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

Figure 23, 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
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.
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 \( \times \) 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,
Computations 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 (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 28A 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. 28B), the graph is intersected only once. Thus, only two areas need be balanced, thereby sim-
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 28C the integrator line was placed on the end of the 24-hour-time period (point z) 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 28D.

Figure 28D is divided for convenience into three time intervals 0-0600, 0600-1200, and 1200-2400. Line A1-B1 establishes the mean of the first 6-hour interval at O1, at the midpoint of the interval. Likewise, A2-B2 establishes the mean of the interval 0600-1200 at O2, and A3-B3 establishes the mean of the interval 1200-2400 at O3. The mean of the first two intervals, which are equal in time, is found by placing the integrator line on O1 and O2 and marking the intersection (point C) of the line O1-O2 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 O1-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**
  - \(< 0.5\) report 0 mg/l or place leader (....) in column.
  - 0.5 - 1 report 1 mg/l.
  - 1 - 9 report one significant figure.
  - 10 - 99 report two significant figures.
  - \(\geq 100\) report three significant figures.

- **Sediment discharge**
  - \(< 0.005\) report 0 tons.
  - 0.005 - 0.01 report 0.01 ton.
  - 0.01 - 0.9 report to nearest 0.01 ton.
  - 1 - 9 report one significant figure.
  - 10 - 99 report two significant figures.
  - \(\geq 100\) 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
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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

\[ \text{milligrams per liter} = C \times \text{parts per million} \]

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](https://example.com/table2)

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<th>( C )</th>
<th>Concentration range (ppm)</th>
<th>( C )</th>
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TOTAL 260.70 -- 69.88 4479 -- 5563.63 89257 -- 9369017.0

Figure 29.—Format table 1, suspended-sediment discharge.
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### SUSPENDED-SEDIMENT DISCHARGE FOR SELECTED DAYS, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

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<th>DATE</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
<th>DATE</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
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<td>519</td>
<td>13</td>
<td>MAY 7</td>
<td>14</td>
<td>3670</td>
<td>265</td>
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<td>JAN 27, 1970</td>
<td>6.0</td>
<td>2180</td>
<td>213</td>
<td>MAY 8</td>
<td>1.9</td>
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<td>JAN 28</td>
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<td>.20</td>
<td>JUN 22</td>
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Figure 30.—Format table 2, suspended-sediment discharge for selected days.

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

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<thead>
<tr>
<th>DATE</th>
<th>TIME (HRS)</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
<th>DATE</th>
<th>TIME (HRS)</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
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<td>14</td>
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<td>DEC 10, 1969</td>
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<td>1200</td>
</tr>
<tr>
<td>JAN 12, 1970</td>
<td>1700</td>
<td>126000</td>
<td>100</td>
<td>34000</td>
<td>JAN 15, 1970</td>
<td>1545</td>
<td>14.0</td>
<td>440</td>
<td>22</td>
</tr>
<tr>
<td>JAN 14, 1970</td>
<td>1830</td>
<td>1.3</td>
<td>8</td>
<td>.03</td>
<td>JAN 18, 1970</td>
<td>1430</td>
<td>26.5</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>FEB 22, 1970</td>
<td>1200</td>
<td>15</td>
<td>3.3</td>
<td>1.2</td>
<td>FEB 26, 1970</td>
<td>0100</td>
<td>21000</td>
<td>350</td>
<td>3450</td>
</tr>
<tr>
<td>FEB 28, 1970</td>
<td>0100</td>
<td>770</td>
<td>212</td>
<td>441</td>
<td>FEB 28, 1970</td>
<td>1845</td>
<td>1800</td>
<td>3400</td>
<td>1200</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>TIME INTERVAL (HRS)</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
<th>TIME INTERVAL (HRS)</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN CONCENTRATION (MG/L)</th>
<th>SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL 27.... 2</td>
<td>1340</td>
<td>41000</td>
<td>12400</td>
<td>JUL 28.... 3</td>
<td>400</td>
<td>5700</td>
<td>770</td>
</tr>
<tr>
<td>JUL 27.... 2</td>
<td>944</td>
<td>30000</td>
<td>6370</td>
<td>JUL 28.... 4</td>
<td>278</td>
<td>3600</td>
<td>450</td>
</tr>
<tr>
<td>JUL 28.... 2</td>
<td>730</td>
<td>21000</td>
<td>3450</td>
<td>JUL 28.... 5</td>
<td>306</td>
<td>11600</td>
<td>12200</td>
</tr>
</tbody>
</table>

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

### TOTAL SEDIMENT DISCHARGE, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME (CPS)</th>
<th>MEAN TEMPERATURE (°C)</th>
<th>MEAN DISCHARGE (CFS)</th>
<th>MEAN SEDIMENT CONCENTRATION (MG/L)</th>
<th>MEAN SEDIMENT DISCHARGE (TONS/DAY)</th>
<th>TOTAL SEDIMENT DISCHARGE (TONS/DAY)</th>
<th>WIDTH (FT)</th>
<th>MEAN DEPTH (FT)</th>
<th>MEAN VELOCITY (FPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEC 10, 1969</td>
<td>1800</td>
<td>12.0</td>
<td>1400</td>
<td>1200</td>
<td>4540</td>
<td>4590</td>
<td>30.3</td>
<td>8.5</td>
<td>4.00</td>
</tr>
<tr>
<td>DEC 30, 1969</td>
<td>1645</td>
<td>14.0</td>
<td>440</td>
<td>22</td>
<td>26</td>
<td>33</td>
<td>25</td>
<td>6.6</td>
<td>2.9</td>
</tr>
<tr>
<td>JUN 12, 1970</td>
<td>1430</td>
<td>26.5</td>
<td>120</td>
<td>200</td>
<td>65</td>
<td>70</td>
<td>10.2</td>
<td>5</td>
<td>3.2</td>
</tr>
<tr>
<td>JUN 14, 1970</td>
<td>0900</td>
<td>28.0</td>
<td>1.6</td>
<td>25</td>
<td>.11</td>
<td>.17</td>
<td>1.8</td>
<td>.2</td>
<td>.45</td>
</tr>
<tr>
<td>JUN 15, 1970</td>
<td>1200</td>
<td>28.5</td>
<td>12</td>
<td>30</td>
<td>.97</td>
<td>.17</td>
<td>2.0</td>
<td>.6</td>
<td>.50</td>
</tr>
<tr>
<td>JUN 16, 1970</td>
<td>1300</td>
<td>28.0</td>
<td>.88</td>
<td>15</td>
<td>.04</td>
<td>.04</td>
<td>1.5</td>
<td>.1</td>
<td>.2</td>
</tr>
</tbody>
</table>

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

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

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.
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

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

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 im-
proved, 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-
COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

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 the 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

<table>
<thead>
<tr>
<th>Time interval (col. 1)</th>
<th>Gage height (ft.)</th>
<th>Shift correction (ft.)</th>
<th>Water discharge, cfs (4)</th>
<th>Sediment concentration, mg/l (5)</th>
<th>Interval X concentration (col. 6)</th>
<th>Computed sediment discharge, tons/interval (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4.17</td>
<td>0</td>
<td>174</td>
<td>8</td>
<td>144.29</td>
<td>1,448</td>
</tr>
<tr>
<td>2</td>
<td>4.32</td>
<td>0</td>
<td>234</td>
<td>80</td>
<td>18,250</td>
<td>240</td>
</tr>
<tr>
<td>2</td>
<td>4.57</td>
<td>0</td>
<td>356</td>
<td>80</td>
<td>28,512</td>
<td>360</td>
</tr>
<tr>
<td>2</td>
<td>4.66</td>
<td>0</td>
<td>403</td>
<td>100</td>
<td>40,348</td>
<td>520</td>
</tr>
<tr>
<td>1</td>
<td>4.85</td>
<td>0</td>
<td>498</td>
<td>188</td>
<td>8,889</td>
<td>1,185</td>
</tr>
<tr>
<td>1</td>
<td>5.75</td>
<td>0</td>
<td>1,210</td>
<td>650</td>
<td>742,900</td>
<td>9,835</td>
</tr>
<tr>
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<td>0</td>
<td>2,520</td>
<td>1,350</td>
<td>17,100,000</td>
<td>21,930</td>
</tr>
<tr>
<td>1</td>
<td>7.65</td>
<td>0</td>
<td>3,710</td>
<td>2,350</td>
<td>36,510,000</td>
<td>46,410</td>
</tr>
<tr>
<td>1</td>
<td>8.10</td>
<td>0</td>
<td>4,760</td>
<td>3,250</td>
<td>43,910,000</td>
<td>56,810</td>
</tr>
<tr>
<td>1</td>
<td>8.20</td>
<td>0</td>
<td>5,380</td>
<td>4,050</td>
<td>53,980,000</td>
<td>68,810</td>
</tr>
<tr>
<td>1</td>
<td>8.53</td>
<td>0</td>
<td>6,490</td>
<td>6,250</td>
<td>77,090,000</td>
<td>96,780</td>
</tr>
<tr>
<td>1</td>
<td>8.62</td>
<td>0</td>
<td>5,490</td>
<td>6,950</td>
<td>64,480,000</td>
<td>83,210</td>
</tr>
<tr>
<td>1</td>
<td>8.58</td>
<td>0</td>
<td>6,080</td>
<td>6,550</td>
<td>80,400,000</td>
<td>104,210</td>
</tr>
<tr>
<td>1</td>
<td>8.47</td>
<td>0</td>
<td>5,650</td>
<td>5,050</td>
<td>53,980,000</td>
<td>68,810</td>
</tr>
<tr>
<td>1</td>
<td>8.57</td>
<td>0</td>
<td>5,300</td>
<td>3,950</td>
<td>39,980,000</td>
<td>52,970</td>
</tr>
<tr>
<td>1</td>
<td>8.18</td>
<td>0</td>
<td>4,920</td>
<td>3,500</td>
<td>34,980,000</td>
<td>44,940</td>
</tr>
</tbody>
</table>

| Total                  | 144.29           | —                     | —                         | —                               | 43,648                        | 520                                          |
| Weighted mean          | 6.01             | —                     | 2,260                     | 43,648                          | 25,400                        | —                                            |

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

<table>
<thead>
<tr>
<th>Time interval (hr)</th>
<th>Divisor d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8,880</td>
</tr>
<tr>
<td>2</td>
<td>4,444</td>
</tr>
<tr>
<td>3</td>
<td>2,963</td>
</tr>
<tr>
<td>4</td>
<td>2,222</td>
</tr>
<tr>
<td>5</td>
<td>1,778</td>
</tr>
<tr>
<td>6</td>
<td>1,481</td>
</tr>
<tr>
<td>7</td>
<td>1,270</td>
</tr>
<tr>
<td>8</td>
<td>1,111</td>
</tr>
<tr>
<td>9</td>
<td>987.6</td>
</tr>
<tr>
<td>10</td>
<td>898.9</td>
</tr>
<tr>
<td>11</td>
<td>808.1</td>
</tr>
<tr>
<td>12</td>
<td>740.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time interval (hr)</th>
<th>Divisor d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8,880</td>
</tr>
<tr>
<td>2</td>
<td>4,444</td>
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<tr>
<td>3</td>
<td>2,963</td>
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<td>4</td>
<td>2,222</td>
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<td>5</td>
<td>1,778</td>
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<tr>
<td>6</td>
<td>1,481</td>
</tr>
<tr>
<td>7</td>
<td>1,270</td>
</tr>
<tr>
<td>8</td>
<td>1,111</td>
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<td>9</td>
<td>987.6</td>
</tr>
<tr>
<td>10</td>
<td>898.9</td>
</tr>
<tr>
<td>11</td>
<td>808.1</td>
</tr>
<tr>
<td>12</td>
<td>740.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interval X concentration (col. 6)</th>
<th>Computed sediment discharge, tons/interval (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>174 X 8</td>
<td>1,448</td>
</tr>
<tr>
<td>4,920 X 3,500</td>
<td>1,940</td>
</tr>
</tbody>
</table>

Method 1: Using daily mean gage height and daily mean water discharge, the daily mean concentration may be computed by dividing the sum of the concentration column of the sediment-discharge sheet, which is computed by dividing the sum of the concentration column by the time, into the product of the daily mean water discharge and the daily mean concentration. The calculation for periods divided into 24 intervals may be simplified by using the divisor, d. If this is done, the time interval is divided into 24 equal parts, and the concentration column is divided by the divisor, d. Values of d given in footnote 1, are: t = 24, c = 0.0027, and T = 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:

\[
\text{tons per interval} = \frac{\text{col. 4} \times \text{col. 5}}{d} = \frac{174 \times 8}{1,448} = 0.94
\]

\[
\frac{4,920 \times 3,500}{8,889} = 1,940.
\]
COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

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 6 a.m. (0500 hrs). The second interval, of 3.6 hours, is one-half the time from midnight to 6 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).

<table>
<thead>
<tr>
<th>Clock time (hrs)</th>
<th>Time interval (hrs)</th>
<th>Gage height (ft)</th>
<th>Shift correction (ft)</th>
<th>Water discharge (cfs)</th>
<th>Sediment concentration (mg/l)</th>
<th>Interval x concentration (col. 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>2.5</td>
<td>4.17</td>
<td>0</td>
<td>174</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>0500</td>
<td>3.5</td>
<td>4.19</td>
<td>0</td>
<td>182</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>0700</td>
<td>2.0</td>
<td>4.32</td>
<td>0</td>
<td>234</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>0900</td>
<td>2.0</td>
<td>4.60</td>
<td>0</td>
<td>370</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>1100</td>
<td>1.5</td>
<td>4.67</td>
<td>0</td>
<td>408</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>1200</td>
<td>1.0</td>
<td>4.73</td>
<td>0</td>
<td>442</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>1300</td>
<td>1.0</td>
<td>5.22</td>
<td>0</td>
<td>744</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>1400</td>
<td>1.0</td>
<td>6.22</td>
<td>0</td>
<td>1,740</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>1500</td>
<td>1.0</td>
<td>7.20</td>
<td>0</td>
<td>3,120</td>
<td>1,900</td>
<td>1,900</td>
</tr>
<tr>
<td>1600</td>
<td>1.0</td>
<td>8.28</td>
<td>0</td>
<td>4,220</td>
<td>2,850</td>
<td>2,850</td>
</tr>
<tr>
<td>1700</td>
<td>1.0</td>
<td>8.50</td>
<td>0</td>
<td>5,090</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>1800</td>
<td>1.0</td>
<td>8.50</td>
<td>0</td>
<td>5,620</td>
<td>5,300</td>
<td>5,300</td>
</tr>
<tr>
<td>1900</td>
<td>1.0</td>
<td>8.50</td>
<td>0</td>
<td>5,750</td>
<td>7,000</td>
<td>7,000</td>
</tr>
<tr>
<td>2000</td>
<td>1.0</td>
<td>8.60</td>
<td>0</td>
<td>5,840</td>
<td>6,400</td>
<td>6,400</td>
</tr>
<tr>
<td>2100</td>
<td>1.0</td>
<td>8.54</td>
<td>0</td>
<td>5,710</td>
<td>4,950</td>
<td>4,950</td>
</tr>
<tr>
<td>2200</td>
<td>1.0</td>
<td>8.41</td>
<td>0</td>
<td>5,430</td>
<td>4,200</td>
<td>4,200</td>
</tr>
<tr>
<td>2300</td>
<td>1.0</td>
<td>8.31</td>
<td>0</td>
<td>5,200</td>
<td>3,700</td>
<td>3,700</td>
</tr>
<tr>
<td>2400</td>
<td>.5</td>
<td>8.10</td>
<td>0</td>
<td>4,760</td>
<td>3,300</td>
<td>1,650</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>144.365</td>
<td>—</td>
<td>54,168</td>
<td>—</td>
<td>43,848</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>—</td>
<td>6.02</td>
<td>—</td>
<td>2,260</td>
<td>—</td>
<td>1,830</td>
</tr>
</tbody>
</table>

Computed sediment-discharge procedure:

Total interval = \( T = \sum (\text{col. 2}) = 24 \)

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

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

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

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

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

The 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 indi-
cates 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.
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:

<table>
<thead>
<tr>
<th>Mean discharge (cfs)</th>
<th>Mean concentration (mg/l)</th>
<th>Suspended sediment tons per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>1.8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3.7</td>
<td>...</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>...</td>
<td>0</td>
</tr>
</tbody>
</table>

(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 x mean concentration x 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
TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS

EXPLANATION
WATER YEAR

1963
1964
1965

Figure 39.—Relation between daily suspended-sediment discharge and water discharge, Thames 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.


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
TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS

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

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

Equipment. -- Stevens A-35 recorder with manometer, and tipping bucket rain gage.
Vekeler Thermograph, in steel shield. 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-64.

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 landslide common to the area. The soils varies from pastures and sagebrush to heavy timber. The timber has been cut 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 Vekeler 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.

Stage-height record. -- Record complete except periods January 4-6, January 20 to February 2-4, 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 gage of sage to be 901.58 ft above mean sea level, datum of 1929, supplementary adjustment of 1956. The office elevation was found to be 3.26 ft and all outside staffs to be correct within 0.31 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. 115-110, were made during the current year. Measurement No. 123 made by an inexperienced hydrometeor 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 13. 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 remaining 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.

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.

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

Concentrations were plotted on a print of the stage-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 20, 1966

Figure 40. -- Station analysis (water, sediment, temperature, and rainfall) showing format and content.
COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

RIO GRANDE BASIN
RIO GRANDE NEAR ARROYO, N. MEX. 6-2875.

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 gauging 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 DN-48 sampler. (Estimate percentage of reported data collected by each.) Three samples were taken for each sec, at 1/3, 1/2, and 2/3 of distance across the stream. An integrated sample for chemical analysis was collected at midsection about 0800 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 at gaging station 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 verticle. 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 basis of the points. Daily mean concentrations were computed from the average of the cross-section samples. Daily sediment discharge was computed by multiplying product of adjusted daily mean discharge and mean concentration by factor 0.0097. 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 calculated 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 20, September 10, and September 20. Analyses were made, but the data were not listed.

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 computing. 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 these 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

Figure 41.--Station analysis (chemical quality and sediment) showing format and content.
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 leved and has stable banks. Station is located on an intermittent stream.

Harry Mudboy
July 25, 1960
COMPUTATION OF FLUVIAL-SEDIMENT DISCHARGE

SACRAMENTO RIVER BASIN

11-3820. THOMES CREEK AT PASSENGA, CALIF.

LOCATION (revised).--Lat 39°25'57", long 122°31'05", in SW 1/4 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.


Sediment concentrations: Maximum daily, 16,100 ppm Jan. 29; minimum daily, 1 ppm on several days.


REMARKS.--Clock stopped Apr. 14, 12; temperature range, 36°F to 53°F.

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

<table>
<thead>
<tr>
<th>DATE</th>
<th>DISCHARGE (CFS)</th>
<th>SILICA (SIO2)</th>
<th>FLUORIDE (P)</th>
<th>CARBONATE BICARBONATE SULFATE (SO4)</th>
<th>CALCIUM (CA)</th>
<th>MAGNESIUM (MG)</th>
<th>SODIUM (NA)</th>
<th>POTASSIUM (K)</th>
<th>BORON (BO)</th>
<th>NITRATE (N)</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct.</td>
<td>28... 2.2</td>
<td>19</td>
<td>0.02</td>
<td>1.3</td>
<td>6.5</td>
<td>1.1</td>
<td>74</td>
<td>0</td>
<td>5</td>
<td>2.3</td>
<td>7.6</td>
</tr>
<tr>
<td>May</td>
<td>15... 3.1</td>
<td>18</td>
<td>0.00</td>
<td>1.5</td>
<td>6.2</td>
<td>0.7</td>
<td>70</td>
<td>0</td>
<td>7.4</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Apr.</td>
<td>16... 7.2</td>
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<td>--</td>
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<td>6.1</td>
<td>0.6</td>
<td>65</td>
<td>0</td>
<td>7.0</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>JUNE</td>
<td>26... 8.8</td>
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<td>--</td>
<td>1.0</td>
<td>4.9</td>
<td>0.5</td>
<td>47</td>
<td>0</td>
<td>4.0</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>JULY</td>
<td>23... 2.4</td>
<td>3.4</td>
<td>--</td>
<td>1.3</td>
<td>1.1</td>
<td>0.2</td>
<td>5</td>
<td>0</td>
<td>2.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Aug.</td>
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<td>--</td>
<td>--</td>
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<td>--</td>
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<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>SEPT.</td>
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<td>--</td>
<td>1.5</td>
<td>6.8</td>
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<td>72</td>
<td>0</td>
<td>7.0</td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

SACRAMENTO RIVER BASIN

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

EXTREME, 1966-67--Continued

Sediment loads: Maximum daily, 273,000 tons Jan. 29; minimum daily, less than 0.05 ton on many days.

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


REMARKS.--Clock stopped Apr. 14, 12; temperature range, 36°F to 53°F.

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

<table>
<thead>
<tr>
<th>DATE</th>
<th>DISCHARGE (CFS)</th>
<th>SILICA (SIO2)</th>
<th>FLUORIDE (P)</th>
<th>CARBONATE BICARBONATE SULFATE (SO4)</th>
<th>CALCIUM (CA)</th>
<th>MAGNESIUM (MG)</th>
<th>SODIUM (NA)</th>
<th>POTASSIUM (K)</th>
<th>BORON (BO)</th>
<th>NITRATE (N)</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct.</td>
<td>28... 2.2</td>
<td>19</td>
<td>0.02</td>
<td>1.3</td>
<td>6.5</td>
<td>1.1</td>
<td>74</td>
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<td>--</td>
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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.)
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.
3. Particle-size analysis: 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, \times sediment concentration, in milligrams per liter, \times 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 rou-
tine 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).

**Selected References**


— 1968, General procedure for gaging streams:


U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1940, Field practice and equipment used in sampling suspended sediment, Report 1 of A study of methods used in measurement and analysis of sediment loads in streams: 175 p.

———1940, Equipment used for sampling bedload and bed material, Report 2 of A study of methods used in measurement and analysis of sediment loads in streams: 57 p.


———1941, Methods of analyzing sediment samples, Report 4 of A study of methods used in measurement and analysis of sediment loads in streams: 203 p.

———1941, Laboratory investigations of suspended-sediment samplers, Report 5 of A study of methods used in measurement and analysis of sediment loads in streams: 99 p.


— 1948, Measurement of the sediment discharge of streams, Report 8 of A study of methods used in measurement and analysis of sediment loads in streams: 92 p.


