbertson.

Types of Records

Two basic types of sediment records—daily and periodic—are published by the Geological Survey.

Daily records are prepared for sites where sufficient determinations of sediment concentration and water discharge are obtained to justify computation of daily sediment discharge. The end product is a tabulation of daily mean concentration, suspended-sediment discharge, and periodic determinations of particle-size distribution of suspended sediment and bed material. These are combined with other quality-of-water data and released, usually by water year (October through following September) and on an annual basis, by the Geological Survey in basic-data reports covering a specific State or in the water-supply-paper series "Quality of Surface Waters of the United States."

Periodic records are prepared for sites where determinations of concentration and water discharge are not sufficient to justify computation of daily sediment discharges or where only miscellaneous samples are obtained. In addition to publication of the records, the data and computations are maintained on file in the district offices of the Water Resources Division and are available for examination or for use in interpretative reports or research.

Checklist for Daily Records

Steps in the procedure for the computation of daily records of fluvial-sediment discharge are given in the following checklist. A checklist for periodic and mixed records is given in the section "Periodic Observation" of this report. Data on stream stage and discharge needed in the daily sediment computation may be obtained from an A–35-analog-recorder chart or a plot of bihourly gage heights or discharge and from data forms 9–192, 9–210, and 9–207. The checklist items are as follows:

Particle-size analyses:
- Compute from laboratory analyses
- Tabulate
- Apply instantaneous water discharge

Tabulate water temperature

Sediment concentration:
- Compute from laboratory analyses
- List sediment measurements
- Copy size-concentration values on concentration notes
- Compute coefficients

Chart computations:
- Plot concentration
- Draw concentration graph
- Review concentration graph
- Compute concentration
- Apply concentration coefficient
- Compute subdivided days
- Check subdivided days

Sediment-discharge worksheet:
- Copy water discharge
- Copy concentration
- Compute sediment discharge
- Compute totals
- Check totals

Sediment–discharge worksheet—Continued
- Compute maximum and minimum
- Insert footnotes

Plot sediment-transport curve

Plot hydrograph

Write or update station description

Write station analysis

Review entire record

Prepare copies for records-processing center

Particle-Size Analysis

Samples of suspended sediment from each sampling site taken at specific or selected times of the year are analyzed for particle-size distribution. These samples indicate the average particle-size distribution of the material transported and should be obtained at various seasons of the year and at sufficient increments of discharge to cover the complete range in seasonal flow. Samples of bed material also are obtained to define the size distribution of bed material at various increments of flow and to define the physical properties of the material available for transport. The type and purpose of the sample dictates to some degree the sampling procedure, the methods used to analyze the sample, and the methods and forms used to present the data. Sampling procedures are discussed in detail in the manual on field methods for fluvial-sediment measurements (Guy and Norman, 1970) and by the U.S. Inter-Agency Committee on Water Resources (1963). Laboratory procedures and methods of analyses are discussed in detail in the manual on laboratory theory and methods for sediment analyses (Guy, 1969).

Evaluation of size data

Particle-size analyses should be evaluated during the review and tabulation process for—

1. Correct method of analysis,
2. Total number of analyses,
3. Range of water discharge,
4. Agreement of concentration and water discharge on the particle-size tabulation with those on the sediment-discharge sheet and published records, of water discharge, and

5. Validity of percentage-finer values.

The number of samples analyzed, methods of sample collection, and method of analysis depend partly on the purpose and scope of the sediment project or data program; results of analyses should be reviewed to determine if the number of samples and method used for analysis fulfills the goals of the sampling program.

Accuracy of the analysis is dependent, among other factors, on the quantity and physical characteristics of the sediment analyzed; an inspection of the data sheet will indicate if a sufficient quantity of material was collected for analysis. Analysis made on samples containing insufficient material may be in error. Particle-size distribution of these samples should be carefully evaluated for accuracy, and if suspect they should not be published. In general, the quantity of sediment needed for analysis is as follows:

Method	Quantity of sediment, in grams — Minimum	Optimum
Dry sieve	50	100
Wet sieve	.05	0.5-1.0
VA tube	.05	1.0-7.0
Pipet	.8	3.0-5.0
BW tube	.5	0.7-1.3

The minimum number of bottles of sample required to provide sufficient sediment for size analysis may be determined from the curves in figure 1. The range of concentration values and percentage finer than 62 microns needed to use figure 1 are available in the station records for the preceding year.

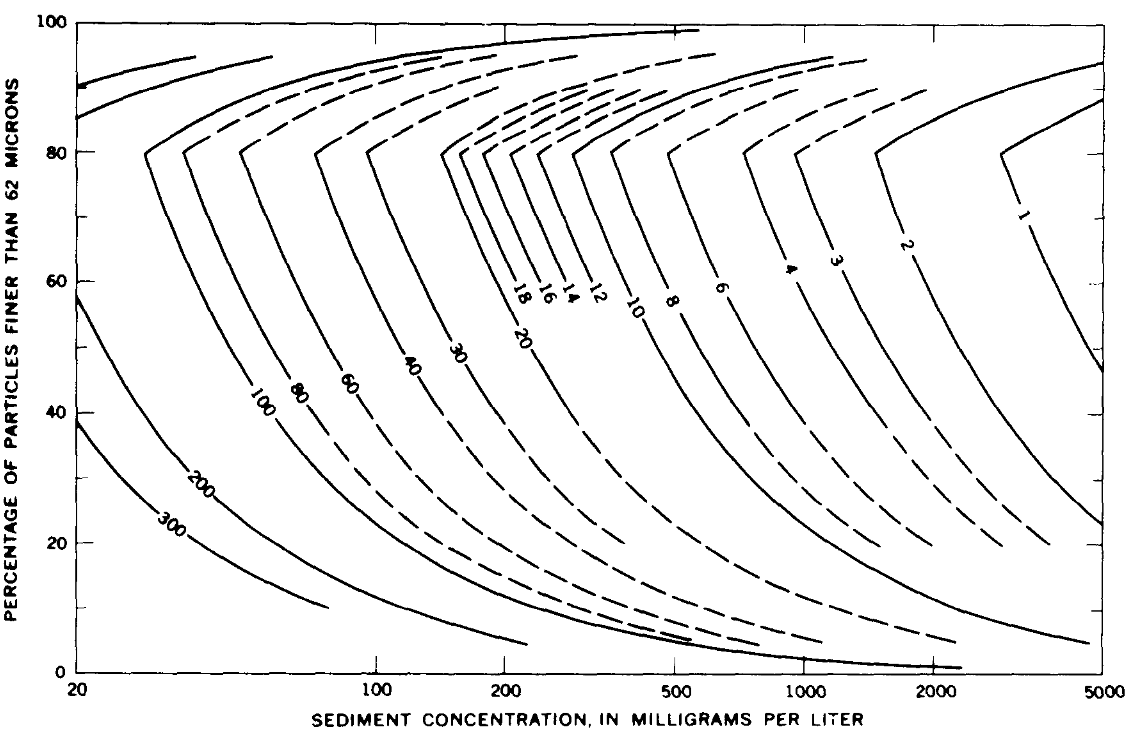

Figure 1.—Minimum number of bottles of sample required to yield sufficient sediment for size analysis. Explanation: Estimate sediment concentration and percentage finer than 62 microns by referring to analysis of samples obtained previously or by visual examination of the sediment sample. The number of bottles required is the value indicated by the line to the left of the intersection of the ordinate and abscissa. Interpolation of number of bottles is made along the abscissa. Values of the number of bottles required were computed on the assumption that each sample bottle contains 350 grams of water-sediment mixture and that a minimum of 0.2 gram of sand for a sieve or visual-accumulation-tube analysis and 0.8 gram of silt and clay for a pipet analysis in 400-milliliter suspension are needed for analysis. The number of bottles required to yield sufficient silt and clay for a bottom-withdrawal-tube analysis is five-eighths of the number indicated.

Tabulation of size data

Particle-size analyses of suspended sediment are tabulated on form 9–1539D, shown in figure 2. This form is also used to tabulate periodic or miscellaneous concentration and particle-size data. Particle-size analyses of bed material are tabulated on form 9–1539E (not illustrated). Examples of offset copy furnished by computer for publication are illustrated in the section on "Format of Sediment Tables."

Instantaneous water discharge at the time of sampling and concentration of the sample analyzed for particle-size distribution are determined and tabulated for each sample. These values must be compared for validity with the daily values published for water discharge in the surface-water records and on the sediment-discharge sheet. Water-discharge values may be computed and listed in the space provided on the particle-size forms or may be listed on the multiple-purpose form described in the section on "Analysis of Cross-Section Concentration Data."

Data from the particle-size analyses should be transcribed neatly on the form shown in figure 2. The data are arranged on the form as follows:

Date of collection.—Tabulate year, month, and day. January 1, 1970, for example, is 700101.

Time (24 hour).—Time is reported in 24-hour local standard time. The hours and minutes are always written to four places and without punctuation. Do not use a.m. or p.m. For example: 0001 hours is 1 minute after midnight; 0100 hours is 1 a.m.; 1048 hours is 10:48 a.m.; 1200 hours is 12 m. (noon); 1430 hours is 2:30 p.m.; and 2400 hours is 12 p.m. (midnight).

Water temperature (°C).—Water-temper-

Form 9-1539D (10-69)

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
Coding Form for Instantaneous Suspended Sediment and Particle Size

Type: 1 Station ident. number: 000000x.00 (1, 2–9) Stream and location: Sample River near Somewhere, U.S.A

Methods of analysis (74-77): B, bottom withdrawal tube; C, chemically dispersed; D, decantation; N, in native water; P, pipet; S, sieve; W, in distilled water; V, visual accumulation tube.
Please do not punch the decimal point unless data appears in the field.

Date Yr. (10-11)	Mo. (12-13)	Day (14-15)	Time (24 hour) (16-19)	Temperature (°C) (20-23)	Discharge (cfs) (24-33)	Susp. sediment concentration (mg/l) (34-40)	Particle size, percent finer (in millimeters) than size indicated: 0.002 (41-43)	0.004 (44-46)	0.008 (47-49)	0.016 (50-52)	0.031 (53-55)	0.062 (56-58)	0.125 (59-61)	0.250 (62-64)	0.500 (65-67)	1.000 (68-70)	2.000 (71-73)	Method of analysis (74-77)
69	10	29	0840	14.0	77.	304	--	--	--	--	--	100	--	--	--	--		S
	11	10	0940	9.5	449.	478	53	62	79	90	98	98	99	100	--	--		SPWC
	12	20	1300	7.0	512.	305						74	81	90	100	--		V
	12	21	1105	7.0	7750.	11500	25	30	37	48	60	67	86	94	98	100		VPWC
	12	21	1410	8.5	12600.	37200	20	26	31	42	55	62	84	94	98	100		VPWC
	12	23	1330	10.5	12800.	44100	16	21	27	39	50	56	72	87	95	97	100	SPWC
	12	28	1020	5.0	1990.	11600	22	29	34	52	65	74	88	95	99	100	-	VPWC
70	01	05	1420	5.5	3700.	12900	17	22	31	40	50	57	76	89	98	100		VPWC
	01	21	1025	6.0	1330.	6030	13	23	34	45	56	65	79	90	96	100		VPWC
	02	27	1220	8.5	830.	3230	18	24	35	47	58	64	82	96	100	--		VPWC

Compiled by *GP* Date *10/9/70* Checked by *RDB* Date *10/12/70*

Punched by ______ Date ______ Verified by ______ Date ______

Figure 2.—Annual tabulation of particle-size analyses of suspended sediment.

ature data are reported to the nearest 0.5 degree Celsius.

Number of sampling points.—Use when reporting bed-material analyses. This is the number of samples obtained in the stream cross section.

The laboratory may report individual analysis for each sample to show variation of bed-material size distribution in the cross section and to provide necessary data for computation of total sediment discharge by the procedure described by Colby and Hembree (1955). Generally the average size distribution in the cross section is published; however, individual analysis may be published if there is a large variation of median diameter among verticals or if there is a need for more detailed information.

Discharge (cfs).—The discharge is usually reported for the time of sampling; however, if no measurment is made or the rating does not justify reporting the instantaneous discharge, the daily mean discharge is reported. If mean discharge is used, change heading to "Mean discharge (cfs)" or use footnote "D" as explained in the section on "Footnotes."

Concentration (mg/l).—All sediment concentrations will be reported in milligrams per liter although they will be determined in the laboratory as parts per million. The supervisor must determine that all concentrations have been properly converted prior to tabulating concentrations or computing sediment discharge.

Sediment discharge (tons per day).—Values for tons per day should be determined as discussed in the section on "Computation of Sediment Discharge." Records tabulated for computer processing do not require computation of sediment discharge because values in this column are computed and listed by computer.

Particle sizes, percent finer than size (in millimeters) indicated.—The sizes for suspended sediment are 0.002, 0.004, 0.008, 0.016, 0.031, 0.062, 0.125, 0.250, 0.500, 1.00, 2.00 mm. The sizes for bed-material analyses are 0.004, 0.062, 0.125, 0.250, 0.500, 1.00, 2.00, 4.00, 8.00, 16.00, and 32.00 mm.

Method of analysis.—In the method of analysis column, the symbols should be recorded in the same order that the methods were used for the analysis. For example:

SBWC
VPWC
SPWC
VPN
SV

The symbols are explained in the headnotes and are standard.

Water Temperature

Temperature is an important physical characteristic of water, and information on water temperature is a necessary part of any study of water quality. It is also an important parameter needed to compute total-sediment discharge. A temperature observation should be obtained with each chemical-quality or sediment sample.

A temperature record may consist of a tabulation of maximum and minimum observations, once-daily observations, or observations obtained during periodic visits to a station. A continuous temperature record may be obtained from one of the many devices that sense and record fluctuations of water temperature on a continuous chart. Maximum and minimum temperatures for each day are computed from the chart and listed as illustrated in figure 3. A tabulation of once-daily temperature observations obtained by field personnel or contract observers is illustrated in figure 4. The form shown in figure 4 is a modified 9–211C.

Those observations taken daily or more frequently will be included in the tables of annual reports; observations obtained at infrequent visits to the station will be published in conjunction with other data, such as the tabulation of particle-size data on form 9–265b (fig. 2) or periodic sediment data (fig. 45). The completed tabulations (fig. 3 or 4) including maximum and minimum values are sent to the records-processing center where they are prepared for publication. The tabular data must be complete, that is with an entry in each space. If no

9-267d

U. S. Department of the Interior - Geological Survey - Water Resources Division

Temperature (°C) of water, Sample River at Sampleville, water year October 1969 to September 1970

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	21.0	16.0	12.5	10.5	6.5	5.0	6.5	5.5	4.5	2.5	6.0	4.0	9.5	6.0	12.5	8.5	23.0	16.5	19.5	17.0	24.0	17.0	24.5	16.0
2	20.5	14.0	13.5	11.0	6.0	5.0	7.0	6.0	5.0	3.0	5.5	4.0	8.0	5.5	13.0	8.0	23.5	16.5	22.5	17.0	24.0	17.5	23.0	17.5
3	20.0	14.5	12.5	11.0	6.0	5.0	6.5	6.5	5.5	3.5	5.0	3.5	7.0	4.5	10.5	8.0	24.0	17.0	23.0	17.5	24.5	17.5	22.5	17.0
4	15.5	15.0	12.0	11.0	7.0	5.0	7.0	6.5	4.0	3.5	6.0	3.5	8.0	6.0	13.0	7.5	23.5	17.5	23.0	17.5	24.5	17.5	22.0	14.5
5	18.5	15.0	13.0	11.5	8.5	7.5	7.5	6.5	5.5	4.0	6.0	4.5	8.0	6.0	16.0	10.0	20.5	17.0	23.5	18.0	24.0	17.0	23.0	14.0
6	18.0	13.5	11.5	10.0	7.5	6.0	7.5	6.5	5.5	3.5	6.5	4.5	8.5	6.5	18.0	12.5	19.5	16.0	23.5	17.5	24.0	17.0	24.0	15.5
7	18.0	13.5	14.0	11.0	7.0	6.5	7.0	5.5	6.0	4.0	7.5	5.0	10.0	6.5	17.5	14.0	17.0	15.5	25.0	17.5	23.5	17.5	24.5	17.0
8	18.0	12.0	14.5	12.5	9.0	7.0	5.5	4.0	6.5	5.0	7.5	4.5	12.0	9.0	18.0	15.0	17.0	15.0	25.5	18.0	24.0	17.0	25.0	17.5
9	18.0	11.0	16.0	13.0	10.0	9.0	4.0	2.0	6.5	4.5	6.5	5.0	10.5	9.0	16.5	14.0	17.0	15.0	25.5	18.5	20.0	17.0	24.5	17.0
10	19.0	14.5	16.0	13.5	11.5	8.0	5.0	4.0	7.0	6.0	7.0	4.5	12.0	8.5	17.0	14.5	17.5	15.5	23.5	18.0	23.0	17.5	23.5	16.0
11	16.5	15.0	14.0	12.5	8.0	6.0	5.5	5.0	7.5	5.5	6.0	3.5	12.5	10.0	20.0	15.0	18.0	15.5	22.0	18.0	23.0	17.5	22.0	16.0
12	16.0	13.5	12.5	9.0	6.5	5.0	7.0	5.5	6.0	5.0	8.0	4.0	11.5	9.0	18.5	15.5	20.0	15.5	25.0	17.5	23.5	17.5	22.0	17.0
13	15.5	12.0	9.0	8.0	7.0	6.0	7.5	6.0	5.5	4.0	8.5	4.5	9.5	7.5	15.5	13.5	20.5	16.0	25.0	17.5	25.0	16.5	20.5	17.5
14	14.5	11.0	8.0	7.0	7.5	6.5	6.0	5.5	5.5	5.0	7.5	4.0	9.0	8.0	18.0	13.0	18.5	16.0	25.0	17.0	24.5	17.0	22.0	16.0
15	16.0	12.0	8.0	7.5	7.5	6.5	5.5	5.0	6.0	5.0	9.0	5.0	11.0	8.5	18.0	14.5	18.5	16.5	24.0	18.0	24.5	17.0	21.5	14.5
16	17.0	12.5	9.0	7.5	6.5	6.0	5.0	4.0	6.0	4.5	7.0	6.0	12.0	9.0	20.0	14.5	24.0	17.0	25.0	17.5	24.5	17.0	21.0	14.0
17	18.5	13.5	10.0	9.0	6.0	6.0	4.5	3.0	6.0	5.0	7.5	6.5	10.0	9.0	21.0	14.5	24.5	17.5	25.5	16.5	24.0	15.0	22.0	15.0
18	17.5	12.5	10.5	9.0	6.0	6.0	5.0	4.5	6.5	5.5	7.5	5.5	12.0	9.5	18.5	14.0	22.5	18.0	26.0	17.0	24.0	17.5	22.5	18.0
19	17.5	13.0	11.0	10.0	6.0	5.0	7.0	5.0	7.5	6.5	7.0	4.5	12.5	9.5	18.0	12.5	21.5	17.5	26.5	16.5	23.0	18.0	20.0	17.5
20	18.0	13.0	10.0	9.5	5.0	3.5	8.0	6.0	6.5	5.0	7.0	6.0	13.0	10.0	19.5	13.0	20.5	17.0	26.5	18.0	25.0	18.5	20.0	16.5
21	17.5	12.5	10.5	9.0	3.5	3.0	8.5	6.5	6.5	5.0	9.0	6.5	13.5	12.0	21.0	14.0	21.0	17.0	26.5	18.5	26.0	18.0	21.0	17.0
22	17.0	11.5	11.0	10.0	4.0	3.0	6.5	5.0	5.5	4.0	10.0	7.0	13.0	11.5	21.5	15.5	23.0	17.5	27.0	18.5	25.5	17.5	22.0	16.5
23	18.0	13.0	10.5	9.0	5.0	4.5	5.5	3.0	4.5	4.5	9.5	7.0	11.5	7.0	21.5	16.0	23.0	17.5	26.5	19.0	24.5	17.5	22.5	17.0
24	19.0	13.5	9.0	8.5	7.0	5.0	5.0	4.0	5.5	4.5	10.0	7.5	9.5	6.5	18.0	15.5	23.5	17.5	24.5	19.0	24.0	17.0	22.5	18.0
25	17.5	13.0	8.5	8.0	6.5	5.5	8.0	5.0	4.5	3.0	10.0	6.0	11.0	6.0	20.0	15.0	20.5	17.5	26.0	19.5	24.0	17.0	22.0	15.5
26	18.0	12.5	8.0	7.0	5.5	4.5	8.5	4.0	6.0	3.0	10.0	6.5	12.0	8.0	17.5	14.0	21.0	15.5	26.5	17.5	24.0	17.0	22.0	17.0
27	18.0	12.0	8.0	7.0	5.5	5.0	4.5	3.0	5.5	5.0	10.5	7.0	13.0	10.0	18.0	13.5	19.5	15.0	20.0	17.0	24.0	17.0	21.5	16.5
28	17.0	11.5	8.0	7.0	5.0	5.0	3.5	3.0	5.0	4.0	10.5	7.5	13.5	11.0	20.0	13.0	23.0	14.5	25.0	17.0	23.5	16.5	21.0	15.5
29	16.5	13.0	8.0	6.0	5.0	4.5	3.5	2.0	—	—	10.5	7.5	12.5	9.5	21.0	14.5	24.0	16.0	25.5	17.5	23.0	17.0	20.5	16.0
30	13.5	12.0	7.5	5.0	5.0	4.0	3.0	1.0	—	—	11.0	8.0	12.0	9.0	21.5	16.0	24.5	17.0	24.5	17.0	23.0	16.5	21.0	16.5
31	14.0	11.0	—	—	5.0	4.0	3.0	2.0	—	—	11.5	8.0	—	—	22.0	16.5	—	—	21.0	17.0	25.0	15.5	—	—

Figure 3.—Maximum and minimum daily water-temperature tabulation.

U S. Department of the Interior - Geological Survey - Water Resources Division

Temperature (°C) of water, Sample Creek near Sampleville, water year October 1969 to September 1970

[Once-daily observation between 1600 and 1800 hours PST]

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	18.0	16.5	10.0	10.5	7.5	8.0	8.5	10.5	16.5	19.5	21.0	20.0
2	17.5	16.0	--	10.5	8.0	7.5	9.0	11.0	17.0	17.0	20.0	20.0
3	17.0	16.5	10.0	11.0	9.0	7.0	8.0	10.5	16.5	19.0	20.0	19.5
4	16.5	17.0	--	10.5	8.5	6.5	8.5	11.0	16.0	20.0	21.0	20.0
5	17.0	17.0	11.0	11.0	9.0	6.0	9.0	12.0	15.0	20.0	20.0	19.0
6	17.5	16.5	11.0	11.5	9.0	7.0	9.5	12.5	14.5	20.5	21.0	18.0
7	17.5	17.0	11.5	11.0	9.5	7.5	10.0	13.0	14.5	20.5	20.0	18.5
8	17.0	17.5	12.0	10.0	9.5	8.5	10.0	12.0	14.0	21.5	20.0	19.5
9	17.0	18.0	12.5	9.5	10.0	8.5	10.5	12.5	14.0	21.5	19.5	18.5
10	17.0	17.5	12.0	10.0	9.5	9.0	11.0	13.0	13.5	20.5	20.0	19.5
11	16.5	17.0	10.5	10.5	9.0	8.5	11.0	13.0	14.5	19.5	21.0	19.0
12	16.5	15.0	10.5	10.0	8.0	8.0	10.0	12.5	16.0	20.0	20.0	20.0
13	16.0	15.0	10.0	10.0	7.0	7.0	9.0	12.5	16.5	20.0	21.0	20.0
14	16.0	14.5	9.5	9.5	7.5	7.0	10.0	11.5	17.0	20.5	21.0	20.5
15	16.5	15.0	10.0	9.5	7.0	6.5	10.5	13.0	18.0	20.5	20.5	19.0
16	16.5	14.0	9.5	9.0	8.0	6.0	11.5	13.5	18.5	20.5	20.5	18.0
17	17.0	14.5	10.0	9.0	8.5	6.5	9.5	14.0	18.5	21.0	21.0	18.5
18	16.5	14.0	10.5	8.0	9.0	6.5	10.0	11.5	17.5	21.0	21.0	17.5
19	16.6	14.0	10.0	9.0	9.0	7.0	9.5	13.0	16.5	21.5	20.0	18.0
20	17.0	13.5	9.5	9.5	9.5	7.0	11.0	14.0	19.0	21.5	19.5	17.0
21	17.0	14.0	9.0	9.5	9.5	8.0	11.0	15.0	18.5	22.0	21.0	18.5
22	17.5	14.0	9.0	9.0	8.5	7.5	10.0	15.6	18.5	22.0	21.5	19.0
23	18.0	13.5	10.0	8.5	8.0	7.5	9.5	14.0	16.5	21.0	20.0	19.5
24	17.0	13.0	10.5	8.0	7.5	8.0	9.5	12.0	16.5	19.0	19.5	18.0
25	17.5	11.0	10.0	9.0	8.0	9.0	10.0	12.0	16.0	22.0	20.0	18.5
26	18.0	11.0	10.5	9.0	8.5	9.5	10.5	11.5	15.5	22.0	19.5	19.0
27	18.0	11.0	10.5	8.0	8.0	9.5	11.0	13.0	15.5	21.0	20.0	18.0
28	17.5	10.0	10.0	7.5	8.0	10.0	10.5	14.0	17.0	20.5	20.5	17.5
29	17.5	11.0	9.5	7.0	--	9.5	10.0	14.5	17.5	20.5	20.0	18.0
30	17.0	10.5	10.0	7.0	--	9.5	10.0	16.0	18.0	21.0	19.5	17.0
31	16.0		10.0	7.0		9.0		16.5		21.0	19.5	

Figure 4.—Tabulation of once-daily water temperatures.

value is available, a leader (..) should be placed in the blank space.

Although temperature data have been published by the Geological Survey in degrees Celsius since October 1967, many temperature measurements are made with a Fahrenheit thermometer and converted to Celsius when recorded on the permanent laboratory and field sheets. Thermograph records may be converted directly to Celsius by template, or the values may be tabulated in Fahrenheit (figs. 3, 4) and the conversion to Celsius made by digital computer. Values recorded on digital tape by temperature monitors also may be converted by computer. All other temperature values, including the "extremes" values for the period of record, should be converted to Celsius (table 1) in

Table 1.—Temperature conversion table to nearest 0.5 degree

[The numbers in the center columns refer to temperatures, either in Celsius or Fahrenheit, which are to be converted to the other scale. If converting Fahrenheit to Celsius, the equivalent temperature will be found in the left columns. If converting Celsius to Fahrenheit, the equivalent temperature will be found in the right columns]

	0 to 24.5			25.0 to 49.5			50.0 to 74.5			75.0 to 100.0	
—18.0	0	32.0	—4.0	25.0	77.0	10.0	50.0	122.0	24.0	75.0	167.0
—17.5	.5	33.0	—3.5	25.5	78.0	10.5	50.5	123.0	24.0	75.5	168.0
—17.0	1.0	34.0	—3.5	26.0	79.0	10.5	51.0	124.0	24.5	76.0	169.0
—17.0	1.5	34.5	—3.0	26.5	80.0	11.0	51.5	124.5	25.0	76.5	170.0
—16.5	2.0	35.5	—3.0	27.0	80.5	11.0	52.0	125.5	25.0	77.0	170.5
—16.5	2.5	36.5	—2.5	27.5	81.5	11.5	52.5	126.5	25.0	77.5	171.5
—16.0	3.0	37.5	—2.0	28.0	82.5	11.5	53.0	127.5	25.5	78.0	172.5
—16.0	3.5	38.5	—2.0	28.5	83.5	12.0	53.5	128.5	26.0	78.5	173.0
—15.5	4.0	39.0	—1.5	29.0	84.0	12.0	54.0	129.0	26.0	79.0	174.0
—15.5	4.5	40.0	—1.5	29.5	85.0	12.5	54.5	130.0	26.5	79.5	175.0
—15.0	5.0	41.0	—1.0	30.0	86.0	13.0	55.0	131.0	26.5	80.0	176.0
—14.5	5.5	42.0	—1.0	30.5	87.0	13.0	55.5	132.0	27.0	80.5	177.0
—14.5	6.0	43.0	— .5	31.0	88.0	13.5	56.0	133.0	27.0	81.0	178.0
—14.0	6.5	43.5	— .5	31.5	88.5	13.5	56.5	134.0	27.5	81.5	179.0
—14.0	7.0	44.5	0	32.0	89.5	14.0	57.0	134.5	28.0	82.0	179.5
—13.5	7.5	45.5	.5	32.5	90.5	14.0	57.5	135.5	28.0	82.5	180.5
—13.5	8.0	46.5	.5	33.0	91.5	14.5	58.0	136.5	28.5	83.0	181.5
—13.0	8.5	47.5	1.0	33.5	92.5	14.5	58.5	137.0	28.5	83.5	182.0
—13.0	9.0	48.0	1.0	34.0	93.0	15.0	59.0	138.0	29.0	84.0	183.0
—12.5	9.5	49.0	1.5	34.5	94.0	15.5	59.5	139.0	29.0	84.5	184.0
—12.0	10.0	50.0	1.5	35.0	95.0	15.5	60.0	140.0	29.5	85.0	185.0
—12.0	10.5	51.0	2.0	35.5	96.0	16.0	60.5	141.0	29.5	85.5	186.0
—11.5	11.0	52.0	2.0	36.0	97.0	16.0	61.0	142.0	30.0	86.0	187.0
—11.5	11.5	52.5	2.5	36.5	98.0	16.5	61.5	143.0	30.0	86.5	188.0
—11.0	12.0	53.5	3.0	37.0	98.5	16.5	62.0	143.5	30.5	87.0	188.5
—11.0	12.5	54.5	3.0	37.5	99.5	17.0	62.5	144.5	31.0	87.5	189.5
—10.5	13.0	55.5	3.5	38.0	100.5	17.0	63.0	145.5	31.0	88.0	190.5
—10.5	13.5	56.0	3.5	38.5	101.5	17.5	63.5	146.5	31.5	88.5	191.0
—10.0	14.0	57.0	4.0	39.0	102.0	18.0	64.0	147.0	31.5	89.0	192.0
— 9.5	14.5	58.0	4.0	39.5	103.0	18.0	64.5	148.0	32.0	89.5	193.0
— 9.5	15.0	59.0	4.5	40.0	104.0	18.5	65.0	149.0	32.0	90.0	194.0
— 9.0	15.5	60.0	4.5	40.5	105.0	18.5	65.5	150.0	32.5	90.5	195.0
— 9.0	16.0	61.0	5.0	41.0	106.0	19.0	66.0	151.0	33.0	91.0	196.0
— 8.5	16.5	62.0	5.5	41.5	107.0	19.0	66.5	152.0	33.0	91.5	197.0
— 8.5	17.0	62.5	5.5	42.0	107.5	19.5	67.0	152.5	33.5	92.0	197.5
— 8.0	17.5	63.5	6.0	42.5	108.5	19.5	67.5	153.5	33.5	92.5	198.5
— 8.0	18.0	64.5	6.0	43.0	109.5	20.0	68.0	154.0	34.0	93.0	199.5
— 7.5	18.5	65.5	6.5	43.5	110.5	20.5	68.5	155.0	34.0	93.5	200.5
— 7.0	19.0	66.0	6.5	44.0	111.0	20.5	69.0	156.0	34.5	94.0	201.0
— 7.0	19.5	67.0	7.0	44.5	112.0	21.0	69.5	157.0	34.5	94.5	202.0
— 6.5	20.0	68.0	7.0	45.0	113.0	21.0	70.0	158.0	35.0	95.0	203.0
— 6.5	20.5	69.0	7.5	45.5	114.0	21.5	70.5	159.0	35.0	95.5	204.0
— 6.0	21.0	70.0	8.0	46.0	115.0	21.5	71.0	160.0	35.5	96.0	205.0
— 6.0	21.5	71.0	8.0	46.5	115.5	22.0	71.5	161.0	36.0	96.5	206.0
— 5.5	22.0	71.5	8.5	47.0	116.5	22.0	72.0	162.0	36.0	97.0	206.5
— 5.5	22.5	72.5	8.5	47.5	117.5	22.5	72.5	162.5	36.5	97.5	207.5
— 5.0	23.0	73.5	9.0	48.0	118.5	23.0	73.0	163.5	36.5	98.0	208.5
— 4.5	23.5	74.5	9.0	48.5	119.5	23.0	73.5	164.0	37.0	98.5	209.5
— 4.5	24.0	75.0	9.5	49.0	120.0	23.5	74.0	165.0	37.0	99.0	210.0
— 4.0	24.5	76.0	9.5	49.5	121.0	23.5	74.5	166.0	37.5	99.5	211.0
									38.0	100.0	212.0

the field. Temperature data are to be observed, reported, and published to the nearest 0.5 degree Celsius.

Suspended-Sediment Concentration

Sediment concentration may be determined as the ratio of the weight of the sediment to the (1) weight of the water-sediment sample, (2) weight of the water in the water-sediment sample, or (3) weight of the pure water equal in volume to the volume of the sample. Discharge-weighted concentration is usually determined by the first method and is the concentration determined by the laboratory and referred to in this manual. Because of convenience in the laboratory, it is determined in parts per million and is defined as the dry weight of sediment divided by the weight of the water-sediment mixture multiplied by 1 million. As the concentration is published in miligrams per liter, however, the values determined in the laboratory must be converted to milligrams per liter prior to computation of sediment discharge or publication.

The discharge-weighted mean concentration in the vertical generally is obtained from depth-integrated samples obtained with standard velocity-weighting samplers. The mean concentration in the vertical also may be obtained from point samples, which represent equal units of depth by (1) weighting each sample by the velocity at each sampling depth or (2) recording the sampling time for each sample and using the weight of the sample collected per second in lieu of point velocity to weight each sample. A discharge-weighted mean in the vertical also may be obtained from a composite of point samples if all samples in the vertical are taken for an equal period of sampling time (U.S. Inter-Agency Committee on Water Resources, 1963, p. 46–50).

The discharge-weighted mean concentration in the cross section may be computed from the mean concentrations of the several sampled verticals. If the sampled verticals represent centroids of equal discharge (EDI method) (Guy, 1970), the mean concentration is the average of the several verticals or is the mean of the composited samples, provided all samples are of the same volume. Thus, samples obtained by the EDI method that are to be composited for particle-size analysis must be the same volume. Samples collected at centroids to define lateral distribution of sediment in the cross section should be analyzed individually and, therefore, do not require an equal volume of water in each sample. If the sampled verticals are uniformly spaced and the same transit rate is used for all verticals (ETR method) (U.S. Inter-Agency Committee on Resources, 1963, p. 41), the mean concentration is the ratio of the total weight of sediment to the total weight of the water-sediment mixture in all samples. Hence, samples collected by the ETR method must be composited either in the laboratory or arithmetically, because the concentration of any individual sample is relatively meaningless.

Concentration data obtained to compute sediment discharge should define the vertical and lateral distribution of concentration in the cross section and the variation of the mean concentration with time. Each sample obtained at daily and periodic stations is analyzed for concentration, and the results are listed in the concentration notes (fig. 5). Concentration notes also include the date and time and identify the sampling and laboratory procedures. Samples may be composited for analysis or analyzed individually.

Compositing, as used here, is the practice of combining the water-sediment mixture of all samples into one container to determine the concentration or particle-size distribution. The mean concentration of a composite sample is the ratio of the total weight of the sediment to the total weight of water-sediment mixture. Samples usually composited are those collected only to define the average concentration in the cross section, those collected for analysis of particle-size distribution, and those collected by the ETR method. Samples analyzed individually are those collected to define the vertical or lateral distribution of concentration in the stream

UNITED STATES DEPARTMENT OF THE INTERIOR
Geological Survey—Water Resources Division
SEDIMENT CONCENTRATION NOTES, DEPTH INTEGRATED SAMPLES (Short form)

Stream and location Sacramento River at Red Bluff, Calif. Computed by VLG Checked by WUS

Date	12-12-63		12-12-63		12-12-63					
Time	7:15am	7:20am	1220 pst	1225	1235 PST	1238	1242	1246	1250	1254
Gage height	7.60		7.60	7.60	7.60					7.60
Sampling Sta.	Box		Di Box	Box	Di 100' REW	200' REW	300' REW	400' REW	500' REW	600' REW
Temp. & Spec. Cond.	46°/	/	48°/	48°/	48°/	/	48°/	/	/	48°/
Remarks	d=8.1		d=8.1 1/2	2/2	d=4.5 1/6	d=8.4 2/6	d=5.4 3/6	d=6.3 4/6	d=3.9 5/6	d=6.1 6/6
Weight of sample: Gross obs.	B.E.		A.L	A.L.	A.L.	AL	AL	AL	AL	AL
Weight of sample: Tare										
Weight of sample: Net	318	364	396	219	311	301	385	312	402	225
Container no.	340		341		342	343	344	345	346	347
Weight of sediment: Gross	22.0397		21.7351		21.8877	21.8473	21.6501	22.1333	21.6566	22.4100
Weight of sediment: Tare	22.0291		21.7293		21.8854	21.8450	21.6471	22.1302	21.6519	22.4068
Weight of sediment: Net	0.0106		0.0058		0.0023	0.0023	0.0030	0.0031	0.0047	0.0032
Weight of sediment: D.S corr										
Weight of sediment: Net										
Conc. (ppm)	16		9		7	8	8	10	12	14
		16		9				10		

Date	12-12-63		12-13-63		12-14-63		12-15-63		12-16-63	
Time	1300	1305	7:15am	7:20	7:15am	7:20	8:00 pst	8:05	7:15am	7:20
Gage height	7.60	7.60	7.60		7.60		7.55		7.55	
Sampling Sta.	Di Box 1/2	2/2								
Temp. & Spec. Cond.	48°/	/	48°/	/	48°/	/	46°/	/	48 /	/
Remarks	d=8.1		1/2	2/2						
Weight of sample: Gross obs.	AL	AL	BE	BE	BE		BE		BE	
Weight of sample: Tare										
Weight of sample: Net	322	331	336	315	335	318	418	359	330	323
Container no.	348		349	350	351		352		353	
Weight of sediment: Gross	22.2037		21.8321	21.8579	21.9524		21.7150		22.7629	
Weight of sediment: Tare	22.1977		21.8286	21.8538	21.9439		21.7061		22.7552	
Weight of sediment: Net	0.0060		0.0035	0.0041	0.0085		0.0089		0.0077	
Weight of sediment: D S corr										
Weight of sediment: Net										
Conc (ppm)	9		10	13	13		11		12	
		9		12		13		11		12

Form 9-265e (Rev. 10-62) 17627

Figure 5.—Short form for sediment-concentration notes.

cross section. Mean concentration in the cross section, or vertical, is computed by weighting the concentration of each sample by the increment of discharge it represents.

Examples of concentration notes are shown in figure 5. Samples individually analyzed are the six-bottle sample of December 12 and the two-bottle sample of December 13. All other samples collected December 12–16 were composited.

The samples collected from 1220 to 1305 hours December 12 were obtained to determine the relation between the mean concentration in the cross section and the mean concentration at the fixed sampling stations. The average concentrations for the fixed sampling station at 1220 to 1225 hours and 1300 to 1355 hours and for six verticals in the cross section at 1235 to 1250 hours are circled.

Adequacy of data

A continuous evaluation of concentration data must be maintained to insure that sufficient samples are obtained and that the samples are of acceptable quality. The step-by-step preparation of records offers a continuing base for cross consultation among personnel responsible for records, laboratory, and fieldwork to evaluate the overall efficiency of the sampling program and to determine if the quantity and quality of the basic data meet desired standards.

Errors in concentration values usually occur because of simple mistakes in sampling procedure or because too few samples were obtained to cover the natural random variation in concentration and size gradation of transported sediment. A description of the sampling procedure is given by Colby (1963, p. 40), by the U.S. Inter-Agency Committee on Water Resources (1963), and by Guy and Norman (1970). Factors that should be evaluated regularly are (1) the number of samples collected in each vertical, (2) the number of verticals sampled in each cross section, (3) the number of samples with respect to time, and (4) the relation of the concentration in the single sampling vertical to average concentration in the cross section.

The number of samples required in each vertical and the number of verticals which must be sampled to determine the mean concentration within acceptable limits may vary with location and time. A study of the variation of concentration in sand-bed streams is given by Hubbell (1960), and a statistical method for determining the number of samples required is described by Guy (1968). Additional information is available in Guy and Norman (1970).

Relation between single-vertical and cross-sectional concentrations

If sediment samples are obtained routinely at a single vertical in a cross section, the relation of the concentration of the single-vertical sample to the mean concentration in the cross section must be determined prior to computation of sediment discharge. This relation, in the form of a coefficient, is determined by an analysis of cross-section concentration data.

Ideally, sufficient samples should be obtained routinely in the cross section to define the mean concentration both in time and space, and if cost were of no concern this procedure might be selected for all operations. In practice, however, we obtain a computation of routine daily samples at from one to three verticals plus less frequent but more comprehensive samples at sufficient verticals in the cross section to define mean concentration in the cross section. This mean concentration is used to determine the departure of the concentration observed at the single vertical, or fixed-sampling vertical, from the mean concentration in the cross section.

This information should be used (1) to relocate the fixed-sampling station at a vertical that is more representative of the average stream concentration or (2) to determine a coefficient to convert the concentration of the fixed-vertical sample to the mean value for the stream cross section. The adequacy of the sample at the fixed vertical may be determined by an inspection and analysis of the data for stations with uniform concentrations in the cross section and by statistical analysis at stations where variation in sediment concentrations exceed the desired accuracy (Hubbell, 1960).

Cross-section coefficient

The ratio of the average sediment concentration in the cross section to the concentration determined by daily samples at a fixed station (box) is computed on the forms shown in figures 6 and 7. This ratio is referred to as the cross-section coefficient.

SEDIMENT DISCHARGE MEASUREMENTS

for Sacramento River at Red Bluff Water year ending Sept. 30, 1964

(1) Date	(2) Time PST	(3) Type of Sample	Concentration (4) a x-sect	(5) b box	(6) Cross-section coef. a/b	(7) G.H.	(8) Shift	(9) Water disch. (cfs)	(10) Sediment disch. (t/d)	(11) Temp. (°C)
10 3 63	0820	x sect conc	8	8	1.0	3.33		10,100	218	13
11 12 63	1615	x sect size	10	11	Say 1.0 .91	2.67		8,240	222	14
12 12 63	1240	x sect conc	10	9	Say 1.0 1.11	3.74		11,300	305	9
1 15 64	1240	x sect conc	4	3	Say 1.0 1.33	2.58		8,000	86	9
1 21 64	0100	obs size		957	–	16.67		60,800	157,000	7
1 21 64	1100	obs size		607	–	7.92		26,200	42,900	7
2-21-64	1115	x sect conc	9	10	Say 1.0 .90	3.03		9,230	224	11
3 29 64	1110	x sect conc	5	5	1.0	1.73		5,820	79	12
5 1 64	1240	x-sect conc	10	11	Say 1.0 .91	3.43		10,400	281	11
6 10 64	1115	x-sect	11	9	Say 1.0 1.22	3.33		10,100	300	11
7 15 64	0925	x-sect	9	8	Say 1.0 1.13	3.85		11,600	282	13
8 19 64	0820	x-sect	9	7	Say 1.0 1.29	3.84		11,600	282	14
9 26 64	0745	x-sect	5	6	Say 1.0 0.83	2.76		8,480	114	14

Figure 6.—Tabulation of sediment data in the cross section.

SEDIMENT DISCHARGE MEASUREMENTS

Station San Joaquin River near Vernalis, Calif. Water year 1963

(1) Date 1962	(2) Mean time	(3) Type of Sample	(4) Concentration a x-sect.	(5) Concentration b box	(6) Coef. a/b	(7) Chart G.H.	(8) Shift	(9) Water disch. (cfs)	(10) Sediment disch. (t/d)	(11) Temp. (°C)
Oct. 10	1340	Engr. x-sect	61.	56	1.09	11.20	-	1,050	173	21
Nov. 18	1210	Engr. x-sect	31	30	use 1.0 1.03	12.22	-	1,600	134	13
Dec. 18	1445	Engr x-sect	44?	46	use 1.0 .96	12.80	-	1,950	232	13
1963										
Jan. 25	1415	Engr. x-sect	28 } 29	26	1.12	12.11	-	D 1,470	115	8
		Engr x-sect.	30							
Feb. 2	0940	Engr Box		? 1630		14.56		3,180	14,000	14
2	1015	Engr. size x-sect.	1530		use 1.0 .97	14.62		3,240	13,500	14
2	1020	Engr conc x-sect	1560							
2	1040	Engr Box		1540						
4	1200	Engr size x-sect	167 } 172	218	.79	23.13		12,200	5,670	12
	1205	Engr. x-sect conc	177							
12	0935	Engr size x-sect	122	154	.79	--		D 9,700	3,200	11
Mar. 12	1010	Engr size x-sect	65	74	.88	--		D 1,750	307	13
Apr. 12	1130	Engr size x-sect	107	120	.89	22.35		11,200	3,240	13
May 7	0930	Engr. x-sect	76	70	1.09	18.56		6,820	1,400	11
14	1430	Engr x-sect	89	78	1.14	22.62		11,600	2,790	16
June 13	0935	Engr. x-sect.	78	74	1.05	19.25		7,420	1,560	20
July 11	0940	Engr x-sect.	84	81	1.04	13.69		2,480	562	22
Aug. 15	0930	Engr x-sect	164	93	? 1.76	11.30		1,050	465	24
Sept 17	1030	Engr x-sect	124	131	.95	12.68		1,810	606	22
Oct. 10					1.00					

D Daily Mean

Figure 7.—Tabulation of sediment data in the cross section.

The manner in which the coefficient is applied depends on the cause of the lateral variation in the distribution of sediment concentration. This variation may be caused, among other reasons, by proximity and quantity of tributary inflow, bed form, channel alinement, source and type of sediment, season, and discharge. Based on these conditions, each record should be analyzed in detail to determine the most efficient and accurate manner for application of the coefficient.

In addition to using the data to adjust the current concentration values, coefficient analysis also may be used to reevaluate the sampling methods and the location of the sampling vertical at the station. This may make it possible to adjust the sampling locations so that a coefficient that is nearly equal to 1.0 will exist for all conditions of flow.

Common methods for determining daily coefficients involve the correlation of the cross-section coefficient with season and gage height or discharge. As an example, coefficient values for the San Joaquin River near Vernalis, Calif., for the 1963 water year (fig. 7) are plotted against discharge and season (fig. 8). The correlation of coefficient with discharge is poor; however, the correlation with season indicates a possible trend. This trend was investigated by plotting the values of the coefficient on the annual hydrograph of discharge and concentration (fig. 9). The seasonal effect indicated on the hydrograph indicates a coefficient of about 1.0 during the late summer and autum, less than 1.0 during the first few months of the storm season (February, March, and April), and more than 1.0 during the sustained high discharge during the irrigation season; this effect is verified by the repetition of this trend during successive years.

Sometimes coefficients show a reasonable correlation with stage, as indicated in figure 10. The values of the coefficient were determined for 2-percent increments or less for the corresponding range in stage (gage height) and tabulated in the figure. These

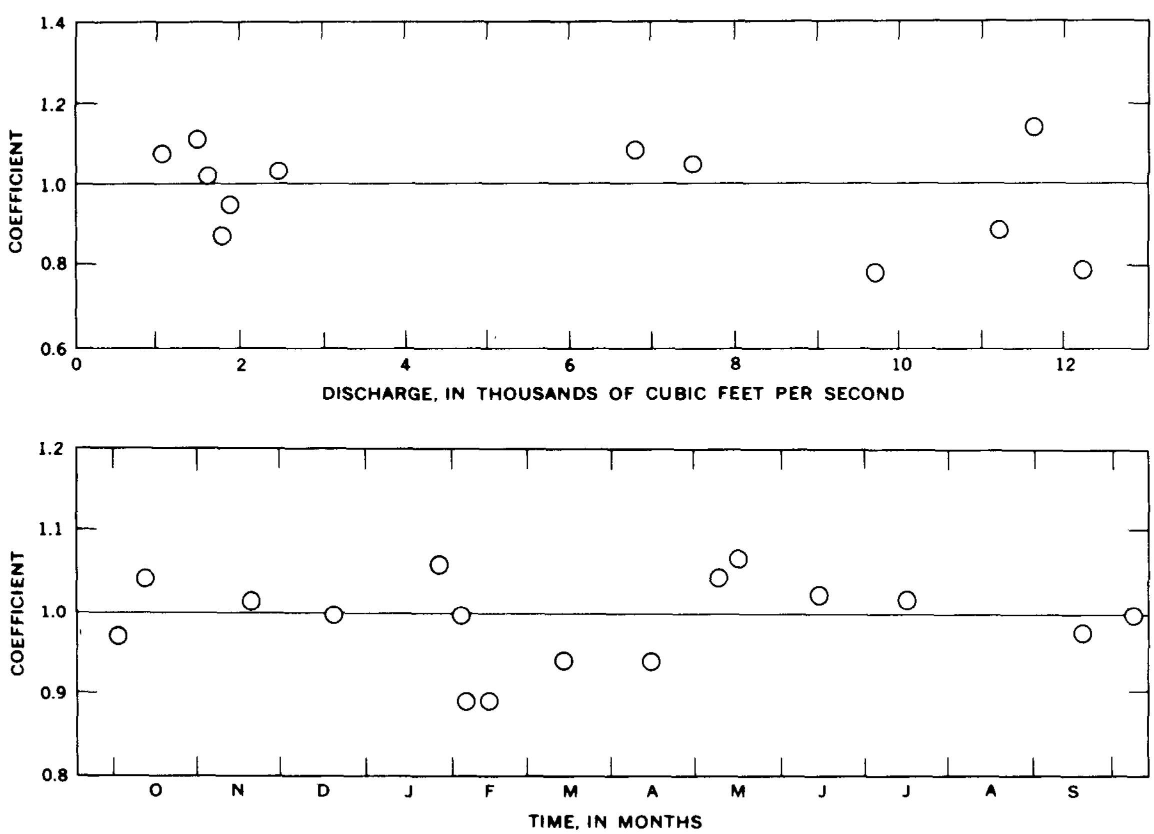

Figure 8.—Relation of cross-section coefficient to discharge and season for San Joaquin River near Vernalis, Calif.

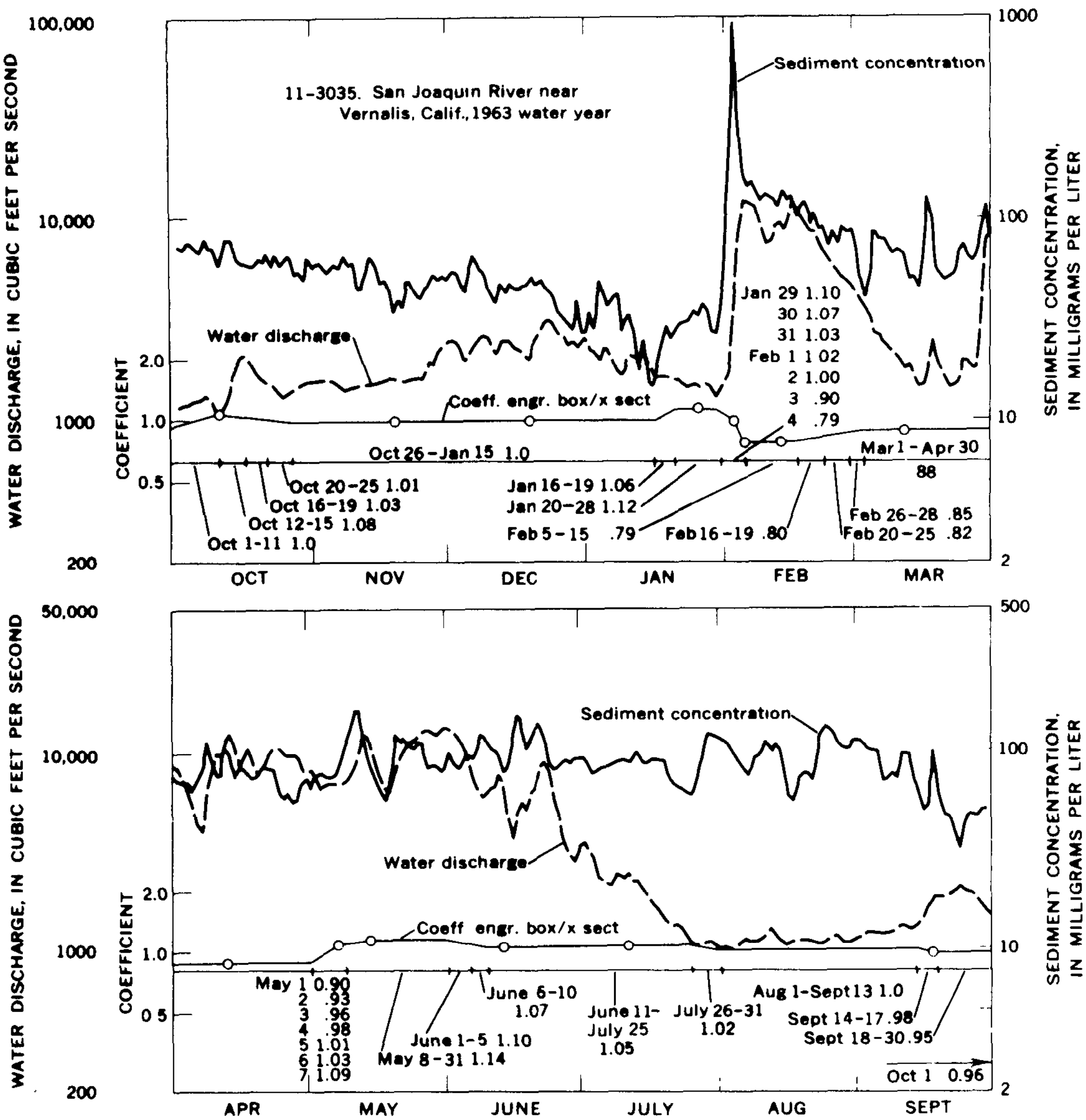

Figure 9.—Water discharge, sediment concentration, and coefficients for correcting observer's single-vertical samples to cross section.

values may be used to correct daily concentration values or concentration values for intervals of a subdivided day.

The average coefficient for the Sacramento River at Red Bluff (fig. 6) was assumed to be 1.0, and no correction was made to the daily concentration values, even though the ratios of individual measurements ranged from 0.83 to 1.33. This example illustrates that the application of a coefficient, as in applying a rating shift to a gage-height value, is a matter of judgment based on the data available. The ratio of $10/9=1.11$ indicates a 10-percent (plus) error, and a correction ordinarily would be made. However, the difference of 1 mg/l (milligram per liter) between the cross section and the box sample may be the result of error in laboratory procedures and the result of rounding numbers; therefore, for all practical purposes, such coefficients are ignored. A variation of a few milligrams per liter above 50 mg/l also is considered negligible, and a coefficient is not applied if the indicated corrections

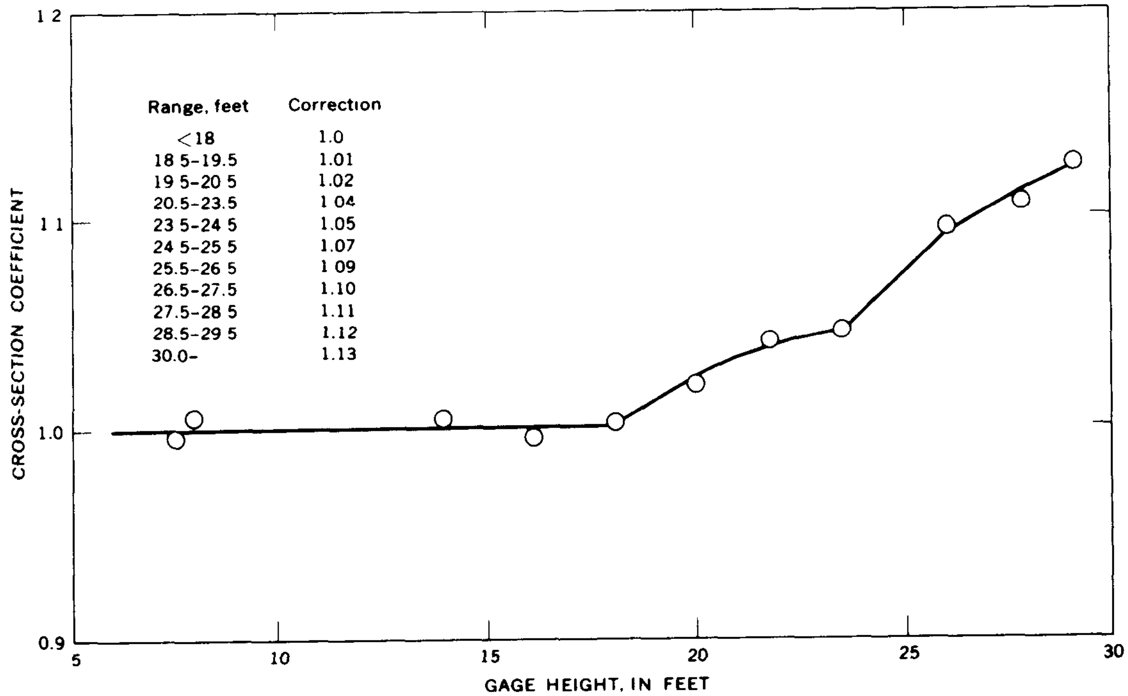

Figure 10.—Relation of cross-section coefficient to gage height.

are random. Coefficients should be applied, however, if all corrections are in the same direction and if the trend persists seasonally and is evident in the record for preceding years.

Variation with time

The number of samples required to define the variation of concentration with time may be difficult to determine from visual inspection of the concentration notes. The effectiveness of the sampling schedule should be evaluated after each storm event. An efficient way to evaluate the adequacy of sampling is to plot the concentration values on the gage-height record as soon as possible after the data are available. Plotting and evaluating the concentrtion data with respect to time are described in the section "Development of a Temporal Concentration Graph."

Analysis of cross-section concentration data

Concentration values obtained from cross-section samples are listed on the multiple-purpose form shown in figures 6 and 7, which may also be used to (1) list particle-size analyses and compute the instantaneous discharge required to complete tabulation of size analyses (fig. 2) and (2) list samples obtained at periodic stations or miscellaneous sites.

The tabulation of cross-section samples is used to compute the coefficient needed to adjust the concentration of samples obtained at a single, or fixed, vertical to the average concentration determined by cross-section sampling. The average concentration of the cross section determined from multiple-vertical sampling is recorded in column 4 (fig. 6), and the concentration for the corresponding date and time of the observer's fixed-sampling vertical or three-vertical set is recorded in column 5. The coefficient used to adjust the observer's samples is the ratio of a/b and is recorded in column 6.

The gage height at the time of sampling is obtained from the corrected gage-height record and recorded in column 7. Any gage height recorded on the bottle, particularly by the observer, should be considered as uncorrected data and generally used only to fix the sample in time, to aid in making necessary corrections to the pen record, or to estimate missing gage-height records. The gage height forms the base for computation of the instantaneous water discharge and the sediment discharge.

An evaluation of the quality of the coefficient for a given sampling design may be made by the method developed by Guy (1968).

Samples collected by the EDI method must have nearly equal volumes for each sampling vertical if they are composited; otherwise the bottles must be analyzed individually, and the concentrations for each cross-sectional set of samples averaged. If this procedure is not followed, the quality of the data obviously is affected. Experience has shown that suspended samples from sand-bed streams occasionally will be contaminated with varying quantities of bed material. Considerable judgment must be exercised in the field and laboratory to insure that these samples are eliminated from the composite.

The determination of sediment discharge requires the use of water discharge; therefore, the accuracy of the computed value for sediment discharge is dependent on the accuracy of measurements of both water discharge and sediment concentration. In many locations, the water discharge can be determined to a high degree of accuracy from the relation of discharge to stage. If, however, the relation of discharge to stage is not stable, as for most sand-bed streams, or an accurate relation is not available, as for a new station, a measurement of water discharge is necessary at the time sediment concentration is sampled in the cross section. Discharge measurements and discharge ratings at gaging stations are discussed by Buchanan and Somers (1965, 1968) and Carter and Davidian (1965, 1968). An earlier detailed description of stream-gaging procedures is found in U.S. Geological Survey Water-Supply Paper 888 (Corbett and others, 1943).

The evaluation and application of daily values of the cross-section coefficient are discussed in the section "Cross-Section Coefficient."

Development of a Temporal Concentration Graph

The next step in the computation procedure for sediment discharge is to translate individual values of concentration into a continuous temporal concentration curve. This step may be reasonably simple if values for water discharge or sediment concentration do not vary greatly and (or) if sufficient samples are obtained to define adequately the changes in concentration with time. Accurate results are obtained from a concentration curve defined adequately by samples because a large number of samples successfully integrate the many complex interrelations among variables affecting the availability and movement of sediment in streams (Guy, 1970).

Development of a temporal concentration graph may be difficult if too few samples were obtained. Preparation of the concentration graph will require application of theoretical and practical principals of sedimentation. Inadequate sampling results in a less accurate graph, and much more time is required to prepare the graph. Because of the extra time, in addition to loss in accuracy, it is usually less expensive to collect additional samples than to estimate the concentration graph.

A sampling program for each station should be designed to obtain optimum results when the desired accuracy of record is balanced against the many physical and economic conditions. A few samples properly spaced with time may adequately define the concentration of a flood event at certain stations, providing that the personnel computing sediment discharge have detailed knowledge of seasonal sediment trends for the complete range of flow conditions experienced. Lack of knowledge of these trends, such as at a new station or a station with a large number of variable conditions affecting sediment erosion and transport, requires an intensive sampling program. Successful station operation requires continuous modification of the sampling program to obtain the best accuracy possible with a reasonable expenditure of time and effort.

Concentration data should be interpreted and the graph drawn by personnel with a knowledge of the sampling program, the physical and cultural environments affecting the stream regimen and sediment sources, and the fundamentals of sediment transport. After the graph is drawn, it should be reviewed and modified as required prior to computation of daily mean concentration values and sediment discharges. Changes in the graph are made easily at this point and may eliminate possible future recomputation.

Difficulties may be encountered while drawing the continuous graph because of paucity of samples, unusual storm events, or periods of missing records. Valuable guidance may be available from past records of sediment discharge at the site and at nearby sites. A study of these records before plotting the data and drawing the graph should be a required part of the computation procedure. Some of the factors that should be considered prior to drawing the concentration graph and examples of concentration graphs are included in the following section.

Plotting symbols and scales

Concentration values are plotted on a gage-height chart or a copy of the chart. If an analog record of stream stage is not available because of the use of digital recorders, a plot of gage height or discharges from the digital record must be made for the important periods of changing stage and concentration, such as during rapid snowmelt or storm runoff.

The symbols and scales used for plotting should be chosen carefully and, if possible, be consistent with those used in preceding years. Suggestions relating to the plotting of concentration values and the choosing of scales are summarized as follows:

1. Adjust concentration values from parts per million to milligrams per liter prior to plotting.
2. If necessary, adjust the plotting times for chart-time corrections and travel time between sampling site and gage.
3. Plot the average value for each set of samples. Individual values of each bottle should be plotted if poor agreement exists among bottles.
4. Use plotting symbols such as the following:
   - ⊙ Observer samples—mean value.
   - ◌ Observer samples—individual samples.
   - △ Technician sample at observer's fixed station (box).
   - ⊡ Technician cross-section sample—mean value.
   - ⊙ Particle-size sample. Use above symbols and circle if sample analyzed for particle-size gradation.
5. Use of a proper plotting scale facilitates computation and checking, increases accuracy of daily mean concentration values picked from the graph, and provides a visual method for comparison and study of various flood events; therefore,
   - (a) Use simple scales such as 1 to 1, 1 to 2, 1 to 5, or multiples of 10 thereof, with zero at the base line.
   - (b) Use as few scales as possible, but do not hesitate to change scale as needed.
   - (c) Plainly mark each change in scale. Use previous year's record as guide to scales. Use the same scale for all events of similar magnitude; such a scale provides a visual means for comparing and evaluating graphs and assists in development of characteristic curves that are extremely helpful in shaping the graph when incomplete sampling data are available.
6. Use a maximum height of the graph 5-8 inches above the base line (0 mg/l) on the gage-height chart. As the concen-

tration decreases after a storm, change the scale when the concentration graph approaches to within 1 or 2 inches of the base line. Experience indicates that personnel drawing a graph near the base line tend to be influenced by the limiting 0-mg/l base line, and therefore values determined from a graph approaching the base line usually are high.

7. Choose a scale, if possible, so that concentration values can be plotted to three significant figures. For example, if a stream has concentrations that range from 300,000 to 400,000 mg/l, a scale of 1 inch=50,000 mg/l allows a maximum height for the graph of 6-8 inches, and concentrations above 100,000 mg/l (2 inches) may easily be plotted to three significant figures. Below 100,000 mg/l the scale can be read only to two significant figures and should be changed.

Theoretical considerations

Considerable information is available on theory of sediment transport and the factors affecting the availability of sediment for transport. Colby (1964a, p. A3) states that

> Relationships of sediment discharge to characteristics of sediment, drainage basin, and streamflow are complex because of the large number of variables involved, the problems of expressing some variables simply, and the complicated relationships among the variables. At a cross section of a stream, the sediment discharge may be considered to depend: on depth, width, velocity, energy gradient, temperature, and turbulence of the flowing water; on size, density, shape, and cohesiveness of particles in the banks and bed at the cross section and in upstream channels; and on the geology, meterology, topography, soils, subsoils and vegetal cover of the drainage area. Obviously, simple and satisfactory mathematical expressions for such factors as turbulence, size and shape of the sediment particles in the streambed, topography of the drainage basin, and rate, amount, and distribution of precipitation are very difficult, if not impossible, to obtain.

References that will aid in understanding the interrelation of some of the above-listed variables and sediment discharge are cited *in pertinent text* sections and are listed at the end of this manual. This list is by no means complete, but will serve as a starting point for those interested in furthering their understanding of sediment transport.

Study of past records

A study of the variation and range of suspended-sediment concentration with time at a given point, or sampling station, reveals many similarities among different flood events. A plot of concentration values with time and with flood stage will define graphs that can be used to estimate concentration graphs for missing periods or for inadequately sampled periods. The absolute values and duration of these values may vary considerably from event to event; however, the shape of the temporal graph may be similar among the several events. Thus, the first step in drawing the concentration graph is to study the plotted points for trends, sketch in the parts of the graph well defined by samples, and study those parts defined previously—for the entire historical record if necessary.

A file of historical concentration graphs that are characteristic of the variation and range of suspended-sediment concentration should be assembled to facilitate the use of these graphs during development of the temporal concentration graph and to reduce the number of past records stored in current files. Characteristic graphs may be different for different basins, and many characteristic graphs may exist for each station.

Relation of water discharge to concentration

The relation of water discharge to concentration is an important aspect to consider when developing the temporal concentration graph. The variation of water discharge, as depicted by the continuous graph of stage on an analog chart or a plot of bihourly discharges from a digital record, provides a valuable clue to the time and magnitude of changes in the sediment concentration of the stream. The relation between water discharge and sediment concentration is not fixed. It is affected by many variables, and the variation and range of concentration during one storm period or during one low or medium streamflow period may differ from the concentrations during other periods, even though the streamflow may be identical or similar. Therefore, interpretation of concentration data and the drawing of the temporal concentration graph always requires consideration of the variables that affect the relation between water discharge and concentration.

Availability of sediment is a major variable affecting sediment concentration. Factors affecting availability are discussed in detail by Guy (1970) and in many texts. The availability for a short period may be considered relatively constant, and curves characteristic of the relation of water discharge to concentration for diverse storm periods, tributary inflow, and seasonal effect may be assembled for ready reference. (See previous section and the section on "Examples of the Sediment-Concentration Graph.") Changes in natural availability of sediment may be caused by such events as forest fires or channel changes, landslides, and mass wasting associated with or accelerated by catastrophic floods. These changes should be noted and considered during development of the concentration graph.

Availability of sediment also is influenced by the activities of man. Activities which may cause rapid and large changes in sediment availability include road construction, dam construction, diversions, land-use changes, logging, urbanization, and gravel mining.

Basin size may affect the correlation of concentration and water discharge and the shape of the concentration graph. In general, the smaller basin has a more predictable relation between water discharge and concentration than the large basin, which is often affected by a larger number of variables. The Colorado River at Grand Canyon, for example, has tributaries affected by many variables. These tributaries include rivers with large flows and very low concentrations as well as streams with small flows and large concentrations. All these water and sediment conditions, plus regulation by upstream dams, imposed on one downstream station cause a large range in concentration for a given water discharge.

Other factors affecting the relation between sediment discharge and streamflow are listed in the section on "Theoretical Considerations."

Estimates for periods of missing data

The shape and magnitude of the temporal concentration graph for individual rises have characteristics based on the principles previously discussed. A knowledge of the typical patterns from past records is helpful when interpreting the concentration data and constructing the concentration graph for periods of inadequate concentration data.

Concentration data are considered inadequate when a significant part of a record cannot be defined within probable limits of 5 or 10 percent. The efficient and reasonably accurate development of a continuous concentration graph or determination of sediment discharge during the period of missing data requires careful study, in which experience and ability to make sound estimates based on concentration data collected during other periods are most helpful. The length of the inadequately defined period may range from 20 minutes to several days. The short period usually occurs on streams having rapid changes of water discharge and concentration and very frequently occurs at the beginning of a rise resulting from intense rainfall. This situation is particularly critical on streams in arid regions and on streams with small drainage areas. Long periods of missing data may occur because the sampling site is inaccessable during floods or because of loss of equipment or samples.

An estimated concentration graph is preferable to direct estimates of sediment discharge. During short periods of missing data, a continuous concentration graph may be estimated accurately and used to compute daily mean concentration and sediment discharge. During long periods of missing data, an accurate estimate of concentration may not be possible, and daily values of sediment discharge must be estimated directly from the historical relation between water and sediment discharge by interstation correlation or by comparison with records obtained at an upstream or downstream station. A complete record of daily values facilitates interpretation or statistical evaluation of the data by computer techniques; therefore, if possible, estimates of both sediment concentration and discharge should be made. During periods that sediment discharge was estimated directly, daily concentration values must be estimated independently of sediment discharge if the period includes rapid or large changes in concentration or water discharge. An independent estimate of daily mean concentration is necessary because published values of concentration are time weighted, and daily time-weighted values of concentration cannot be computed from daily values of water and sediment discharge that represent periods of changing streamflow and concentration. If an acceptable estimate of concentration is impossible, no daily concentration will be published, and a leader (..) will be placed in the concentration column.

The methods or combination of methods used to estimate missing data may vary from station to station and seasonally for the same station. Each period of missing data, therefore, must be studied, and the best estimate made on the basis of existing data and circumstances; regardless of the method chosen the estimate should be verified by a second method. A partial list of methods commonly used to estimate sediment data follows.

Visual comparison with adequately defined concentration graphs

The visual procedure, when supplemented by the two succeeding methods, probably is the most common and accurate method used to construct concentration graphs for periods when data are insufficient. The principles involved are discussed in more detail elsewhere in the manual and especially in the sections on "Study of past records" and "Examples of the sediment-concentration graph." Each station should be sampled in detail during sufficient runoff events to provide a catalog of the shape and magnitude of the sediment curves pertinent to the station.

The shape of the concentration graph with respect to the gage-height graph should be carefully considered as to the time the rapid increase starts, the time of peak concentration, and the slope of the recession curve. Typical concentration graphs of the various types, such as advanced, simultaneous, and lagging, are illustrated in figures 11, 12, and 13.

Hydrographic comparison with records of upstream and downstream stations

Hydrographic comparison is an excellent tool to check the accuracy of the concentration record and sampling program, as well as to estimate periods of missing records. Each record should routinely be compared with adjacent station records wherever possible, and consideration should be given to significant natural and manmade differences that would account for discrepancies in the computations.

Short periods of missing concentration data can be estimated on the basis of the concentration curve for an adjacent station. Longer periods of missing sediment data can be estimated by comparing values of daily sediment discharge plotted on hydrograph form 9-284 (fig. 25).

Water-sediment relation curves

The relation between water discharge and sediment discharge may be expressed by an average curve. This curve is called a sediment-transport curve and is used frequently to estimate periods of missing data or to extend records.

The types of sediment-transport curves are numerous, and the selection of the correct type for each use is important. According to

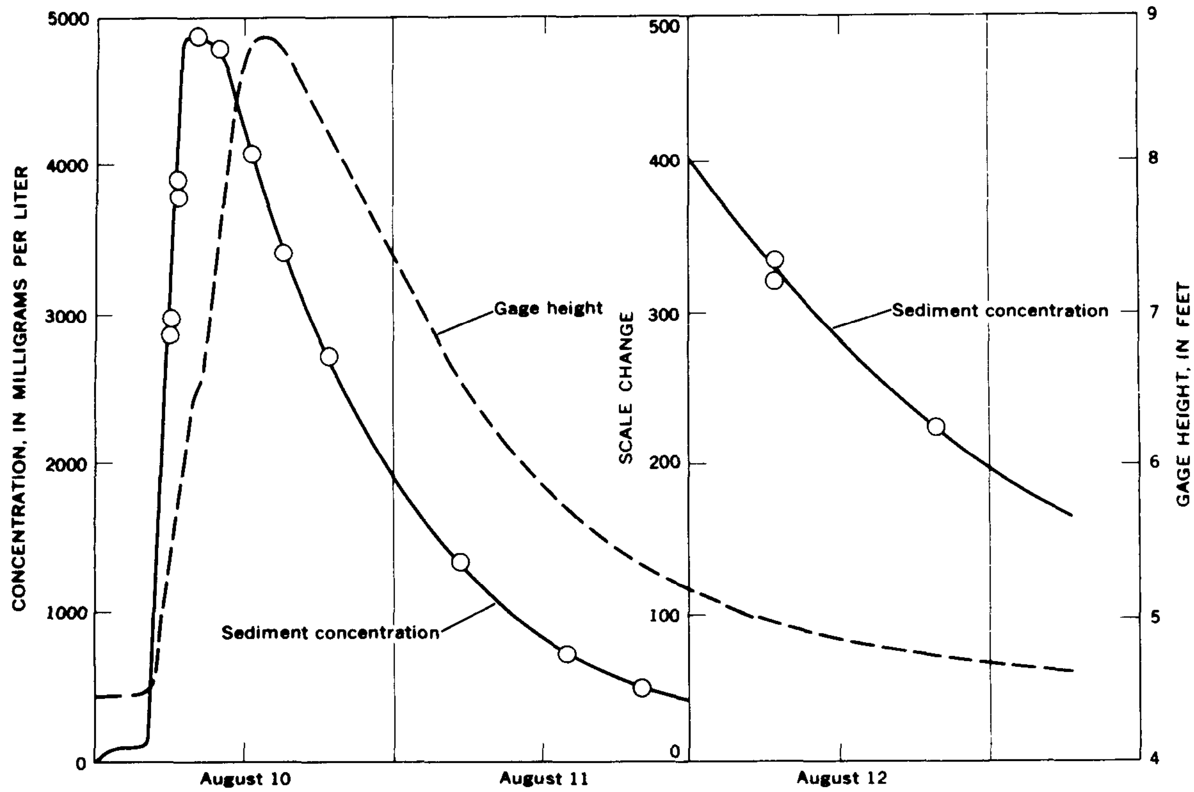

Figure 11.—Advanced concentration during excess runoff periods.

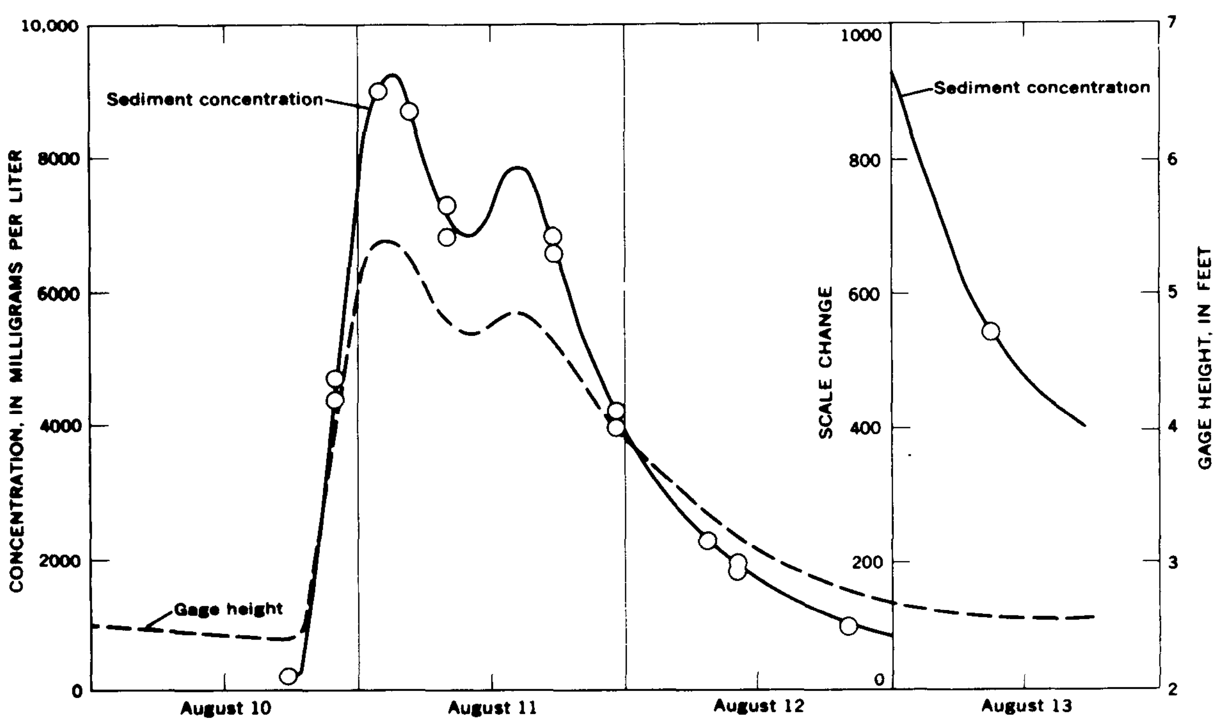

Figure 12.—Simultaneous concentration during excess runoff periods.

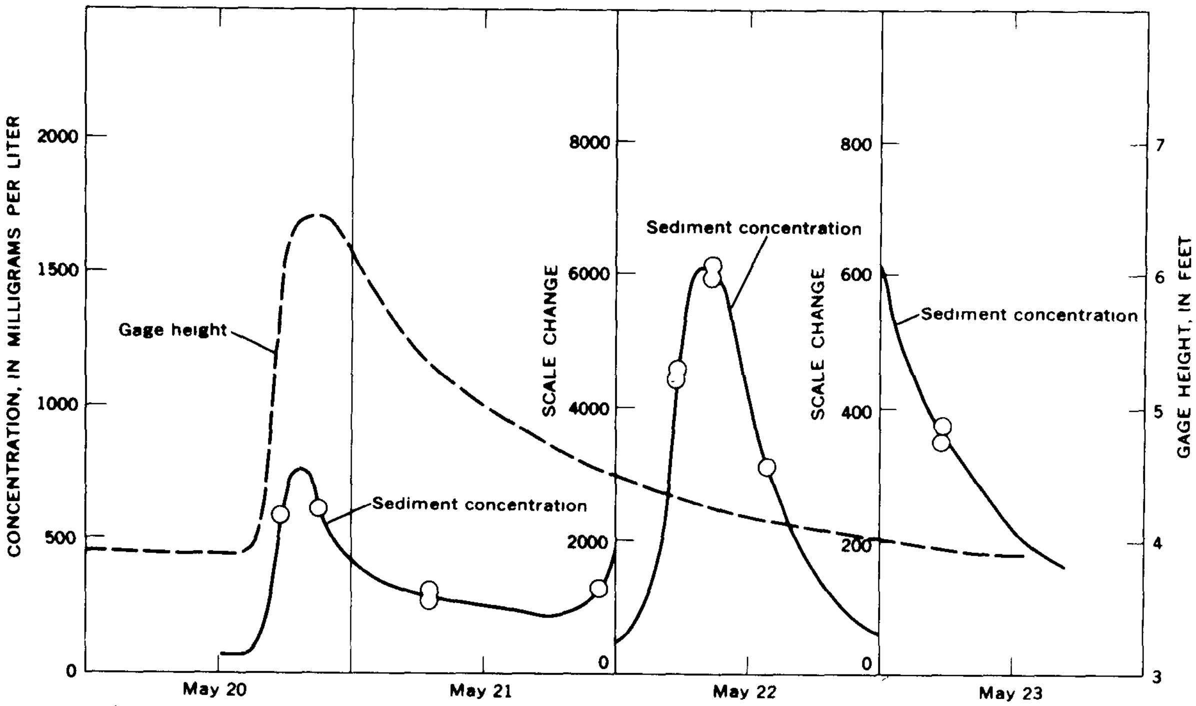

Figure 13.—Lagging concentration during excess runoff periods.

Colby (1956a), sediment-transport curves may be classified according to either the period of the basic data that define a curve or the kind of sediment discharge that a curve represents. Thus sediment-transport curves may be classified as instantaneous, daily, monthly, annual, or flood-period curves. The instantaneous sediment-transport curves are defined by concurrent measurements of sediment discharge and water discharge for periods too short to be materially affected by changes in flow or concentration during the measurements. Daily, monthly, annual, and flood-period sediment-transport curves usually are defined by and expressed as average sediment and water discharges for periods of days, months, years, or flood periods, respectively. They can be defined by and expressed as total quantities of sediment and water discharges during the respective lengths of time. On the basis of the kind of sediment that they represent, sediment-rating curves may be classified as suspended-sediment rating curves, unmeasured sediment-rating curves, and total-sediment rating curves. These sediment-rating curves may be further divided according to size of particles for which the defining sediment discharges were computed.

The simplest relation between sediment discharge and water discharge is represented by an instantaneous sediment-transport curve. Such a curve is not affected by the extent or pattern of changes in concentration or flow. It is likely to be the most suitable curve from which to determine the effect of different factors on the basic relation between sediment discharge and water discharge and on departures from this relation. On the other hand, an instantaneous sediment-transport curve is not theoretically applicable to the direct computation of daily sediment discharges from daily water discharges except for days on which the rate of water discharge was about constant throughout the day. In practice, however, an instantaneous curve may agree with a daily curve within limits of accuracy of their definition.

Daily or instantaneous sediment-transport curves adjusted for factors that account for some of the scatter from an average curve may be used to compute approximate daily, monthly, and annual sediment discharge. Colby (1956a) describes in detail the selection of the proper type transport curve and the use, preparation, and adjustment of transport curves.

Methods to improve water-sediment relation curves are discussed also by Guy (1964). Two methods using water-sediment relation curves to estimate concentration or discharge are: (1) a plot of the total water discharge versus total sediment discharge or concentration for each storm event or flood period (fig. 14) and (2) a cumulative unit graph relating total water discharge and total sediment discharge for individual storms (fig. 15).

These plots generally are most applicable to small streams with a uniform source of sediment and a low base flow. For many streams the correlations may be greatly improved if the base flow is subtracted from the water discharge. Data must be available for a number of adequately defined hydrographs representing a range of flow and seasons to insure reasonable success with these methods.

The procedures for using these methods are apparent from the illustrations. The limitations of their use will depend on the

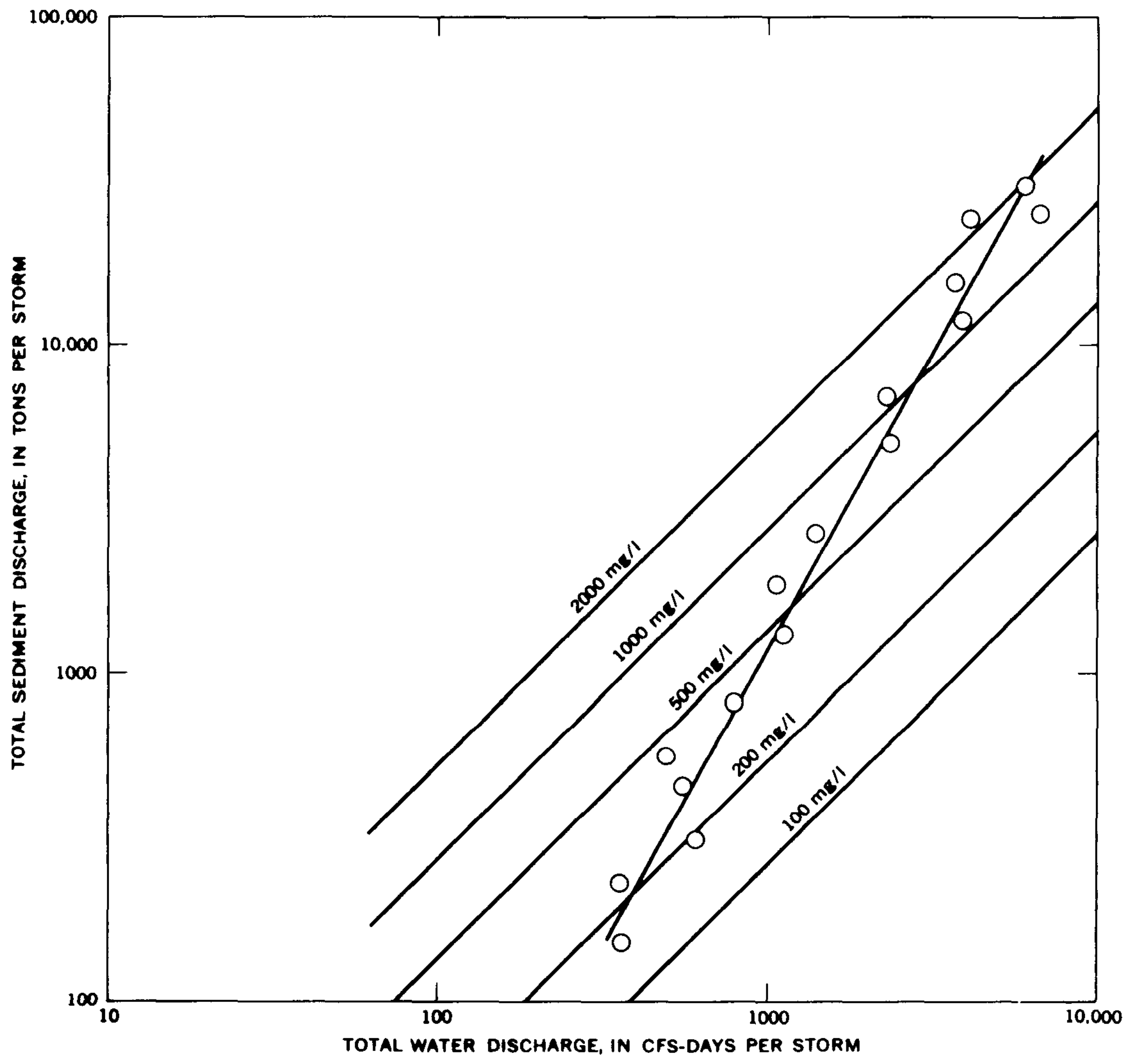

Figure 14.—Sediment-transport curve on a storm basis with indicated mean concentration.

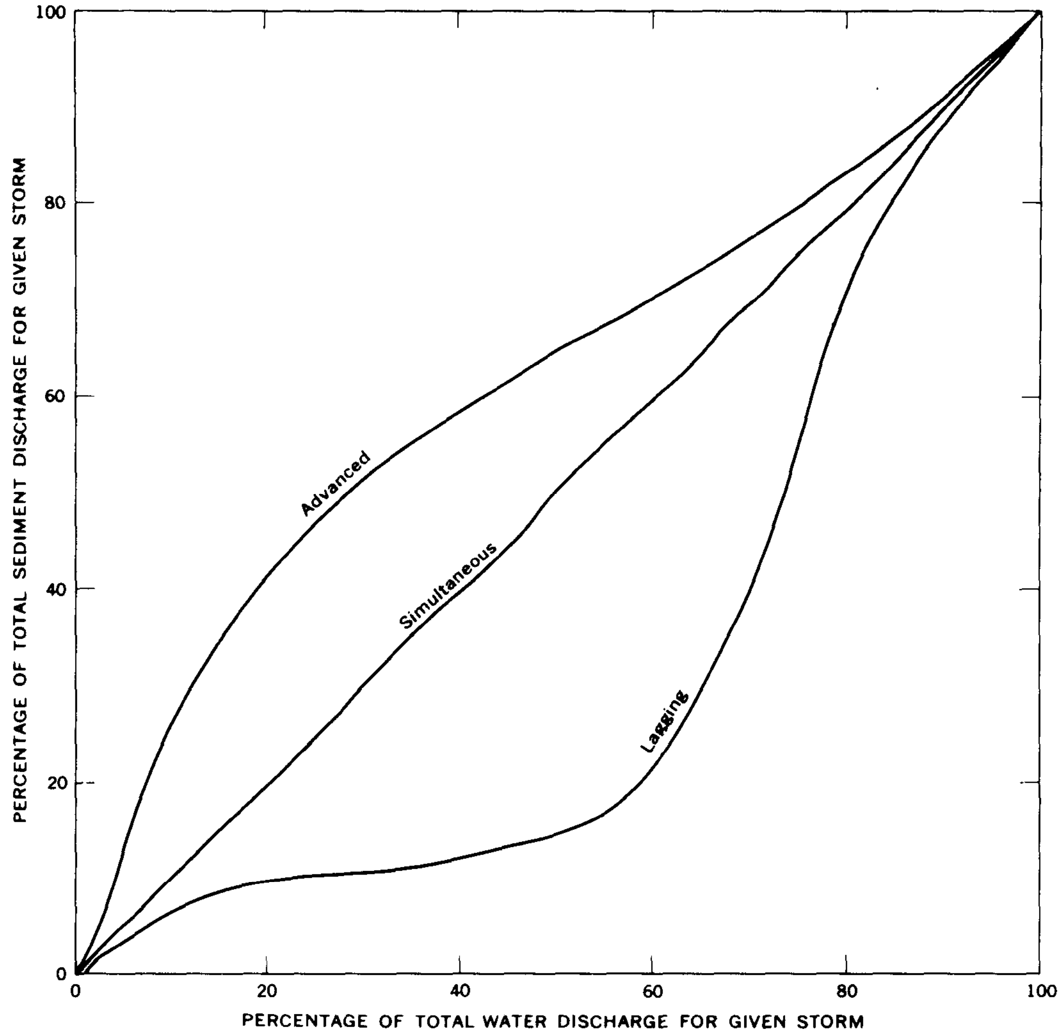

Figure 15.—Cumulative unit relation of total water discharge and total sediment discharge for typical advanced, simultaneous, and lagging types of concentration graphs.

circumstances encountered with the individual record; consequently, as in other interpretive studies, judgment is required. For example, the sediment-transport curve plotted on a storm basis (fig. 11) may be biased (1) if several years of record were used in its preparation and the sediment yield from the basin was changing significantly with time as a result of changing land use or (2) if an unusual number of off-season storms occurred. The change in the sediment yield of a basin was illustrated by a study of 9 years of data of Brandywine Creek, Pa. (Guy, 1957). The cumulative unit graph (fig. 12) is used in conjunction with the total sediment-discharge method to provide estimates for subdividing the storm hydrograph into smaller increments. These methods may or may not be useful in the development of a continuous concentration graph for extended periods of insufficient data, but they are useful for estimating sediment discharge.

Instantaneous values of concentration from advanced and lagging graphs (figs. 11, 13) plot as "loops" on the sediment-transport curves, and this loop effect should be considered if values from the transport curve are used to estimate the shape and magnitude of the continuous-concentration graph for periods of missing records. Daily values also may plot as a loop on the transport curve because of the variation with time of the factors affecting sediment transport and of the subdivision effect.

Suspended-sediment discharges computed from any sediment-transport curves, except curves for some streams that transport mostly sands, will be less accurate than sediment discharges computed from frequent samples. The difference in accuracy may or may not be worth the difference in cost of operation. This decision will depend on the particular sampling station and the use to be made of the sediment records.

Flow-duration curves have been widely used with instantaneous or daily sediment-rating curves to compute the average sediment discharge for long periods of time when no samples were collected. In principle, and within the limits of averaging and multiplying averages, the method is equivalent to computing average sediment discharge from a daily sediment-transport curve and daily water discharges. The flow-duration curve is used only as a convenient method for abbreviating the distribution of daily water discharges and thereby shortening the computations.

Examples of the sediment-concentration graph

The preceding sections discuss many reasons for the variation of sediment concentration with time and discharge. This section presents examples of (1) the relation between concentration and discharge (or gage height) for basins of various size, climatic conditions, geology, and land use and (2) variations of this relation that may occur in a large basin.

Figure 16 is an example of the typical, sharp discharge peak and concentration graph produced when high-intensity rainfall of short duration occurs over a small basin and the stream channel is dry or has only low flow prior to the storm. The typical con-

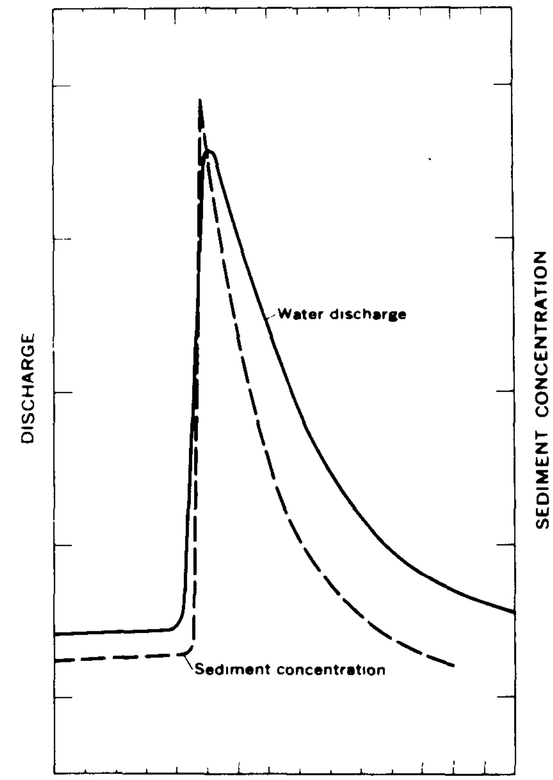

Figure 16—Typical effect of high-intensity short-duration rainfall on discharge and concentration for a small-drainage-basin stream having a very small amount of base flow or none.

centration graph will rise rapidly and peak at or slightly before the discharge peak, after which it decreases rapidly, generally at a faster rate than the recession in water discharge. The shape of the recession curve usually is parabolic. At the discharge peak, the concentration may fluctuate rapidly for a short period before starting to recede. The duration of the concentration peak is seldom greater than that of the water-discharge peak. Note that the concentration did not start to increase prior to the increase in water discharge.

An example of a concentration graph of a stream in a small basin, Corey Creek near Mainesburg, Pa., (12.2 sq mi) when the runoff increased at a slower rate is shown in figure 17. This basin generally has better vegetal cover, less intense precipitation, a more humid climate, and a higher base flow than the basin illustrated in figure 16.

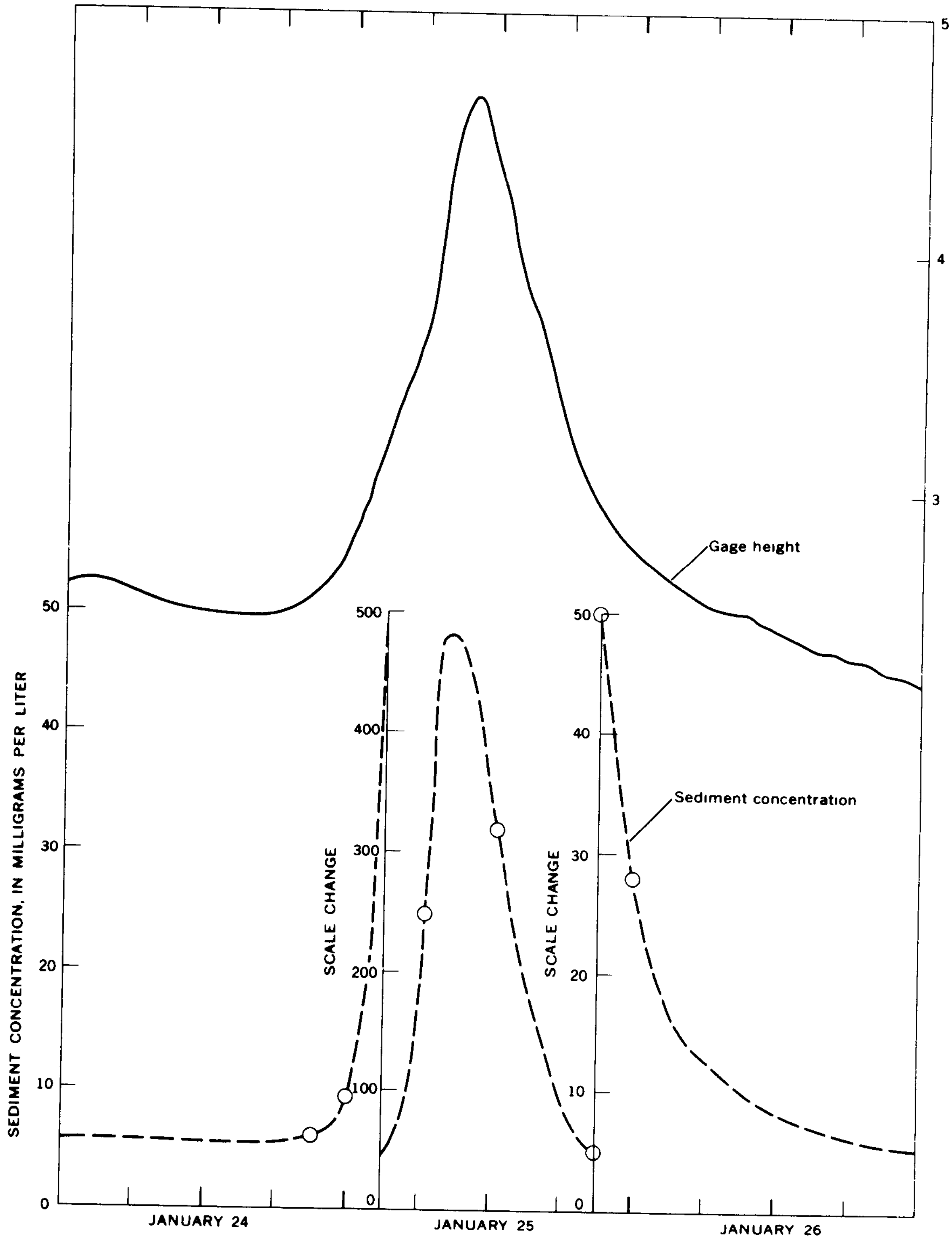

Figure 17.—Gage height and sediment concentration, Corey Creek near Mainesburg, Pa.

Figure 18 shows the effect on sediment concentration in the Rio Grande near Ber-

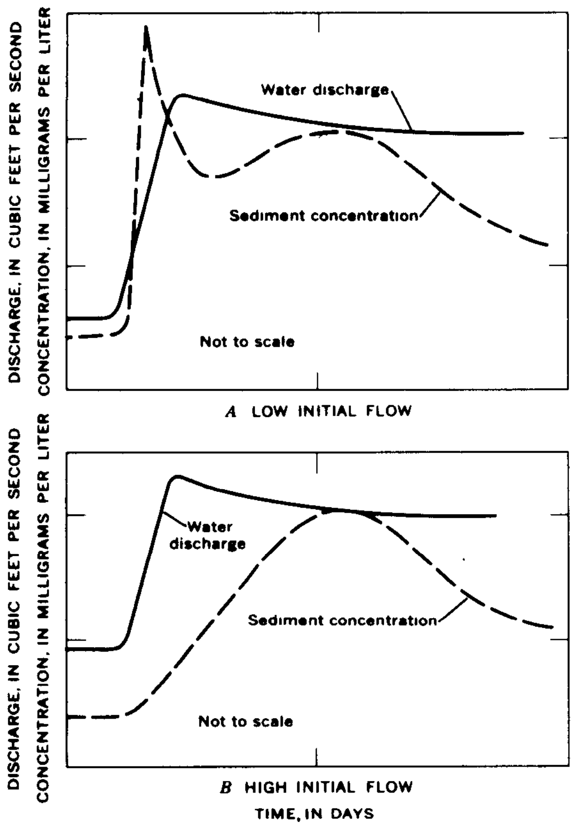

Figure 18.—Effect of two different flow conditions on discharge and concentration for the Rio Grande near Bernalillo, N. Mex.

nalillo, N. Mex., of two separate releases of water from a tributary reservoir over 100 miles upstream. In both instances, the release is at the same rate of discharge; the major difference is in the quantity of water in the stream at the time of release (the initial flow). The shape of the hydrograph is similar in both cases, but there is a marked difference in the sediment-concentration graph owing to the initial flow conditions. Figure 18*A* illustrates low initial flow conditions. The released water erodes sediment from the bed and the banks of the stream and causes an initial sediment peak, followed by the usual recession, similar to that illustrated in figure 16. After the initial recession another rise in concentration occurs which represents the suspended material contained in, or picked up by, the released water. Figure 18*B* illustrates the effect of initial channel storage on concentration. Because of high initial flow, the change in stage and velocity is less, and there is little or no additional erosion of sediment from the bed and banks of the stream by the initial increase in flow. The concentration pattern for the released water, however, is the same as that for figure 18*A*. The interface between the water initially in the river and the released water is defined not only by the changes in suspended sediment but also by a change in temperature and conductivity. In other words, the water represented by the hydrograph peak preceding the sediment-concentration graph is water that was in the channel prior to the release and moved downstream ahead of the release.

The examples shown in figures 19-22 illustrate for the Colorado River near San Saba, Tex., the range of concentration peaks and the variation of concentration with time which can occur in a river that drains a large basin of diverse geologic, topographic, climatic, and land-use characteristics.

The graphs for the period May 1-6, 1952 (fig. 19), illustrate a typical water-discharge peak and sediment-concentration graph for a large stream when the flow was caused by thunderstorm activity in a small area of the basin. The graphs differ from those shown for a small basin (fig. 16) in that (1) the increase in discharge from 0400 and 1700 hours May 1 is water previously in the channel and (2) the rate of increase of discharge was attenuated by the distance from the source to the station. These two differences cause the significant rise in concentration to be delayed.

Several general conclusions regarding the sediment characteristics of this station can be inferred from figure 19 and illustrate the type of analysis that should be applied to each station record. First, the concentration from 0400 to 1700 hours on May 1 is only slightly larger than the concentration on the preceding day and illustrates a general rule that the concentration graph seldom will show a large increase before the actual storm

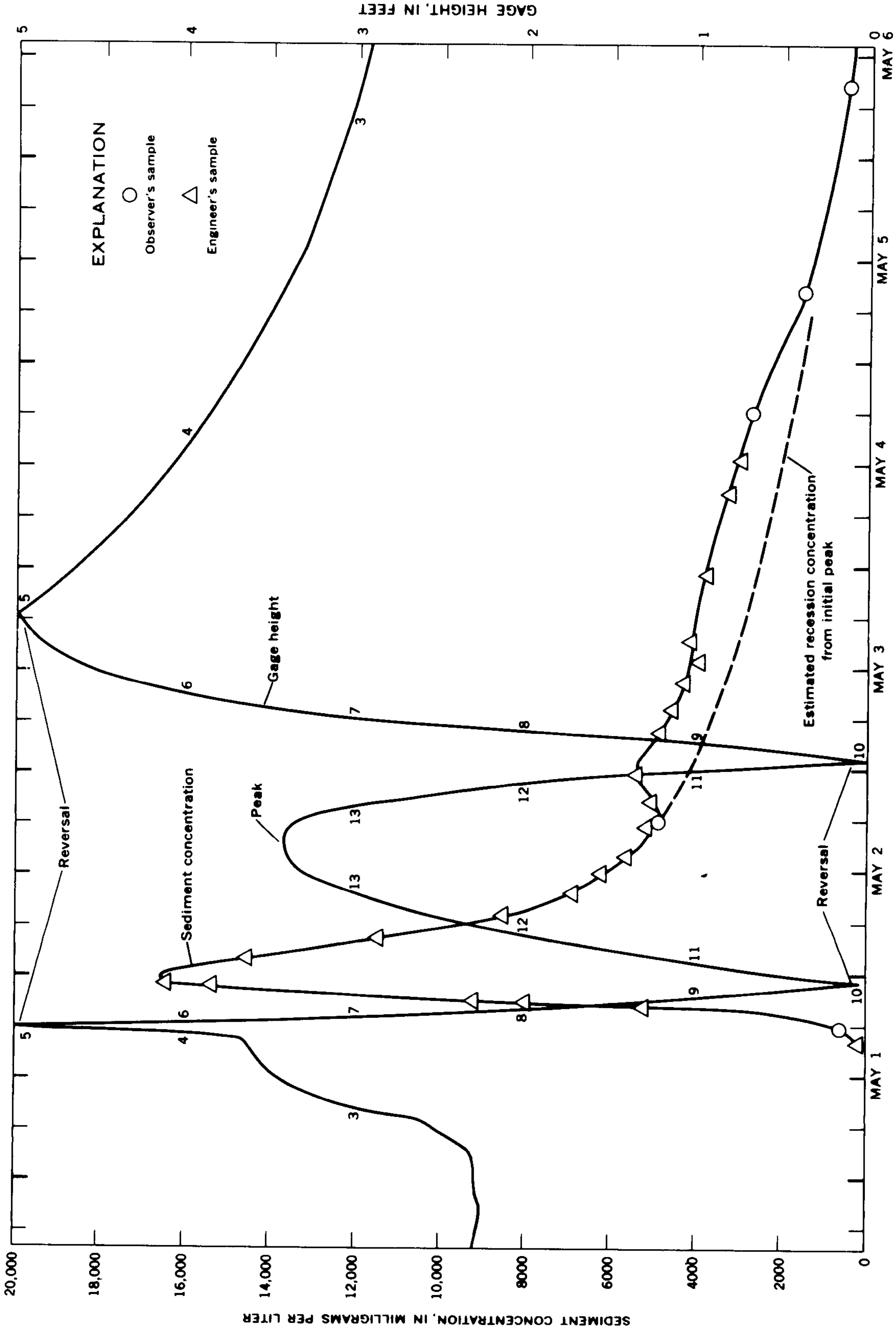

Figure 19.—Gage height and sediment concentration, Colorado River near San Saba, Tex., May 1-6, 1952.

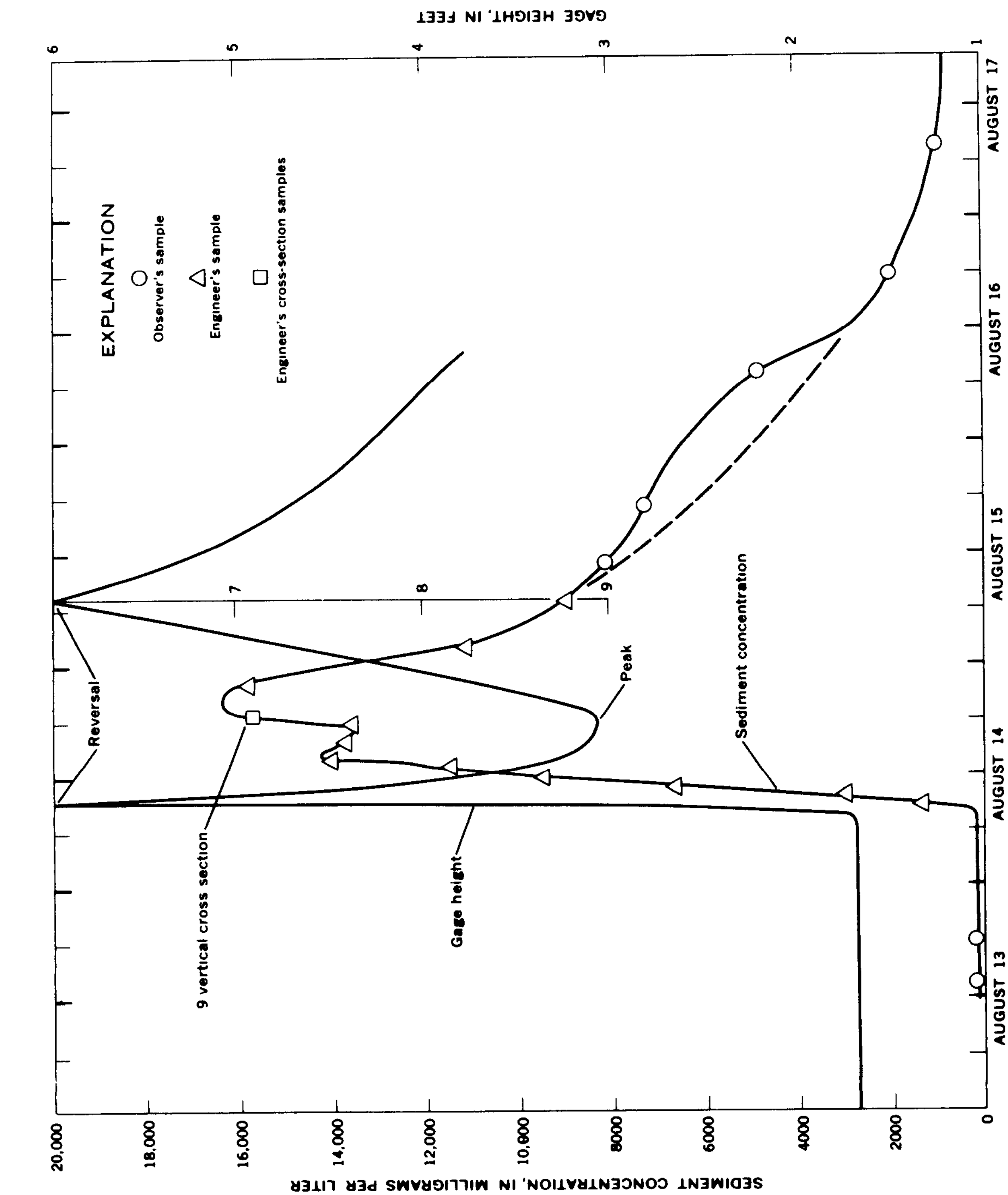

Figure 20.—Gage height and sediment concentration, Colorado River near San Saba, Tex., August 13-17, 1951.

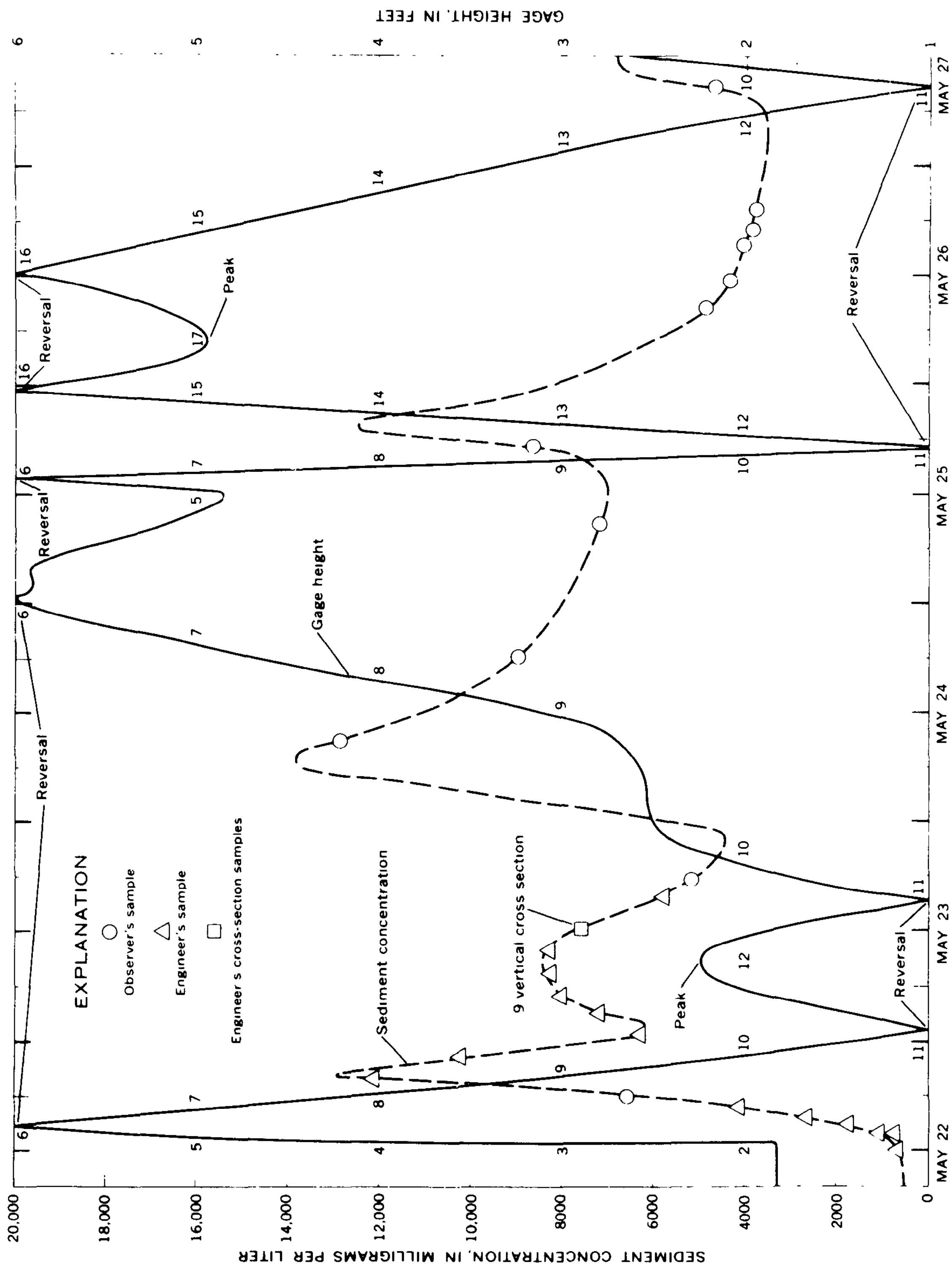

Figure 21.—Gage height and sediment concentration, Colorado River near San Saba, Tex., May 22-27, 1951.

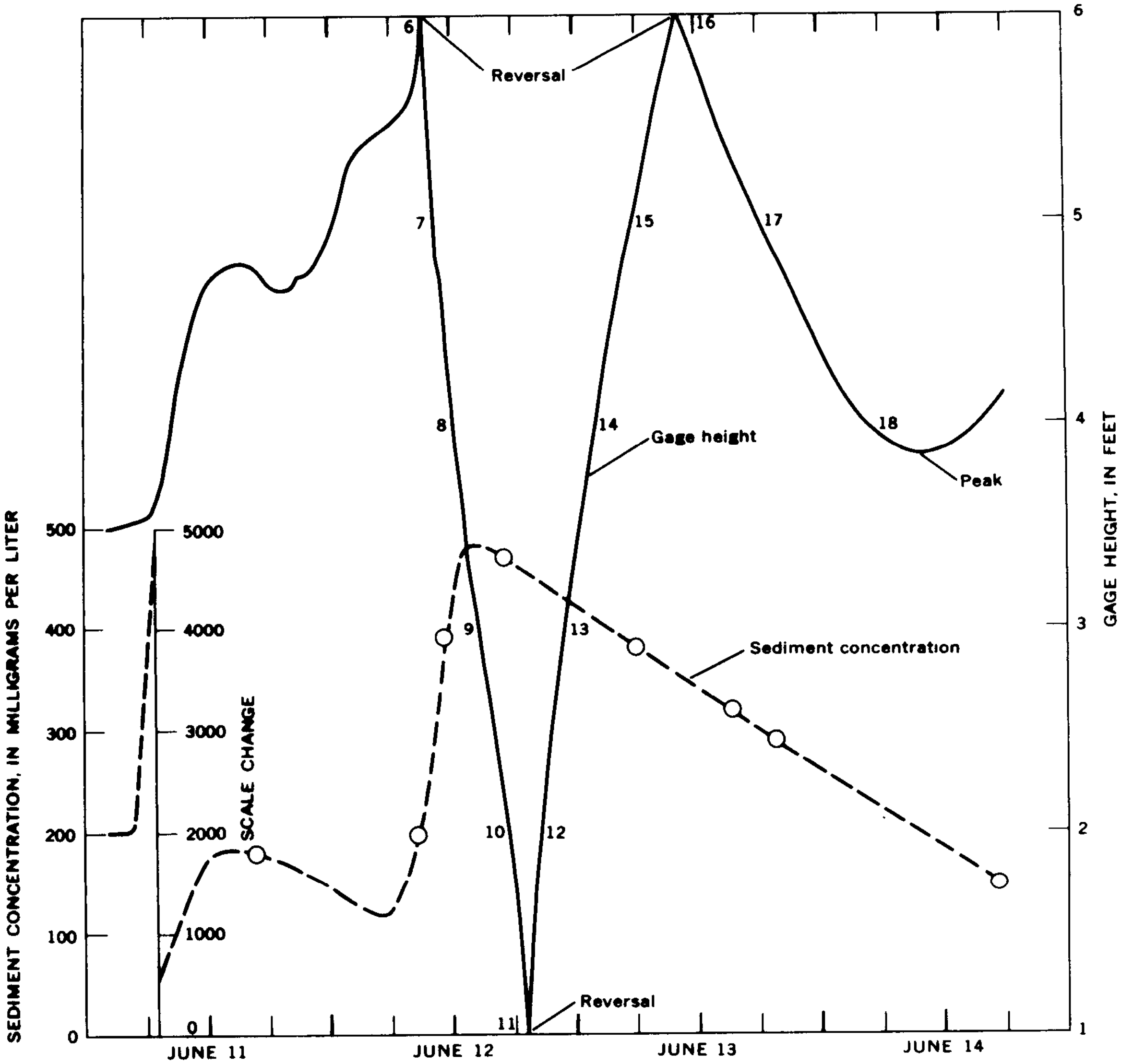

Figure 22.—Gage height and sediment concentration, Colorado River near San Saba, Tex., June 11-14, 1951.

water reaches the station—in this instance, at about 1630 hours. Second, the water peak occurred about 24 hours after the first storm water reached the station, although the concentration peak occurred about 7 hours after the first storm water reached the station.

These graphs illustrate that, for this station, the concentration peak usually precedes the water peak and indicate that, by a comparison of the initial peaks in figures 19-22, the longer the time period between the first arrival of storm water and the storm peak, the longer the time interval between the concentration peak and water peak. Or, conversely, the concentration peak occurred about 7 hours after the initial storm water reached the station, even though the time interval between the initial storm water reaching the station and the water peak increases. Although this time interval (7 hours) should not be considered a firm rule at this station, it could be used in conjunction with the general shape of the concentration curve shown in figure 19 to describe adequately the curves in figures 19-22 even though only two samples had been collected each day.

The May 1-6 rise (fig. 19) has a near

classic hydrograph recession; however, the concentration graph fails to follow the classic pattern. The sediment recession seems normal until 1800 hours May 2, after which the concentration increases and is somewhat above the normal recession curve until about 1200 hours May 5. For purposes of illustration, a normal concentration recession line was estimated for May 2-5 and is represented by a dashed line. The sediment represented by the difference in the estimated graph and the graph based on samples probably was introduced into the main stem by inflow from a small storm on one or more tributaries in the lower part of the basin. The tributary flow contained a higher concentration of suspended sediment than the river, but the water discharge was insufficient to be noticed on the stage record. The effect of various sediment sources superimposed on one hydrograph is more pronounced in the examples to follow.

The period August 13-17, 1951 (fig. 20), has a hydrograph similar to that previously discussed (fig. 19), and runoff apparently came from one source. Correspondingly, the sediment-concentration graph would be expected to have a single rise and characteristic recession. The sediment samples indicate, however, that possibly three major sources of water and suspended material combined to form the single water peak. The initial concentration peak occurred about 4 hours prior to the water peak. Then a tributary flow of higher concentration combined with the initial flow and caused a secondary, and higher, concentration peak. Evidence of a third source of material is indicated by the change in recession rate of concentration about 0300-0800 hours August 16. Finally, on August 16 the sediment concentration dropped abruptly to a level that may have occurred August 15 had the flood peak contained water and sediment from only one source.

The graphs for May 22-27, 1951 (fig. 21), indicate the effect of several peaks produced from several rainstorms or from drainage of several subbasins, or from both. The first increase in discharge was rapid, and the initial concentration peak was conventional, although the peak concentration was not as high as that previously experienced (fig. 20). The difference between this graph and those in the previous examples may be the result of different antecedent conditions in the basin or sediment from a different subbasin. The second concentration peak superimposed on the original sediment recession could not be predicted from the gage-height trace. The third concentration peak may be anticipated because of the abrupt decrease in rate of recession about 2200 hours May 23. The fourth concentration peak, that of May 25, apparently follows the characteristic pattern. The fifth peak (May 27) could not be anticipated from study of the hydrograph and may have been caused by small downstream tributary flow or more likely by bank sloughing which followed the extensive period of high flow.

The period June 11-14 (fig. 22) has a higher water discharge than the preceding examples and a longer delay time between arrival of the first floodwater and the peak discharge, as usually characterized by long periods of general low-intensity rainfall. The sediment concentrations are lower than in the preceding examples. The low concentration may be attributed to antecedent conditions caused by the May storms or, more likely, to the less intense rainfall but longer duration of the June storms.

The examples discussed previously demonstrate some of the variations in concentration graphs that may be expected in a large basin when the runoff events are produced in upstream tributaries of diverse characteristics by isolated rainfall of short duration and high intensity. Figure 23 illustrates a storm event on a large stream, Susquehanna River at Harrisburg, Pa. (drainage area, 24,100 square miles), that drains a basin consisting of three major physiographic provinces with generally good vegetal cover. The March 3-14 flood was caused by intermittent rainfall that occurred March 2-10 throughout the State. The sediment concentration started to increase with the increase in water discharge, unlike the example in

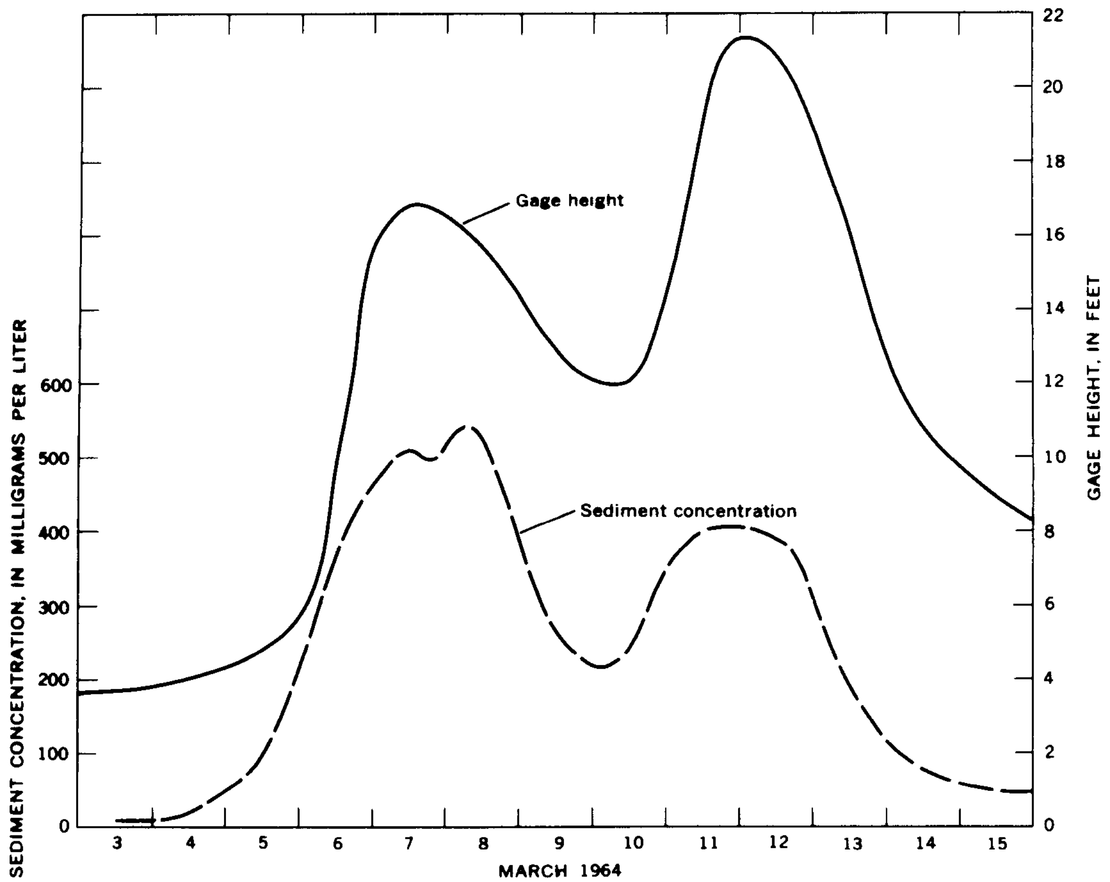

Figure 23.—Gage height and sediment concentration, Susquehanna River at Harrisburg, Pa.

figure 19, because the source area of the water and sediment was local as well as upstream and the concentration continued to increase until the discharge started to decrease. Even so, there was a small secondary concentration peak March 8. The second water-discharge peak on March 11-12, although higher than the first peak, had a lower concentration because less soil was readily available for erosion after the first few days of rain.

The hydrograph of the discharge and suspended-sediment concentrations of the Willamette River at Portland, Ore., during the recordbreaking floods of December 1964 (fig. 24) is a good example of the relation between discharge and concentration for a large flood on a large river. The discharge continued to increase for 4 days until it reached a peak. Sediment concentration, however, reached the maximum value the second day following the beginning of the rise and decreased over 50 percent by the time the water discharge reached a maximum value. Several common characteristic trends may be noted here: (1) The large increase in discharge at the outset caused a minor increase in concentration, (2) the discharge increased slowly for several days to reach a maximum value whereas the concentration increased rapidly and reached a maximum value, in less time, and (3) the water discharge receded slowly, being sustained by additional rainfall and contributions from bank and channel storage, whereas the concentration receded rapidly after reaching the maximum value.

Snowmelt discharge and sediment concentration

The relation between water discharge and

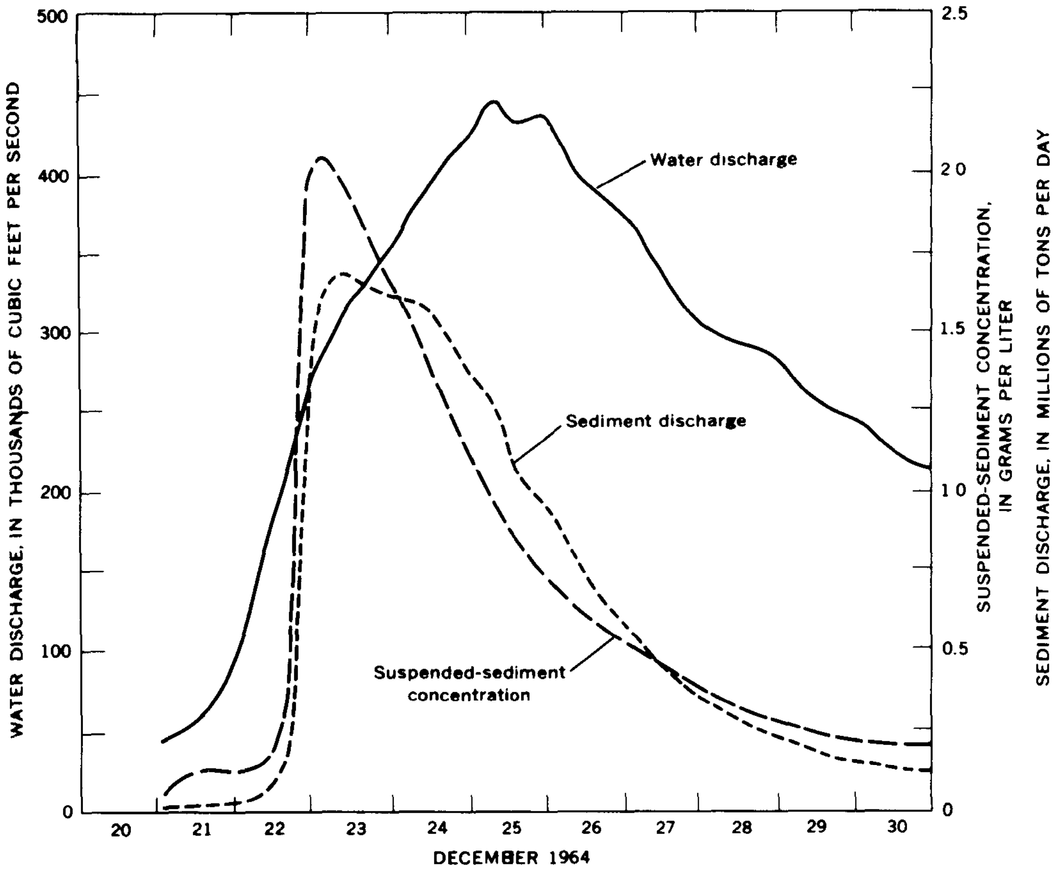

Figure 24.—Suspended-sediment concentration, sediment discharge, and water-discharge, Willamette River at Portland, Oreg., December 21-30, 1964. (After Waananen and others, 1971, p. 116.)

suspended-sediment concentration during snowmelt generally is different from that during periods of runoff from rainfall; also the correlation is poorer during snowmelt. This change in relation must be considered when constructing the concentration graph and interpreting the sediment-transport curve.

Increases in concentration relative to increases in water discharge are small during snowmelt runoff as compared with rainfall runoff, and sharp concentration peaks do not occur at or near the time of the water peak such as those illustrated in figures 16 and 17. Gage-height and concentration graphs of a 10-day snowmelt period are shown in figure 25.

The peak and trough of the diurnal fluctuations of sediment may or may not be in phase with those for water. The time the water peak occurs at the station is related to the distance between the snowmelt source and the gage, and the amount of lag between water and concentration peaks is a function of the distance between the sampling point and the source of the material. This relation may be determined usually from two samples per day.

The relation between daily values of water discharge and sediment concentration in a stream with substantial snowmelt runoff is shown in figure 26. The water discharge and concentration were low during the winter months. The first appreciable snowmelt in late March contained a large quantity of sediment. The snowmelt runoff continued to increase throughout April, although the concentration decreased after the initial rise and remained generally below 4,000 mg/l during the major snowmelt period in May

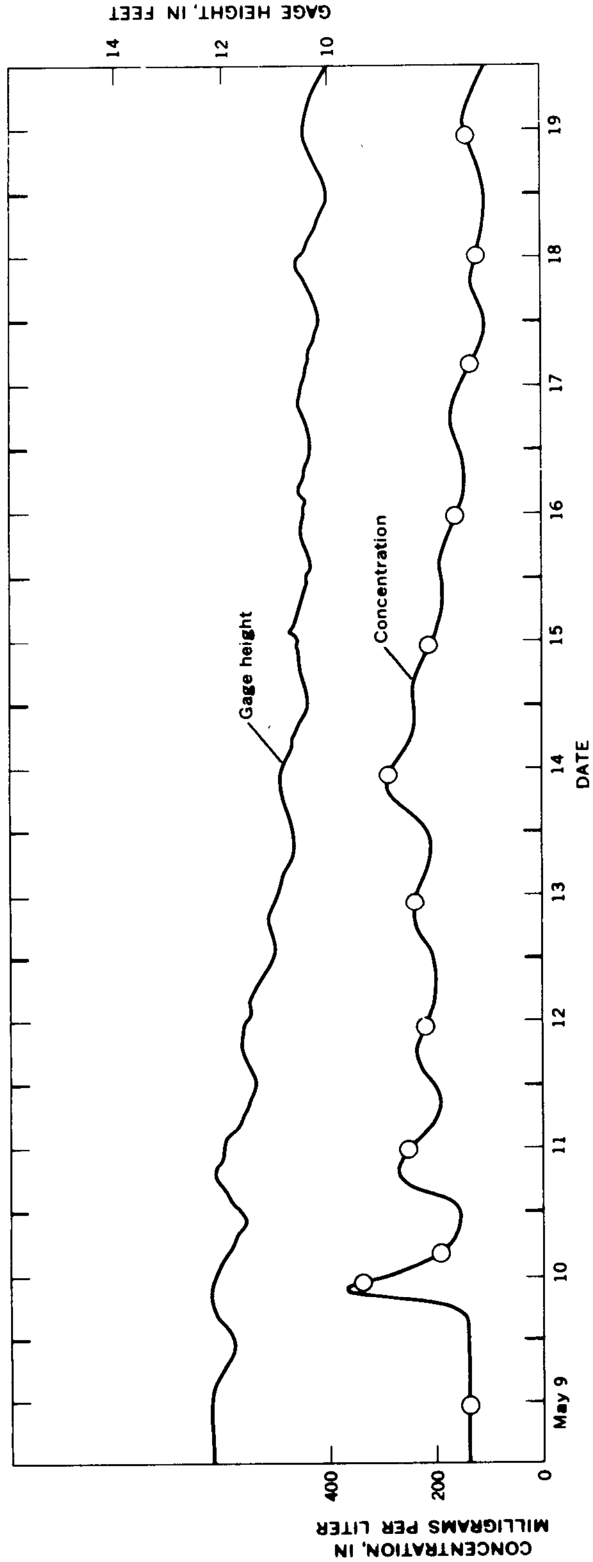

Figure 25.—Temporal relation of sediment concentration to water discharge during a snowmelt period.

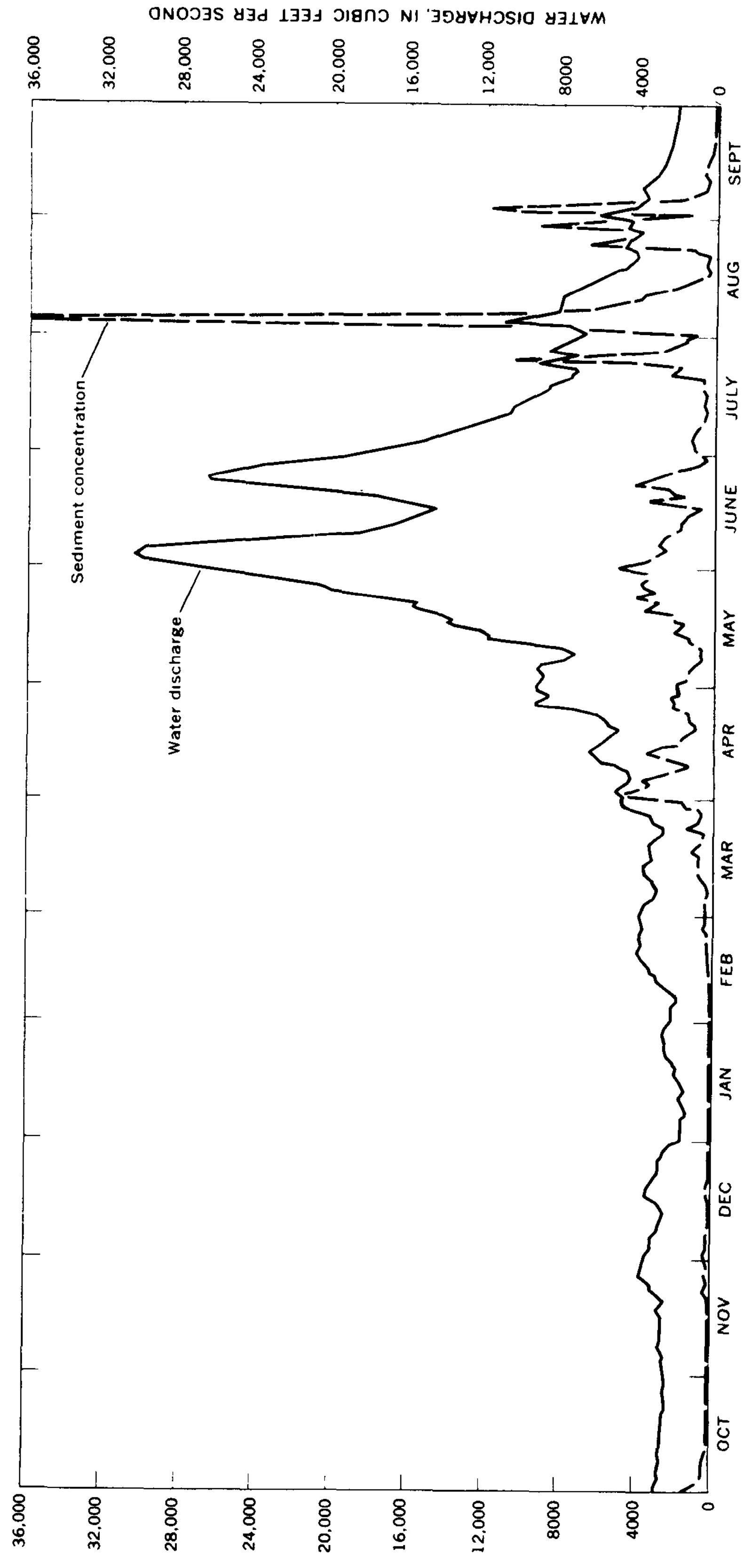

Figure 26.—Relation of water discharge to sediment concentration, Green River at Green River, Utah, 1951.

and June.

During the storm-runoff period July 22-September 1, sediment concentrations were considerably larger than those during the snowmelt period. The rainfall on August 1-2 caused an increase in discharge from 7,000 to 11,000 cfs (cubic feet per second), but the corresponding concentration increased from 1,000 to 39,000 mg/l. The maximum snowmelt runoff which started May 9 caused an increase in discharge from 7,000 to 30,000 cfs and an increase in concentration only from 500 to 5,000 mg/l.

Application of cross-section coefficient

Coefficients may be applied to concentration values in several ways. Two methods discussed here are (1) correction of the concentration value arithmetically after values have been computed from the concentration graph and (2) correction or adjustment graphically of the concentration graph prior to computing concentration values from the graph. The second method is needed especially in a subdivided period where the coefficient may change with stage and discharge.

In the first method, concentration for each day, or part of day, for the water year is computed from the concentration graph and tabulated on a copy of the recorder chart. When the coefficients are computed, as illustrated in figures 9 and 10, the appropriate correction to each concentration value is written below the daily concentration. The adjusted concentration value then as computed, entered below the other values, and underscored so no error will be made when the value is transferred to the sediment-discharge worksheet. If the subdivided-day method of computation is used and the coefficient values vary during the day, then the concentration value for each interval must be corrected. This is accomplished by tabulating coefficient values taken from a table similar to that given in figure 10 in an additional column in table 3 and by correcting each concentration value in column 5 prior to computing the sediment discharge.

In the second method, the correction is made graphically by adjusting the concentration graph. This method is useful particularly if the transported material is coarse and the ratio (a/b) of mean concentration in the cross section to mean concentration in the single vertical (col. 6, fig. 6) is correlative with gage height or discharge. The concentration graph in figure 27 was adjusted graphically by using the coefficient values determined in the plot in figure 10. The range in gage height affected by each coefficient value was marked on the trace of the gage-height graph. The concentration value determined from the sediment-concentration graph for each range was multiplied by the appropriate coefficient, and an × placed at the location of the corrected value. An adjusted sediment-concentration graph, following the trend of the original (unadjusted) concentration graph, was then drawn through the adjusted values. Computation of suspended-concentration values, either for daily values or for intervals of a day, may be made directly from the adjusted graph.

Because the reasons for the lateral variation of sediment concentration may differ from station to station and even at the same station, the application of corrections to concentration cannot be reduced to a few simple methods. Hence, as in the construction of the concentration graph, each application of coefficient requires imagination and ingenuity as well as a knowledge of the station and the fundamentals of sediment transport.

All coefficients and adjustments should be applied to the concentration graph, or values, prior to computation of sediment discharge. Any corrections not yet made, and specifically those which vary during a subdivided period, should be made while computing the subdivided period. Additional columns may be added to table 3 to show the coefficient and corrected concentration for each interval.

Adjustments are necessary also if the intervals of a subdivided period do not equal 24 because the recorder is operating too fast or too slow. If the divisor, d (footnote 1,

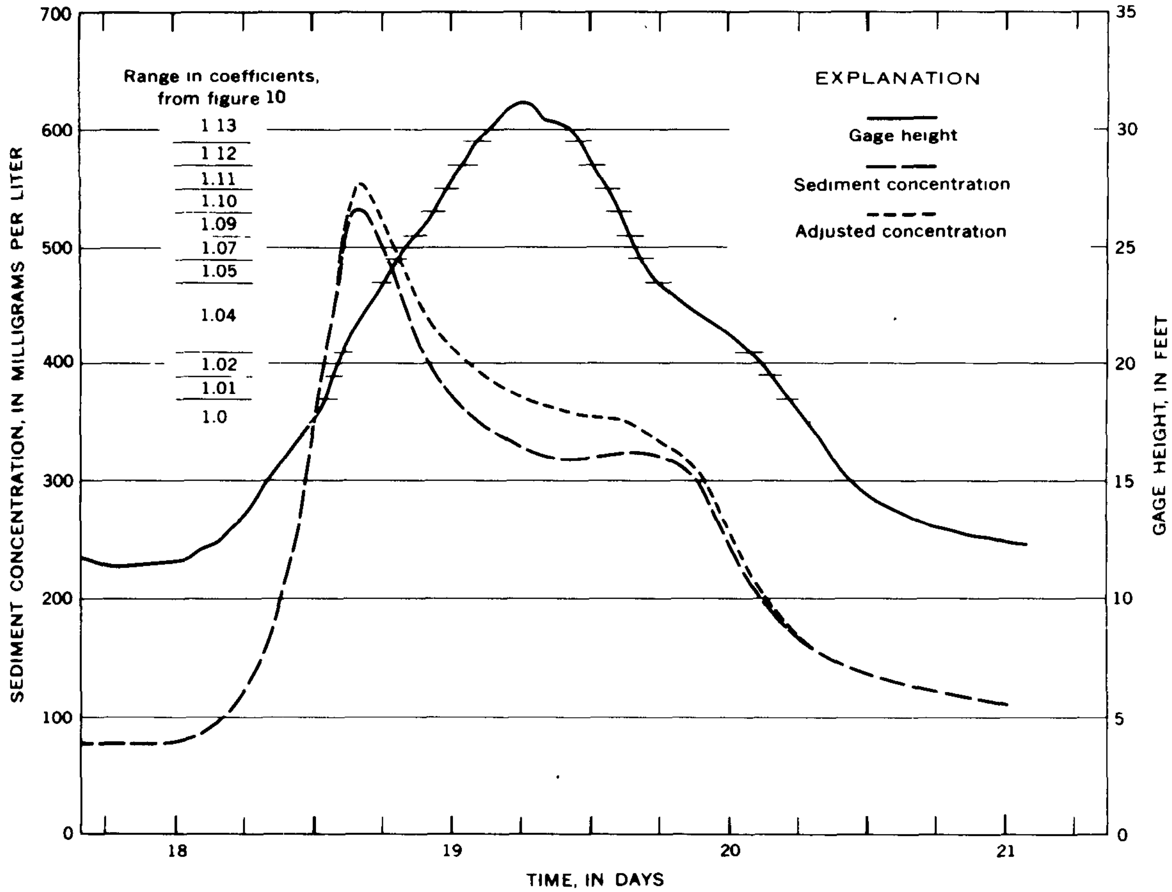

Figure 27.—Graphical adjustment of concentration.

table 3), based on 24 intervals per day, is used to compute the discharge per interval when the total interval, T, is different from 24, each interval must be corrected by $24/T$.

Computation of Daily Mean Concentration

The daily mean sediment concentration is the time-weighted mean value and is computed from the concentration graph described in previous sections. Each computed daily value is listed near the bottom of the chart at the midpoint (usually noon) of the day it represents.

Mean concentration values may be determined arithmetically or graphically. The arithmetic mean is obtained either by (1) selecting values from the concentration graph that represent uniform intervals of time and taking the arithmetic average or by (2) selecting values from the graph that represent unequal intervals of time and weighting these values by the time intervals represented by the concentrations. These methods or variations of these methods are also used to determine the average concentration for each interval of a subdivided period.

The mean concentration is determined graphically by use of an integrator—a simple device consisting of a thin sheet of clear plastic about 6 inches long and 3 inches high and with a fine visible line scribed through the center of the sheet parallel with the long axis. A clear plastic 45° or 30°-60° triangle also may be used. A small hole is drilled through the plastic near the center of the line to accommodate a pencil point. The average is determined by placing the line on the plastic over the concentration graph with the hole at the midpoint of the time interval. The line is adjusted vertically or rotated until half the area is above the graph and below the line and half the area is below the graph and above the line. The average concentration is the value where the line intersects the midpoint of the time interval and may be marked on the chart by placing a point of a pencil through the hole in the plastic. This graphical method is used to compute the daily mean concentration for days not subdivided as well as to determine mean concentrations for smaller intervals of time when the day is subdivided.

Because most personnel familiar with computations of water-discharge and sediment records are thoroughly familiar with the graphical method, only a brief discussion is included. A demonstration of the method by experienced personnel plus a little practice and ingenuity is sufficient to obtain acceptable values of mean concentration from the concentration graph.

Figure 28 illustrates ways to use the integrator. The line on the plastic, represented by the line *A-B*, is placed on the graph so that half the area is above the graph and below the line and half the area is below the graph and above the line. In figure 28*A* the line *A-B* is parallel to the base line and intersects the graph in two places. The area below the graph (designated 1) is equal to the sum of the two areas above the graph (designated 2). By placing the line on the integrator to intersect at the beginning of the 24-hour period (point *x* in fig. 28*B*), the graph is intersected only once. Thus, only two areas need be balanced, thereby sim-

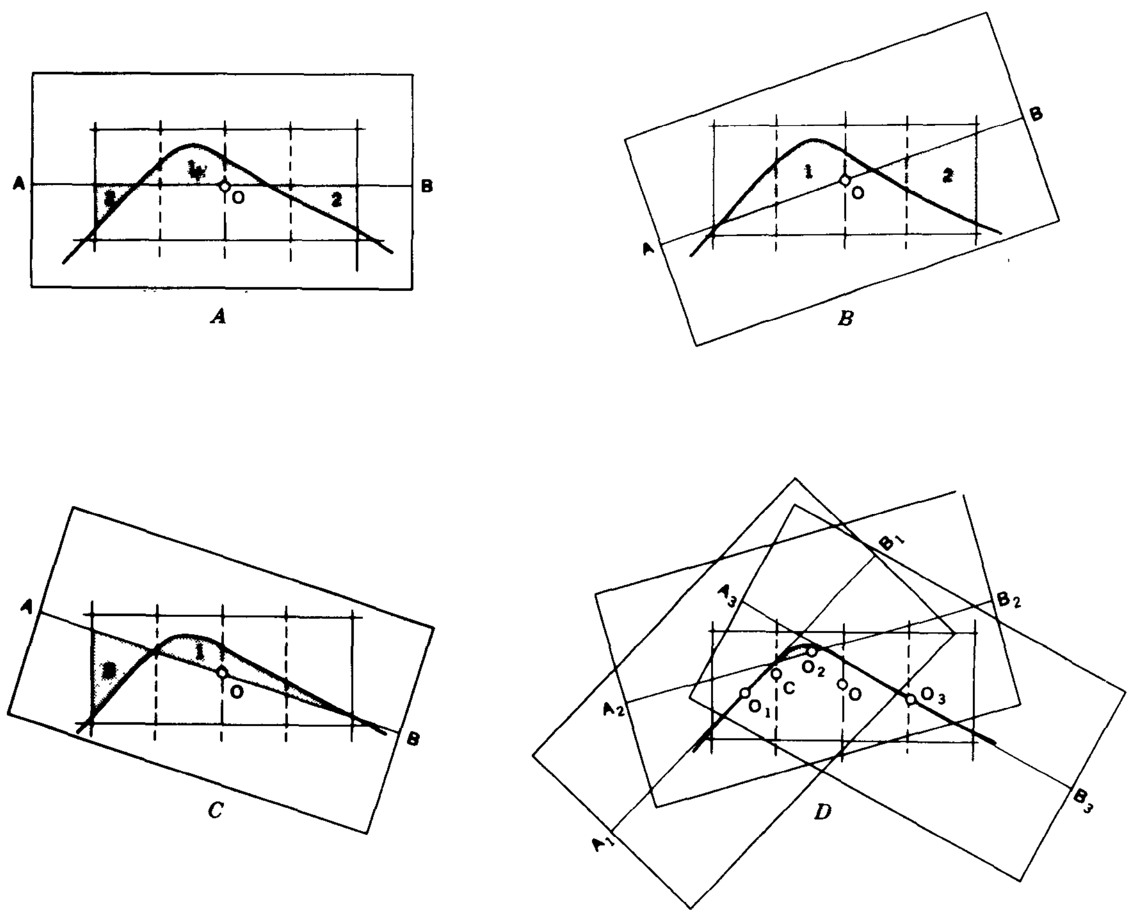

Figure 28.—Determination of mean concentration by graphical method.

plifying the visual balancing of the areas. The balancing of the areas can be further simplified by trial-and-error placing of the integrator to produce areas of uniform geometric appearance. Hence, in figure 28*C* the integrator line was placed on the end of the 24-hour-time period (point x) to test for uniformity of areas. As the graphs analyzed became more complex, a combination of the approaches in *A*, *B*, and *C* was used, and the time period (usually 24 hours) was divided into several parts, each representing nearly straight lines or small areas to be balanced. This approach is the one usually practiced by experienced personnel and is illustrated in figure 28*D*.

Figure 28*D* is divided for convenience into three time intervals—0-0600, 0600-1200, and 1200-2400. Line A_1-B_1 establishes the mean of the first 6-hour interval at O_1 at the midpoint of the interval. Likewise, A_2-B_2 establishes the mean of the interval 0600-1200 at O_2, and A_3-B_3 establishes the mean of the interval 1200-2400 at O_3. The mean of the first two intervals, which are equal in time, is found by placing the integrator line on O_1 and O_2 and marking the intersection (point *C*) of the line O_1-O_2 with the midpoint of the combined time interval, in this case 0600. The mean of the two 12-hour intervals is found at intersections of a line O_3-C and the midpoint of the combined time interval, *O*. In each of the examples, the mean is at point *O* on the midpoint of time intervals.

A value of mean concentration is determined for each day for which a graph has been constructed. For periods of constant, usually low, discharge and low constant concentration, the daily concentration sample will approach the daily mean concentration, and there will be no need to construct a graph to compute daily values. For these periods, sample values may be transferred directly to the sediment-discharge sheet with no intermediate calculation.

Footnotes

Footnotes are used to describe laboratory and computation procedures and to qualify estimated values. The appropriate footnote should be determined as each value is computed and entered after the concentration value on the gage-height graph. The footnote then can be transferred to the sediment-discharge worksheet simultaneously with copying of the concentration values on the worksheet.

Footnotes generally are not processed or stored by electronic computer; therefore, no footnotes will be listed on the tables of data processed by computer for publication. If footnotes are desired on these tables, they must be added manually by typewriter. Footnotes, however, should be limited to the minimum needed to explain and clarify the data or to describe unusual conditions that affected collection or quality of data.

Sediment footnotes and symbols do not follow the rules listed in the United States Government Printing Office "Style Manual," revised edition, January 1967; they are standardized here and have the same meaning regardless of their position in the table. The proper placement of footnotes in the table is described in the section on "Sediment-Discharge Worksheet."

Footnotes and references and the sequence in which they must appear if used on the sediment-discharge worksheet are listed as follows:

- E Estimated. (When there are 6 or more days in a year with the footnote E, delete E and insert the following headnote under the table title: "When no daily concentrations are reported, loads are estimated.")
- S Computed by subdividing day.
- A Computed from estimated-concentration graph.
- C Composite period.
- D Daily mean discharge.

Footnotes E and A are used to identify noteworthy estimated values, such as maximum and minimum values of concentration and sediment discharge, and to explain any missing values of concentration. Daily sediment-discharge values based on interpolation for short periods of low or uniform flow are not identified; hence, the sampling program must be scheduled to assure that samples are collected at some predetermined frequency, even during periods of low and uniform flow. Records that include long periods of estimated daily sediment discharges and contain the maximum sediment discharge of the year should be explained in the remarks paragraph of the station analysis. Also, conditions that influence sediment discharge such as unusual flow conditions, diversions, or construction activities should be described.

Footnote C is used to identify concentrations that are average values for a period. These average concentrations are obtained by compositing samples during periods of low concentration when fluctuations in concentration are assumed to be small. Daily values of concentration are more useful than average values for statistical treatment or interpretation of sediment trends. Daily values of concentration, therefore, should be published whenever available, and unless the analytical costs are prohibitive, the concentration of each sample should be determined in the laboratory.

Footnote D is used on tabulations of particle-size analyses to identify daily values of water discharge.

Significant Figures

Rounding of sediment-concentration and discharge values is standardized to accommodate and facilitate the computation, processing, and storage of data by electronic computer. Beginning with the 1968 water year, the number of significant figures reported in data releases is as follows:

Sediment concentration		*Sediment discharge*	
<0.5	report 0 mg/l or place leader (....) in column.	<0.005	report 0 tons.
0.5- 1	report 1 mg/l.	0.005-0.01	report 0.01 ton.
1 - 9	report one significant figure.	.01 - .09	report to nearest 0.01 ton.
10 -99	report two significant figures.	.10 -99	report two significant figures.
>100	report three significant figures.	>100	report three significant figures.

The monthly and annual sediment discharges are the unrounded sums of the daily values. No monthly or annual values will be shown for concentration.

The use of two significant figures below 1.0 is not intended to imply accuracy, but does make the published records of sediment compatible with those of water discharge and will facilitate computer processing of the data. A statement explaining the accuracy of published values may be included in the introductory text of the basic-data report.

Computer Programs

The description of the computation procedure thus far has been related entirely to manual preparation of records. Data-processing equipment has outmoded many manual procedures, and many additional changes undoubtedly will occur in the future. Automation, however, will not change the fundamental methods described for manual processing; therefore, each individual involved in the computation of sediment discharge should be familiar with and thoroughly understand the computation procedure and be able to compute records by the manual method.

A simplified computer program is now available for general use. This program performs the routine computations described in the sections on "Computation of Sediment Discharge," "Computation of Subdivided Days," and "Sediment-Discharge Worksheet" and lists the data for offset reproduction. The program does not eliminate the need to interpret concentration and water data and define a concentration graph.

Basic data needed for computer computation of sediment discharge are identical with those needed for manual processing and include the following:

1. Water discharge and sediment concentration for each day as described in the section on "Sediment-Discharge Worksheet."
2. Water discharge, concentration, and clock time or time interval as described in

the section on "Computation of Subdivided Days."

Format of Sediment Tables

Prior to October 1967 sediment data were typed or listed by automatic data-processing equipment on forms similar to those illustrated in figures 2, 38, and 45. Data published subsequent to October 1967 are processed and the results listed by electronic computer for publication in one or more of the methods in figures 29-35.

Computation of Sediment Discharge

Sediment discharge is determined by multiplying the water discharge, in cubic feet per second, by the concentration of suspended sediment, in milligrams per liter, and a coefficient:

$$Q_s = Q_w \times C_s \times k,$$

where

Q_s is the sediment discharge, in tons per day (tons/day),

Q_w is the water discharge, in cubic feet per second (cfs),

C_s is the concentration of suspended sediment, in milligrams per liter (mg/l),

and

k is a coefficient that is based on the unit of measurement of water discharge and that assumes a specific weight of 2.65 for sediment.

Units of measurement

The concentration of suspended sediment, C_s, is reported in milligrams of sediment per liter of water-sediment mixture. However, as a matter of convenience, it is determined in the laboratory in parts per million, which is the dry weight of suspended material per million equal weights of water-sediment mixture, or milligrams per kilogram, and is found by the formula

$$\text{parts per million} = \frac{\text{weight of sediment} \times 1{,}000{,}000}{\text{weight of water-sediment mixture}}$$

or

$$1 \text{ ppm} = \frac{0.0010 \text{ g}}{1{,}000 \text{ g}} = \frac{1 \text{ g}}{1{,}000{,}000 \text{ g}}$$

Concentration in milligrams per liter is the weight in milligrams (mg) of sediment per thousand milliliters (ml) of mixture and is the ratio of dry weight of sediment to the volume of mixture, or

$$\text{milligrams per liter} = \frac{0.0010 \text{ g}}{1{,}000 \text{ ml}} = \frac{1 \text{ mg}}{1{,}000 \text{ ml}}$$

The numerical values of parts per million and milligrams per liter are equal when the density of the mixture is equal to 1.00, and for all practical purposes, 1 liter weighs 1,000 g (grams). An increase in concentration increases the density of the mixture, and the laboratory value of concentration in parts per million must be corrected by the ratio, C, of the density of the water-sediment mixture to the density of water. Thus,

$$\text{milligrams per liter} = C \times \text{parts per million}.$$

The values of the conversion factor C, are given in table 2. These values are based on

Table 2.—Conversion factors, C, for sediment concentration: parts per million to milligrams per liter

[The factors are based on the assumption that the density of water is 1.000 (plus or minus 0.005), the range of temperature is 0°-29°C, the specific gravity of sediment is 2.65, and the dissolved-solids concentration is less than 10,000 ppm. This table supersedes table 1 in Guy (1969)]

Concentration range (ppm)	C	Concentration range (ppm)	C
0- 15,900	1.00	322,000-341,000	1.26
16,000- 46,800	1.02	342,000-361,000	1.28
46,900- 76,500	1.04	362,000-380,000	1.30
76,600-105,000	1.06	381,000-399,000	1.32
106,000-133,000	1.08	400,000-416,000	1.34
134,000-159,000	1.10	417,000-434,000	1.36
160,000-185,000	1.12	435,000-451,000	1.38
186,000-210,000	1.14	452,000-467,000	1.40
211,000-233,000	1.16	468,000-483,000	1.42
234,000-256,000	1.18	484,000-498,000	1.44
257,000-279,000	1.20	499,000-514,000	1.46
280,000-300,000	1.22	515,000-528,000	1.48
301,000-321,000	1.24	529,000-542,000	1.50

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SUSPENDED-SEDIMENT DISCHARGE, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968

DAY	OCTOBER MEAN DISCHARGE (CFS)	OCTOBER MEAN CONCENTRATION (MG/L)	OCTOBER SEDIMENT DISCHARGE (TONS/DAY)	NOVEMBER MEAN DISCHARGE (CFS)	NOVEMBER MEAN CONCENTRATION (MG/L)	NOVEMBER SEDIMENT DISCHARGE (TONS/DAY)	DECEMBER MEAN DISCHARGE (CFS)	DECEMBER MEAN CONCENTRATION (MG/L)	DECEMBER SEDIMENT DISCHARGE (TONS/DAY)
1	.60	4	.01	66	247	87	1410	913	3820
2	.30	4	0	62	40	6.7	780	318	670
3	.30	4	0	58	22	3.4	470	140	-178
4	0	--	0	28	7	.53	345	70	65
5	0	--	0	19	4	.21	205	35	19
6	.30	2	0	14	4	.15	160	20	8.6
7	.30	2	0	18	3	.15	130	11	3.9
8	.60	1	0	80	100	45	117	9	2.8
9	.80	1	0	318	651	690	241	65	42
10	.80	1	0	459	542	1290	330	121	313
11	.80	1	0	254	326	388	1010	742	2430
12	.80	1	0	340	300	289	422	110	125
13	1.1	2	.01	148	65	26	275	40	30
14	1.4	4	.02	80	22	4.8	218	22	13
15	4.7	5	.06	55	8	1.2	196	20	11
16	6.1	4	.07	42	4	.45	163	17	7.5
17	6.1	4	.07	37	2	.20	134	10	3.6
18	6.1	3	.05	33	2	.18	117	10	3.2
19	6.1	2	.03	30	2	.16	134	15	5.4
20	6.1	2	.03	28	1	.08	500	249	461
21	6.1	1	.02	33	1	.09	8630	8100	258000
22	6.1	1	.02	42	1	.11	29800	57900	5070000
23	6.1	1	.02	39	1	.11	15600	46300	2110000
24	6.6	1	.02	42	1	.11	9300	36500	1020000
25	7.0	1	.02	378	369	561	5030	25500	346000
26	7.5	2	.04	232	65	41	4300	22300	259000
27	9.0	2	.05	148	22	8.8	3230	15500	135000
28	19	3	.15	486	541	1330	2050	11000	60900
29	80	226	60	595	360	723	1550	10700	44800
30	48	66	8.6	315	78	66	1340	9430	34100
31	22	10	.59	--	--	--	1070	7950	23000
TOTAL	260.70	--	69.88	4479	--	5563.43	89257	--	9369012.0

Figure 29.—Format table 1, suspended-sediment discharge.

SUSPENDED-SEDIMENT DISCHARGE FOR SELECTED DAYS, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DATE	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	DATE	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)
NOV 28, 1969..	4.4	519	13	MAY 7........	14	3670	265
JAN 27, 1970..	6.0	2180	213	MAY 8........	1.9	140	.72
JAN 28........	1.5	50	.20	JUN 22........	4.2	1410	122
MAR 6........	3.4	143	2.6	JUN 23........	.42	80	.09
MAR 7........	42	449	28	AUG 3........	2.0	1030	61
MAR 8........	1.5	70	.28	AUG 4........	5.7	3700	372
MAR 15........	6.6	795	26	AUG 5........	.98	490	4.0
MAR 16........	1.8	50	.24	AUG 24........	14	3950	968
APR 17........	1.5	326	3.5	AUG 25........	27	1270	640

Figure 30.—Format table 2, suspended-sediment discharge for selected days.

SUSPENDED-SEDIMENT DISCHARGE MEASUREMENTS, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DATE	TIME	DISCHARGE (CFS)	CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	DATE	TIME	DISCHARGE (CFS)	CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)
DEC 6, 1969	0450	42	14	1.6	JUN 10......	1430	45	12	1.5
JAN 12, 1970	1700	126000	100	34000	JUN 22......	2300	219	69	41
JAN 14......	1830	1.3	8	.03	JUL 1......	1530	.80	12	.03
FEB 22......	1200	13	33	1.2	AUG 12......	1200	14	8	.30
FEB 28......	0100	770	212	441	AUG 15......	1845	108	15	4.4

Figure 31.—Format table 3, suspended-sediment discharge measurements.

SUSPENDED-SEDIMENT DISCHARGE DURING PERIODS OF HIGH FLOW, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DATE	TIME INTER-VAL (HRS)	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	DATE	TIME INTER-VAL (HRS)	MEAN DISCHARGE (CFS)	MEAN CONCEN-TRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)
JUL 27......	2	1340	41000	12400	JUL 28......	15	625	11600	12200
JUL 27......	2	944	30000	6370	JUL 28......	3	400	5700	770
JUL 28......	2	730	21000	3450	JUL 28......	4	278	3600	450

Figure 32.—Format table 4, suspended-sediment discharge during periods of high flow.

TOTAL SEDIMENT DISCHARGE, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DATE	TIME	WATER TEM-PERA-TURE (°C)	DISCHARGE (CFS)	SUSPENDED SEDIMENT CONCEN-TRATION (MG/L)	SUSPENDED SEDIMENT DISCHARGF (TONS/DAY)	TOTAL SEDIMENT DISCHARGE (TONS/DAY)	STREAM CHARACTERISTICS WIDTH (FT)	MEAN DEPTH (FT)	MEAN VELOCITY (FPS)
DEC 10, 1969	1800	12.0	1400	1200	4540	4590	30.3	8.5	4.00
DEC 30......	1545	14.0	440	22	26	33	25	6.6	2.9
JUN 12, 1970	1430	26.5	120	200	65	70	10.2	5	3.2
JUN 14......	0900	28.0	1.6	25	.11	.17	1.8	.2	.45
JUN 15......	1200	28.5	12	30	.97	.17	2.0	.6	.50
JUN 16......	1300	28.0	.88	15	.04	.04	1.5	.1	.2

Figure 33.—Format table 5, total sediment discharge.

a water density of 1.00 g/cc and a sediment density of 2.65 g/cc. They are calculated to three significant figures in 2-percent steps. Computation errors from use of these factors will be less than 1 percent and will average zero.

Values of concentration determined in the laboratory as parts per million should be converted to milligrams per liter by laboratory personnel on the form, sediment-concentration notes (fig. 5). For concentrations under 16,000 ppm, the values of parts per million and milligrams per liter are assumed to be equal. For concentrations over 16,000 ppm, the corrected value in milligrams per liter should be penciled plainly below the concentration on the form as a reminder to the user that parts per million is different from milligrams per liter. In any event, personnel who transfer the data from the laboratory forms for other uses are responsible for the correct use of the data and should check the basic data to determine that the conversion was correctly made.

After the data are converted to milligrams per liter, the only coefficient needed to compute sediment discharge is k, which is equal to 0.0027 in the English system of units. The coefficient, k, includes the conversion of water discharge and is a constant for a given system of measurement. The derivation and value of k to determine tons per day in English and metric units follows.

If the weight of a cubic foot of water-sediment mixture is assumed to be 62.4 pounds, then

$$k=\frac{(60\times 60\times 24)\text{ seconds per day }\times 62.4\text{ pounds per cubic foot}}{2{,}000\text{ pounds per ton}\times 1{,}000{,}000}=0.0027,$$

and the computation of sediment discharge is

$$Q_s=Q_w\times C_s\times 0.0027\text{ tons per day (English short tons).}$$

A metric ton is 2,204.62 pounds avoirdupois, or 1.1023 English short tons, and a cubic meter is 35.31 cubic feet. To convert English short tons to metric tons multiply by 0.9072, or substitute factor 0.00245 in place of 0.0027 in the preceding equation.

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970
(METHODS OF ANALYSIS: B, BOTTOM WITHDRAWAL TUBE; C, CHEMICALLY DISPERSED; N, IN NATIVE WATER; P, PIPET; S, SIEVE; V, VISUAL-ACCUMULATION TUBE; W, IN DISTILLED WATER)

DATE	TIME	WATER TEMPERATURE (°C)	DISCHARGE (CFS)	SEDIMENT CONCENTRATION (MG/L)	SEDIMENT DISCHARGE (TONS/DAY)	PARTICLE SIZE: PERCENT FINER THAN THE SIZE (IN MILLIMETERS) INDICATED .002	.004	.008	.016	.031	.062	.125	.250	.500	1.00	2.00	METHOD OF ANALYSIS
MAR 27, 1970	1050	7.0	2020	254	1390		36		41		58	68	93	100			VPWC
MAY 24.......	0550	11.5	603	11400	18600		78		99		100	--	--				PWC
MAY 26.......	1255	16.5	800	10100	21800		71		96		100	--	--				PWC
JUN 10.......	1700	14.0	2410	17900	116000		44		63		94	99	100				VPWC
AUG 10.......	1615	19.0	784	39600	86900		59		78		97	100	--				VPWC
AUG 12.......	1130	19.0	1470	46000	189000		50		67		93	99	100				VPWC
AUG 19.......	1000	14.5	885	36000	89200		48		68		90	98	100				VPWC
AUG 23.......	1355	21.0	8260	39900	92300		37		52		83	97	100				VPWC
AUG 24.......	1235	17.5	3040	12600	103000		46		63		88	97	100				VPWC

Figure 34.—Format table 6, particle-size distribution of suspended sediment.

PARTICLE-SIZE DISTRIBUTION OF SURFACE BED MATERIAL, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970
(METHODS OF ANALYSIS: O, OPTICAL ANALYZER; P, PIPET; S, SIEVE; V, VISUAL-ACCUMULATION TUBE)

DATE	TIME	WATER TEMPERATURE (°C)	NUMBER OF SAMPLING POINTS	DISCHARGE (CFS)	PARTICLE SIZE — PERCENT FINER THAN THE SIZE (IN MILLIMETERS) INDICATED .004	.062	.125	.250	.500	1.00	2.00	4.00	8.00	16.00	32.00	METHOD OF ANALYSIS
NOV 29, 1969	1515	9.0		440	0	3	10	53	97	100	--	--	--			SV
JAN 30, 1970	1330	12.0		206	0	1	10	48	86	97	98	99	100			SV
MAR 22......	1240	16.5		143	0	1	10	51	86	98	99	99	100			SV

Figure 35.—Format table 7, particle-size distribution of surface bed material.

Water-discharge data in the metric system usually are reported in cubic meters per second, and sediment-discharge data in metric tons per day. If water data are in cubic meters per second, the weight of 1 cubic meter of water is 1 metric ton, and the time interval is 24 hours; thus

$$k=\frac{86{,}400 \text{ seconds per day} \times 1 \text{ ton per cubic meter}}{1{,}000{,}000}$$
$$=0.0864,$$

and the computation of sediment discharge becomes

$$Q_s=Q_w\times C_s\times 0.0864 \text{ (metric tons)}.$$

Computation of subdivided days

The term "subdivide" refers to the division of data for a calendar day into shorter periods of time to obtain correct daily mean values of water or sediment discharge when one or both change beyond certain limits during the day. The values for these periods are then summed to obtain values of water or sediment discharge.

The basic reasons for subdivision of data for a day to compute water discharge and the reasons for subdivision to compute sediment discharge are different. Computation of daily mean water discharge requires subdivision of the day when the gage height is changing because the relation between stage and discharge is curvilinear, and the daily discharge corresponding to a mean gage height will be less than the true mean discharge. Computation of a daily mean sediment discharge requires subdivision of the day when both water discharge and concentration are changing because the average of the products of two variable quantities is not the same as the product of the averages of the quantities. Subdivision is not required if either discharge or concentration is constant during the day.

Water-discharge values for subdivided days frequently are calculated in advance of sediment calculations and are listed on the recorder chart of the gage-height record. However, because the reasons for subdivision to determine water discharge and the reasons for a subdivision to compute sediment discharge are not the same, a subdivision for water discharge may not be adequate for sediment discharge. Colby (1956b) sums it thus:

> A common source of errors is incorrect division of the day into parts. An inept type of subdivision may be little better than no subdivision at all. Far too often the same separation of the day into parts is used for both the computation of water discharge and the computation of sediment discharge.

The concentration graph should be prepared prior to computation of water discharge, and the initial subdivision made on the basis of change in both water discharge and concentration. If subdivisions and computations of water discharge were made prior to preparation of the concentration graph, a new subdivision of water discharge may be necessary to compute sediment discharge. The new subdivision may divide the day into different parts and into a larger number of parts. Any new water-discharge values added to the subdivision should be carefully computed and checked. Usually when a period is subdivided into a larger number of intervals, the accuracy of the value of daily mean water discharge is improved, and the finite value of the daily water discharge is increased. If the increase in daily mean water discharge over the previously computed value is significant, the original value should be revised. This significant increase will not occur, however, if the original subdivision was adequate.

Figure 36 is a guide to indicate if subdivision is necessary to maintain computations within specified limits of error. The maximum and minimum discharge and the maximum and minimum concentration are determined for the day, or for a trial period, and the ratios of these values plotted on the guide. In practice, a precise computation and plotting of ratios is not necessary, and a quick mental calculation of the ratios and a visual location of these on the guide will suffice.

Subdivided days are computed primarily by two methods which are referred to herein as the mean-interval method and the mid-

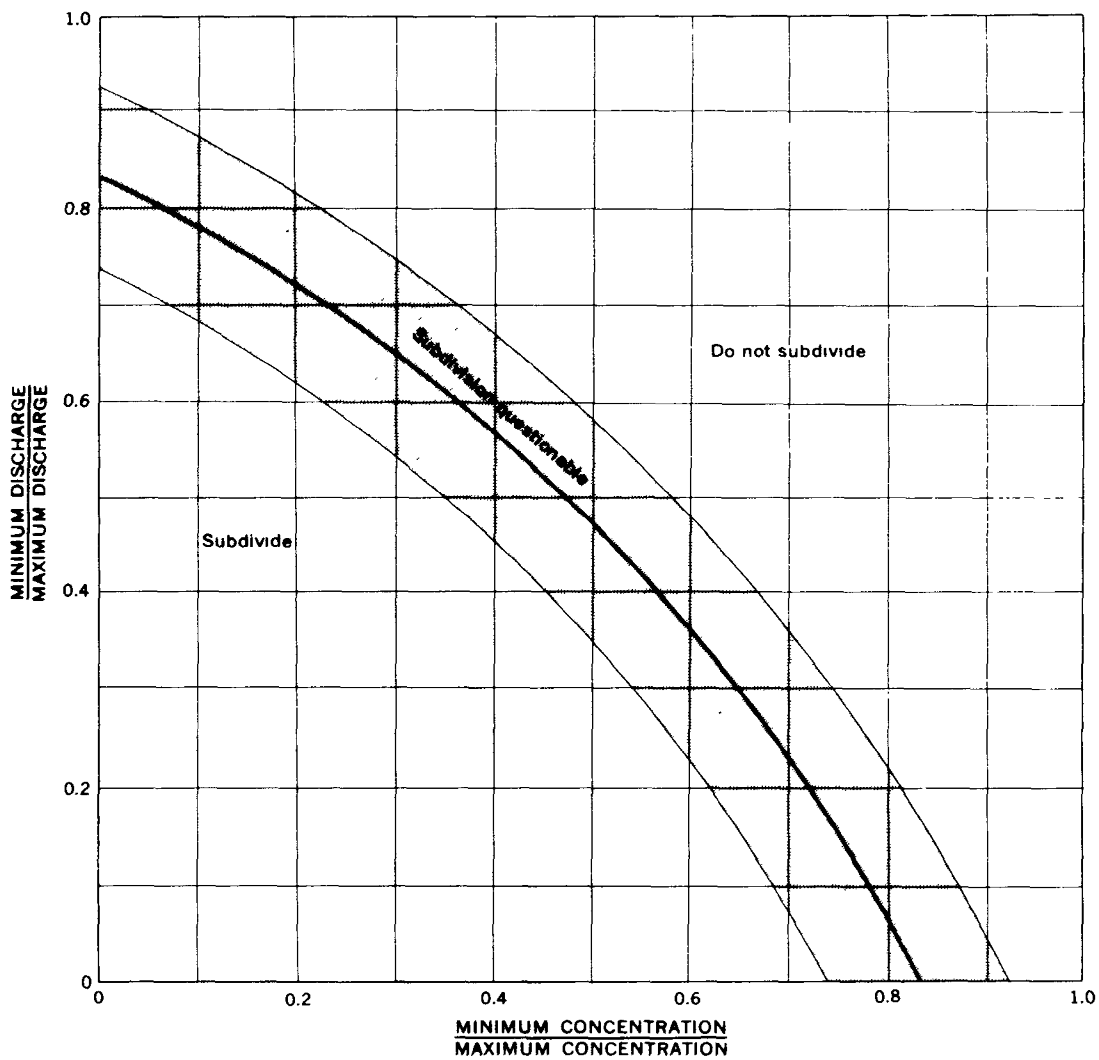

Figure 36.—Guide to subdivision, assuming accuracy about 5 percent (after Colby, 1956b).

interval method. These methods are analogous to the mean-section and midsection methods of computing streamflow from water-discharge measurements described by Buchanan and Somers (1965).

Mean-interval method

The mean-interval method of computation of sediment discharge requires the determination of the mean water discharge and mean sediment concentration for several short periods of time during a day. The products of the two variables for each interval are then time weighted and summed to obtain daily mean discharge. This method is convenient if an analog record of gage height is available and mean values of gage height (or water discharge) and concentration can be determined graphically. Graphical determination of these values for an interval of a day may be made in the manner described in the section on "Computation of daily mean concentration."

An example of the mean-interval method is given in table 3. The daily sediment-discharge data were computed by two procedures:

1. Sediment discharge computed for each time interval and summed to obtain daily discharge (col. 7).
2. Sediment discharge computed by summing the product of water discharge, time interval, and concentration in the calculator and multiplying the summation by k/T, where k is the coefficient, 0.0027, and T is the summation of hours in the time-interval column, or number of intervals used in subdividing the day. In this latter procedure, column 7 is not computed. This procedure is the one most commonly used.

An advantage resulting from use of the first procedure is the listing of actual sediment-discharge values or tonnage for each time interval (col. 7, table 3). This method is most convenient to use if the computations are made by slide rule or by a calculator that does not cumulatively multiply. These data are useful for direct application to special studies of water and sediment-discharge relations.

Midinterval method

The midinterval method of computation of sediment discharge assumes the values of water discharge and sediment concentration for a specific time represent the average values for the time interval that extends ahead and behind halfway to the preceding and following clock times. The term "midinterval" is not precisely descriptive because if the successive time intervals are unequal the values are not at the midpoint. However, if the time intervals are equal then the values are at the midpoint of the time interval. This method is usually used when the gage-height record is a printout of a digital record.

An example of the midinterval method is given in table 4. Values of gage height and concentration are tabulated for the clock time (col. 1), and the time interval and water discharge are computed. Sediment discharge is computed by summing the product of the water discharge, sediment concentration, and time interval in the calculator and multiplying the summation by k/T, where k is the coefficient, 0.0027, and T is the summation of hours in the time-interval column, or the number of intervals used in subdividing the day.

If subdivision was not used for the data in table 4, then the 24-hour sediment discharge would be

$$Q_s = Q_w \times C_s \times 0.0027 = 2{,}260 \times 1{,}830 \times 0.0027$$
$$= 11{,}200 \text{ tons per day.}$$

The error caused by not subdividing is

$$25{,}400 - 11{,}200 = 14{,}200 \text{ tons per day,}$$

and the ratio of Q_s computed from daily mean values to Q_s computed by the sub-

Table 3.—Computation of subdivided day, mean-interval method

Time interval (col. 1): Time during which there is insignificant change in water discharge and sediment concentration or during which the maximum change is within limits specified by the allowable range in stage and by the guide to subdivision (fig. 36). The number of intervals used will depend on the accuracy required.

Gage height (col. 2): The average gage height for the time interval corrected for any mechanical errors. It is usually determined graphically.

Shift correction (col. 3): The adjustment applied to gage height to account for variations in the rating. This column may be omitted if no shift is needed.

Water discharge (col. 4): The mean discharge for the interval; obtained from rating tables.

Sediment concentration (col. 5): The mean concentration for the interval; usually determined graphically from the concentration graph.

Interval × concentration (col. 6): The product of the time interval (col. 1) and concentration (col. 5). The daily mean concentration, published in the concentration column of the sediment-discharge sheet, is computed by dividing the sum of col. 6 by the sum of col. 1. Col. 6 can be omitted for simple computations; col. 1 × col. 5 may be accomplished mentally and entered directly in the calculator and multiplied by water discharge (col. 4).

Computer sediment discharge, procedure 1 (col. 7): The discharge for the interval is computed by multiplying the product of the qtc (col. 4 × col. 6) by 0.0027 and dividing by the time, or total length of the interval. The calculation for periods divided into 24 intervals may be simplified by using the divisor, d. If this is done, col. 6 may be omitted. Values of d, given in footnote 1, are T/tk, where t is the interval, k, is 0.0027, and T is 24. Tons per day is the numerical sum of interval values. An example of the computation of the first and last intervals, using d from footnote 1, is

$$\text{tons per interval} = \frac{\text{col. 4} \times \text{col. 5}}{d} = \frac{q \times c}{d} = \frac{174 \times 8}{1{,}481} = 0.94$$

$$= \frac{q \times c}{d} = \frac{4{,}920 \times 3{,}500}{8{,}889} = 1{,}940.$$

Computed sediment discharge, procedure 2:

Total interval $= T = \Sigma$ (col. 1) $= 24$

$$\text{Daily mean gage height} = \frac{\Sigma\,(\text{col. 1} \times \text{col. 2})}{T} = \frac{144.29}{24} = 6.01$$

$$\text{Daily mean water discharge, } Q_w = \frac{\Sigma\,(\text{col. 1} \times \text{col. 4})}{T} = \frac{54{,}286}{24} = 2{,}260$$

$$\text{Daily mean concentration, } C_s = \frac{\Sigma\,(\text{col. 1} \times \text{col. 5})}{T} = \frac{43{,}648}{24} = 1{,}820$$

$$\text{Tons per day, } Q_s = \frac{\Sigma q(tc)}{T}\,k = \frac{\Sigma\,(\text{col. 4} \times \text{col. 6})}{T} \times 0.0027$$

$$= \frac{225{,}767{,}432}{24} \times 0.0027 = 25{,}400$$

	Time interval, t (1)	Gage height (ft) (2)	Shift correction (ft) (3)	Water discharge, q (cfs) (4)	Sediment concentration, c (mg/l) (5)	Interval × concentration, tc (col. 1 × col. 5) (6)	Computed sediment discharge, procedure 1 (tons/interval) (7)
	6	4.17	0	174	8	48	1
	2	4.32	0	234	30	60	2
	2	4.57	0	355	80	160	6
	2	4.66	0	403	100	200	9
	1	4.83	0	498	180	180	10
	1	5.75	0	1,210	650	650	88
	1	6.80	0	2,520	1,350	1,350	383
	1	7.55	0	3,710	2,350	2,350	981
	1	8.10	0	4,760	3,350	3,350	1,790
	1	8.39	0	5,380	4,600	4,600	2,780
	1	8.53	0	5,690	6,200	6,200	3,970
	1	8.62	0	5,890	6,950	6,950	4,610
	1	8.58	0	5,800	5,500	5,500	3,590
	1	8.47	0	5,550	4,600	4,600	2,870
	1	8.37	0	5,330	3,950	3,950	2,370
	1	8.18	0	4,920	3,500	3,500	1,940
Total	24	144.29	—	54,286	—	43,648	25,400
Weighted mean		6.01	—	2,260	—	1,820	—

[1] Divisors used to compute sediment discharge in procedure 1 for a given time interval:

Time interval, t (hr)	Divisor, d	Time interval, t (hr)	Divisor, d
1	8,889	13	683.8
2	4,444	14	634.9
3	2,963	15	592.6
4	2,222	16	555.6
5	1,778	17	522.9
6	1,481	18	493.8
7	1,270	19	467.8
8	1,111	20	444.4
9	987.6	21	423.3
10	888.9	22	404.0
11	808.1	23	386.5
12	740.7	24	370.37

Table 4.—Computation of subdivided day, midinterval method

Clock time (col. 1): The actual time, given in 24-hour time, for which values are tabulated. Sufficient values must be chosen to assure that the maximum change in successive values of water discharge and sediment concentration is within the limits specified by the allowable range in stage and by the guide to subdivision (fig. 36).

Time interval (col. 2): The sum of one-half the time back to the preceding clock time and one-half the time to the following clock time. The first interval, of 2.5 hours, is one-half the time from midnight (0000 hrs) and 5 a.m. (0500 hrs). The second interval, of 3.5 hours, is one-half the time from midnight to 5 a.m. (2.5 hrs) plus one-half the time from 5 a.m. to 7 a.m. (1 hr). This may also be computed by taking one-half the difference of alternate hours (except the first and last) as follows:

$$\text{First interval: } \frac{0500\text{-}0000}{2} = 2.5$$

$$\text{Second interval: } \frac{0700\text{-}0000}{2} = 3.5$$

$$\text{Third interval: } \frac{0900\text{-}0500}{2} = 2.0$$

Cols. 3-6: See explanation for columns 2-5, table 3.

Interval × concentration (col. 7): See explanation for column 6, table 3.

	Clock time (hrs) (1)	Time interval, t (hrs) (2)	Gage height (ft) (3)	Shift correction (ft) (4)	Water discharge, q (cfs) (5)	Sediment concentration, c (mg/l) (6)	Interval × concentration, tc (col. 2 × col. 6) (7)
	0000	2.5	4.17	0	174	8	20
	0500	3.5	4.19	0	182	8	28
	0700	2.0	4.32	0	234	40	80
	0900	2.0	4.60	0	370	90	180
	1100	1.5	4.67	0	408	100	150
	1200	1.0	4.73	0	442	120	120
	1300	1.0	5.22	0	744	320	320
	1400	1.0	6.22	0	1,740	1,000	1,000
	1500	1.0	7.20	0	3,120	1,900	1,900
	1600	1.0	7.83	0	4,220	2,850	2,850
	1700	1.0	8.26	0	5,090	4,000	4,000
	1800	1.0	8.50	0	5,620	5.300	5,300
	1900	1.0	8.56	0	5,750	7,000	7,000
	2000	1.0	8.60	0	5,840	6,400	6,400
	2100	1.0	8.54	0	5,710	4,950	4,950
	2200	1.0	8.41	0	5,420	4,200	4,200
	2300	1.0	8.31	0	5,200	3,700	3,700
	2400	.5	8.10	0	4,760	3,300	1,650
Total	—	24	144.365	—	54,168	—	43,848
Weighted mean	—	—	6.02	—	2,260	—	1,830

Computed sediment-discharge procedure:

Total interval $= T = \Sigma$ (col. 2) $= 24$

$$\text{Daily mean gage height} = \frac{\Sigma\ (\text{col. } 2 \times \text{col. } 3)}{T} = \frac{144{,}365}{24} = 6.02$$

$$\text{Daily mean water discharge, } Q_w = \frac{\Sigma\ (\text{col. } 2 \times \text{col. } 5)}{T} = \frac{54{,}168}{24} = 2{,}260$$

$$\text{Daily mean concentration, } C_s = \frac{\Sigma\ (\text{col. } 2 \times \text{col. } 6)}{T} = \frac{43{,}848}{24} = 1{,}830$$

$$\text{Tons per day, } Q_s = \frac{\Sigma q\ (tc)}{T}\ k = \frac{\Sigma\ (\text{col. } 5 \times \text{col. } 7)}{T} \times 0.0027$$

$$= \frac{226{,}035{,}716}{24} \times 0.0027 = 25{,}400$$

divided-day method is

$$\frac{11{,}200}{25{,}400} = 0.44.$$

In practice, this ratio is computed for each subdivided day during the computation process because it gives an index to the value, or need, to subdivide. For large streams, it also provides an excellent basis for experienced personnel to estimate the need to subdivide the next day. As the flood peak recedes and concentration values decline, the ratio for each successive day will approach 1.00; subdivision is not necessary when the ratio for the preceding day is 0.95 or greater.

The excellent agreement between average values for corresponding variables in tables 3 and 4 is notable. Such close agreement indicates sufficient subdivision. A similar check also is possible when additional intervals are added to previously subdivided water-discharge values. If weighted gage-height values are the same, but water discharge increases significantly, then the original subdivision of water discharge was insufficient. This reasoning can be extended through computation of sediment discharge. If additional intervals fail to significantly change daily mean values of water discharge, concentration, or sediment discharge, then the period is subdivided into sufficient intervals.

Data for the examples in tables 3 and 4 are taken from the gage-height and the concentration graph in figure 37. Data may be recorded and computations made on a copy of the gage-height chart or on a separate sheet.

Sediment-Discharge Worksheet

At this point a continuous sediment-concentration graph has been drawn and reviewed. Concentration values for daily periods and subdivided periods have been computed, and all coefficients applied. Sediment discharge and time-weighted concentrations have been computed for each subdivided day. These values and computations now are ready for the next step—entering the data on the sediment-discharge worksheet (fig. 38).

The sediment-discharge worksheet and the tabulation of particle-size analyses (fig. 2) are the major products of the basic-data-collection program and are published annually. These are the forms from which copies are made to furnish preliminary information to the various data users and which are furnished to the records-processing center. These forms, therefore, should be filled out completely, neatly, and accurately—both in content and editorially. Editorial procedure and rules are based on the United States Government Printing Office "Style Manual," revised edition, January 1967. Specific rules are further explained in "Suggestions to Authors of the Reports of the United States Geological Survey," fifth edition, 1958.

If the electronic computer program is used, values of water discharge and sediment concentration are compiled and punched on data cards; sediment discharge is not computed by the method that follows. Part of the output of the computer program is a listing of sediment data in a form suitable for publication. Records computed manually on the worksheet also are sent to the records-processing center to be listed by computer for publication. An example of the offset copy—prepared from data on the worksheet (fig. 38)—produced by the automatic data-processing equipment is illustrated in figure 29.

The technical and editorial accuracy of the product depends on each individual who has a part in its preparation. Each value should be checked for accuracy, and each tabulation should be evaluated for editorial correctness. Data should not be listed with the intent of allowing the checker, or reviewer, to discover and correct errors. It is much easier to keep errors out of the tabulation than to correct them at a later date, if ever.

A list of the technical and editorial rules used in the preparation of the sediment-discharge worksheet (fig. 38) follows.

Heading of table:

1. Enter the number and name of station in capital letters.
2. Fill in the correct time period. If the period is not a complete water year, change the months to agree with period of record.
3. Fill in headnote, if applicable. See rules for footnote E in section on "Footnotes."

Body of table:

1. Mean discharge:
   - (a) Copy the water discharge from form 9-192 or printout. Use exact figures listed in surface-water data because perfect agreement must exist between data listed in surface-water and water-quality publications.
   - (b) Omit footnotes in this column.
   - (c) Omit explanation or qualifications concerning water discharge.
2. Mean concentration:

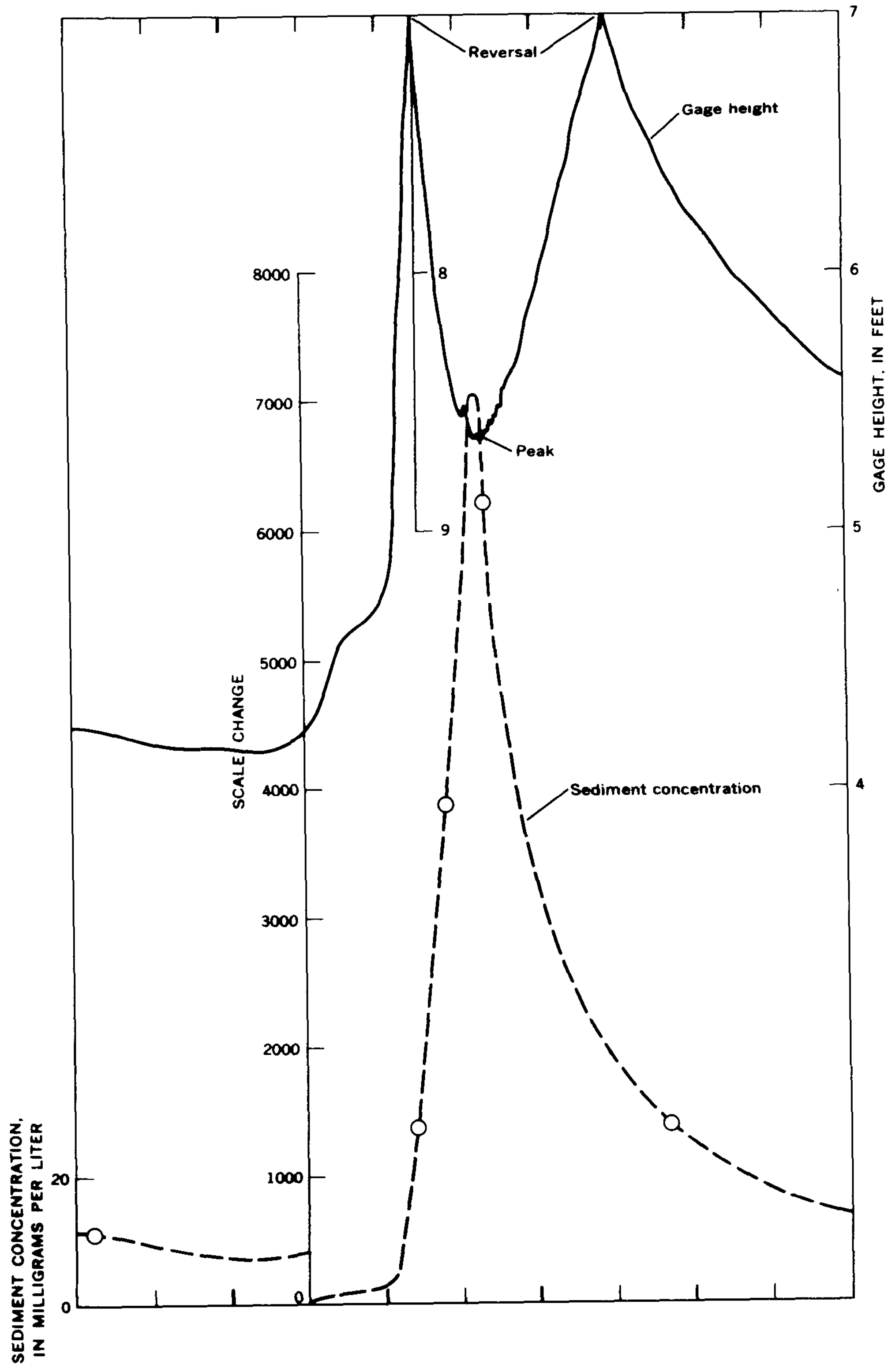

Figure 37.—Gage height and sediment concentration for a subdivided day.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY WATER RESOURCES DIVISION

11-382x SAMPLE CREEK NEAR SOMEWHERE, CALIF

Suspended sediment, water year October 1967 to September 1968

Day	October Mean discharge (cfs)	October Mean concentration (mg/l)	October Tons per day	November Mean discharge (cfs)	November Mean concentration (mg/l)	November Tons per day	December Mean discharge (cfs)	December Mean concentration (mg/l)	December Tons per day
1	0.60	8	0.01	66	247	S 87	1,410	913	S 3820
2	.30	4	0	62	40	67	780	318	670
3	.30	4	0	58	23	3.4	470	140	178
4	0	--	0	28	7	.53	345	70	65
5	0	--	0	19	4	.21	206	35	19
6	.30	2	0	14	4	.15	160	20	8.6
7	.30	2	0	18	3	.16	130	11	3.9
8	.60	1	0	20	100	S 46	117	9	2.8
9	.80	1	0	318	651	S 690	241	65	42
10	.80	1	0	459	542	S 1,390	330	121	S 812
11	.80	1	0	254	336	S 381	1,010	742	S 2430
12	.80	1	0	340	300	S 289	422	110	125
13	1.1	2	.01	148	65	26	278	40	30
14	1.4	4	.02	80	22	4.8	218	22	13
15	4.7	5	.06	55	8	1.2	196	20	11
16	6.1	4	.07	42	4	.45	163	17	7.5
17	6.1	4	.07	37	2	.20	134	10	3.6
18	6.1	3	.05	33	2	.18	117	10	3.2
19	6.1	2	.03	30	2	.16	134	15	5.4
20	6.1	2	.03	28	1	.08	500	249	S 461
21	6.1	1	.02	33	1	.09	8,630	8,100	S 258000
22	6.1	1	.02	42	1	.11	29,800	57900	S 5,070,000
23	6.1	1	.02	39	1	.11	15,600	46300	S 2,110,000
24	6.6	1	.02	42	1	.11	9,300	36,500	S 1,020,000
25	7.0	1	.02	378	369	S 561	5,030	25,500	346,000
26	7.5	2	.04	232	65	41	4,300	22,300	269,000
27	9.0	2	.06	148	22	8.8	3,230	15,500	135,000
28	19	3	.15	486	541	S 1,330	2,050	11,000	60900
29	80	226	S 60	595	360	S 723	1,550	10700	44800
30	48	66	8.6	315	78	66	1,340	9430	34,100
31	22	10	.59				1,070	7950	23,000
Total	268.70		69.88	4,479		5,563.43	89,257		9,369,012.4

Day	January Mean discharge (cfs)	January Mean concentration (mg/l)	January Tons per day	February Mean discharge (cfs)	February Mean concentration (mg/l)	February Tons per day	March Mean discharge (cfs)	March Mean concentration (mg/l)	March Tons per day
1	860	7000	16,300	1,080	6200	16,300	490	850	1130
2	880	6,700	16,500	1,070	5060	14,600	434	630	738
3	930	7000	17,600	920	4100	10200	420	540	612
4	780	5200	11,000	880	3650	8670	371	515	516
5	2,080	11,900	S 78,600	1,040	4900	13800	371	420	421
6	1,270	8620	S 29,800	962	3400	8830	437	600	692
7	961	6,900	17,700	810	2700	5900	378	540	551
8	770	4,800	9,980	695	2400	4500	344	485	450
9	780	4,950	10,400	626	2050	3460	326	418	368
10	951	6,550	16,800	562	1660	2520	312	410	348
11	1,150	8,800	A 27300	532	1780	2510	338	422	385
12	1,100	8,500	A 25,200	490	1600	2120	371	504	505
13	995	6,600	17,700	469	1220	1,540	350	350	331
14	973	5,650	14600	462	1050	1310	302	275	224
15	1,150	6,500	20200	434	910	1070	284	288	221
16	1,220	7,100	23400	413	920	1020	264	295	226
17	1,270	6,950	23800	379	880	948	277	300	226
18	1,420	8,150	31200	406	780	855	257	255	177
19	1,580	8,450	36,000	427	880	1,010	252	275	187
20	1,500	7,250	29,400	462	1,000	1,250	235	330	209
21	1,260	5,980	20,300	490	1,000	1,320	240	315	204
22	1,030	5,500	15,300	490	990	1,310	290	435	341
23	2,120	15,400	S 156,000	448	850	1,020	296	410	328
24	2750	14,400	S 119,000	406	600	658	296	408	326
25	1,470	8,300	32,900	385	580	603	262	330	233
26	1,150	6,900	21,400	378	520	S 531	279	385	290
27	962	6,150	16,000	755	3340	S 7,880	302	380	310
28	870	5,360	12,600	554	1600	2,390	237	268	186
29	900	5,160	12,500	517	1140	1,590	240	297	168
30	1,170	5,960	18,800				257	282	196
31	1,290	5,960	20,700				274	302	223
Total	37,582		910,380	17,672		128,185	9,858		11,332

Day	April Mean discharge (cfs)	April Mean concentration (mg/l)	April Tons per day	May Mean discharge (cfs)	May Mean concentration (mg/l)	May Tons per day	June Mean discharge (cfs)	June Mean concentration (mg/l)	June Tons per day
1	284	830	253	594	1350	2170	246	110	73
2	320	456	393	506	1000	1370	223	98	59
3	279	390	294	462	860	1060	214	90	52
4	279	344	259	441	650	774	201	70	38
5	290	280	219	434	415	568	196	62	28
6	274	220	163	448	370	449	192	53	27
7	284	300	230	462	310	387	184	54	27
8	1,010	4,110	S 12,800	465	340	418	156	45	19
9	702	4,720	S 3,640	462	355	443	141	36	14
10	434	660	773	476	380	488	127	33	11
11	367	530	511	514	430	593	123	31	10
12	427	610	703	538	445	646	114	29	8.9
13	448	800	968	578	450	702	97	26	6.8
14	476	700	900	572	390	602	91	24	5.9
15	892	--	E 11,000	568	370	563	91	22	5.4
16	1,390	--	E 12,000	572	318	491	77	20	4.2
17	900	--	E 7800	580	300	470	72	19	3.8
18	4,910	--	E 53,000	519	266	373	77	16	3.1
19	3,660	10700	103,000	498	250	336	72	13	2.5
20	2,580	7900	54,000	484	248	324	67	14	2.5
21	2,180	6700	39,400	488	220	290	69	16	3.0
22	1,360	4,600	16900	404	178	194	69	25	4.7
23	1,080	4000	11,400	356	140	134	69	21	3.9
24	1,010	3300	9,000	325	117	103	67	17	3.1
25	495	3000	8,600	300	110	89	62	13	2.2
26	1,030	2850	7,860	285	119	92	60	11	1.8
27	1,020	3200	8,810	290	140	110	53	10	1.4
28	951	2600	6,680	295	180	143	51	10	1.4
29	830	2600	5,830	296	160	127	51	11	1.5
30	695	2200	4,180	286	130	100	53	11	1.6
31				270	110	80			
Total	28,087		386,506	13,721		14,668	3,365		425.2

Day	July Mean discharge (cfs)	July Mean concentration (mg/l)	July Tons per day	August Mean discharge (cfs)	August Mean concentration (mg/l)	August Tons per day	September Mean discharge (cfs)	September Mean concentration (mg/l)	September Tons per day
1	53	12	1.7	7.0	5	0.10			
2	48	10	1.3	5.9	4	.06			
3	46	7	.87	6.7	4	.06			
4	46	7	.87	6.1	4	.07			
5	42	8	.91	6.2	4	.06			
6	41	7	.77	4.1	6	.04			
7	33	6	.53	3.0	4	.03			
8	30	6	.49	3.4	4	.04			
9	28	7	.53	2.8	3	.02			
10	28	5	.38	2.2	2	.01			
11	28	4	.30	1.7	2	.01			
12	27	4	.29	1.1	2	.01			
13	28	4	.30	.91	3	.01			
14	30	3	.24	.80	2	0			
15	30	3	.24	.80	2	0			
16	28	3	.23	.72	2	0			
17	24	3	.19	.59	1	0			
18	19	3	.15	.54	1	0			
19	16	3	.13	.37	2	0			
20	15	3	.12	.31	1	0			
21	15	3	.12	.22	1	0			
22	14	3	.11	0	--	0			
23	13	3	.11	0	--	0			
24	12	3	.10	0	--	0			
25	10	4	.11	0	--	0			
26	11	5	.15	0	--	0			
27	9.8	7	.19	0	--	0			
28	9.0	5	.12	0	--	0			
29	8.8	3	.07	0	--	0			
30	9.1	4	.10	0	--	0			
31	7.4	6	.12	0	--	0			
Total	758.6		11.84	53.76		0.52	0		0

Load max daily 5,070,000 tons Dec 22; min daily 0 tons many days

Conc max daily 57,900 mg/l Dec 22; min daily no flow mg/l many days

	Discharge	Concentration	Load
Copied	RDB	ADB	RDB ADB RDB
Checked	ADB	RDB	ADB RDB ADB
Date			

Total discharge for period/year (cfs-days) 205,073.96

Total load for period/year (tons) 10,818,153.87

E Estimated
S Computed by subdividing day
A Computed from estimated-concentration graph

[No footnotes will be published except E on Apr 15-18]

Figure 38.—Worksheet for annual suspended-sediment discharge.

(a) Copy values of concentration from graph.

(1) During low-flow periods, if samples are not collected daily, tabulate concentrations for days actually sampled, and estimate missing concentrations on basis of values for adjoining days and the water-discharge hydrograph. A concentration will be determined for each day of flow, if possible. On the worksheet the sampled concentrations are tabulated near the right-hand margin of the concentration column; the interpolated, or estimated, concentrations are tabulated near the left-hand margin of the column. Separation of the sampled and estimated values is for convenience only and aids in checking and reviewing the record. Punched cards for automatic data processing must contain both water discharge and concentration.

(2) During periods of changing concentration, a concentration graph may have been estimated on the basis of adjacent records and other data. The daily mean concentrations from the estimated graphs should be copied in the concentration column and the footnote A entered in the tons per day column. If a concentration graph cannot be estimated and sediment discharge is determined by indirect means such as a sediment-transport curve, then enter a leader (..) in the concentration column and the footnote E in the tons per day column. If 6 or more days require the footnote E, then delete E and use a headnote.

(b) Show concentrations less than 0.5 mg/l either as a leader (..) or as zero. If the water discharge is zero, a leader will be placed in the concentration column and a zero in the tons per day column:

Mean discharge (cfs)	*Suspended sediment*	
	Mean concentration (mg/l)	*Tons per day*
3.7	1	0.01
1.8	1	0
.18	1	0
.18	....	0
0	....	0

(c) Report concentrations in whole numbers only. Values are rounded as instructed in the section on "Significant figures."

(d) Omit footnotes, with the exception of C, in the concentration column. Avoid the use of composite values. Daily values should be shown whenever possible.

(e) Copy footnotes recorded on gage-height chart that explain the concentration or sediment-discharge computation in the tons per day column.

(f) Copy sediment discharge (tons per day) and footnotes for subdivided days at the time concentration values are copied from chart.

3. Tons per day:

(a) Enter sediment discharge for subdivided days and footnotes at the time concentration values are copied from the chart.

(b) Compute sediment discharge for days where average concentration and water values are given. The daily sediment discharge is mean discharge × mean concentration × 0.0027.

(c) Round sediment-discharge values according to the instructions in the section on significant figures.

(d) Estimate sediment discharge for days where concentration is not shown.

(e) Plot all values of water and sediment discharge on logarithmic paper in the form of a sediment-transport curve (fig. 39). Check values that

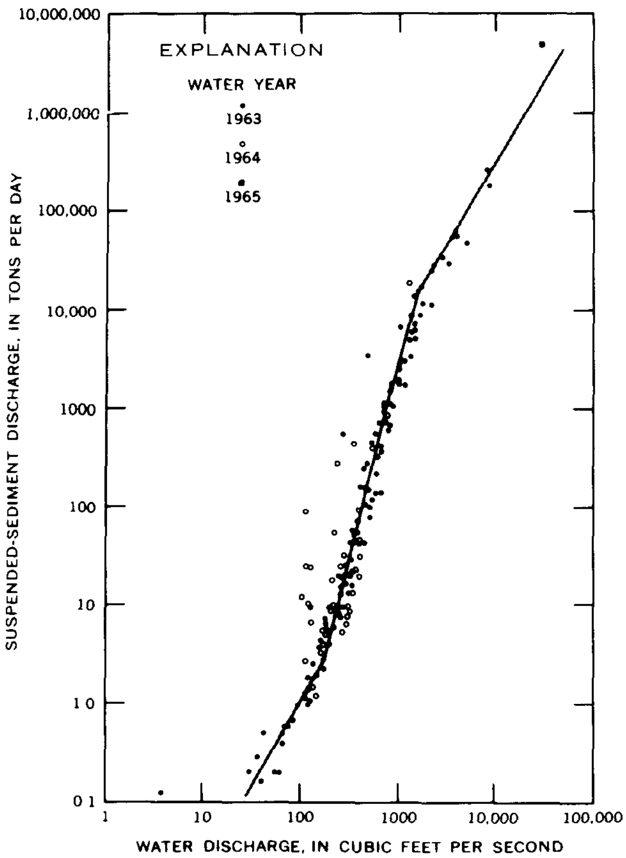

Figure 39.—Relation between daily suspended-sediment discharge and water discharge, Thomes Creek at Paskenta, Calif., 1963-65 water years.

deviate significantly from the average curve for decimal point error, incorrect concentration graph, error in computation, or error in water-discharge values. This plot is useful particularly on large streams having storm runoff events that last several days and where seasonal changes may be significant.

(f) Make revisions as necessary; however, do not try to revise a sediment-discharge value because the value is not consistent with an assumed pattern. The value may not agree because of unusual circumstances, which occur infrequently. These infrequent occurrences often may be verified by comparing them with log plots of water and sediment discharge made for previous years.

(g) Compute and check monthly and annual totals.

(h) Insert and check footnotes.

(i) Compute, record, and check maximum and minimum concentration and sediment discharge.

Station Analysis

A station analysis is a concise summary of (1) equipment used at the station, (2) stream conditions that may affect the quality of the sediment record with respect to particle-size distribution, concentration, and sediment transport, (3) the sampling procedures used, and (4) special methods used to compute sediment discharge.

The analysis of the sediment record may include a summary of chemical-quality sampling procedures and frequency, constituents determined, and special analytical methods. If the sediment records are prepared by the same office preparing the surface-water records, the analyses for the water records and sediment records may be combined. A consolidated analysis including all records collected at one station is preferred because the basic information concerning location, physiography, land use, and climate are common to each analysis. An individual analysis may be necessary when the records are not prepared by the same office or because of conflicts with local needs.

Items that should be considered in a consolidated analysis of sediment discharge, chemical quality, temperature, and rainfall records include:

Equipment type and location.

Equipment changes and date of change.

Important land-use changes that will probably affect the quantity and quality of runoff, such as burn areas, logging, construction, urbanization, and mining.

Temperature record: completeness, accuracy, and reliability.

Rainfall record: completeness, accuracy, and reliability, if obtained in connection with gaging station.

Sediment-sampling methods: regular or special techniques, number of sediment-discharge measurements made, and reliability of observer.

Gage-height record including the datum corrections.

Water-discharge record including the stage-discharge rating.

Concentration graph and sediment-discharge computations, and coefficients applied.

Particle-size analyses: number, methods of analysis, and average percentage of clay, silt, and sand.

Chemical quality: sampling procedures and frequency, constituents determined, and special analytical methods.

Remarks concerning other aspects that affect the record.

An example of a station analysis associated with water, sediment, temperature, and rainfall records is given in figure 40, an analysis for chemical quality and sediment records is given in figure 41, and an analysis for sediment records is given in figure 42.

Station Description Heading

A complete station description heading is prepared for each new station when a chemical or sediment data-collection program is started. It is revised when changes in location or operation warrant. Otherwise, no changes are made in the heading on an annual basis except the dates and figures for records available and extremes. A station description heading as published in the water-quality-data report is shown in figure 43.

Station headings may be updated and typed by the originating office or, once prepared, may be put on punched tape and filed at the records-processing center. This tape is used as input to an automatic typewriter which produces a final copy for offset printing. A major advantage of the taped heading is that the period of records and extremes can be updated without rewriting the remainder of the heading. This eliminates the need for copying, typing, checking, and reviewing the major part of the heading each year.

A copy of the heading (fig. 44) is furnished the office that computed the record. This copy will be used to update the heading for the next water year. The procedure is as follows:

1. Use red pencil to update heading.
2. Location should be changed only when major change occurs in sampling point or gaging station.
3. Drainage area is the value used in the surface-water-data report for the same water year.
4. Records available: Update the final data under "Sediment records" to include current records. Example: For 1968 records, line out 1967 in red, and write in 1968.
5. First "Extremes" paragraph lists extremes for current water year only. Thus, all dates and extremes probably will be changed.
6. Second "Extremes" paragraph shows extremes for period of record, including current year.

   The first date, 1961-67, is the period which includes all other dates in the paragraph. In the example, water-temperature records extend from 1961-67, thus the date is not repeated after water temperatures. Sediment-concentration record is 1962-67, which is included in, but different from, the first date; thus, it is placed after sediment concentrations and sediment loads. The last date must be lined out and updated, as shown in the example.

   Maximum and minimum values and the dates of occurrence may or may not need to be changed.

   Line out and update extremes and dates that change. Check all extremes and dates that remain the same. All dates and figures must be updated or checked.
7. Remarks: Revise this paragraph as required. This paragraph includes information regarding changes in sampling

NORTH FORK OF RED RIVER NEAR GLENWOOD, CALIF. 11-3789.00

STATION ANALYSIS
(Water, sediment, temperature, and rainfall)
1966 Water Year

Equipment.--Stevens A-35 recorder with manometer, and tipping bucket rain gage Weksler Thermograph, in steelox shelter. D-49 sediment sampler located on upstream side of bridge 1.2 miles downstream from gage. Measuring cable 0.3 mile below gage. Observer equipped with DH-48.

Hydrologic changes.--The area upstream varies in elevation from 900 ft to 7,600 ft. It is composed chiefly of sandstone, shale, and greenstones intruded by ultramafic rocks largely altered to serpentine. The combination of sheared rocks, steep slopes and heavy precipitation produces the landslides common to the area. The cover varies from pastures and sagebrush to heavy timber. The timber has been and is continuing to be heavily logged. Owing to the impermeability of the soil and mantle rock, base-flow is poorly sustained and the bulk of the runoff in both water and sediment is storm produced.

Temperature record.--Record complete except period November 12 to December 4 when Weksler clock stopped. Water temperature observations made at time of sediment samples were available for part of period.

Rainfall record.--Record complete for the year.

Sediment record.--Samples were taken about three times a week during low-flows, once a day during medium-flow, and one or more times a day during high-flows. All samples were depth-integrated and considered of fair to good quality.

Gage-height record.--Record complete except periods January 4-6, January 20 to February 2, and June 19 to July 1 when manometer malfunctioned. Observer's staff-gage readings were available for some of these periods.

Datum corrections.--Levels of June 20, 1966, found datum of gage to be 901.58 ft above mean sea level, datum of 1929, supplementary adjustment of 1956. The orifice elevation was found to be 3.26 ft and all outside staffs to be correct within 0.01 ft. No corrections applied.

Rating.--The streambed at the station is composed of sand, gravel, cobblestones, and a few large boulders. A gravel riffle just downstream forms the low-water control. The channel, with banks which are steep and of fairly stable base rock, forms the medium- and high-water control. There is extensive gravel mining 0.5 mile above the station which at times affects the discharge rating and concentration curve.

Sixteen discharge measurements, Nos. 115-130, were made during the current year. Measurement No. 123 made by an inexperienced hydrographer during a period of rapidly changing stage was not used in the analysis. Rating No. 4 in use at the close of the previous water year was continued in use until the high-water of January 12. Measurements after this date indicate an extensive scour and partial return to conditions similar to that existing prior to the December 1964 flood. Therefore, rating No. 5 was developed for use during the remainder of the year. This rating was based on measurements made after the January flood, is well defined and is the same as all previous ratings above 12,000 cfs.

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Discharge.--Rating No. 4 was used with small low-water shifts to the peak of January 12. Rating No. 5 was used direct for the remainder of the year. Discharge for periods of no gage height record were estimated on basis of observer's staff readings and hydrographic comparison with other stations in the basin.

Concentration graph and sediment load.--Eleven sediment measurements, depth-integrated at 3 to 5 verticals in the cross section, were made during the year.

Observer samples consisting mostly of two bottles were taken at the center of the stream cross section. The samples were analyzed separately and compared. In most cases the individual samples agreed fairly well. Several bottles differed considerably, and the unreasonable value was not used in this analysis.

Concentrations were plotted on a print of the gage height graph and the concentration curve developed. There were sufficient samples on the rises to adequately define the concentration curve. No coefficient was needed for the observer samples. Standard procedures were used to determine the daily sediment discharge.

Particle size.--Ten samples were analyzed. They ranged in concentration from 122 to 11,600 ppm and in discharge from 780 to 50,000 cfs. Average results of the analysis show 65 percent of material transported to be finer than 62 microns. All particle-size analyses in the silt-clay range were made using distilled water, with a dispersing agent added, as a settling medium.

Remarks.--Water discharge records are good. Suspended sediment records are fair.

James L. Cook
January 26, 1968

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Figure 40.—Station analysis (water, sediment, temperature, and rainfall) showing format and content.

RIO GRANDE BASIN
RIO CHAMA NEAR ABIQUIU, N. MEX. 8-2875.

STATION ANALYSIS
(Chemical Quality and Sediment)
1960 Water Year

Sampling program.--Collection of chemical quality and sediment samples on a daily basis was begun on January 15, 1959. Temperature observations are made on samples collected for chemical analyses only. The observer collects sediment samples twice daily from cable car at gaging station during normal flow periods and at more frequent intervals during periods of high flow. All samples are depth integrated and taken with either a D-43 or DH-48 sampler. (Estimate percentage of reported data collected by each.) Three samples were taken for each set, at 1/3, 1/2, and 2/3 of distance across the stream. An integrated sample for chemical analysis was collected at midsection about 0830 daily. No samples were obtained during several intervals in December and January. The collection of samples and records maintained by observer, John H. Jones, is satisfactory.

Equipment.--U.S. D-43 sediment sampler installed in metal shelter on bridge 100 yards upstream from gaging station. A cableway is available for sediment-discharge measurements at normal gaging section one quarter of a mile upstream from water-stage recorder.

Special sediment measurements.--Sixteen sediment discharge measurements were made during the year. Each measurement constituted a cross section, consisting of depth-integrated samples from five to seven verticals. No coefficients were applied as the three regular samples showed virtually no change with any discharge measurement.

Sediment-discharge computations.--The mean daily concentrations obtained at the station were plotted on a print of the gage-height chart and a smooth concentration curve drawn on a basin of the points. Daily mean concentrations were computed from the average of the cross-section sample. Daily sediment discharge was computed by multiplying product of adjusted daily mean discharge and mean concentration by factor 0.0027. On 7 days of rapidly changing water discharge and concentration the graphs were subdivided and total sediment discharge for the day was computed by summing the sediment discharge for appropriate intervals of the day.

Size analysis.--Thirty-three particle-size analyses were made on samples taken at this station during the year, of which 25 were tabulated for publication. The sample for April 10 was analyzed five times in different ways and at different concentrations. The bottom withdrawal results were unsatisfactory and only one decantation was listed for this date. Three bed material samples were taken August 12, September 10, and September 20. Analyses were made, but the data were not listed.

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Chemical quality methods.--The midsection samples collected at this station are considered to give a representation of quality as there is no inflow immediately above the station. The stream is quite uniform in composition both in depth and width as reflected in three sets of cross-section samples taken throughout the year. Conductance was run on all daily samples prior to compositing. Composite samples are made by discharge-weighted method. Composite analyses during the year are equivalent to a 1.1 adjusted complete analysis.

Remarks.--Sediment records at this station are considered fair during the year except during the period of December and January when many samples were missing and it was necessary to estimate sediment discharge guided by discharge variations or by interpolation. The records during those 2 months are considered poor. At times the observer was unable to make more than one trip a day though his instructions were to obtain two sets of samples. This station is on a regulated stream below El Vado Reservoir and all sediment originated downstream from this reservoir. The channel is sandy, but banks are fairly stable. No diversions or tributary inflow for several miles upstream from sampling site. The chemical quality was quite uniform throughout the year because of leveling effects of the reservoir.

Published and unpublished data for the 1960 water year are on file at the Albuquerque office.

John Doe
December 12, 1960

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Figure 41.—Station analysis (chemical quality and sediment) showing format and content.

SACRAMENTO RIVER BASIN

11-4525.00 CACHE CREEK AT YOLO, CALIF.

STATION ANALYSIS
(Sediment)
1959 Water Year

Equipment.--A U.S. D-49 sediment sampler is stored at the station and used from the cable provided for stream measuring. A Stevens A-35 water-stage recorder is located on the left bank upstream from U.S. Highway 99W bridge.

Sampling frequency.--Samples were collected once a day during low flow and two or more times a day on most days of discharge. All samples were depth integrated and were collected with a D-49 or USDH-48 sampler. The collection of samples and records maintained by the observer, Herman Gonzales, was fair to poor. Water-temperature observations were generally made at the time sediment samples were collected.

Concentration graph.--Most of the suspended-sediment samples consisted of three bottles, each taken at a separate vertical in the stream cross section. The samples were analyzed separately to facilitate comparison. If any one bottle seemed to be considerably different, more weight was given to the ones that seemed more reasonable. In most cases the individual bottles agreed fairly well with each other. All concentrations were plotted on a print of the gage-height graph, and a smooth graph was drawn on the basis of the plotted concentrations. The two major rises were sampled often enough to define adequately the concentration curve.

Suspended-sediment discharge computation.--The suspended-sediment discharge, in tons per day, was computed from the daily mean water discharge as determined at the stream-gaging station and the daily mean sediment concentration as determined at the sediment-measuring station. On days of rapidly changing flow conditions the graphs were subdivided and the total suspended-sediment discharge for the day was computed by averaging the suspended-sediment discharge for appropriate small intervals of the day. Streamflow data were furnished by the Sacramento Surface Water area office.

Particle size.--Twelve samples were analyzed for particle size resulting in 12 observations of particle-size gradation in the sand, silt, and clay range. The samples ranged in concentration from 12 to 7,970 ppm and water discharge from 122 to 14,000 cfs. Average results of the analyses show 16 percent of the material transported to be coarser than 62 microns and 41 percent to be finer than 4 microns. All particle-size analyses in the silt-clay range were made using distilled water, with a dispersing agent added, as the settling medium.

Remarks.--Suspended-sediment records for the year are considered fair. Water discharge records for the year are considered good. The streambed at the station is composed of sand, gravel, and cobblestones. The stream is leveed and has stable banks. Station is located on an intermittent stream.

Harry Mudboy
July 25, 1960

Figure 42.—Station analysis (sediment) showing format and content.

SACRAMENTO RIVER BASIN

11-3820. THOMES CREEK AT PASKENTA, CALIF.

LOCATION (revised).--Lat 39°52'57", long 122°33'03", in SW¼NW¼ sec.4, T.23 N., R.6 W., Tehama County, at gaging station 0.25 mile upstream from Digger Creek, and 0.3 mile upstream from highway bridge at Paskenta.
DRAINAGE AREA.--194 sq mi.
RECORDS AVAILABLE.--Chemical analyses: October 1958 to September 1967.
Water temperatures: October 1961 to September 1967.
Sediment records: October 1962 to September 1967.
EXTREMES, 1966-67.--Water temperatures: Maximum, 94°F Aug. 18, 23; minimum, freezing point Dec. 27, 28, Jan. 6.
Sediment concentrations: Maximum daily, 16,100 ppm Jan. 29; minimum daily, 1 ppm on several days.

CHEMICAL ANALYSES IN MILLIGRAMS PER LITER, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968

DATE	DIS-CHARGE (CFS)	SILICA (SIO2)	DIS-SOLVED IRON (FE)	CAL-CIUM (CA)	MAG-NE-SIUM (MG)	SODIUM (NA)	PO-TAS-SIUM (K)	BICAR-BONATE (HCO3)	CAR-BONATE (CO3)	SULFATE (SO4)	CHLO-RIDE (CL)
OCT.											
28...	2.2	19	.01	20	1.3	6.5	1.1	74	0	5.0	2.7
MAR.											
15...	3.1	18	.00	19	1.5	6.2	.7	70	0	7.0	1.9
APR.											
16...	7.2	18	--	18	1.5	6.1	.8	65	0	7.0	1.9
JUNE											
20...	8.8	20	--	11	1.0	4.8	.5	47	0	4.0	1.2
JULY											
23...	2.4	3.4	--	1.3	.1	1.1	.2	5	0	2.0	1.0
AUG.											
15...	3.1	--	--	--	--	--	--	--	--	--	--
SEPT.											
12...	1.2	21	--	18	1.5	6.8	.9	72	0	7.0	1.3

SACRAMENTO RIVER BASIN

11-3820. THOMES CREEK AT PASKENTA, CALIF.--Continued

EXTREMES, 1966-67--Continued
Sediment loads: Maximum daily, 273,000 tons Jan. 29; minimum daily, less than 0.05 ton on many days.
EXTREMES, 1961-67.--Water temperatures: Maximum, 94°F Aug. 18, 23, 1967; minimum, freezing point on several days in December and January of most years.
Sediment concentrations (1962-67): Maximum daily, 57,900 ppm Dec. 22, 1964; minimum daily, no flow Oct. 4, 1964.
Sediment loads (1962-67): Maximum daily, 5,070,000 tons Dec. 22, 1964; minimum daily, 0 ton Oct. 4, 1964.
REMARKS.--Clock stopped Apr. 14-12; temperature range, 38°F to 53°F.

CHEMICAL ANALYSES IN MILLIGRAMS PER LITER, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968

DATE	FLUO-RIDE (F)	NITRATE (NO3)	BORON (B)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	DIS-SOLVED SOLIDS (TONS PER DAY)	HARD-NESS (CA,MG)	NON-CAR-BONATE HARD-NESS	SODIUM AD-SORP-TION RATIO	SPECI-FIC COND-UCTANCE (MICRO-MHOS)	PH
OCT.											
28...	.2	.0	.02	97	.13	.58	56	0	.4	134	7.6
MAR.											
15...	.2	.1	.00	--	.12	.74	54	0	.4	137	7.9
APR.											
16...	.2	.4	.07	--	.12	1.67	51	0	.4	126	7.7
JUNE											
20...	.1	.1	.00	--	.09	1.57	32	0	.4	92	7.4
JULY											
23...	.0	--	.00	--	.01	.07	4	0	.3	14	6.4
AUG.											
15...	--	.0	--	--	--	--	--	--	--	--	--
SEPT.											
12...	.1	.5	.00	--	.13	.30	51	0	.4	133	7.5

Figure 43.—Heading and chemical-quality tabulation in annual water-quality-data report. (Heading and tabulation are on two pages that are published face to face or back to back.)

SACRAMENTO RIVER BASIN

11-3820. THOMES CREEK AT PASKENTA, CALIF.

LOCATION ~~(revised)~~.--Lat 39°52'57", long 122°33'03", in SW¼NW¼ sec.4, T.23 N., R.6 W., Tehama County, at gaging station 0.25 mile upstream from Digger Creek, and 0.3 mile upstream from highway bridge at Paskenta.

DRAINAGE AREA.--194 sq mi.

RECORDS AVAILABLE.--Chemical analyses: October 1958 to September 1968 ~~1967~~.

Water temperatures: October 1961 to September 1968 ~~1967~~.

Sediment records: October 1962 to September 1968 ~~1967~~.

EXTREMES, 1967-68 ~~1966-67~~.--Water temperatures: Maximum, 30°C ~~94°F~~ Aug. 31 ~~18~~, ~~25~~; minimum, freezing point on several days during December and January. ~~Dec. 27, 28, Jan. 6~~.

Sediment concentrations: Maximum daily, 10,700 mg/l ~~16,100 ppm~~ Jan. 14 ~~20~~; minimum daily, 1 mg/l ~~ppm~~ on many ~~several~~ days.

Sediment loads: Maximum daily, 149,000 ~~272,000~~ tons Jan. 29; minimum daily, ~~less than~~ 0.01 ~~0.05~~ ton on several ~~many~~ days.

EXTREMES, 1961-68 ~~67~~.--Water temperatures: Maximum, 34°C ~~94°F~~ Aug. 18, 23, 1967; minimum, freezing point on several days in December and January of most years.

Sediment concentrations (1962-68 ~~67~~): Maximum daily, 60,200 mg/l ~~57,000 ppm~~ Dec. 22, 1964; minimum daily, no flow Oct. 4, 1964.

Sediment loads (1962-68 ~~67~~): Maximum daily, 5,070,000 tons Dec. 22, 1964; minimum daily, 0 ton Oct. 4, 1964.

REMARKS.--~~Clock stopped Apr. 14-12; temperature range, 38°F to 63°F.~~ Chemical-quality records furnished by California Department of Water Resources. Where no maximum or minimum is shown, temperature is once-daily observation.

(make updating in red)

Figure 44.—Updated station heading.

location during the water year, water temperatures, sampling procedures, and reference to discharge records if (1) sampling site and gaging stations were at different locations or (2) discharge records were furnished by other agencies. Reference may also be made to upstream factors affecting water and sediment movement and to periods of affected or estimated record.

Periodic Observations

Sediment samples are obtained at some stations on a periodic or infrequent basis, and at a few stations, samples are obtained monthly or more frequently during the periods of storm runoff. Data obtained on an infrequent basis that cannot be used to compute daily sediment-discharge records as described in the procedure used for daily stations are tabulated on form 9-1539D as illustrated in figure 45.

Periodic observations of suspended-sediment discharge are published as daily suspended sediment, illustrated in figure 30, or as instantaneous suspended sediment, illustrated in figure 31. They also may be combined with particle-size distribution and published as illustrated in figure 34.

The data for periodic observations may be tabulated on form 9-265b in the same format as that for particle-size distribution shown in figure 2 and described in the section on "Tabulation of Size Data."

Footnotes used for periodic tabulations are standard and are the same as those used for daily tabulations. (See section on "Footnotes.") Periodic or miscellaneous concentration and particle-size data are tabulated on form 9-1593D as described in the section on "Tabulation of Size Data" (fig. 2).

Checklist for periodic records

A checklist for tabulation of periodic samples follows. The editorial rules and computation procedures are the same as those described for the similar step for daily stations.

1. Size analysis: Compute and review for proper procedures and accuracy.
2. Concentration notes: Compute and evaluate for validity and sampling technique.

Form 9-1539D (10-69)

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
Coding Form for Instantaneous Suspended Sediment and Particle Size

Type 1 Station ident number 00000000 Stream and location Sample Creek near Somewhere, U.S.A.

Methods of analysis (74-77): B, bottom withdrawal tube; C, chemically dispersed; D, decantation; N, in native water; P, pipet; S, sieve, W, in distilled water; V, visual accumulation tube.
Please do not punch the decimal point unless data appears in the field.

Date Yr	Mo	Day	Time (24 hour)	Temperature (°C)	Discharge (cfs)	Susp. sediment concentration (mg/l)	Particle size, percent finer (in millimeters) than size indicated 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	Method of analysis
69	10	11	1520	14.5	170.	95						70	74	77	96	100		S
	12	11	1400	4.0	142.	10						--	--	--	--	--	--	--
70	01	15	1000	.5	108.	12						--	--	--	--	--	--	--
	02	19	1440	7.0	224	14						--	--	--	--	--	--	--
	03	30	1105	6.0	995.	412	23	28	39	48	63	71	89	96	99	100		VPWC
	05	18	1300	11.0	595.	31						60	74	91	100			S
	07	16	1320	29.0	20.	39						--	--	--	--	--	--	--

Compiled by GP Date 10/9/70 Checked by RDB Date 10/12/70
Punched by Date Verified by Date

Figure 45.—Tabulation of periodic sediment data.

3. Particle-size analyses: Compile in chronological order on form similar to that illustrated in figure 45.
4. Water discharge:
   (a) Report water discharge for time each sample was collected if instantaneous values are published (figs. 31-35).
   (b) Report daily mean discharge if daily mean concentrations are published (figs. 29, 30).
5. Sediment discharge: Compute sediment discharge, in tons per day. Sediment discharge is equal to water discharge, in cubic feet per second, × sediment concentration, in milligrams per liter, × 0.0027. Sediment discharge is not computed if data are punched for computer processing.
6. Review for editorial and technical correctness.
7. Station description heading is not prepared for periodic records.

Combined periodic and seasonal observations

A sediment record for a station where sediment samples were collected on a periodic basis for part of the year and on a daily or more frequent basis for the remainder of the year may be compiled in two parts. This type of record may occur because of a change in station operation or because of seasonal effect on the stream discharge and sediment concentration. The periodic part of the record consists of a tabulation of samples which are collected infrequently during routine visits and which do not provide sufficient information for computation of daily sediment discharge. These samples are combined with particle-size data on the form illustrated in figure 45.

The second part of the record consists of daily discharges computed by the same procedures described previously, and the sediment-discharge worksheet (fig. 38) is completed for as many complete, consecutive months as data are available. A station description and an analysis are prepared as described for computation of records for daily stations.

Transmittal of Completed Data

The completed compilation of water-quality data includes the following items:

1. Station heading (fig. 44).
2. Chemical analyses (fig. 43).
3. Temperature tabulation (figs. 3, 4).
4. Sediment discharge:
   Daily records (fig. 38).
   Periodic records (fig. 45).
5. Particle-size distribution of suspended sediment (fig. 2).
6. Particle-size distribution of bed material (fig. 35).

Each originating office should forward the records for which they are responsible through appropriate channels to be reviewed, consolidated, and forwarded to the records center for processing. Each record submitted for publication should be designated as to publication format desired (figs. 29-35).

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☆ U.S. Government Printing Office: 1977—240-961/121