Investigations of Sediment Transportation Middle Loup River At Dunning, Nebraska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1476

Prepared in cooperation with the U. S. Bureau of Reclamation as part of a program of the Department of the Interior for development of the Missouri River basin

Investigations of Sediment Transportation Middle Loup River At Dunning, Nebraska

With APPLICATION OF DATA FROM TURBULENCE FLUME

By D. W. HUBBELL *and* D. Q. MATEJKA

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By D. W. HUBBELL and D. Q. MATEJKA

ABSTRACT

An investigation of fluvial sediments of the Middle Loup River at Dunning, Nebr., was begun in 1946 and expanded in 1949 to provide information on sediment transportation. Construction of an artificial turbulence flume at which the total sediment discharge of the Middle Loup River at Dunning, Nebr., could be measured with suspended-sediment sampling equipment was completed in 1949. Since that time, measurements have been made at the turbulence flume and at several selected sections in a reach upstream and downstream from the flume.

The Middle Loup River upstream from Dunning traverses the sandhills region of north-central Nebraska and has a drainage area of approximately 1,760 square miles. The sandhills are underlain by the Ogallala formation of Tertiary age and are mantled by loess and dune sand. The topography is characterized by northwest-trending sand dunes, which are stabilized by grass cover. The valley floor upstream from Dunning is generally about half a mile wide, is about 80 feet lower than the uplands, and is composed of sand that was mostly stream deposited. The channel is defined by low banks. Bank erosion is prevalent and is the source of most of the sediment load. The flow originates mostly from ground-water accretion and varies between about 200 and 600 cfs (cubic feet per second). Measured suspended-sediment loads vary from about 200 to 2,000 tons per day, of which about 20 percent is finer than 0.062 millimeter and 100 percent is finer than 0.50 millimeter. Total sediment discharges vary from about 500 to 3,500 tons per day, of which about 10 percent is finer than 0.062 millimeter, about 90 percent is finer than 0.50 millimeter, and about 98 percent is finer than 2.0 millimeters. The measured suspended-sediment discharge in the reach near Dunning averages about one-half of the total sediment discharge as measured at the turbulence flume.

This report contains information collected during the period October 1, 1948, to September 30, 1952. The information includes sediment discharges; particle-size analyses of total load, of measured suspended sediment, and of bed material; water discharges and other hydraulic data for the turbulence flume and the selected sections.

Sediment discharges have been computed with several different formulas, and insofar as possible, each computed load has been compared with data from the turbulence flume. Sediment discharges computed with the Einstein procedure did not agree well, in general, with comparable measured loads. However, a satisfactory representative cross section for the reach could not be determined with the cross sections that were selected for this investigation. If the computed cross section was narrower and deeper than a representative cross section for the reach, computed loads were high; and if the computed cross section was wider and shallower than a representative cross section for the reach, computed loads were low.

Total sediment discharges computed with the modified Einstein procedure compared very well with the loads of individual size ranges and the measured total loads at the turbulence flume. Sediment discharges computed with the Straub equation averaged about twice the measured total sediment discharge at the turbulence flume. Bed-load discharges computed with the Kalinske equation were of about the right magnitude; however, high computed loads were associated with low total loads, low unmeasured loads, and low concentrations of measured suspended sediment coarser than 0.125 millimeter. Bed-load discharges computed with the Schoklitsch equation seemed somewhat high; about one third of the computed loads were slightly higher than comparable unmeasured loads. Although, in general, high computed discharges with the Schoklitsch equation were associated with high measured total loads, high unmeasured loads, and high concentrations of measured suspended sediment coarser than 0.125 millimeter, the trend was not consistent. Bed-load discharges computed with the Meyer-Peter and Müller equation varied progressively with changes in several hydraulic parameters, compared reasonably with total and unmeasured sediment discharges, and increased fairly consistently as the concentration of measured suspended sediment coarser than 0.125 millimeter increased.

Size analyses indicated that bed material varies both laterally and vertically. Composites of at least five samples, but preferably more, seem to be necessary for an adequate determination of the bed-material size distribution. The size distribution for the top 1 inch or so of the bed is generally finer than that for the top 6 inches. The bed-material size distribution determined from 6-inch core samples does not seem to vary with either water temperature or water discharge.

Values of z_1, the measured exponent for the equation of the vertical distribution of suspended sediment, that are less than about 0.7 are generally larger than associated z's that are determined from the theoretical equation. Values of z_1 varied inversely with about the 0.6 power of k, the Von Karman coefficient for turbulent exchange, throughout a range for k of 0.4–4.00. Also, z_1 can be expressed roughly as a power of z; the power depends on which system of fall velocities is used.

INTRODUCTION

The investigation of fluvial sediments of the Middle Loup River at Dunning, Nebr. (fig. 1), was begun on April 11, 1946. This investigation was undertaken at the request of and in cooperation with the U. S. Bureau of Reclamation and was made as a part of the program of the Department of Interior for the development of the Missouri River basin. Initially, suspended-sediment measurements were made at a partly contracted section. In 1948, at the request of the Bureau of Reclamation, an artificial turbulence flume at which the total sediment discharge of the Middle Loup River could be measured was designed and constructed. After the turbulence flume was completed in May 1949, the investigation was expanded to include periodic measurements in an alluvial reach upstream and downstream from the flume. In this reach, measurements were made at six river sections (fig. 2), which represent different channel configurations, in order to relate the characteristics of the flow and sediment with sediment discharge. However, no more than five sections were used during the same period of time; consequently, the periods of record

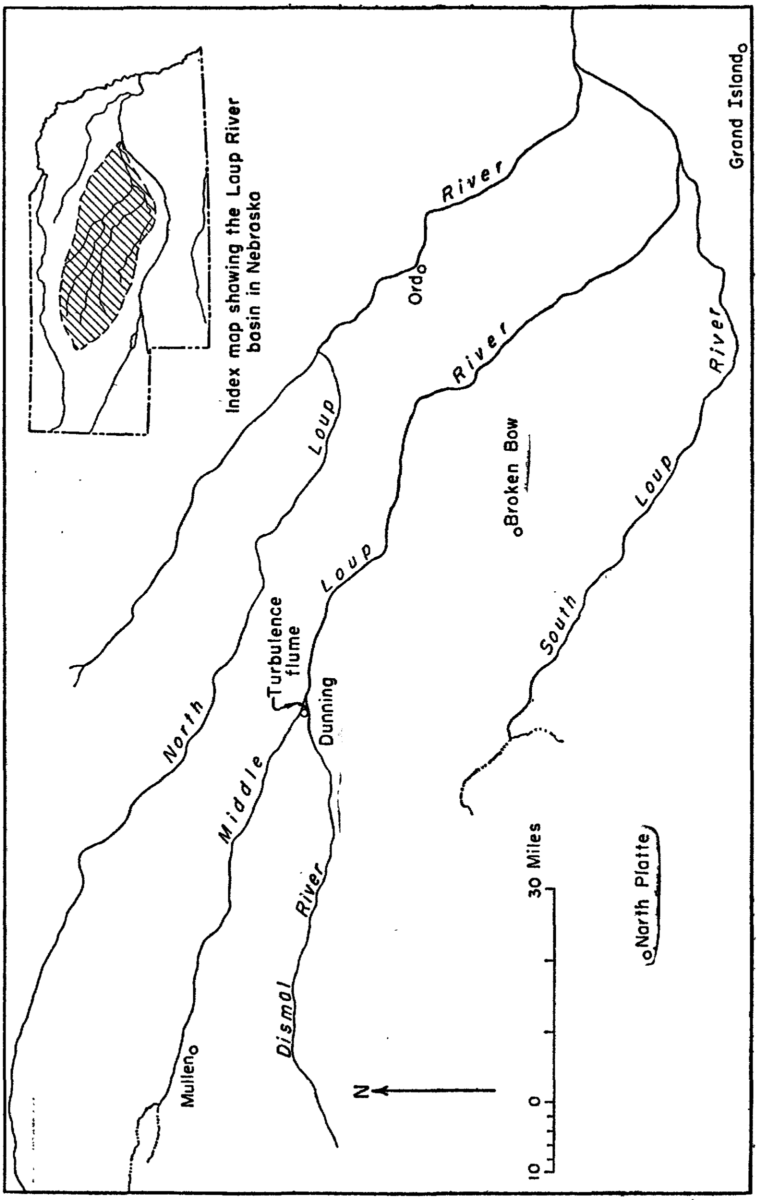


FIGURE 1.—Map of the Loup River basin, Nebraska.

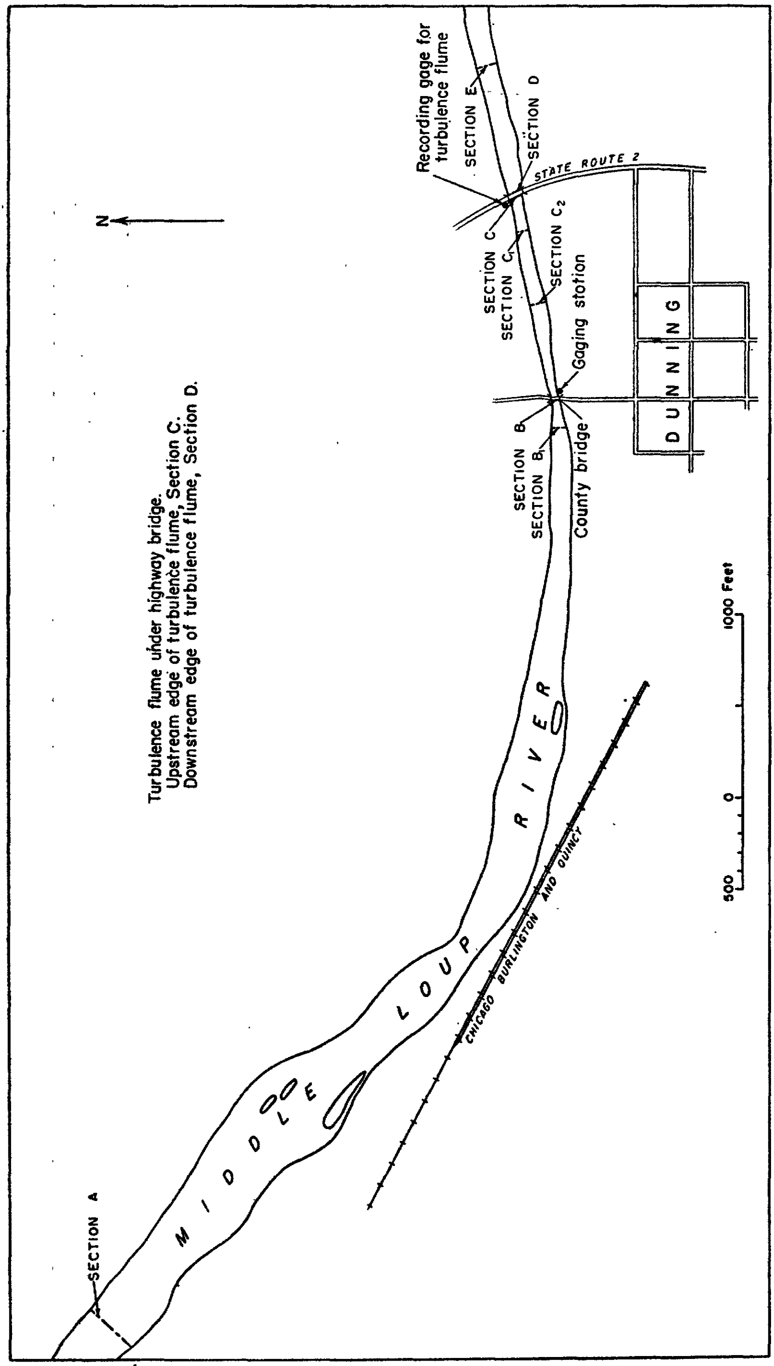


FIGURE 2.—Reach of the Middle Loup River near Dunning, Nebr.

for the different sections varied. After March 20, 1950, daily measurements of suspended-sediment discharge were discontinued at the partly contracted section, and the daily total sediment discharge was measured at the flume.

This report was prepared to summarize the data from this investigation and to show the results of sediment-transport studies that are based on these data—particularly comparisons of measured sediment discharges with sediment discharges computed from formulas. Specifically, the report contains a summary of sediment data and associated hydraulic information for the turbulence flume and the six river sections during the period October 1, 1948, to September 30, 1952; computations of sediment discharge by several different methods, including a modification of the Einstein functions (Colby and Hembree, 1955); evaluations of several methods for computing sediment discharge; and a discussion of some aspects of sediment transport on the basis of the field data.

Included in this report are data presented by Vice and Serr (written communication) for the period August 17 to September 14, 1949, some computations of sediment discharge by E. L. Pemberton in 1950 (written communication), and some of the information from P. C. Benedict, M. L. Albertson, and D. Q. Matejka (1955).

DEVELOPMENT OF THE TURBULENCE FLUME

The turbulence flume was constructed to provide information on total sediment discharge. Such information was needed for determining accurately the annual total sediment discharge of the Middle Loup River at Dunning, Nebr.; for evaluating formulas and methods that could be used to compute sediment discharge at other locations in the Loup River basin; for modifying or developing, if necessary, formulas or methods that compute sediment discharge; for studying various sediment and hydraulic relationships; and for designing proposed river structures in the Loup River basin.

The idea that a structure could be designed so that it would produce sufficient turbulence to suspend the total sediment discharge of a stream prompted the development of the turbulence flume. Consideration was given at first to a modified Parshall flume and later to a straight-sided flume having vertical baffles or water jets in the floor. The flume having vertical baffles was selected as the most feasible design because it was independent of mechanical operation and would only affect the stream regime initially.

Model studies of the flume and subsequent preliminary designs for the prototype were made by the Civil Engineering Department, N. A. Christensen, Dean, and M. L. Albertson, Head of Fluid Mechanics Research, through the Research Foundation, Colorado

Agricultural and Mechanical College, Fort Collins, Colo. P. C. Benedict, W. M. Borland, Thomas Maddock, and J. H. Honnold conferred frequently with representatives of the college during the model studies.

R. E. Oltman prepared the structural design and the construction plan and specifications for the prototype. The turbulence flume was constructed by the U. S. Geological Survey under the supervision of R. E. Oltman, who was succeeded by R. B. Vice. Permission was granted by the Nebraska Department of Roads and Irrigation for the construction of the flume beneath the bridge on State Route 2 at Dunning, Nebr.

The characteristics of the Middle Loup River at Dunning were especially favorable for the construction and operation of a turbulence flume. The stream is representative of other streams in the Loup River basin; the streamflow, which is derived mostly from ground water, remains fairly constant throughout the year; the stream bed consists almost entirely of sands; the stream channel for about 1,500 feet upstream from the flume site is straight and has a uniform and nearly constant cross section; the reach at Dunning was downstream from a proposed reservoir and upstream from a proposed diversion structure; and a U. S. Geological Survey stream-gaging station was already in operation at Dunning.

PERSONNEL AND ACKNOWLEDGMENTS

The part of the investigation by the Geological Survey was under the supervision of P. C. Benedict, regional engineer. Operation of the flume and of the selected river sections was planned by the personnel of the Geological Survey and by W. M. Borland and K. B. Schroeder, Hydrology Branch, and J. H. Honnold, O. H. Hansen, and J. F. Mayne, Region 7, of the Bureau of Reclamation. The collection of basic data was under the supervision of R. B. Vice, of the Geological Survey. E. F. Serr III, and later D. Q. Matejka, of the Geological Survey, were in charge of fieldwork. J. F. Mayne assigned engineers from the area office at Grand Island, Nebr., to help with fieldwork from August 17 to September 14, 1949. K. B. Schroeder supervised the Bureau of Reclamation personnel who computed some sediment discharges with the modified Einstein procedure. Mean daily and certain other water discharge data were furnished by D. D. Lewis, district engineer of the Geological Survey.

BASIC INFORMATION

In this part of the report, the turbulence flume and the six selected river sections are described, and the basic data are discussed. In addition, lateral distributions of stream velocity, of stream depth, and of measured suspended-sediment concentration as well as vertical distributions of velocity and of measured suspended sediment are shown. Water- and sediment-discharge measurements, water temperatures at times of measurements, and water-surface slopes are given in table 1. Data from cross-section soundings are given in table 2. Particle-size analyses of measured suspended sediment, bed material, and point-integrated samples are given in tables 3, 4, and 5, respectively. Point velocities given in tables of particle-size analyses and shown in vertical distributions are nozzle velocities, which are computed from the time required to accumulate the sample, the volume of the sample, and the cross-sectional area of the nozzle opening.

DEFINITIONS

To help clarify a few general terms used in sedimentology and some specific terms used in this report, definitions and a brief discussion on various systems of nomenclature are given.

Sediment particles move by sliding or rolling, by skipping (saltation), and in suspension. Ordinarily, large heavy particles move by rolling or sliding, and small light particles move by saltation and in suspension. However, the mode of movement of any particle depends not only on the size of a particle but also on other physical characteristics of the particle and on the forces exerted on the particle. Therefore, many particles probably move by all the modes of transport rather than by only one mode. Quantitatively, the rate of sediment movement by each mode is probably fairly constant for any sustained flow condition.

Most existing sediment-discharge formulas have been developed for computing only some part of the total sediment discharge or only the discharge of the sediment that is moved by one of the modes of transport. As a result, various systems of nomenclature have been used to distinguish between the parts of the total sediment discharge. Usually, the total sediment load is divided into bed load and suspended load, and the saltation load is considered to be either insignificant or a part of the bed load and the suspended load. Bed load, sometimes called surface creep, is the moving sediment that is in contact with the bed or that is very near the bed; thus, bed load includes all sliding and rolling sediment and some skipping sediment. The suspended load includes all suspended sediment and some skipping sediment.

Most bed-load formulas are based on the theory that particles are set in motion if the forces exerted on the particles are sufficient to lift the particles from the bed and (or) to overcome the frictional resistance between the particles and the bed. However, the concept of a shear or tractive force created by the component of fluid weight in the direction of flow has been adopted as a measure of the forces by some investigators, whereas physical characteristics of the boundary and various flow parameters have been considered to be the measure by other investigators.

Suspended-sediment formulas are based on the turbulence-suspension theory, which explains the phenomena of sediment suspension by fluid turbulence.

Einstein (1950) has divided the total sediment load into wash load and bed-material load. Wash load is composed of the particles that, for given hydraulic conditions, are not in significant quantities in the bed. This load is washed through the channel in nearly continuous suspension. Bed-material load is the part of the load that is picked up from the bed and that is readily returned to the bed. The term "bed-material load" does not imply a mode of movement, for bed-material load is conveyed as both bed load and suspended load. Einstein has defined bed load as the sediment that moves through the bed layer, a layer 2 grain diameters thick, above the nonmoving bed.

The total sediment load may be divided also into measured sediment discharge and unmeasured sediment discharge. Neither of these discharges is intended to pertain to any particular mode of movement; however, measured sediment discharge is usually composed of only suspended sediment and, therefore, is often called measured suspended-sediment load. Measured sediment discharge is computed from the measured suspended-sediment concentration. Because equipment currently available for sampling suspended sediment cannot collect water-sediment mixture close to the bed, not all the suspended sediment is represented in the samples. Unmeasured sediment discharge is the difference between the total sediment discharge and the measured sediment discharge; it includes all sliding or rolling, usually all skipping, and some suspended-sediment particles—in other words, all bed-load discharge and some suspended-sediment discharge.

Some of the specific terms in this report are defined as follows:

Fluvial sediment is sediment that is transported by, is suspended in, or has been deposited from water.

Water discharge is the rate of flow of a stream and includes the fluvial sediment and dissolved solids that are transported in the water.

Suspended sediment is the sediment that at any given time is moving in suspension in water and is maintained in suspension by the upward components of turbulent currents or by colloidal suspension.

Depth-integrated sediment sample is a water-sediment mixture collected in a sampler that moves vertically at a constant transit rate and that admits the mixture at a velocity about equal to the stream velocity at every point of its travel. Depth-integrating samplers now in general use are the U. S. DH–48, U. S. D–43, U. S. D–49, and U. S.

P–46; the U. S. P–46 sampler is designed for point integrating but can be used for depth integrating. These samplers normally collect water-sediment mixture only from the surface to about 0.3, 0.4, 0.4, and 0.4 foot, respectively, above the stream bed.

Point-integrated sediment sample is a water-sediment mixture accumulated continuously during a given period in a sampler that is held as nearly as possible at a fixed point and that admits the water-sediment mixture at a velocity about equal to the instantaneous stream velocity at the point. The U. S. P–46 and the U. S. DH–48 are now in general use as point-integrating samplers; the U. S. DH–48 sampler is designed for depth integrating but, with certain physical modification and (or) sampling techniques, can be used for point integrating.

Measured suspended sediment is the part of the total quantity of suspended sediment that is represented by samples collected with suspended-sediment samplers. A sediment sample normally represents the suspended sediment for a limited depth and a limited width of the cross section. For a depth-integrated sample, the limited depth is from the water surface to the lowest point of collection. Samples from several verticals are required for representation across the entire width.

Sediment concentration is the ratio of the weight of sediment to the weight of water-sediment mixture, in parts per million. A part per million is a unit weight of sediment in a million unit weights of water-sediment mixture.

Mean concentration is a composite of the concentrations at different points of flow and is obtained by weighting the concentration at each point with the stream velocity at that point. Therefore, the concentration of a depth-integrated sample or samples is a mean concentration.

Measured suspended-sediment concentration is the mean concentration of the measured suspended sediment.

Sampling zone or sampled zone is that part of a cross section through which the measured suspended sediment moves. For this report, sampling zone refers to the entire width.

Measured suspended-sediment discharge or load is a rate of sediment movement and is computed as the product of the measured suspended-sediment concentration, the total water discharge, and a constant for converting the units to a weight per unit time, generally tons per day. Because the total water discharge is used in the computation, the measured suspended-sediment discharge includes not only the discharge of suspended sediment in the sampled zone but also a part of the discharge of suspended sediment in the unsampled zone.

Suspended-sediment discharge measurement is a determination of suspended-sediment discharge that is made from sufficient suspended-sediment samples at a cross section to define the mean concentration within the sampled zone and from an adequately determined water discharge.

Bed load is the sediment that moves along in essentially continuous contact with the stream bed.

Bed-load discharge is the weight of bed load passing a section in a unit of time and is generally expressed in tons per day.

Bed-material discharge or load is the part of the total sediment load consisting of particles whose sizes are the same as those present in significant quantities in the bed. In this report, bed-material load includes all material coarser than the largest standard separation size (see headings on table 4) at which no more than 10 percent of the bed material is finer.

Wash load is the part of the total sediment load consisting of particles whose sizes are finer than those present in significant quantities in the bed. In this report, wash load includes all sizes finer than the largest standard separation size (see headings on table 4) at which no more than 10 percent of the bed material is finer.

Total sediment concentration is the concentration of all the sediment passing a given section in a stream.

Total sediment discharge or load is the weight of all the sediment passing a section in a unit time. It is also a product of the total sediment concentration, the total water discharge, and a constant for converting the units to a weight per unit time—generally tons per day.

Unmeasured sediment discharge or load is the difference between total sediment discharge and the measured suspended-sediment discharge. More particularly, it is the sum of the bed-load discharge and the product of the water discharge in the unsampled zone, a constant for converting the units to a weight per unit time, and the difference between the mean concentrations of suspended sediment in the unsampled and sampled zones.

Geometric mean size is the size that is computed as the square root of the product of the upper and lower limits of the size range. In this report the range of the smallest particle sizes was arbitrarily assumed to be 0.002–0.062 millimeter.

Effective width is the width determined by applying an appropriate horizontal angle correction to the width rather than to the velocity or discharge. The effective width of a channel is the sum of the effective widths for each section of a water-discharge measurement. It is also the length of a discontinuous line that crosses the channel and that is normal to the direction of flow at every point on the line.

Effective area is the sum of the products of the effective width and measured depth for each section of a water-discharge measurement.

MIDDLE LOUP RIVER

The Middle Loup River upstream and for some distance downstream from Dunning is in the sandhills region of north-central Nebraska. The sandhills are underlain by the Ogallala formation of Tertiary age and are mantled by loess and dune sand to a depth that in some places exceeds 100 feet. The topography is formed by northwest-trending sand dunes, which are stabilized by grass cover. The vertical distance from the crests to the low places between the dunes is about 50 feet. The valley floor of the river upstream from Dunning is generally about half a mile wide and is about 80 feet lower than the uplands. The valley floor is composed of sand that was mostly deposited by the stream and that is topped in some places with a thin layer of soil. Grass meadows or brush and trees border the channel, which is defined by low banks. Meanders are not well developed, although bank erosion is prevalent and is the source of most of the sediment load; however, some sections of the channel near Dunning have been stabilized by brush riprap, which generally has been effective in protecting the banks from scour. The drainage area of the river upstream from Dunning is approximately 1,760 square miles, of which about 80 square miles contributes directly to surface runoff (U. S. Geol. Survey, 1954). Flow is mainly derived from ground-water accretion along the entire channel. During the period October 1, 1945, through September 30, 1952, at Dunning, Nebr., the maximum daily discharge was 630 cfs (cubic feet per second), the minimum was 100 cfs, and the mean was 381 cfs. The Dismal River (fig. 1), which flows from the west, enters the Middle Loup River about 1½ miles east of Dunning.

TURBULENCE FLUME

The turbulence flume is under the bridge on State Route 2 at Dunning, Nebr., about 1,200 feet downstream from the gaging station. (See fig. 2.) Benedict, Albertson, and Matejka (1955) gave the following physical description of the prototype turbulence flume:

The turbulence flume is a structure for inducing turbulence sufficient to suspend substantially the total sediment load of a stream. The flume consists of a series of 1-ft by 2-ft movable baffles, one continuous 0.5-ft permanent baffle, and a 6-in. by 16-in. wooden baffle (measuring sill) attached to a reinforced-concrete slab 82 ft wide and 38 ft long. The 1-ft by 2-ft baffles are galvanized steel sheets supported by two round rods inserted in pipe sockets embedded in the concrete slab. The permanent baffle, a 6-in. by 4-in. angle, and the wooden measuring sill are bolted to the concrete slab.

The concrete slab, which is the floor of the flume, is supported at each end by interlocking sheet-steel piling driven to a depth of 10 ft. The top of the slab is just below the average elevation of the stream bed at a discharge of approximately 400 cu ft per sec. The wooden end sill, which is bolted to the downstream end of the slab, was designed to produce a reverse roller to prevent scour of the stream bed immediately downstream from the flume.

* * * Walkways were installed immediately below the upstream edge of the slab and immediately downstream from the measuring sill to simplify the collection of depth-integrated sediment samples. * * *

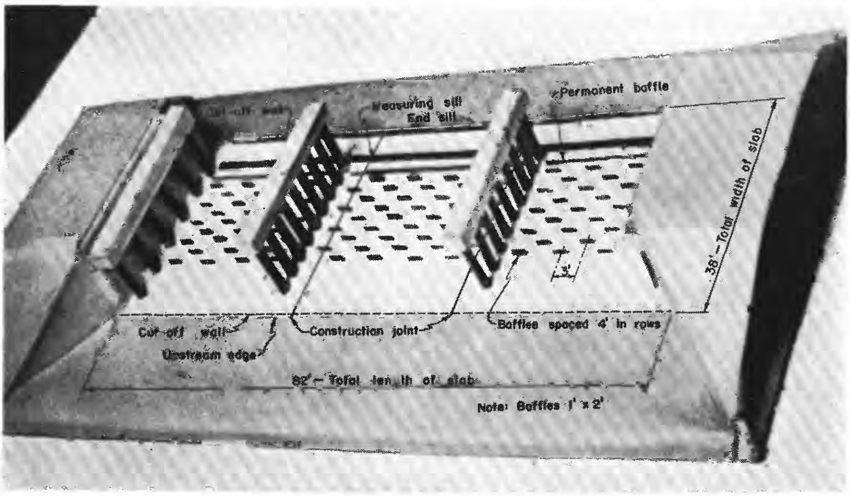
The flume operation during the test period was considered satisfactory except for the intermittent deposition of sand on the measuring sill. This deposition indicated that the turbulent energy was insufficient to suspend the total sediment load during maximum dune movement through the flume. On the basis of the results of the model studies, the first two rows of baffles at the upstream end of the flume were raised 0.5 ft on March 29, 1951.

Plate 1 and figure 3 show the placement of the baffles, measuring sill, end sill, and walkways.

Water-surface profiles along both banks on July 8, 1952, (fig. 4) show that the presence of the flume in the channel affects the flow only locally in a reach of about 300 feet upstream and 300 feet downstream from the flume. Beyond this reach the stream conditions are about the same as they were before the flume was installed. Ordinarily, the fall at the right side of the flume is greater than that at the left, and it is associated with a greater discharge per foot of width. Upstream from the flume, the thalweg of the flow follows the right bank. Downstream, the left bank is overhung with brush, and the channel bends to the right. Because the tendency of the flow is to concentrate on the right side of the flume, flow at the left side sometimes has velocities that are insufficient for suspending the particles, and the baffles become partly covered; however, the measuring sill remains clean most of the time. An average profile of the stream probably would show backwater upstream from the flume, an increased slope through the flume (associated with increased velocity and turbulence), and a flatter than natural slope downstream from the end sill of the flume (probably resulting from a regain in elevation head with a decrease in velocity head).

SECTION C

Section C is at the upstream side of the turbulence flume. (See fig. 2, and pl. 2.) Streamflow measurements were made, and suspended-sediment samples were collected at section C to define the measured suspended-sediment concentration and discharge entering the flume. These measurements were usually made from a walkway that spanned the 82-foot width of the river. Particle-size analyses of measured suspended sediment show that about 88 percent of the sediment is coarser than 0.062 millimeter and that sieve diameters of about half of the total sands are between 0.125 and 0.25 millimeter.



SKELETON MODEL OF PROTOTYPE FLUME

(Benedict, Albertson, and Matejka, 1955)

A. APPROACH TO THE TURBULENCE FLUME

The water-stage recorder for the turbulence flume is at the left. July 14, 1953, water discharge about 350 cfs.

B. SECTION C FROM THE LEFT BANK

The apparent fall through the turbulence flume is partly from superelevation of downstream side of bridge. July 14, 1953, water discharge about 350 cfs.

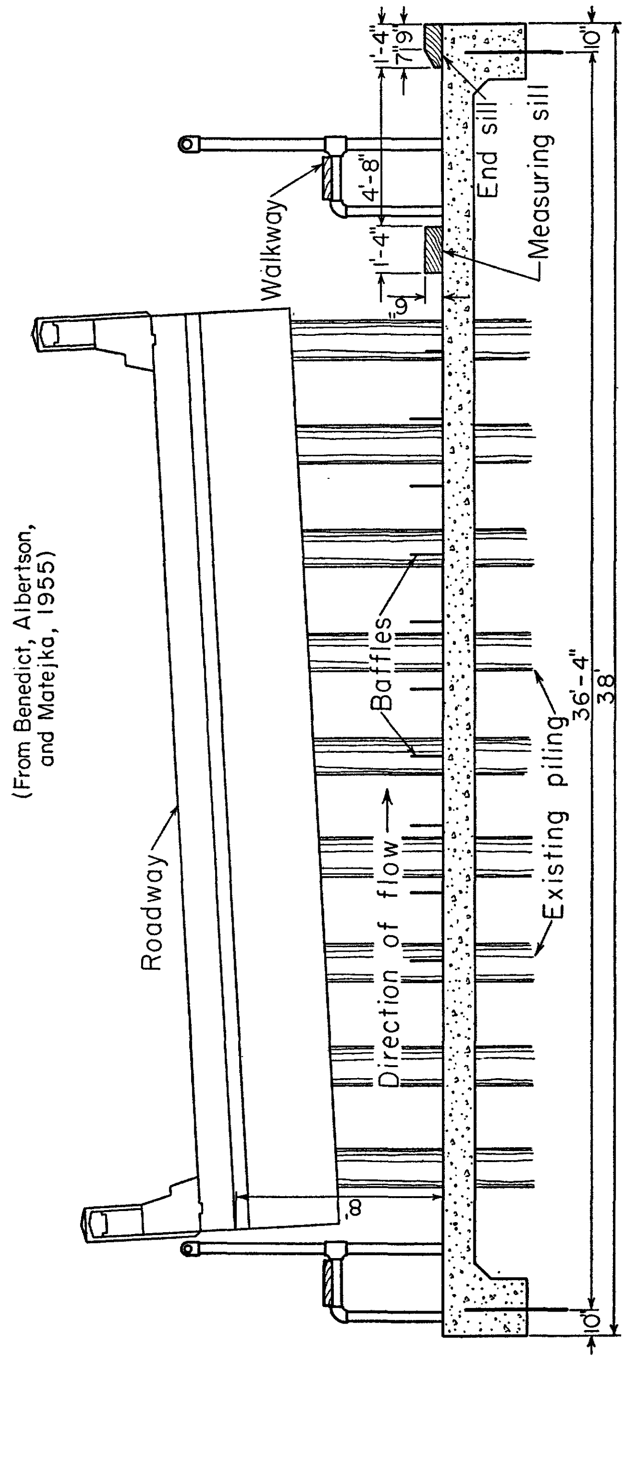


FIGURE 3.—Section of flume and highway bridge.

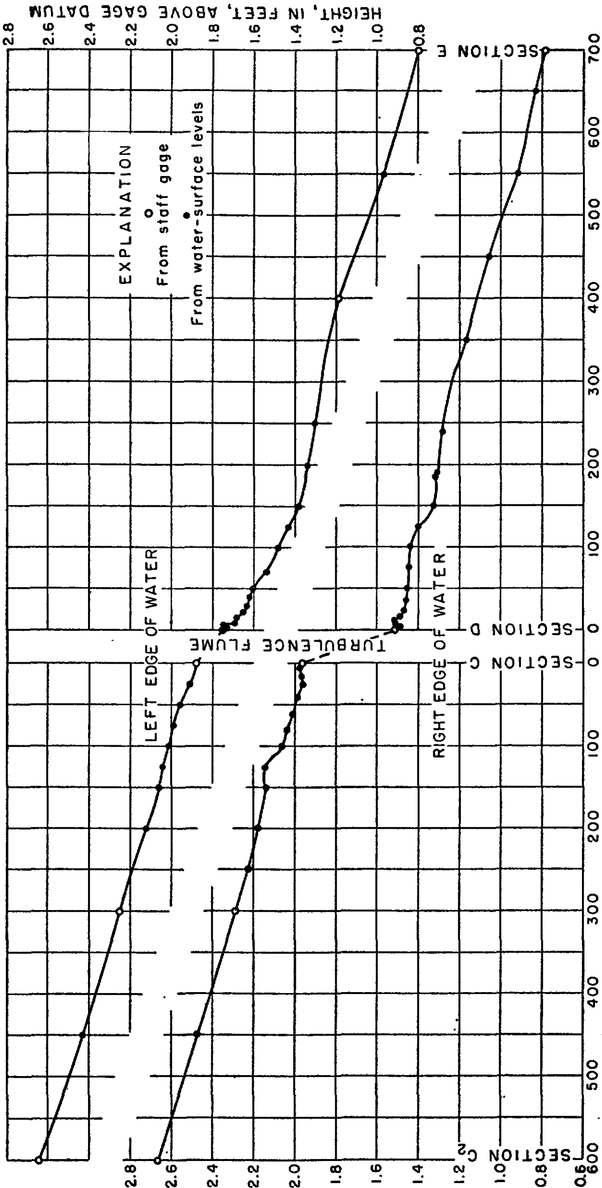


FIGURE 4.—Water-surface profile, July 8, 1952.

Also, only a very small percentage of the sediment is coarser than 0.50 millimeter.

Some bed-material samples were collected at or very near section C. The particle-size analyses of these samples show that the median sieve diameter is in the 0.25- to 0.50-millimeter size range. The bed-material size distribution and the measured suspended-sediment size distribution for two different medium flows are shown in figure 5.

The lateral distributions of depth, stream velocity, and measured suspended-sediment concentration varied with dune movement into the flume. Figure 6 shows lateral distributions for 3 different days.

Vertical distributions of the suspended sediment and flow entering the flume are defined from point-integrated samples collected at section C. These distributions indicate slightly more turbulence at section C than at the selected river sections; z_1 values (see "Variations in z_1") are lower and vertical-velocity distributions are more uniform at section C than at section B, which is probably the most turbulent of the selected river sections. Figure 7 shows the vertical distributions of velocity, suspended-sediment concentration, and percentage of particles coarser than 0.25 millimeter at section C on July 18, 1950.

Both a permanent water-stage recorder and a continuous water- and air-temperature recorder are housed together about 15 feet upstream from section C (pl. 2A). Daily maximum and minimum water temperatures are not given here but are published annually in the U. S. Geological Survey Water-Supply Papers of the series, Quality of Surface Waters of the United States. A staff gage on the left bank serves as the outside gage for the recorder and is also used in association with staff gages on the right bank at sections C and D to establish the fall through the flume.

Measurements were begun at section C on the assumption that possibly the difference in concurrently measured suspended-sediment discharges at this section and at section D would be representative of the unmeasured sediment discharge of an average reach of the stream. However, early measurements indicated that this assumption was generally invalid because measured suspended-sediment concentrations and discharges at section C were not representative of those at unconfined river sections. Suspended-sediment discharges at section C were generally comparable to those at section B, a very narrow confined section, and were often greater than those at sections A and E, unconfined sections, by 100–200 tons per day.

SECTION D

Section D is at the downstream side of the measuring sill of the turbulence flume (fig. 2 and pl. 3*A*). From the walkway spanning the section, samples normally are collected with a U. S. DH–48 hand

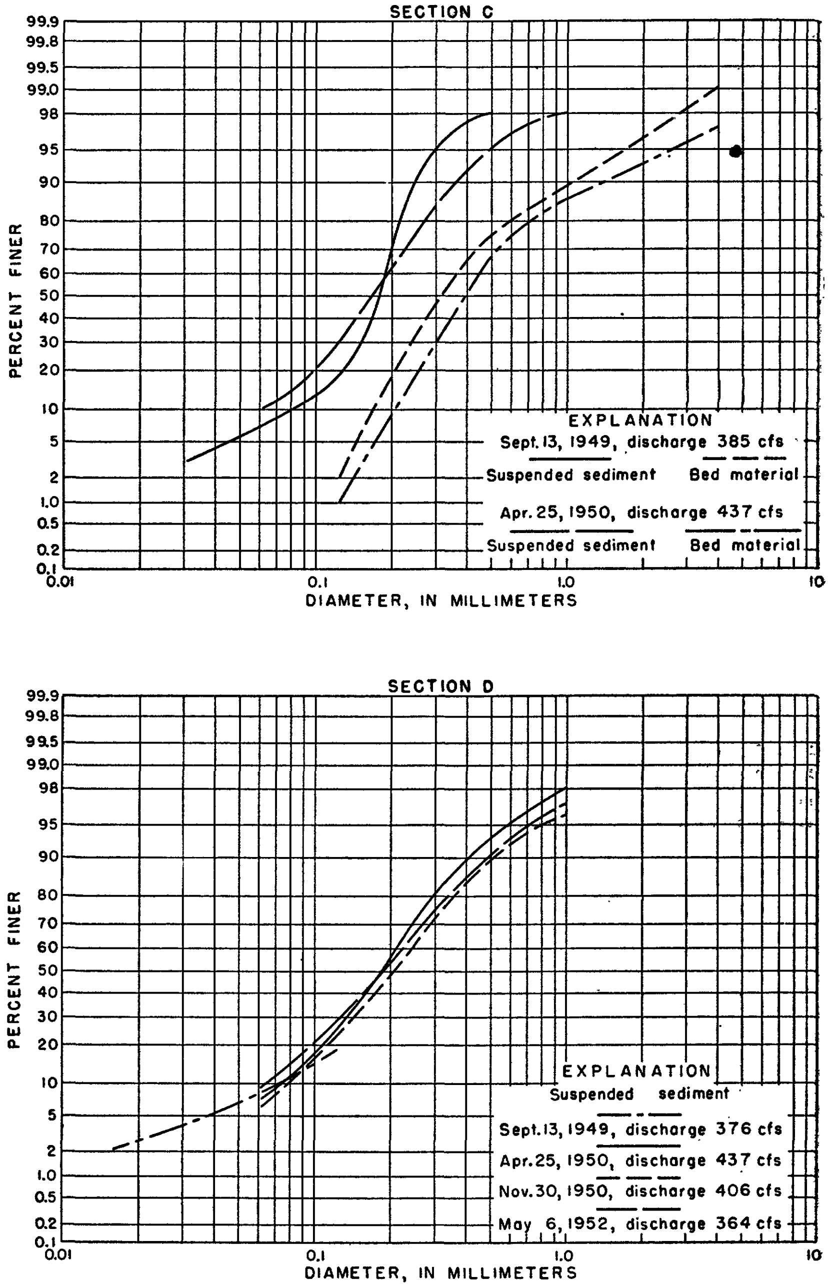


FIGURE 5.—Particle-size distributions of measured suspended sediment and bed material, sections C and D.

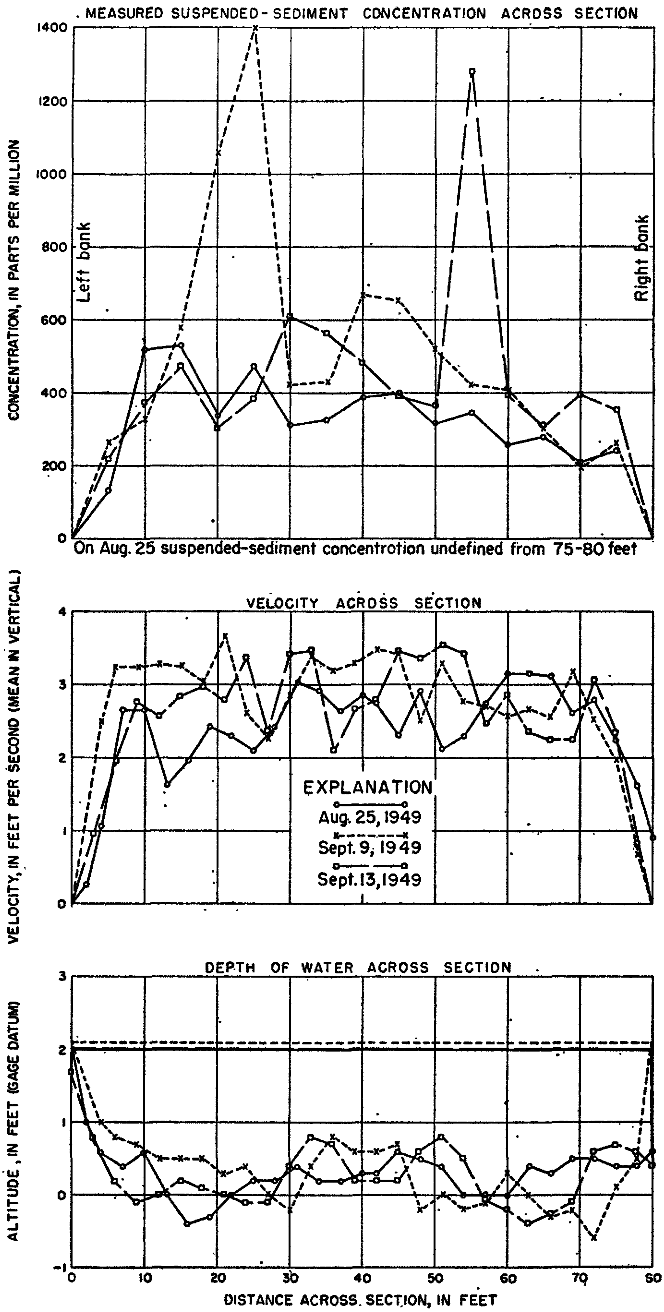


FIGURE 6.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section C.

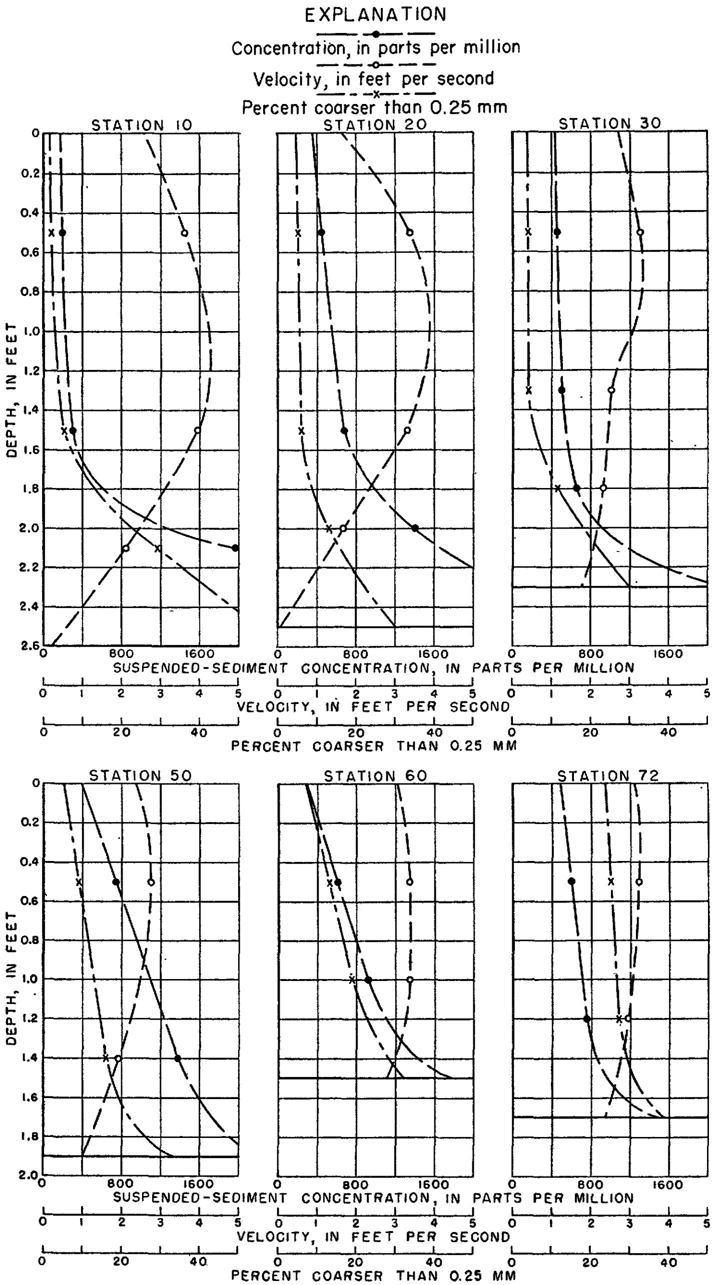


FIGURE 7.—Vertical distributions of suspended-sediment concentration, velocity, and percent coarser than 0.25 mm, section C, July 18, 1950.

A. SECTION D FROM THE LEFT BANK

July 14, 1953, water discharge about 350 cfs.

B. SAMPLING AT SECTION D

Note the guide bracket for the sediment sampler and the walkway which is raised to the winter position. April 9, 1952, water discharge about 450 cfs.

A. SECTION A FROM THE RIGHT BANK

The tallest tree is adjacent to the left edge of the section. July 14, 1953, water discharge about 350 cfs.

B. SECTION B FROM THE LEFT BANK

The water-stage recorder for the gaging station is on the right bank behind the bridge. The ditch at the left connects with a pond and contributes no inflow. April 9, 1952, water discharge about 450 cfs.

sampler. (See pl. 3*B*.) A portable bracket, which can be hooked over the measuring sill, guides the sampler so that, when the sampler is moved vertically along the bracket, the nozzle of the sampler traverses the entire depth of flow from the water surface down to the top of the measuring sill. As long as the measuring sill is free of sand deposits, all the sediment passing over the sill can be sampled regardless of the vertical distribution of sediment. Thus, concentrations determined from depth-integrated samples represent the total sediment concentration, which is used in computing the total sediment discharge.

Two different types of samples were collected at section D. Daily samples consisted of depth-integrated samples collected at stations 10, 30, 50, and 70; cross-section samples consisted of depth-integrated samples collected at 15 verticals or more, spaced either at equal increments of width or according to water discharge. The daily samples were collected once or twice a day by a local observer, and daily samples and cross-section samples were collected periodically by engineers. Concentrations from the daily samples were used to define a continuous concentration curve from which a time-weighted mean concentration for each day was determined. However, because the time-weighted mean concentrations were sometimes unrepresentative of the cross section as a whole, they were corrected by using a determined relation between the cross-section samples and the daily samples. Forty-four ratios of the concentrations from daily samples to the concentrations from cross-section samples during part of the 1950 water year and all the 1951 and 1952 water years averaged 1.03 and ranged from 0.72 to 1.61.

The relation between the concentrations of cross-section samples and daily samples fluctuates. The relation does not seem to be affected by any of the common flow parameters; but it is, of course, affected by variations in the lateral distribution of sediment in the cross section, which is in turn affected by dune movement into the flume. An analysis of data collected on June 27, 1951, (Benedict, Albertson, and Matejka, 1955) indicates the extent of the variations of daily sample concentrations with time. Concentrations from depth-integrated sediment samples collected at 5-minute intervals over a 4-hour period at the 4 daily sampling stations indicate that the concentration of any sample at any time might vary as much as ±83.5 percent from the true mean for the vertical. Also, the concentration determined from 1 bottle at each of the 4 stations might vary from the average concentration as much as ±25 percent, and a concentration determined from 2 bottles at each of the 4 stations might vary from the average concentration as much as ±19 percent. Two bottles at each of the four verticals are normally collected to obtain daily sample concentrations.

Records of sediment loads (total load) passing section D are published in a continuing series of water-supply papers entitled, Quality of Surface Waters of the United States. The published daily loads are computed from daily mean water discharges and from daily mean concentrations that are corrected to represent cross-section concentrations. Monthly and annual sediment loads passing section D during the period March 22, 1950, through September 30, 1952, are given in table 6. During most of the year, monthly loads are fairly constant, although they are usually highest in late winter and early spring.

Data from measurements of water and suspended-sediment discharges indicate that Q_{ts}, the total sediment discharge, varies about

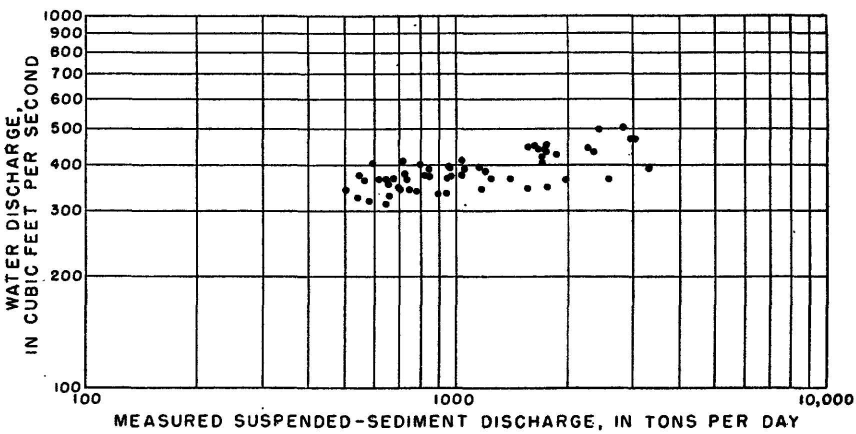


FIGURE 8.—Sediment-transport curve for section D at the turbulence flume.

as the cube of Q_w, the water discharge, ($Q_{ts}=C_1Q_w^3$); however, the relationship is not well defined. (See fig. 8.)

Size analyses of depth-integrated samples represent the size distribution of the total load of the stream and show that about 90 percent of the sediment is coarser than 0.062 millimeter and that about 35 percent of the total is in the 0.125- to 0.25-millimeter size range. Figure 5 shows the size distribution of the material passing the flume on 4 different days of medium water discharge. The percentage of suspended sediment in individual size ranges is fairly constant except possibly at relatively high and low concentrations (fig. 9).

Generally at section D, the depth decreases and the velocity of flow increases from the left to the right bank. However, the measured suspended-sediment concentration follows a random pattern; the concentrations have a tendency to be highest in the center bay of the

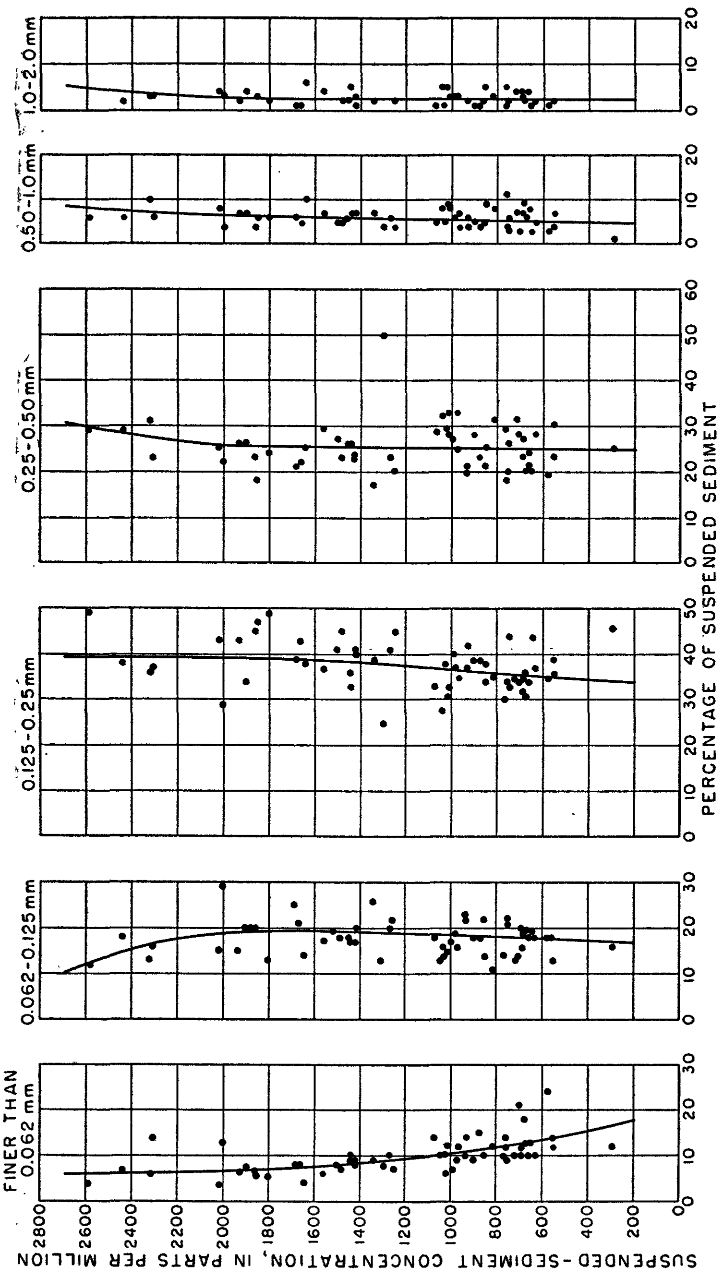


FIGURE 9.—Variation of the percentages of suspended sediment in size ranges with concentration, section D.

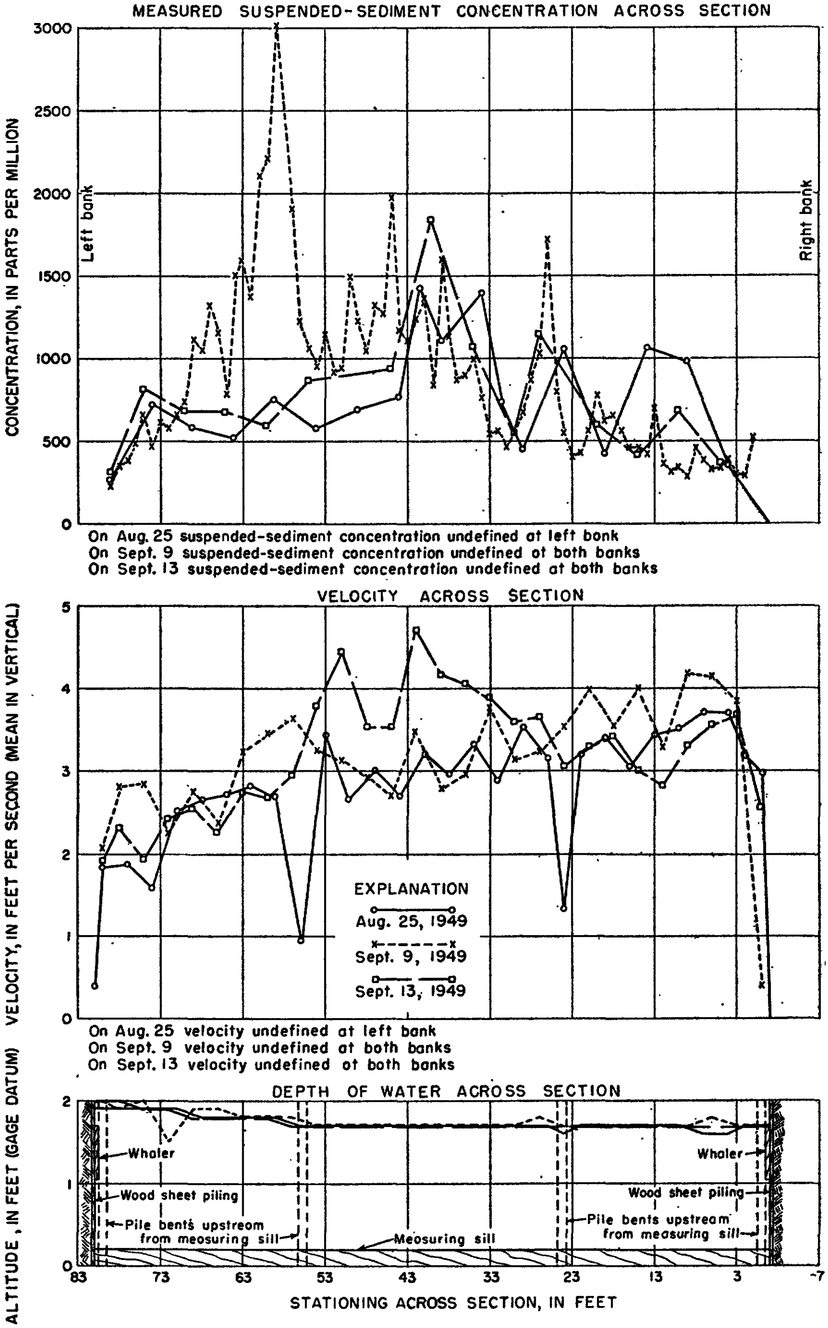


FIGURE 10.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section D.

flume. Lateral distributions on 3 days are shown in figure 10. The lateral distribution of sediment depends largely on dune movement into the flume. Consequently, concentrations are high in one part of the flume at one time and in another part at another time. A description of the dune movement into the flume is given by Benedict, Albertson, and Matejka (1955).

The crest of the large dunes when approaching the flume would, at times, be at an elevation higher then the top of the baffle plates in the flume. As these dunes moved toward the upstream baffle plate, it appeared that the baffle would be covered. However, when each dune reached a point within 1 ft of the baffle plate, the downstream side of the dune would begin to be carried into suspension; in this manner, most of the dunes were prevented from covering the baffles. Occasionally, however, the dunes were sufficiently large to cover the upstream baffle and move on to the second baffle. In moving from the upstream baffle to the second baffle, a higher percentage of such a dune was carried into suspension so that the dune was never able to cover completely any of the baffles in the second row. As the dune moved downstream, the upstream baffle slowly emerged through the top of the dune. The dune was rapidly forced into suspension by the increased turbulence and was carried downstream.

The vertical distribution of velocity and sediment as defined by point-integrated sediment samples at section D indicates, to some extent, the capability of the turbulence flume to suspend the total sediment load. The sediment concentration and the distribution of coarse sediment particles are relatively uniform throughout the depth most of the time; therefore, the flow can be considered sufficiently turbulent to maintain the total sediment load in suspension. Figures 11, 12, and 13 show some of the information from point samples collected at the flume on 3 different days. In these figures, the percentages by weight of sediment coarser than 0.25 millimeter have been plotted against depth. The size division at 0.25 millimeter was selected because it represents a sufficiently coarse fraction of the sediment to reflect the capability of the flume to suspend the entire sediment load. The basic distributions illustrated in these figures persist at all times except when flow through the flume is affected by debris or ice.

Only one sample has been collected from bed material that has been deposited on the sill. (See table 4, sec. D.) The sample is much coarser than bed-material samples at the selected river sections.

SELECTED RIVER SECTIONS

SECTION A

Section A, the farthest upstream section in the reach, is about 7,200 feet upstream from the turbulence flume and about 6,000 feet upstream from the gaging station. (See fig. 2.) This section is the widest selected river section in the reach (pl. 4*A*) and is typical of other wide sections of the stream. Bank-to-bank width is about 340 feet; however, flow usually is not distributed over the entire width but

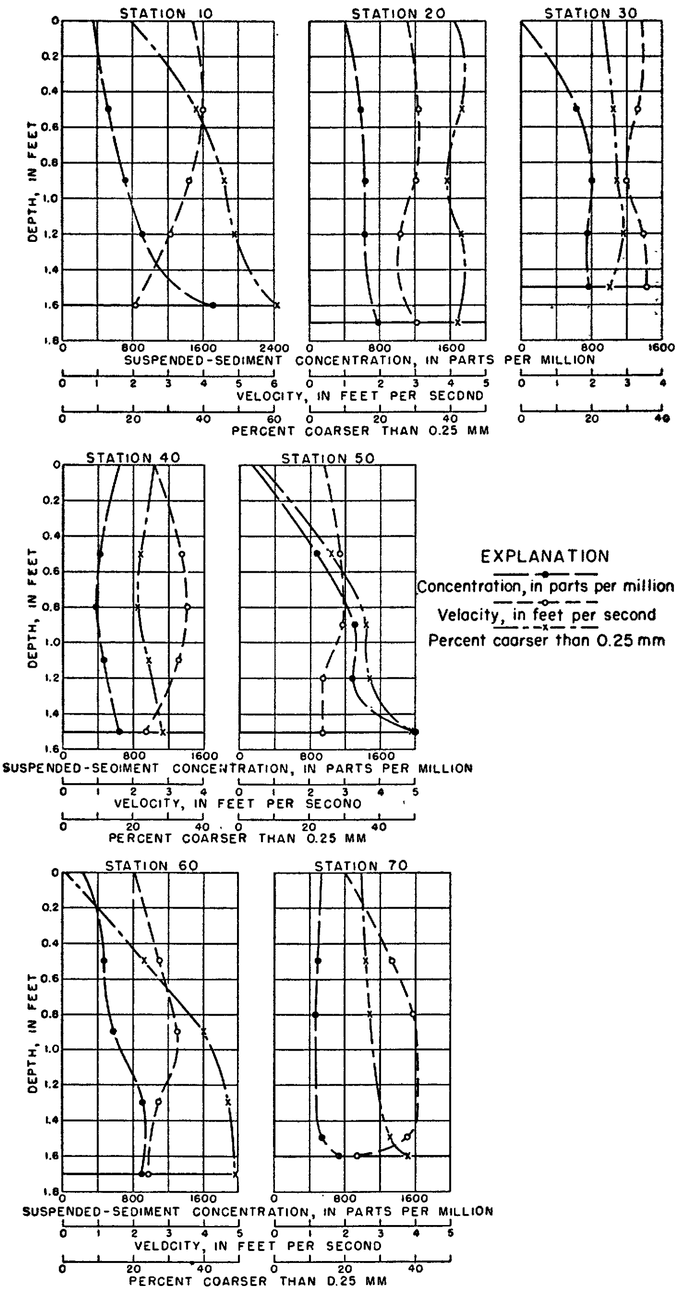


FIGURE 11.—Vertical distributions of suspended-sediment concentration, velocity, and percent coarser than 0.25 mm, section D, August 30, 1950.

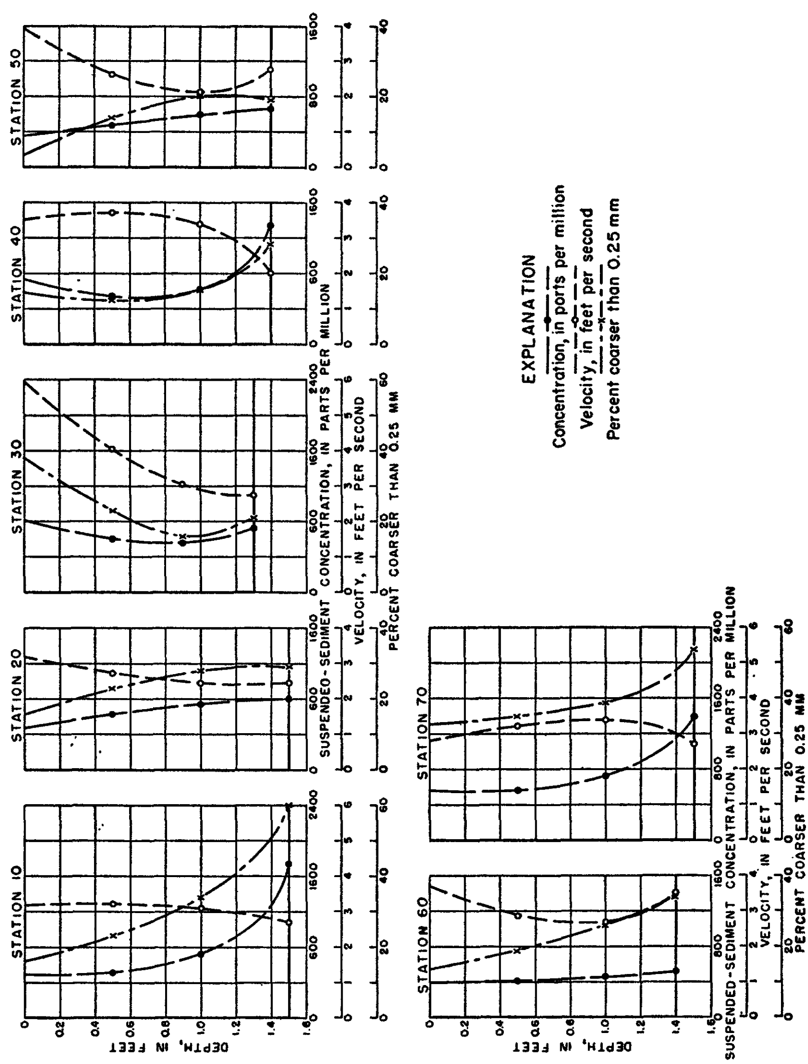


FIGURE 12.—Vertical distributions of suspended-sediment concentration, velocity, and percent coarser than 0.25 mm, section D, August 13, 1952.

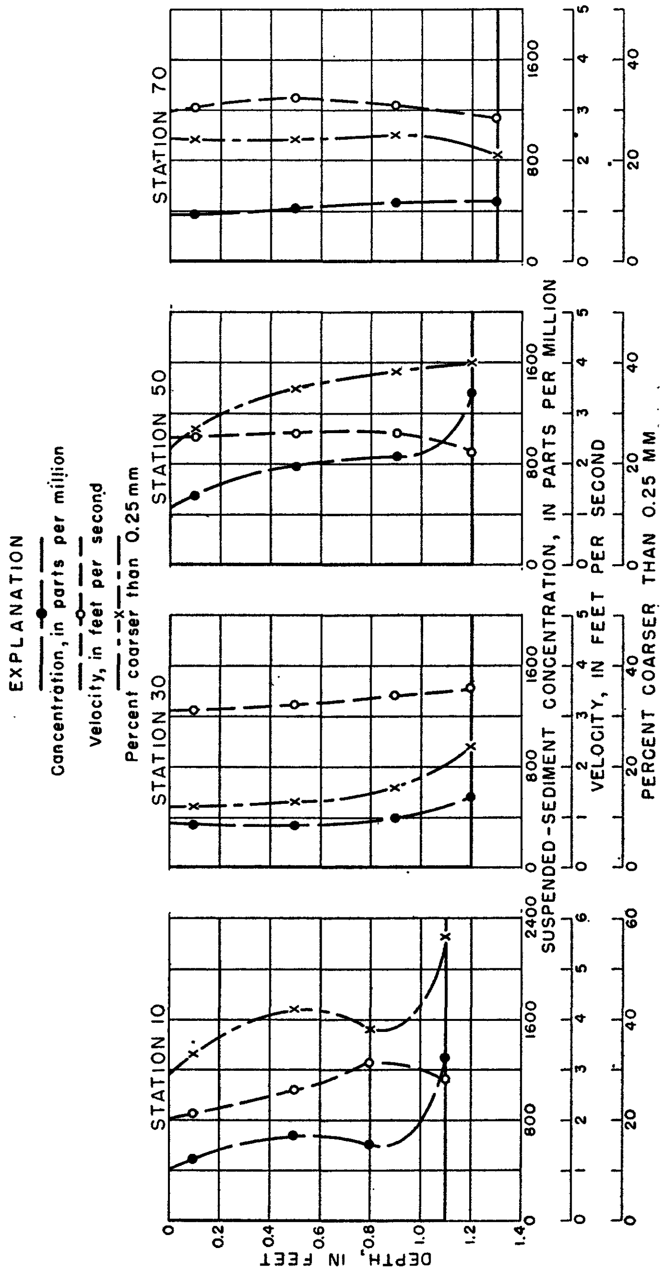


FIGURE 13.—Vertical distributions of suspended-sediment concentration, velocity, and percent coarser than 0.25 mm, section D, September 10, 1952.

is interspaced with either sandbars or pools of still water. Generally, up to one-third of the width of flow is less than 0.5 foot deep. The sand-bed configuration is continually changing, rapidly at times, as dunes migrate into and through the section. Dune heights and widths vary across the section. Low (0.2 foot), wide dunes are generally in the shallower parts of the section. However, flows at shallow depths do not always cause low, wide dunes; sometimes they form a flat plateaulike bed whose downstream edge is actually a long dune crest. When flow is swift over these flat beds, bed load is transported to and deposited at these downstream edges. In deeper flows, dune heights range from only a few tenths to nearly a foot. Generally, the higher dunes are relatively narrow. The upstream and downstream faces of these dunes have relatively steep slopes, and the depressions or troughs between successive dunes give an impression of holes in the stream bed.

Because of the irregularities across the section in both the streambed configuration and the water discharge, section A is unfavorable for either measuring water discharge or sampling suspended sediment; it is particularly unfavorable unless a relatively large number of verticals are measured or sampled. However, water- and sediment-discharge measurements are made at this section because it typifies other wide sections of the stream.

At section A the cross-sectional area of flow in the shallow parts of the stream represents usually a substantially larger percentage of the total area than the discharge in the shallow parts does of the total discharge. As a result, mean section velocities computed by dividing the total measured discharge by the total measured area are often low with respect to the velocities associated with the areas of major sediment discharge. Therefore, these mean section velocities are unsuitable in computations of sediment discharge with methods in which the mean velocity is an important parameter.

Particle-size analyses of the measured suspended sediment show that about 40 percent is in the 0.125- to 0.25-millimeter size range and about 75 percent is coarser than 0.062 millimeter, whereas particle-size analyses of the bed material show that about 45 percent is in the 0.25- to 0.50-millimeter size range and about 70 percent is coarser than 0.25 millimeter. The measured suspended-sediment size distribution and the bed-material size distribution for two medium flows are shown in figure 14.

Lateral distributions of stream velocity, depth, and measured suspended-sediment concentration on 3 days are given in figure 15. Parts of the measured suspended-sediment concentration curves are undefined because no samples were collected in the separate channels or because the velocity of flow reached zero and no samples were collected

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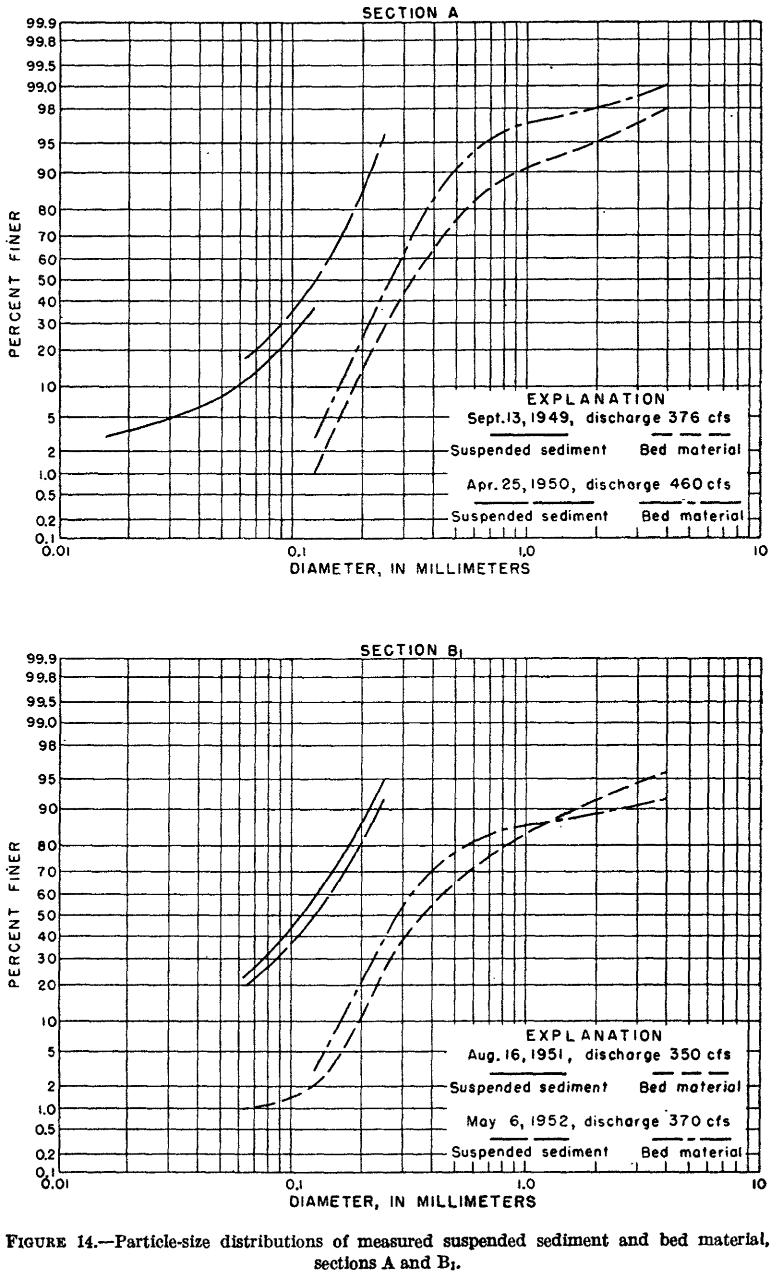


FIGURE 14.—Particle-size distributions of measured suspended sediment and bed material, sections A and B_1.

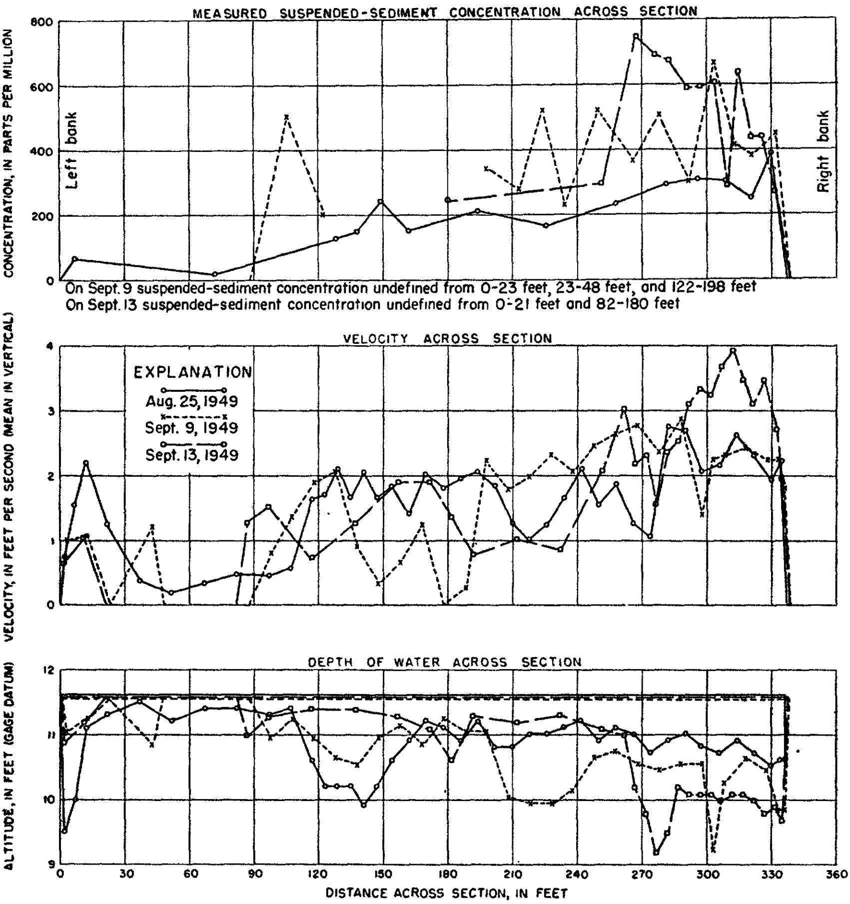


FIGURE 15.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section A.

at or near the point of zero velocity. No point-integrated samples were collected; so the vertical distributions remain undefined.

Staff gages were placed on both banks at section A and on both banks 300 feet upstream and downstream from section A; however, the local water-surface slope determined from the readings of these gages usually is questionable. The slope varies across the section from one individual channel to another. Also, transverse flow at the section causes differences in the slope along each bank. Despite these difficulties, local slopes were determined as well as possible. In addition, overall slopes from section A to section E (fig. 2) are defined by the gage-height traces from temporary water-stage recorders at both sections.

SECTION B_1

Section B_1 is about 1,400 feet upstream from the turbulence flume and about 200 feet upstream from the gaging station. (See fig. 2.) It is at the upstream end of the straight approach to the flume and is narrower than most sections of the stream—usually about 95 feet wide. The hydraulic characteristics of the section are not affected by backwater except occasionally when ice lodges at the county bridge, 150 feet downstream, or at the flume. The sand-bed configuration changes rather slowly, and the bed is scoured at times along the left bank to a deposit of peat. Ordinarily, the bed shape remains fairly constant. As a result of these factors, section B_1 is one of the better sites for stream gaging.

At this section, about 80 percent of the measured suspended sediment is coarser than 0.062 millimeter. Particles larger than 0.50 millimeter are rare, and the largest percentage in any size range is about 40 percent in the 0.125- to 0.25-millimeter range. The median diameter of bed material, as that at the other selected sections, falls in the 0.25- to 0.50-millimeter size range. The measured suspended-sediment size distribution and the bed-material size distribution are shown in figure 14.

Stream depth and velocity are usually fairly uniform across the section. Lateral distributions of these quantities and of measured suspended-sediment concentration on 3 different days are shown in figure 16.

At this section, local water-surface slopes were not determined and point-integrated sediment samples were not collected.

SECTION B

Section B is at the county bridge about 150 feet downstream from section B_1 and about 50 feet upstream from the gaging station. (See fig. 2 and pl. 4*B*.) Both the upstream and the downstream sides of the bridge have been designated as section B. The daily sampling station, Middle Loup River at Dunning, was maintained at this section from April 11, 1946, to March 21, 1950, and measured suspended-sediment loads during that period are published in water-supply papers (U. S. Geological Survey, 1953, 1954, 1955).

Because the section is more constricted than the others, the measured suspended-sediment discharges are higher than those at the other selected river sections and the measured suspended sediment is slightly coarser, although the bed material has about the same size distribution.

The flow at this section is confined by the bridge abutments to a width of about 65 feet. Although the bed configuration changes radically from time to time, the stream velocity across the section is fairly uniform, and the section is usually satisfactory for stream

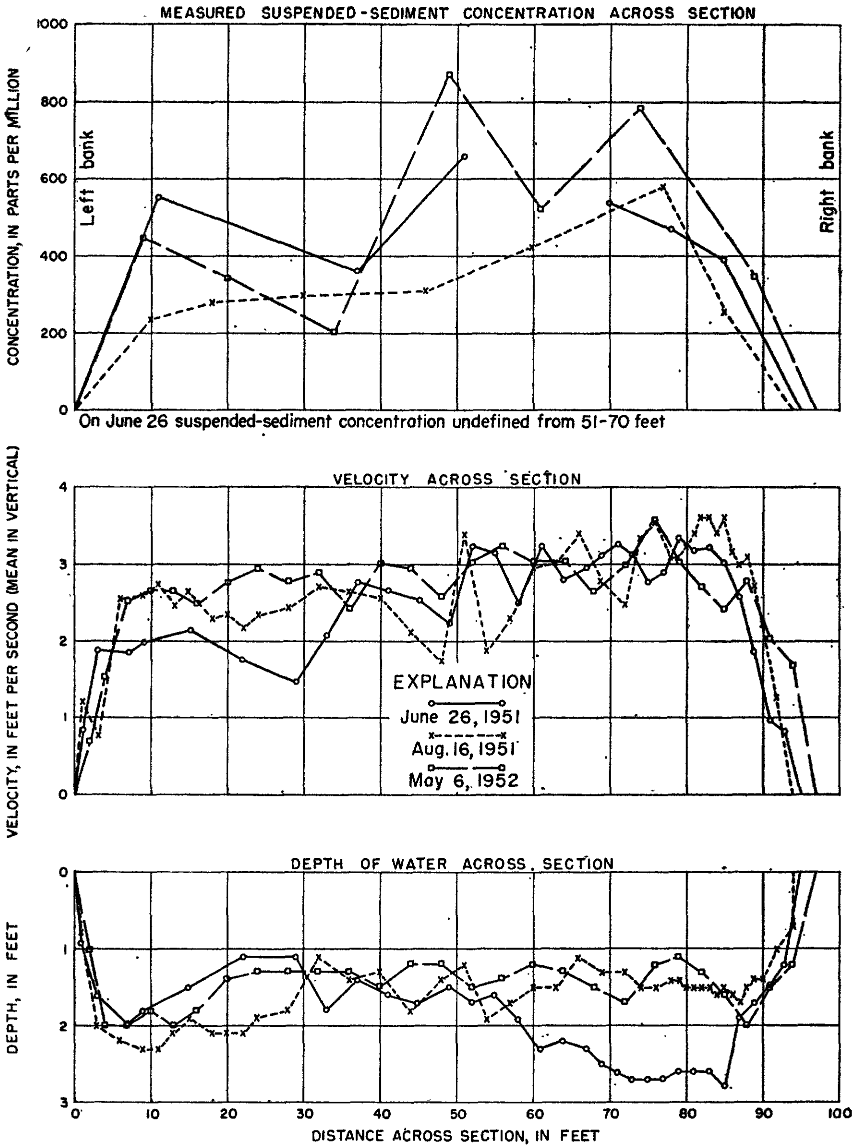


FIGURE 16.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section B_1.

gaging. The measured suspended-sediment concentration is also fairly uniform across the section. Lateral distributions of measured suspended-sediment concentration, stream velocity, and depth are shown in figure 17.

Some point-integrated samples have been collected at section B. Vertical distributions of velocity, suspended-sediment concentration,

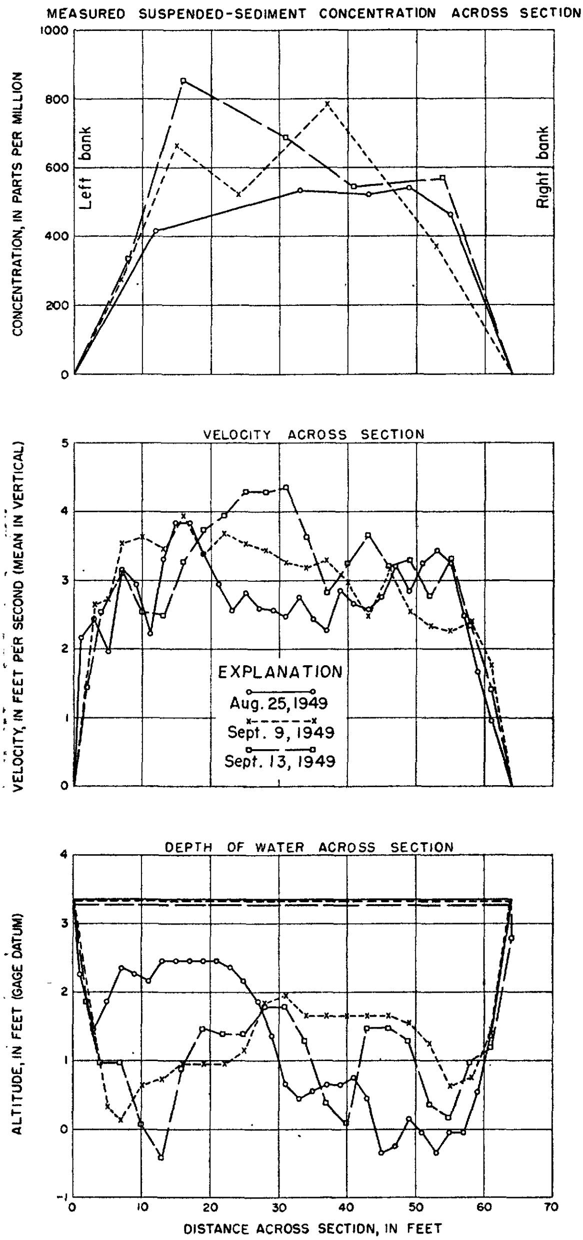


FIGURE 17.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section B.

and percentage coarser than 0.25 millimeter from these samples are shown in figure 18. These vertical distributions indicate that the flow at section B is somewhat more turbulent than would be expected at an unconfined alluvial section.

Water-surface slopes were not determined at section B.

Measurements of water and suspended-sediment discharges were made at a section 25 feet upstream from the upstream side of the county bridge. This section has not been listed separately because only three measurements were made there; however, these measurements are used in subsequent computations. Information from these measurements as well as particle-size analyses of both measured suspended sediment and bed material is given with similar data for section B.

Two of the water-discharge measurements show that the section 25 feet upstream from section B is about 71 feet wide. The third measurement was evidently not made at exactly the same section as the other two because the width is given as 77 feet. Lateral distributions of depth and stream velocity for the two similar measurements are shown in figure 19. The lateral distribution of measured suspended-sediment concentration is not defined because suspended-sediment samples were not analyzed by individual verticals.

Neither local-slope data nor point-integrated samples were collected at the section 25 feet upstream from section B.

SECTION C_2

Section C_2 (pl. 5*A*) is about 600 feet upstream from the entrance of the turbulence flume and about 540 feet downstream from the gaging station. (See fig. 2.) Usually, it is a reasonably good gaging section and the sand bed is no more changeable than that at any of the other sections in the reach. However, at times the top part of the bed approaches an almost fluid state, and then the accuracy of the streamflow measurement is somewhat questionable.

The particle-size distributions of both the measured suspended sediment and the bed material at section C_2 are about the same as those at the other normal sections. Several distributions for section C_2 are shown in figure 20.

Section C_2 is about 83 feet wide. The greatest depths and the largest measured suspended-sediment concentrations are ordinarily in the left half of the channel, although the stream velocity is usually fairly uniform across the section. Lateral distributions of stream depth, velocity, and measured suspended-sediment concentration are shown in figure 21 on 3 different days.

Since the spring of 1952, both banks at and near section C_2 have been stabilized with brush riprap. The addition of the riprap affected

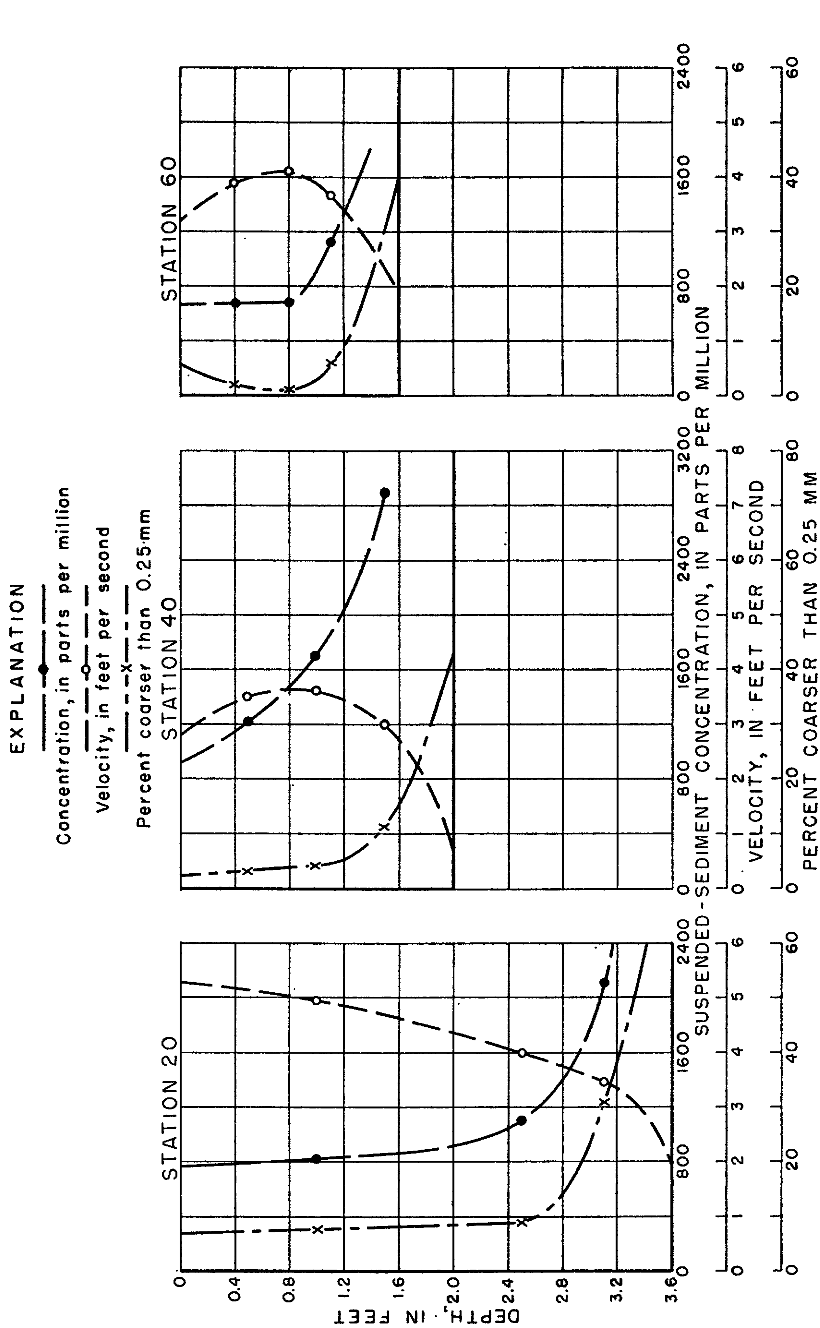


FIGURE 18.—Vertical distributions of suspended-sediment concentration, velocity, and percent coarser than 0.25 mm, section B, March 21, 1950.

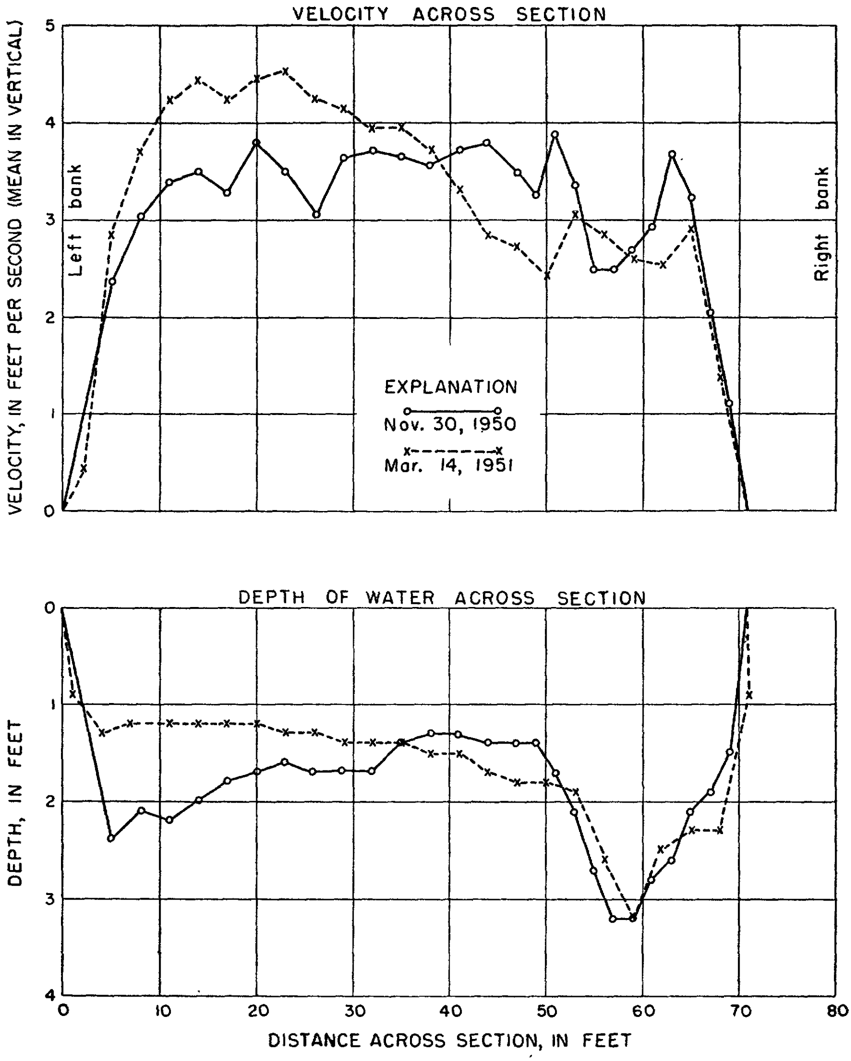
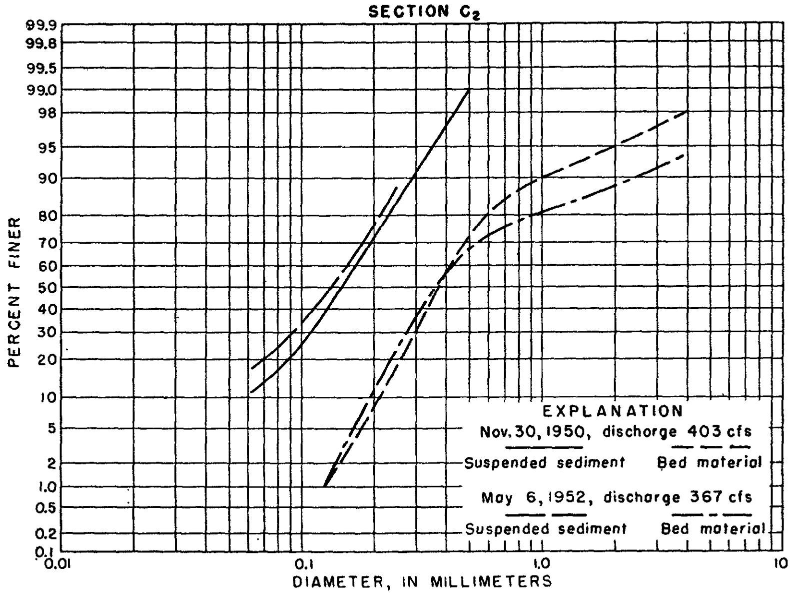


FIGURE 19.—Lateral distributions of depth and stream velocity, 25 feet upstream from section B.

the section only on the left bank for a distance of about 8 or 9 feet into the channel. This effect is best seen in figure 21 by comparing curves for May 6, 1952, with curves for the other 2 days.

Staff gages are on both banks at the section and 300 feet upstream and downstream from the section. Local slopes have been determined from the readings of these gages except at times when backwater from lodged ice at the flume affected the section.



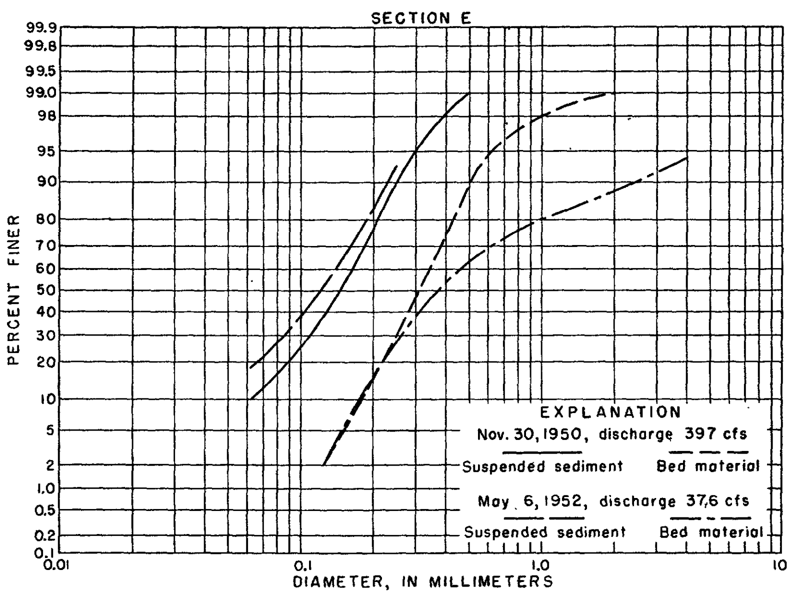


Figure 20.—Particle-size distributions of measured suspended sediment and bed material, sections C_2 and E.

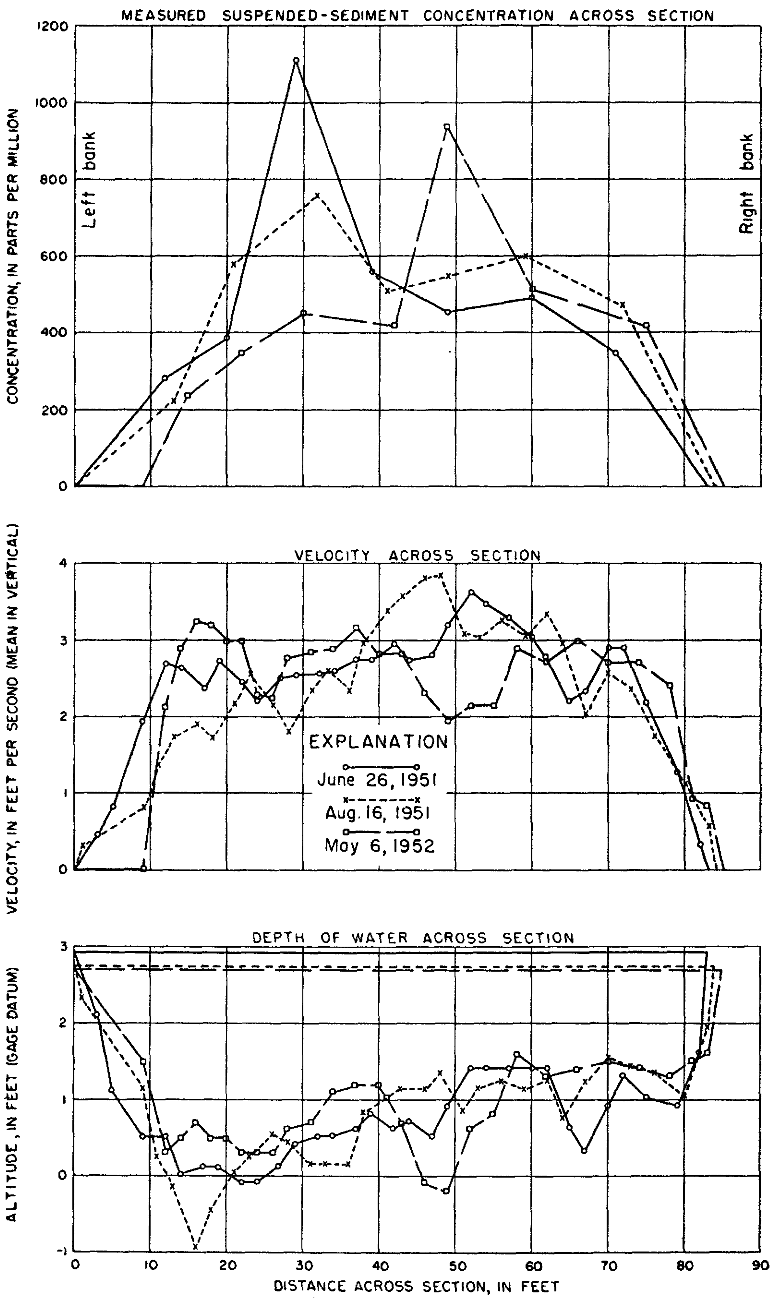


FIGURE 21.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section C_3.

SECTION C_1

Section C_1 is about 195 feet upstream from section C. (See fig. 2, and pl. 5*A*.) Only 2 water-discharge measurements and 4 suspended-sediment discharge measurements were made at this section. Also, 1 measurement of streamflow and suspended-sediment discharge was made at a section 300 feet upstream from section C, and data from this measurement have been included with those from section C_1.

Section C_1 is similar to section C_2 except that the depths and velocities across the section are more uniform. No information is available on the lateral distribution of measured suspended sediment; so figure 22 shows only the lateral distributions of depth and velocity defined by the two streamflow measurements at the section.

The slope of the water surface at section C_1 is affected by backwater from the turbulence flume. Water-surface profiles along both banks on July 8, 1952, (fig. 4) show that the slope is generally flatter in the approach to the flume than in other reaches near Dunning. Because

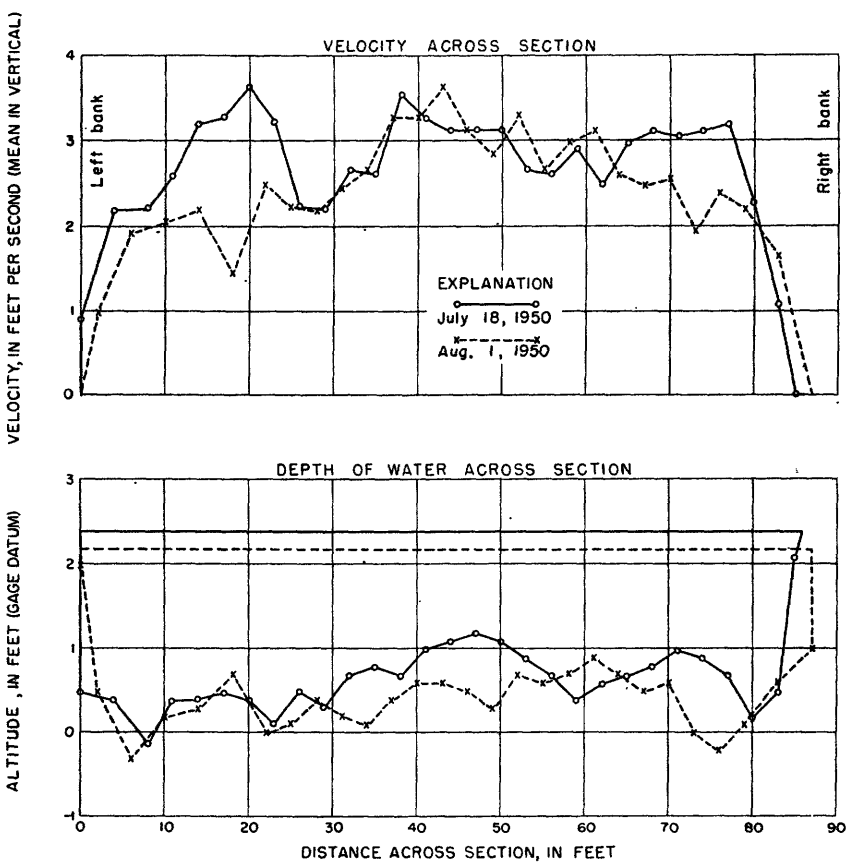


FIGURE 22.—Lateral distributions of depth and stream velocity, section C_1.

A. CHANNEL REACH FROM THE LEFT BANK

This reach is between the State highway and county-road bridges. Section C_1 is at the left. July 14, 1953, water discharge about 350 cfs.

B. SECTION E FROM THE RIGHT BANK

The men in the stream mark the section. The temporary water-stage recorder at the left bank is about 15 feet downstream. July 14, 1953, water discharge about 350 cfs.

section C_1 is in the area of changing slope, measurements were discontinued there; subsequent measurements were made at section C_2.

SECTION E

Section E (pl. 5*B*) is more typical of the channel in the reach near Dunning than any of the other selected sections. It is about 700 feet downstream from the turbulence flume and about 1,900 feet downstream from the gaging station. (See fig. 2.) The width of the section is about 150 feet, and the highest water discharge per foot of width is generally near the right bank. Sandbars form in the center of the channel during periods of low flow and cause some transverse flow. Changes in the sand-bed configuration are less rapid at section E than at any of the other selected sections with the exception of section B_1, even though the type of dune movement and the configuration of dunes are similar to those at section A. As a result of these channel characteristics, section E is a good gaging section.

The size distribution of the measured suspended sediment at section E is about the same as that at the other selected river sections. About 80 percent of the measured suspended sediment is coarser than 0.062 millimeter, and about 40 percent is in the 0.125- to 0.25-millimeter size fraction. Many bed-material samples were collected at section E. Included with the ordinary samples are special samples collected to determine the extent of the lateral variation of bed-material size distribution. In addition, other special samples were collected to determine the variation of bed-material size distribution with depth into the bed. The measured suspended-sediment size distribution and the bed-material size distribution for two medium water discharges are shown in figure 20.

Generally at section E, the greatest depths are along both banks, although the stream velocity is fairly constant across the section except when sandbars are present. However, the measured suspended-sediment concentration follows no consistent lateral pattern. Lateral distributions of stream depth, velocity, and measured suspended-sediment concentration on 3 days are shown in figure 23.

The turbulence flume upstream seems to have little effect, if any, on the hydraulic or sediment characteristics of section E. The profiles in figure 4 and the readings from staff gages on both banks at section E and 300 feet upstream and downstream from section E show that the local water-surface slope is about the same as that at the other sections not influenced by the flume.

GAGING SECTIONS

The gaging sections normally used for water-discharge measurements for the gaging station are included in the reach between sections

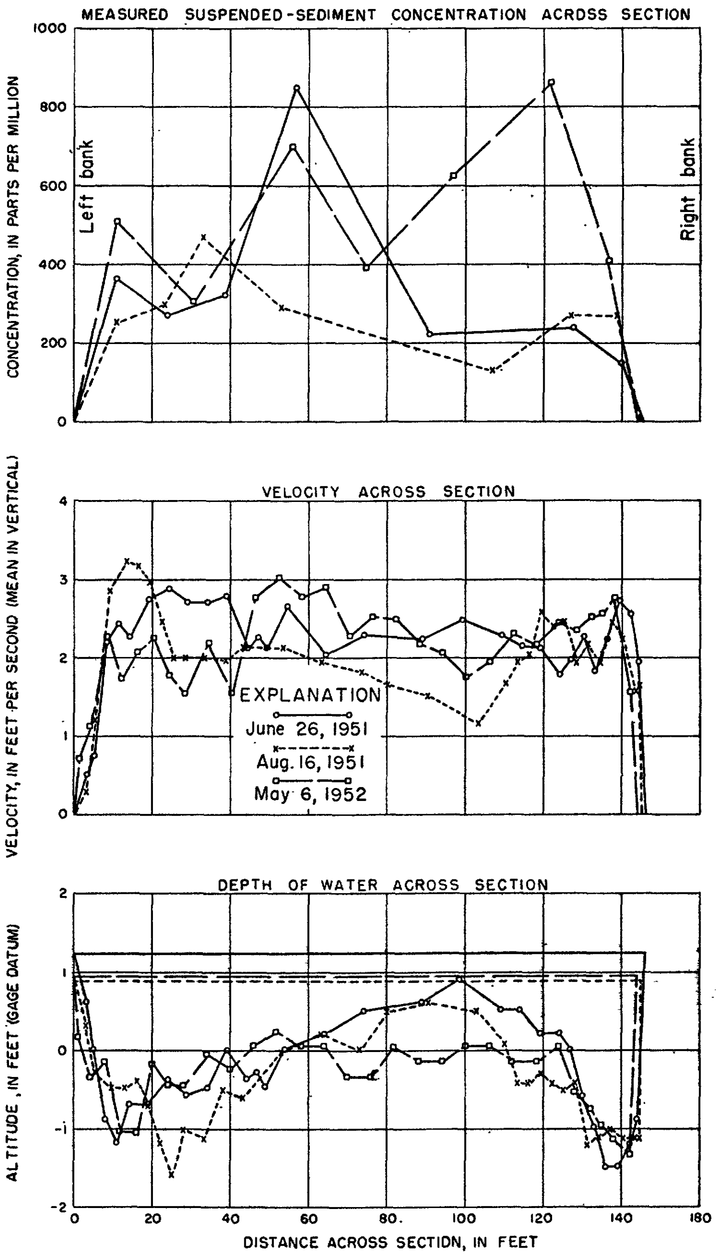


FIGURE 23.—Lateral distributions of depth, stream velocity, and measured suspended-sediment concentration, section E.

B_1 and C_2 (fig. 2). Throughout this reach, the channel is straight, and the shape and stability of the bed at any gaging section are fairly similar to those at the nearest selected section.

In this report, the term "gaging section" refers to a section which is not one of the selected river sections and at which only streamflow measurements were made. Whenever streamflow and sediment data were concurrently collected at any section other than a selected section, these data are included with the data for the nearest selected section and are differentiated from the selected section by an appropriate footnote. Such data should be treated as though they were collected at the selected section.

SEDIMENT DISCHARGES BY FORMULAS

One of the purposes of the turbulence flume is to provide information that can be used for evaluating the accuracy of formulas and methods for computing the sediment discharge of streams having sediment and hydraulic characteristics similar to those of the Middle Loup River. The accuracy of methods that give the total sediment discharge or the bed-material discharge can be evaluated by directly comparing computed discharges with measured total sediment discharges or measured bed-material discharges. However, the accuracy of methods that give the bed-load discharge or the discharge of sediment on and near the bed can only be estimated. Unmeasured sediment discharge, which can be determined from the measured total sediment discharge, can be used in estimating the accuracy. Ratios of the mean concentration in the unsampled zone to that in the sampled zone can also be used. The development of the final form of the equation for determining these ratios is as follows (a list of definitions of all symbols is given on p. 79): By definition (see p. 10)—

$$Q_{uM}=Q_{ts}-Q_{sM}$$

in which—

Q_{uM} is the unmeasured sediment discharge, in tons per day.

Q_{ts} is the total sediment discharge in the cross section in tons per day.

Q_{sM} is the measured suspended-sediment discharge in the cross section, in tons per day. (See p. 19.)

Also, by definition (see p. 10)—

$$\begin{aligned} Q_{uM}&=Q_{usM}+G_b \\ &=K_oK_{oo}Q_w\ (Conc_u-Conc)+G_b \end{aligned}$$

in which—

Q_{usM} is the unmeasured suspended-sediment discharge, in tons per day.

G_b is the bed-load discharge, in tons per day.

K_o is a constant for converting the units to tons per day.

K_{oo} is the fraction of flow in the unsampled zone. (See p. 54, step 9.)

Q_w is the water discharge, in cubic feet per second.

$Conc_u$ is the mean concentration, in parts per million, of the suspended-sediment discharge in the unsampled zone.

$Conc$ is the measured suspended-sediment concentration in parts per million (mean concentration in the sampled zone).

By expressing $Conc_u$ as a factor R times $Conc$—

$$
\begin{aligned}
Q_{usM} &= K_o K_{oo} Q_w \ (RConc - Conc) \\
&= K_o Q_w Conc \ (R-1) K_{oo} \\
&= Q_{sM} K_{oo} \ (R-1)
\end{aligned}
$$

and—

$$
\begin{aligned}
R &= (Q_{usM}/Q_{sM}K_{oo}) + 1 \\
&= [(Q_{ts} - Q_{sM} - G_b) \ / \ Q_{sM}K_{oo}] + 1
\end{aligned}
$$

The factor R is the number of times the mean concentration in the unsampled zone is greater than that in the sampled zone; or, in other words, it is the ratio of the mean concentration in the unsampled zone to that in the sampled zone. Of course, the ratio varies with the sediment and flow characteristics, the fraction of the depth sampled, and particularly the amount of wash load. High concentrations of wash load can mask out relatively large errors in bed-load discharge; however, the concentrations of wash load in the Middle Loup River are very low. If the ratios and any measurable parameters could be correlated, the total load could be estimated from the measured suspended-sediment load, the computed bed-load discharge, and a ratio.

Six different methods for computing sediment discharge are described and evaluated in this section of the report. These methods include the Einstein method, which computes the bed-material discharge; the modified Einstein procedure, which computes the total sediment discharge; and the Straub, Kalinske, Schoklitsch, and Meyer-Peter and Müller methods, which compute either the bed-load discharge or the discharge of sediment on and near the bed. These methods were evaluated on the basis of computations, in many of which the same basic data were used. For each method, except for the Einstein procedure, enough computations were made to be sure that the computations were representative of the different conditions of the river and that reasonable comparisons could be made between similar methods.

EINSTEIN PROCEDURE

H. A. Einstein (1950) has presented a method for computing the bed-material discharge. The computation consists essentially of computing the sum of the suspended-sediment load (exclusive of wash load) that is obtained from an integration of the product of the theoretical vertical distributions of velocity and suspended sediment and the bed-load discharge, determined from the probability of particles eroding from the bed; the probability of erosion is a function of a flow parameter. Bed load is considered to be discharged through a bed layer 2 grain diameters thick, and the suspended sediment is considered to be discharged from the water surface to the bed layer. The concentration of suspended sediment at the top of the bed layer is equated to the concentration in the bed layer, which is a function of the bed-load discharge.

Computations are made for a representative cross section of the channel and an average energy slope. Einstein suggests that the representative cross section should be determined by averaging the areas and the wetted perimeters of a number of sections in a typical reach that is of sufficient length to permit an adequate definition of the overall energy slope.

The reach of the Middle Loup River at Dunning extends from section A to section E, a distance of about 7,950 feet. (See fig. 2.) Twenty computations of sediment discharge were made for this reach; data from one or more sections in the reach are used in each computation. Because only a limited number of cross sections were selected for this investigation, the computations did not include as many sections as recommended by Einstein to define adequately the representative cross section. However, they do show some of the characteristics of the Einstein method and some of the effects the computed representative cross section has on the computed sediment discharge.

For the 4- and 5-section Einstein computations, water-surface slopes (assumed to be equal to energy slopes) were determined from gage-height traces of temporary recorders at sections A and E. For the 1- and 3-section computations, an average overall-reach slope of 0.00132 was used. For all computations, the bed-material size distribution was determined by averaging the mean distributions from the included sections (see table 4 for the mean bed-material size distribution for each section), and the representative cross sections were determined by averaging the effective areas and the effective widths (wetted perimeters) of the included sections. Because the Einstein method is devised to compute only the bed-material discharge, the load of sediment smaller than 0.125 millimeter (wash load) was not computed. The total load was approximated by summing the computed load and the average measured suspended-sediment load for the uncomputed fractions at the sections. The computed loads and the comparable measured loads at section D are given in table 7.

Loads computed with data from more than one section are compared with the daily mean sediment loads at section D, and the one-section computations are compared with instantaneous loads at section D.

Computations other than those shown in table 7 have been made by using various combinations of sections and also by using weighting procedures in an effort to determine the best representative cross section. The four-section combination of sections A, B (or B_1 or 25 feet upstream from B), C_2, and E gave the best results. The computed total loads for these 4-section combinations averaged 81 percent and ranged from 26 to 150 percent of the measured total loads. The individual percentages had a standard deviation of 49. If percentages are considered to be distributed normally, the standard deviation indicates that about two-thirds of all similar computations will be in a range of 81 $\pm$49 percent of the measured total load. These 4-section computations include 1 wide section, 2 narrow sections, and 1 medium-width section. When only 3 sections—2 narrow and 1 of medium width—were combined, the computed total loads averaged 236 percent and ranged from 69 to 497 percent (standard deviation, 184 percent) of the measured total loads. The 5-section computation, combining data from 1 wide section, 3 narrow sections, and 1 medium-width section, was 190 percent of the measured total load.

These computations indicate that the Einstein method is sensitive to the computed representative cross section, at least in shallow streams (3 feet or less). For the Dunning reach, when the computed representative cross section is narrow and deep, the computed loads are too high; when it is wide and shallow, the computed loads are too low. In the 4-section computations, even though the representative cross section was weighted with 2 narrow sections (these narrow sections represent only a small percentage of the total reach length), the average computed loads were still too low. This fact suggests that the areas and widths were weighted too much with section A. Generally, flow through wide sections does not distribute evenly over the entire width, but it divides into relatively shallow and relatively deep channels. The mean depth of flow where the major part of the sediment load is discharged will ordinarily be distinctly different from that for the entire cross section. Thus, if an alluvial channel is wide and the flow is braided, computed loads based on average total areas and widths may be too low. The effect of the representative cross section on computations is emphasized by comparison of the one-section computations with the measured loads. Four computations for section C_2, a very narrow section, averaged 540 percent and ranged from 139 to 1,241 percent (standard deviation, 483 percent) of the measured total loads. However, 4 computed total loads at section E, a section with an area and width approaching those of a representative cross section, averaged 115 percent and ranged only from 31 to 240 percent (standard deviation, 94 percent) of the measured total load.

Total loads from the four-section and section E computations are plotted against comparable measured total loads in figure 24. The figure shows the lack of agreement between the computed and measured total loads even though the average percentage indicates a reasonably good comparison. Included in the figure are computed total sediment discharges for section E that are based on computations of bed-material discharge made by E. L. Pemberton in 1950 (written

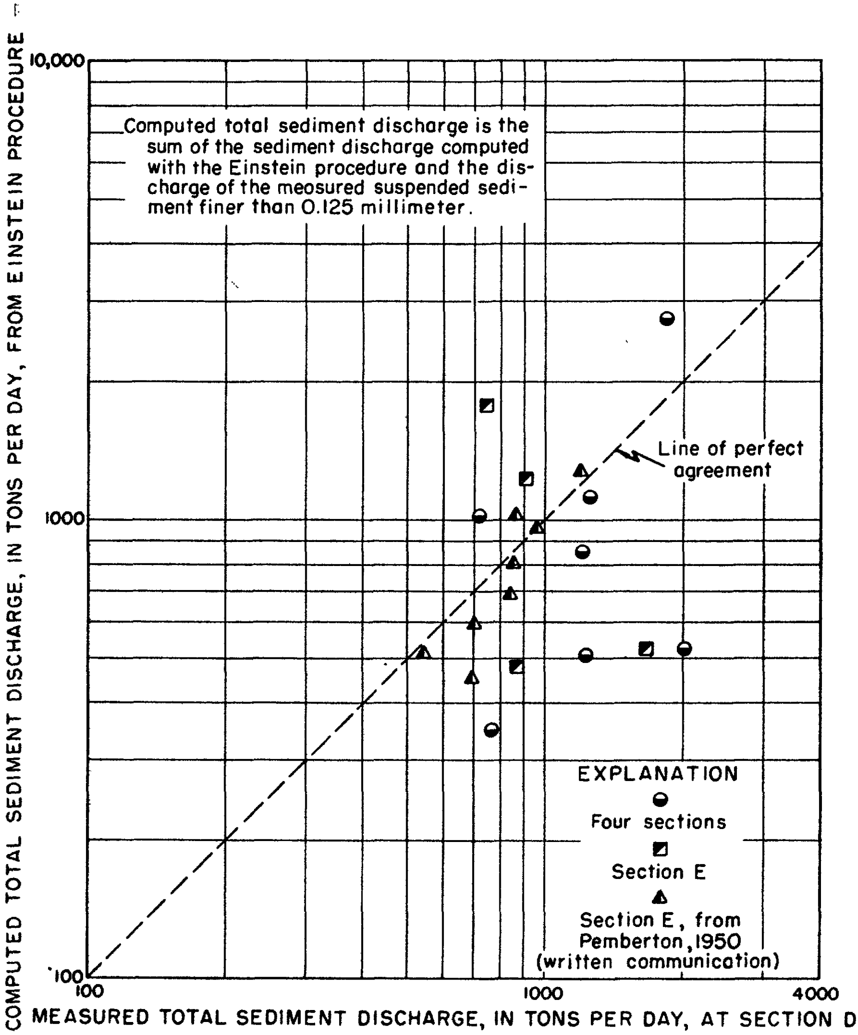


FIGURE 24.—Total sediment discharge computed from Einstein procedure plotted against measured total sediment discharge at section D.

communication). The Pemberton computations were made by using a slope of 0.00128 and a slightly different bed-material size distribution for section E than the one used for this report.

Comparisons of the computed loads larger than 0.125 millimeter (bed-material discharge) to the measured loads for the same fractions showed less accuracy (more percentage deviation) than the comparisons of computed total loads to the measured total loads. The 4-section computations averaged 82 percent but ranged from 13 to 167 percent (standard deviation, 64 percent) of the measured loads; the 5-section computation was 232 percent of the measured load; and the 3-section computations averaged 314 percent and ranged from 65 to 756 percent (standard deviation, 304 percent) of the measured loads. These comparisons are better indicators of the accuracy of the Einstein method than are comparisons of total loads. However, none of the comparisons are fair tests of the accuracy of the Einstein method because the number and location of the cross sections, which were selected for this investigation, did not meet Einstein's recommendations.

The size distributions of the computed loads do not compare favorably with the size distributions of the measured loads. In most of the computations the largest part of the total load was in the 0.25- to 0.50-millimeter fraction. However, the largest part of the measured total load was usually in the 0.125- to 0.25-millimeter fraction.

MODIFIED EINSTEIN PROCEDURE

A modification of the Einstein procedure for computing the total sediment discharge of an alluvial stream has been presented by Colby and Hembree (1955). The modification was developed during a study of the Niobrara River near Cody, Nebr., and is based on Einstein formulas (1950), but it differs from the Einstein procedure in four phases.

The following information from a given section at a given time is required for the computation of total load by this modified procedure: effective width, mean depth, and mean velocity of the flow; concentration and particle-size distribution of the suspended sediment in the sampled zone; particle-size distribution of the bed material; water temperature; average depth at the sampled verticals and distance from the bottom of the sampled zone to the stream bed.

MODIFIED FORMULA FOR SHEAR VELOCITY

For the modified formula the shear velocity is computed from a transposed form of equation 9 of H. A. Einstein (1950, p. 10) in which the shear velocity and hydraulic radius are the same as those given by G. H. Keulegan (1938), except the shear velocity is designated as

u_m and for a wide channel the hydraulic radius is replaced by the mean depth, d.

$$u_m=\sqrt{(RS)_m g}$$

$$=\frac{\bar{u}}{5.75 \log_{10}\left(12.27 \frac{dx}{k_s}\right)} \quad \text{(a)}$$

in which—

$(RS)_m$ is the quantity that is obtained by solving equation a for $(RS)_m$ from a known numerical value of $\bar{u}$.

g is the gravity constant, 32.2 feet per second per second.

$\bar{u}$ is the mean velocity, in feet per second, in the cross section and is usually from a streamflow measurement.

x is a dimensionless transition parameter.

k_s is the bed-material size, in feet, considered to be representative of bed roughness—used by Einstein (1950) as equal to D_{65}.

where—

D_{65} is the particle size at which 65 percent of the bed material by weight is finer.

Solution of equation a is by trial; x is the trial factor. Plate 6 shows the relationship of x to k_s/δ where—

$$\delta=\frac{11.6\nu}{u_m} \quad \text{(b)}$$

in which—

δ is the thickness, in feet, of the laminar sublayer.

ν is the kinematic viscosity, in square feet per second.

MODIFIED FORMULA FOR COMPUTING TOTAL SUSPENDED-SEDIMENT DISCHARGE OF SOME SIZE FRACTIONS

The suspended-sediment load of a size fraction moving through a cross section can be expressed by a form of Einstein's equation 33 (1950, p. 18).

$$Q_s=\frac{5.75}{2.303} w u_* d c_a \left(\frac{A}{1-A}\right)^z (PJ_1+J_2)$$

in which—

Q_s is the suspended-sediment discharge of a size range.

w is the effective width of the cross section.

u_* is the shear velocity.

c_a is the concentration of sediment particles of a size fraction at a distance, a, above the stream bed.

A is the distance of the lower limit of integration above the stream bed divided by the mean depth, d.

z is the exponent of the equation that describes the vertical distribution of suspended sediment.

P is a parameter, and J_1 and J_2 are integrals.

$$P = 2.303 \log_{10}\left(30.2\frac{dx}{k_s}\right)$$

$$J_1 = \int_A^1 \left(\frac{1-y}{y}\right)^z dy$$

$$J_2 = -\int_A^1 \left(\frac{1-y}{y}\right)^z \log_e (y)\, dy$$

where—

y is a distance above the stream bed.

Also, the equation for the concentration distribution in a vertical (Einstein, 1950, equation 29, p. 17) can be written in the form—

$$c_y = c_a \left(\frac{d-y}{y}\right)^z \left(\frac{A}{1-A}\right)^z \qquad \text{(c)}$$

in which—

c_y is the concentration of sediment particles of a size fraction at the distance, y, above the stream bed.

For any given distance, a, $c_a[A/(1-A)]^z$ is necessarily constant. Thus—

$$\frac{5.75}{2.303} w u_* d c_a \left(\frac{A}{1-A}\right)^z = K$$

in which—

K is a constant.

By substitution—

$$Q_s = K(PJ_1 + J_2).$$

If a single prime mark designates association with the sampling depth and a double prime mark designates association with the total depth through which suspended sediment is discharged, the ratio of the measured suspended sediment of a size fraction discharged through the sampling zone, Q_s', to the suspended sediment of the size fraction discharged through the total depth, Q_s'', can be transposed and expressed by—

$$Q_s'' = Q_s' \frac{(PJ_1'' + J_2'')}{(PJ_1' + J_2')}. \qquad \text{(d)}$$

MODIFIED FORMULAS FOR THE EXPONENT z

In the modified procedure, computations of the total sediment discharge can be made with a z determined for each size range by any 1 of 4 different methods; however, computations are generally made with a z called z_2.

In accordance with equation c, c_y versus $(d-y)/y$ plotted on logarithmic coordinate paper establishes z_1 for a given size fraction. (z_1 is the slope of the line.)

Figure 25 shows z_1 plotted against z_m where z_m equals $V_s/0.4u_m$. At a given cross section and time, $0.4u_m$ is a constant; thus, the slope of a line defined by any individual set of z_1's shows the variation of that set with V_s, the fall velocity of the geometric mean particle size of a size range. The average of all the slopes indicates that z_1 is proportional to the 0.7 power of the fall velocity when V_s is from Rubey's equation (1933).

Q_s'' can be computed from Einstein's equation 61 (1950, p. 40) if the equation is written as—

$$Q_s''=i_BQ_B(PI_1''+I_2'')$$

in which—

i_BQ_B is the bed-load rate for the entire width (sediment discharge, in tons per day, through the bed layer of particles of a size fraction).

I_1'' is a mathematical abbreviation that contains J_1''.

$$I_1''=0.216\frac{A^{z-1}}{(1-A)^z}J_1''$$

$$=K_1J_1''$$

I_2'' is a mathematical abbreviation that contains J_2'' and is negative.

$$I_2''=0.216\frac{A^{z-1}}{(1-A)^z}J_2''$$

$$=K_1J_2''$$

where—

K_1 is a constant for a given section and time and equals I_1''/J_1'' or I_2''/J_2''.

This equation combined with equation d gives—

$$\frac{Q_s'}{i_BQ_B}=\frac{(PI_1''+I_2'')(PJ_1'+J_2')}{(PJ_1''+J_2'')} \tag{e}$$

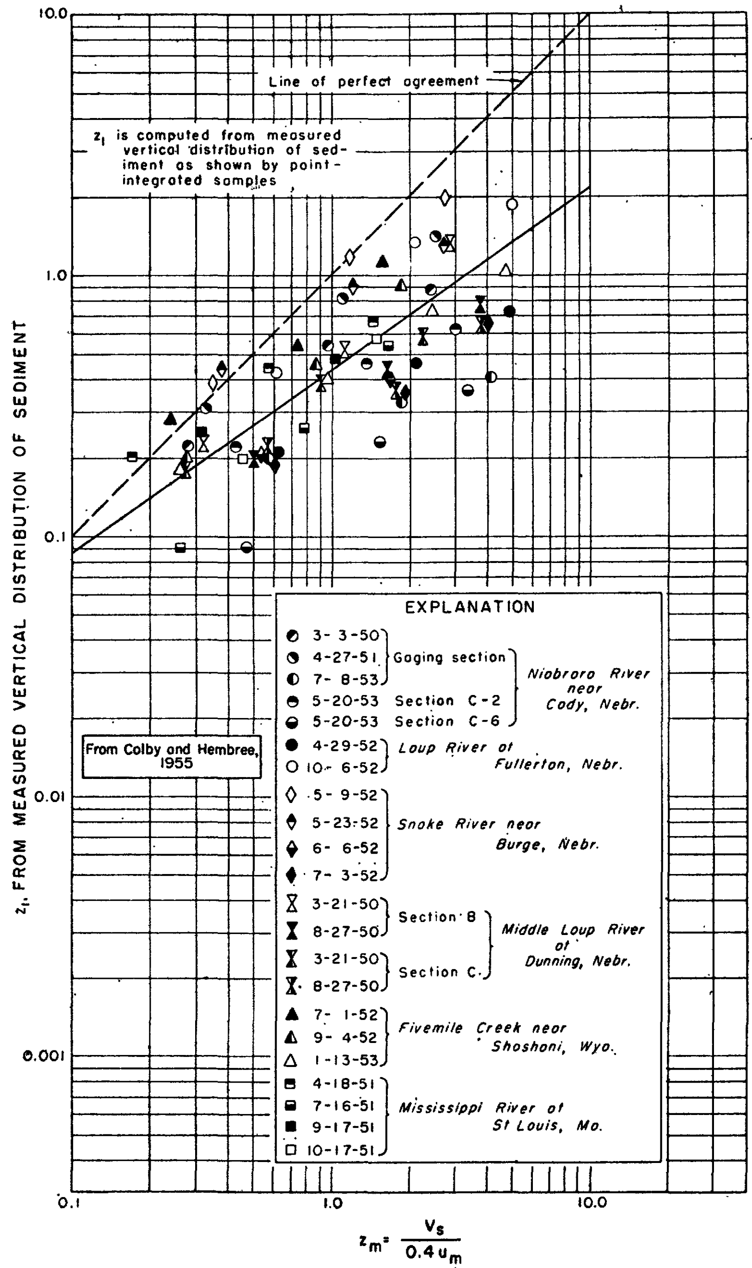


Figure 25.—z_1 plotted against z_m.

or—

$$\frac{Q_s'}{i_B Q_B}=\frac{I_1''}{J_1''}(PJ_1'+J_2') \tag{f}$$

$$=\frac{I_2''}{J_2''}(PJ_1'+J_2')$$

Equation f is given by Colby and Hembree (1955, equation C) for computing z_2. Because Q_s' and $i_B Q_B$ are computed independently of z, only one numerical value for z will determine I and J quantities to satisfy equation f.

A z_3 can be computed from Q_s' and Q_s'''. Q_s''' is the measured total sediment discharge of a size fraction for the entire width. Einstein's equation 63 (1950, p. 40) can be written in the form—

$$Q_s'''=i_B Q_B(PI_1''+I_2''+1) \tag{g}$$

Eliminating $i_B Q_B$ by use of equation e—

$$\frac{Q_s'}{Q_s'''}=\frac{(PI_1''+I_2'')(PJ_1'+J_2')}{(PI_1''+I_2''+1)(PJ_1''+J_2'')} \tag{h}$$

Only one z_3 will give I and J quantities that will satisfy equation h with a given Q_s' to Q_s''' ratio.

Colby and Hembree (1955) have designated a z from an empirical equation as z_4. They have used the equation $z_4=4.6\,(V_s)^{0.7}$; however, they point out that an equation of this type does not contain any parameter of flow or turbulence and is not likely to be generally applicable to streams other than the one for which it was defined.

MODIFIED FORMULAS FOR FLOW AND BED-LOAD TRANSPORT INTENSITIES

Einstein's equation 54 (1950, p. 37) defines the flow intensity for a size fraction by—

$$\Psi_*=\xi Y(\beta/\beta_x)^2\Psi$$

in which—

- ξ is a hiding factor of grains in a mixture and decreases to 1.0 for particle sizes large enough to make D/X greater than 1.5.
- Y is a pressure correction in the transition from smooth to rough flow and is a function of k_s/δ.
- β is equal to $\log_{10}$ (10.6).
- β_x is equal to $\log_{10}$ $(10.6Xx/k_s)$.
- Ψ is a function for correlating the effect of the flow with the intensity of bed-load transport.

where—

- D is the geometric mean size, in feet, of a size fraction.
- X is the characteristic grain size of the bed mixture.

For the modified procedure, Ψ is from Einstien's equation 49 (1950, p. 36); however, $(RS)_m$ is substituted for $R'S_e$.

$$\Psi=(S_s-1)\frac{D}{(RS)_m}$$

in which—

S_s is the specific gravity of the solid sediment particles.

A flow intensity computed with the substitution in the Ψ equation does not have the same numerical value as a flow intensity computed with the original Einstein equation. Many numerical values for $Y(\beta/\beta_x)^2$ were computed by Colby and Hembree (1955); they ranged from 0.3 to 0.6 and averaged about 0.4. Combining the 0.4 with the modified equation for Ψ gives an average equation of the flow intensity for particle sizes for which ξ is equal to 1 (Colby and Hembree, 1955, equation I).

$$\Psi_m=0.4(S_s-1)\frac{D}{(RS)_m} \qquad \text{(i)}$$

For the particle sizes small enough for ξ to be greater than 1.0, a function different from equation i had to be selected. The selected equation was Einstein's equation 11 (1950, p. 10), which for the modified procedure (Colby and Hembree, 1955, equation H), becomes—

$$\Psi_m=(S_s-1)\frac{D_{35}}{(RS)_m} \qquad \text{(j)}$$

in which—

D_{35} is the particle size, in feet, at which 35 percent of the bed material by weight is finer.

In a computation of the load of a size fraction, the larger Ψ_m from equations i and j is used. Thus, a Ψ_m from equation j is always used for particle sizes smaller than 2.5 D_{35}, and for all such sizes Ψ_m is a constant.

This application of equations i and j is somewhat analogous to Einstein's use of ξ. Equation i replaces the part of the curve in Einstein's figure 7 (1950) for which ξ equals 1.0, and equation j replaces the part for which ξ is greater than 1.0. Use of equation j gives a flow intensity that does not change with particle size. A constant flow intensity for the smaller particle sizes could be computed from Einstein's equation 54 (1950, p. 37) if the ξ versus D/X curve had a slope of 1.0 for values of D/X less than 1.0. Colby and Hembree (1955, fig. 44) illustrate that when z is considered to be proportional to the 0.7 power of the fall velocity, the ξ versus D/X curve does have an average slope of about 1.0.

Flow intensities computed as Ψ_m are different from those computed as Ψ_*. However, for the modified procedure, Ψ_m is used for Ψ_*, and the Φ_* determined from the Ψ_* versus Φ_* curve (Einstein, 1950, fig. 10) is divided by two to obtain the intensity of bed-load transport. A z_2 determined from an i_BQ_B that is computed from $\Phi_*/2$ has about the same numerical value as a comparable z_3. Also, a load computed with such a z_2 is comparable to the measured total load.

COMPUTATION PROCEDURE

Colby and Hembree (1955) have presented an explanation of the total load computation procedure; however, a brief explanation is presented here to review the essentials of the procedure. A sample total load computation based on information from measurements of water and sediment discharges made on December 14, 1950, at 3:30 p. m. is shown in plate 7. This sample computation is merely for illustration, and none of the numerical values are referred to in the following step-by-step explanation.

The computation form (pl. 7) is separated into four major computation blocks, which are headed: block I, preliminary data and computations; block II, computation of i_BQ_B; block III, computation by z_2; and block IV, computation by z_x.

Step 1.—Fill in line 1, block I, with the basic data in pound-foot-second units; w, effective width; $\bar{u}$, mean velocity; d, mean depth; d_s, average depth at the verticals sampled; D_{65} (or k_s) and D_{35}, particle size at which 65 and 35 percent, respectively, of the bed material by weight is finer; *Conc*, measured suspended-sediment concentration (in parts per million); Q_{sM}, measured suspended-sediment discharge (in tons per day); and *Temp*, water temperature in degrees Fahrenheit. (The English system of units is used throughout the computation.)

Step 2.—Solve the converted form of equation a, line 2, block I, for $\sqrt{(RS)_m}$ after assuming a trial x.

Step 3.—Compute $(RS)_m$ from the $\sqrt{(RS)_m}$ determined by step 2.

Step 4.—Compute the shear velocity, u_m, from $\sqrt{(RS)_m g}$, in which $\sqrt{(RS)_m}$ is from step 2 and g is the gravity constant, 32.2 feet per second per second.

Step 5.—Compute δ from equation b, in which ν is the kinematic viscosity, in square feet per second, at the indicated water temperature and u_m is from step 4. Tables or graphs of the kinematic viscosity of water are given in most text books on fluid mechanics and engineering handbooks.

Step 6.—Calculate k_s/δ and enter plate 6 for x. If the trial x is not about the same as the x from the plate, repeat steps 2 through 6.

Step 7.—Solve for P, (p. 48) on line 3.

Step 8.—Determine A', on line 4, from $A'=d_n/d_s$, in which d_n is the vertical distance, in feet, not sampled; that is, the distance from the bottom of the sampled zone to the stream bed.

Step 9.—From fig. 26, find the percentage of flow in the sampled zone by using the computed A' and P.

Step 10.—Compute the load in the sampled zone (Q_{ts}') by multiplying the percentage of flow in the sampled zone by the measured suspended-sediment discharge (Q_{sM}).

Step 11.—List the percentage of measured suspended sediment in each size range under the geometric mean size of the range (line 5) on line 6 if the percentages were determined from an actual size analysis or on line 7 if they were determined by some other means. Line 8 is not completed unless the size distribution of the measured total load is known and is to be used in checking the accuracy of the computed total load.

Step 12.—List in column 1, block II, each geometric mean size of the size ranges that have appreciable bed-load discharge (i_BQ_B).

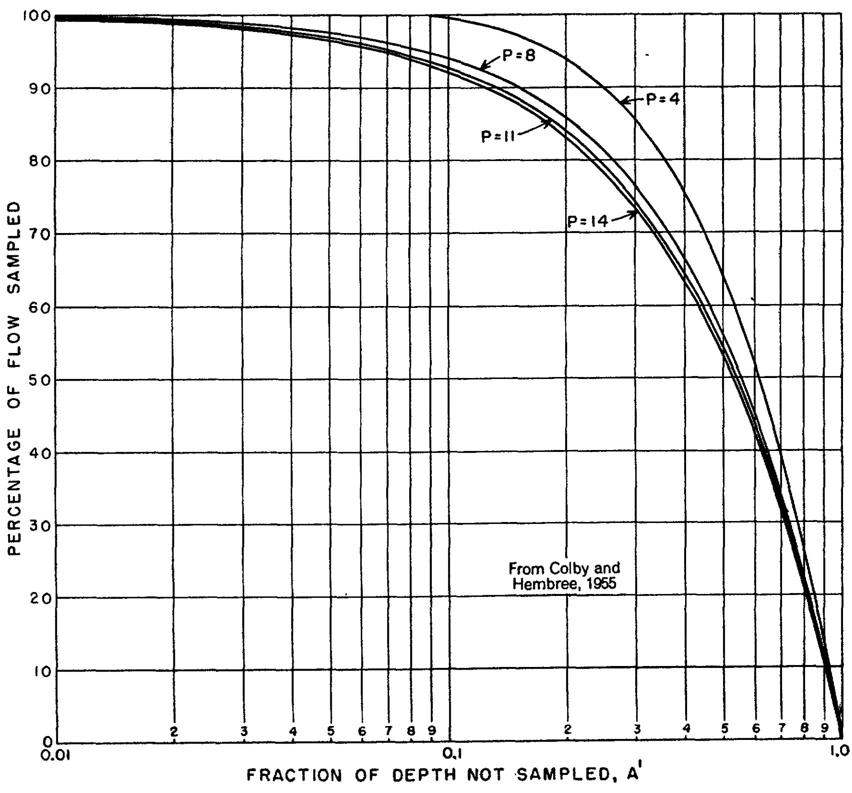


FIGURE 26.—Vertical distribution of streamflow.

Step 13.—Compute a Ψ_m for each size range, first by equation i and then by equation j. List the larger Ψ_m in each size range in column 2.

Step 14.—Determine the Φ_* for each size range from plate 8 by using Ψ_m in column 2 in place of Ψ_*. Divide each Φ_* by 2 and enter the quotients in column 3.

Step 15.—Einstein (1950, step 34, p. 59) has defined $i_B q_B$, the sediment discharge in pounds per second per foot of width through the bed layer of particles of a size fraction, as the product of the intensity of bed-load transport, i_b, s_s, $g^{3/2}$, $D^{3/2}$, and $(S_s-1)^{1/2}$. For the modified method this equation may be written as—

$$i_B q_B=\frac{\Phi_*}{2}\, i_b s_s g^{3/2} D^{3/2} (S_s-1)^{1/2}=1{,}200 i_b D^{3/2} \frac{\Phi_*}{2} \qquad \text{(k)}$$

in which—

the intensity of bed-load transport is represented by Φ_* in the Einstein method and by $\Phi_*/2$ in the modified method. The intensity of bed-load transport is dimensionless.

i_b is the fraction by weight of bed material in a size range.

s_s is the mass density of the sediment and equals the product of 2.65 and 1.94 slugs per cubic foot (5.14 slugs per cubic foot).

S_s is the specific gravity of the sediment (2.65).

List the value of 1,200 $D^{3/2}$ for each size range in column 4. D is the geometric mean size of the size range.

Step 16.—Enter the fraction of bed material in each size range (i_b) in column 5.

Step 17.—Compute $i_B q_B$ for each size range from equation k in step 15 and list in column 6.

Step 18.—Compute the constant 43.2w for entry in column 7. This w is the effective width, and 43.2 is a constant converting pounds per second to tons per day.

Step 19.—Compute $i_B Q_B$ for each size range and enter in column 8. $i_B Q_B$ is the product of $i_B q_B$ and 43.2w.

Step 20.—List in column 9, block III, the geometric mean size of all the size ranges that are transported. (Column numbers for blocks III and IV are at the bottom of block IV.)

Step 21.—Compute the load in the sampled zone of each size range (Q_s') as the product of the load in the sampled zone (Q_{ts}') (line 4, block I) and the percentage of measured suspended sediment in each size range (from lines 6 or 7, block I). If the percentages from line 6 are used, enter the product in column 10; if from line 7, enter the product in column 11.

Step 22.—Copy in column 12 each $i_B Q_B$ from column 8, block II.

Step 23.—Compute A'' for each size range from $A''=2D/d$ and enter in column 15. A'' is equal to the distance of the lower limit of integration above the stream bed, a, divided by d. Einstein (1950, p. 25) shows the relation, $a=2D$.

Step 24.—The large box, headed "Determination of reference z_2," in block III is used in this step. Select the reference size. The reference size should be the geometric mean size of a size range that is represented in appreciable quantitites in both bed-load discharge and suspended-sediment discharge. For streams in which the bed-load discharge is a substantial part of the total load, the reference size range ordinarily will be the range that has the greatest total sediment discharge. Once the reference size is selected, it can be used for all subsequent computations. Compute the value of the ratio Q_s'/i_BQ_B (left-hand side of equation f) for the reference size. Assume a z_2 for the reference size (fig. 27 will aid in a first approximation for many shallow streams) and solve the right-hand side of equation f with values from plates 9, 10, and 11, using A' and A'' with the assumed z_2 of the reference size. When the right and left sides of the equation balance, the assumed z is the proper z_2 for the reference size range.

Step 25.—Because z varies with about the 0.7 power of fall velocity and because flow characteristics that might cause z to vary are constant at a given cross section and time, the z_2 for the other size ranges can be computed by proportion from the z_2 for the reference size range.

$$z_{2u}=z_{2r}\left(\frac{V_{su}}{V_{sr}}\right)^{0.7} \tag{m}$$

in which—

z_{2u} is the unknown and required z_2 for a size range.

z_{2r} is the known z_2 for the reference range.

V_{su} is the fall velocity of the geometric mean size of the range requiring the z_2.

V_{sr} is the fall velocity of the geometric mean size of the reference range.

Curves for the different size ranges of $(V_{su}/V_{sr})^{0.7}$ (called multipliers) versus temperature are plotted on plate 12; the 0.125- to 0.25-millimeter size range is the reference range. The z_2 for any size range is the product of the z_2 for the reference range and the multiplier at the indicated water temperature for the size range. List in column 13 the multiplier for each size range.

Step 26.—Compute the z_2 for all size ranges from the z_2 for the reference range and the multiplier. (See equation m.)

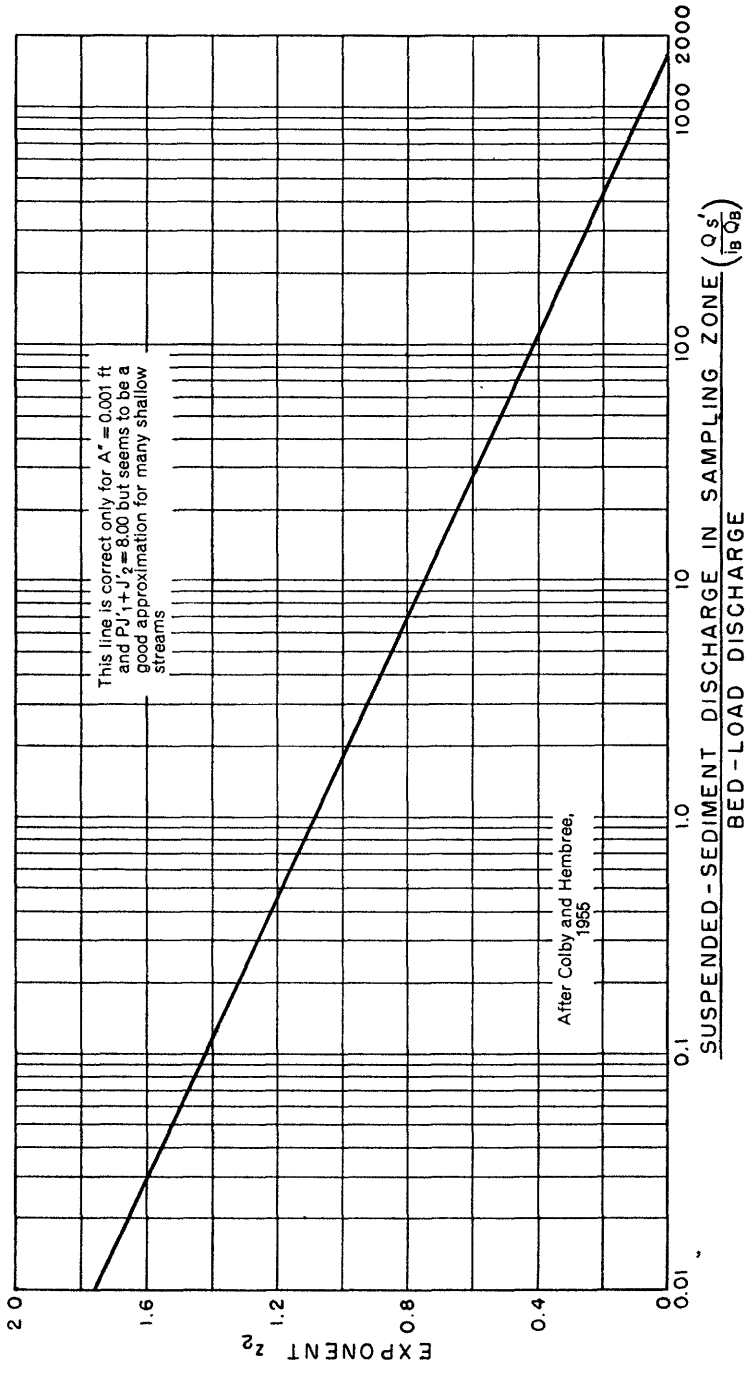


FIGURE 27.—Approximate relation of z_2 to the ratio of suspended-sediment discharge in the sampling zone to bed-load discharge.

Step 27.—Complete columns 16, 17, 18, and 19 for the size ranges where the z_2 is less than about 0.9; use plates 9 and 10 and the z_2, A', and A'' for each size range.

For low values of z, variations of z result in low rates of change in $PJ_1''+J_2''$ and high rates of change in $PI_1''+I_2''$. For high values of z, variations of z result in the reverse. For a z of about 0.9, the rate of change in $PJ_1''+J_2''$ and $PI_1''+I_2''$ is about equal. Either equation d or equation g can be used to compute the total load of a size fraction. (Any appreciable values of i_BQ_B must be added to values from equation d for the total load.) If z is less than 0.9, the load should be computed with equation d; if z is greater than 0.9, the load should be computed with equation g. When z_2 is used, the z_2 for the reference size is determined by using both $PJ_1''+J_2''$ and $PI_1''+I_2''$. (See equation e.) Therefore, loads computed for the reference size with either equation d or g will be about the same.

Step 28.—Compute the ratio $(PJ_1''+J_2'')/(PJ_1'+J_2')$ (equation d) from P (line 3, block I) and the information computed in step 27. J_2 is always negative. List the ratios in column 20.

Step 29.—Complete columns 21 and 22 for all size ranges for which no J was determined; use plates 11 and 13 and the z_2 and A'' for each size range.

Step 30.—Compute $PI_1''+I_2''+1$ (equation g) for entry in column 23 from P and the information in columns 21 and 22. I_2'' is always negative.

Step 31.—Compute the total sediment discharge of all the size ranges for which J quantities were determined; it is the product of the values in column 20 and in column 10 or 11 (see equation d) plus any appreciable values of i_BQ_B. Enter the total sediment discharge in the appropriate column—either 24 or 25.

Step 32.—Compute the total sediment discharge of all the size ranges for which I quantities were determined; it is the product of the values in columns 12 and 23. (See equation g.) Enter the total sediment discharge in either column 24 or 25.

Whenever any type of z other than z_2 is used in the computation, steps 20 through 24 are altered. An example using a z_x will be explained in the following steps. The symbol z_x is used to represent either z_1, z_3, or z_4.

Step 20a.—Compute z_x for the reference size according to the information on pages 49 to 51. (See explanation of reference size in step 24.)

Step 21a.—List in column 9, block IV, the geometric mean size of all the size ranges of sediment that are transported.

Step 22a.—Compute and enter Q_s' for each size range according to step 21.

Step 23a.—Compute A'' for each size range according to step 23 and enter the values in column 15, block IV.

Step 24a.—The large box, headed "Determination of reference z_x and comparable i_BQ_B," in block IV is used in this step. For a given z_x, A'', A', and Q_s', only one i_BQ_B will satisfy equation f. In other words, at a given cross section and time and for a given z_x, only one i_BQ_B will reproduce the measured suspended sediment in the sampled zone. (For the reference size, if the z_x is the same as the computed z_2, the computed i_BQ_B will be the same as the i_BQ_B in column 8, block II.) Solve directly for i_BQ_B of the reference size; use equation f and the reference size Q_s', z_x, A'', and A'. Enter the value in column 12, block IV.

Step 25a.—Proportion each i_BQ_B listed in column 8, block II, in the same proportion as that between the i_BQ_B computed in step 24a and the i_BQ_B listed for the reference size in column 8, block II. Enter the value of each proportioned i_BQ_B in column 12, block IV.

Step 26a.—Continue as before, starting with step 25.

Ideally, the total sediment discharge would be computed by summing the sediment discharges through increments of width, throughout each of which all the various hydraulic parameters are constant. However, if computations are made for sections or parts of sections through which the velocities are fairly uniform laterally, the results will be satisfactory because lateral changes in velocity have more effect on the total load computations than lateral changes in other parameters—particularly if the velocities are less than 1.5 feet per second. Colby and Hembree (1955) advise avoiding sections in which a large percentage of the cross-sectional area has flow at velocities of generally less than 1.5 feet per second. However, they suggest that the total sediment discharge of such sections can be computed by summing the individual sediment discharge of segments of the cross section; the flow in each segment should have relatively constant velocities.

COMPUTATIONS BY THE MODIFIED EINSTEIN PROCEDURE

Sixty-three total sediment discharges for the selected river sections were computed with the modified Einstein method. The loads, by individual size fractions, computed for each section and time are listed and compared with the measured loads at section D (at comparable times) in table 8. The computed total loads ranged from 64 to 166 percent and averaged 112 percent of the measured total load. The standard deviation of the 63 individual percentages was 22 percent. Thus, if an infinite number of similar computations were made and the computed loads were expressed as percentages of the measured total load, roughly two-thirds of the percentages would be within ±22 percent of the mean percentage, and the chances are 19 out of 20 that the mean percentage would be within a range of 107 to 117 percent of the measured total load. A comparison between the computed total load and the measured total load is shown on figure 28. The discontinuous dashed lines indicate the computed total load in percentage of the measured total load. The 112 percent is an unweighted average of the individual percentages. However, if computations are made to determine a continuous accumulation of sediment, a weighted average is more representative of the accuracy of the method. The sum of the computed total sediment loads was

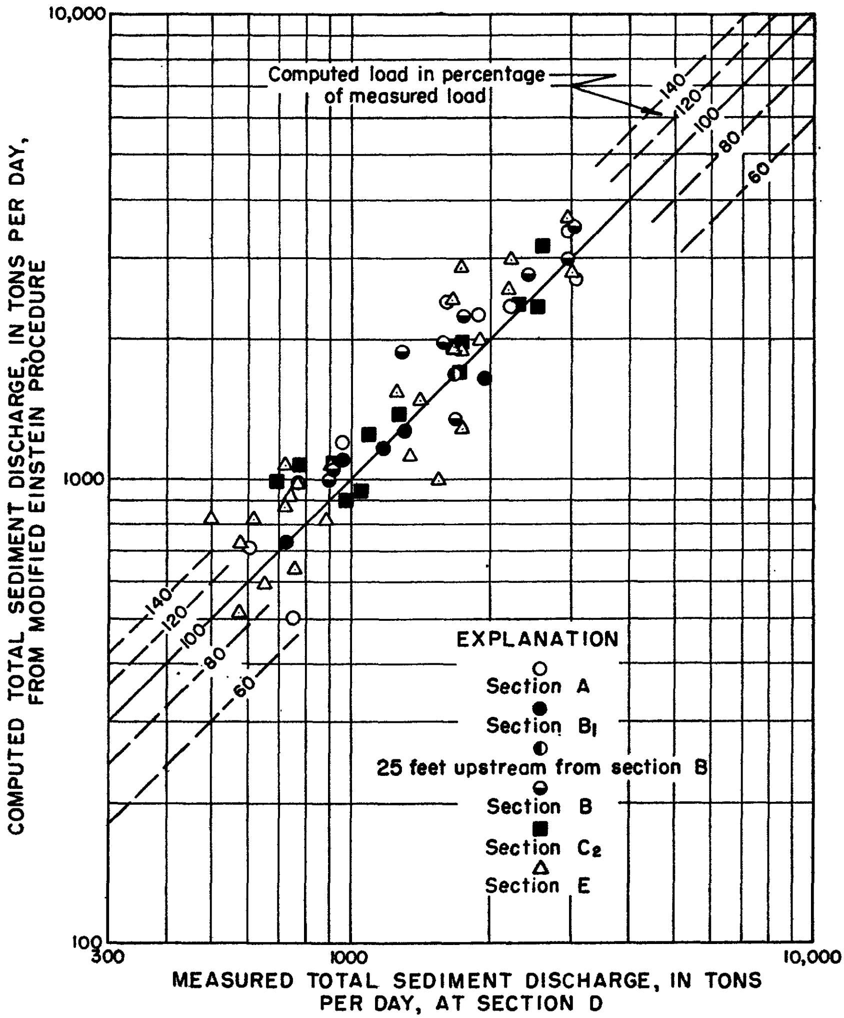


FIGURE 28.—Computed sediment discharge from modified Einstein procedure plotted against measured total sediment discharge at section D.

111 percent of the sum of the measured total sediment loads at the turbulence flume at comparable times.

In this report, the following information from each section was used for the computations of total sediment discharge: The average bed-material size distribution that was determined from all available samples, other than special samples, collected at the section; the measured suspended-sediment concentration and size distribution; the measured sediment discharge computed from the rated water discharge, except when the load was computed by parts; multipliers based on fall velocities from Rubey's equation. Most of the computed total loads for section A and some of the computed total loads for section E were determined from individual computations for each of two parts or more of the section. The procedure of computing the total sediment discharge at a section by parts usually improved the agreement between the computed and the measured total loads.

STRAUB EQUATION

L. G. Straub (U. S. Cong., 1935) developed, for various flow conditions, a series of equations from the original formula by P. du Boys. The Du Boys formula is based on the ideas that bed sediment is moved by a shear, or tractive, force created by the component in the direction of flow of the weight of water above the bed and that there is a critical shear at which general movement will begin. The formula is intended to compute the discharge of sediment that moves along or near the bed. A form of Straub's equation 8 (U. S. Cong., 1935, p. 1135) was selected for this report.

$$G=43.2\ \theta S^2\ [\Sigma wd(d-d_o)]$$

in which—

G is the sediment discharge, in tons per day.

43.2 is a constant for converting pounds per second to tons per day.

θ corresponds to Straub's Ψ, the transportation characteristic, in pounds per cubic foot per second.

S is the slope of the energy gradient and in this report is considered to be equal to the slope of the water surface.

d_o is the minimum depth at which bed sediment will move and equals $\tau_c/\gamma S$.

where—

τ_c is the critical tractive force, in pounds per square foot, at which general sediment movement begins.

γ is the specific weight of water and equals 62.4 pounds per cubic foot.

Straub determined the following values for θ and τ_c:

Mean diameter, in millimeters, of bed material	θ	τ_c
0.125	523,000	0.0162
.25	312,000	.0172
.50	187,000	.0215
1.0	111,000	.0316
2.0	66,200	.0513
4.0	39,900	.089

Values of θ and τ_c for the median diameter of bed material were determined for use in the computations in this report from graphs of θ and τ_c versus particle size that were based on the above table. The sediment load was determined by summing $wd(d-d_o)$ for about 30 subsections of the cross section.

Loads from computations for section E are shown with other pertinent data in table 9. Comparisons show that the computed loads are generally much too high and that they are, on the average, about twice the measured total loads at section D. The equation seems to be more suitable for deep streams or shallow streams that have flat gradients than for streams that have hydraulic characteristics like those of the Middle Loup River.

KALINSKE EQUATION

A. A. Kalinske (1947) has developed an equation for computing the bed-load discharge of unigranular material. The basis for the equation is that the bed-load discharge is equal to the product of the average velocity of the particles, the weight of each particle, and the number of particles. From an analysis of the turbulent variations in stream velocity in the zone of bed-load movement, the average particle velocity is related to the ratio of the critical tractive force (or critical shear) to the total shear. The product of the particle weight and number simplifies to the product of a constant, the specific weight of a particle, and the part of the bed area taking shear. Kalinske also presented a method for adapting the equation to sand mixtures. In the adaption, the load of each size range is computed independently, and the part of the bed taking shear for each size range is expressed as a proportion of the whole bed area taking shear. In this report, a form of Kalinske's equation 10a is used for sand mixtures.

$$g_b=43.2\ wu_*\ \gamma_s D p_i\ 7.3\ (\overline{U}_g/\overline{U})$$

in which—

g_b is the bed-load discharge, in tons per day, for a size range.

43.2 is a constant for converting pounds per second to tons per day.

u_* is the shear velocity, in feet per second, and equals $\sqrt{dSg}$ for wide channels.

γ_g is the specific weight of sediment particles, in pounds per cubic foot.

D is the mean particle-size diameter, in feet, of a size range and in this report is used as the geometric mean.

p_i is the part of the bed area occupied by the particles in the size range and is equal to $p(i_b/D)/m$.

7.3 is a constant.

$\overline{U}_g/\overline{U}$ is the ratio of the mean speed of movement of the particles of a size range to the mean velocity of flow at the grain level and is a function of τ_c/τ_o for constant values of r, the relative intensity of turbulence. (Fig. 29 is used to obtain $\overline{U}_g/\overline{U}$ from τ_c/τ_o.)

where—

p is the part of the bed area taking shear and has experimentally been shown to equal 0.35 for unigranular material.

m is the summation of all values of i_b/D for the various size ranges that compose the bed.

τ_o is the total shear at the bed and equals γdS.

The total bed-load discharge, G_b, is the sum of the g_b for each size range in the bed.

The results of 17 computations for section E by the Kalinske equation are given in table 9. Computed discharges seem to be in the proper order of magnitude; however, the range of the discharges for the different hydraulic conditions was relatively small. In general, low discharges were associated with high total sediment discharges and high unmeasured sediment discharges, and high discharges were associated with low total sediment discharges and low unmeasured sediment discharges. In addition, figure 30, which is a graph of the concentration of measured suspended sediment coarser than 0.125 millimeter plotted against computed bed-load discharge, shows that low discharges are associated with high concentrations and that high discharges are associated with low concentrations. According to the equations for the vertical distribution of sediment and the relationships between bed-load discharge and suspended-sediment concentration presented by Einstein (1950), the concentration of suspended bed-material load and the concentration of the measured suspended bed-material load will generally increase as bed-load discharge increases.

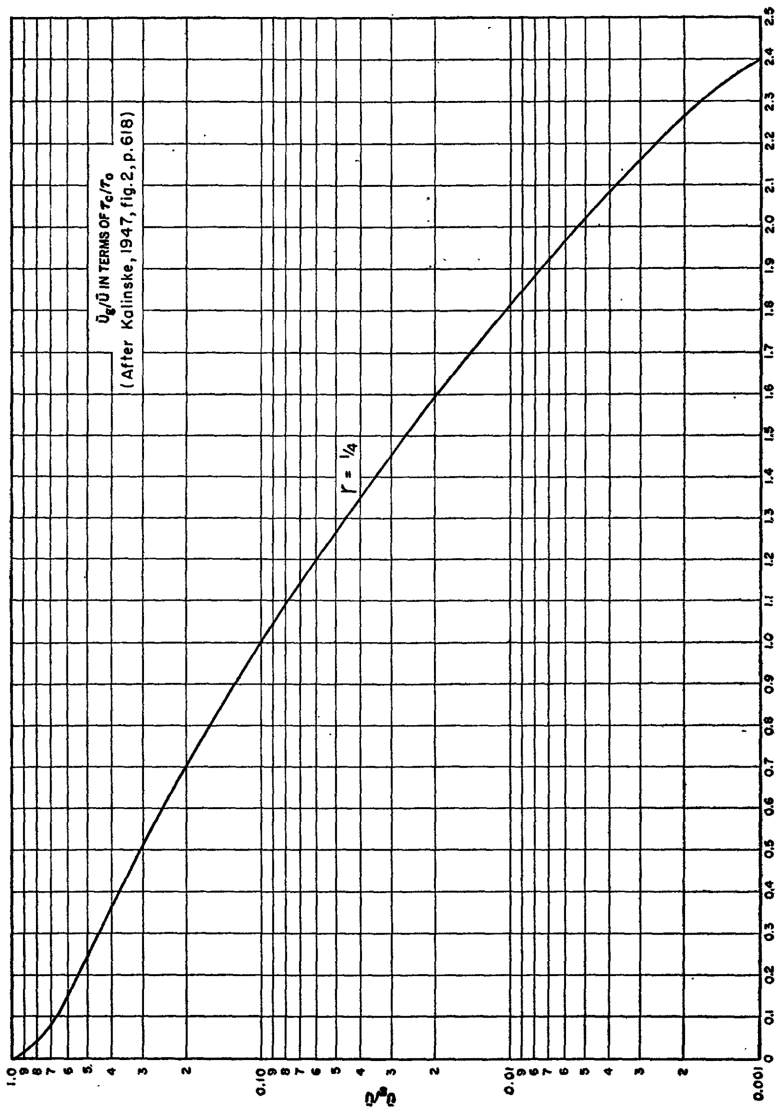


FIGURE 29.—$\overline{U}_s/\overline{U}$ in terms of τ_c/τ_o.

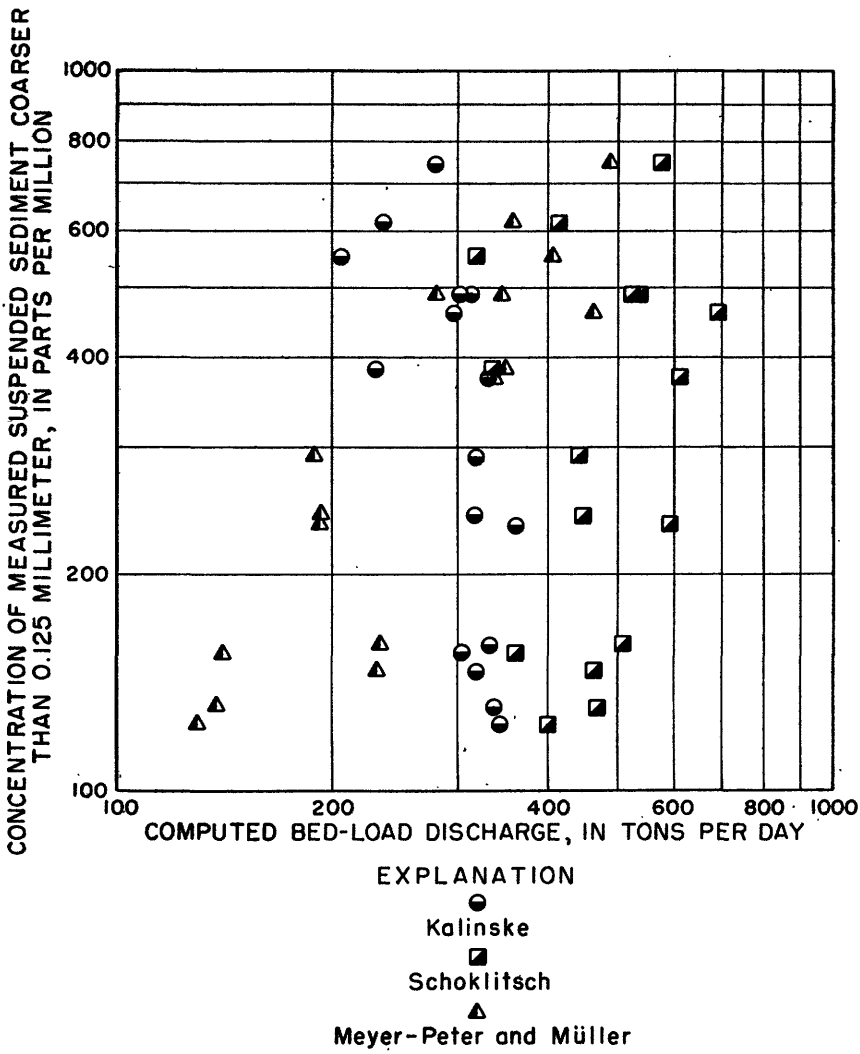


FIGURE 30.—Computed bed-load discharge plotted against concentration of measured suspended sediment coarser than 0.125 mm.

SCHOKLITSCH EQUATION

Samuel Shulits (1935, p. 644–646, 687) has published a discussion of the Schoklitsch bed-load equation. The basis for this equation is that bed material will begin to move at some critical flow and that the bed-load discharge is proportional to the work done by the part of the tractive force in excess of that needed to overcome the resistance along the wetted perimeter. If A_o is the cross-sectional area of a flow that is just sufficient to move the bed material and A_f is the cross-sectional area of flow, with no change in width, the effective part of the tractive force in moving bed material is $\gamma S(A_f - A_o)$. Also, if the velocity of the tractive force is proportional to the mean velocity of flow, $\bar{u}$, then the work done by the effective part of the tractive force is $c_1\bar{u}\gamma S(A_f - A_o)$ or $c_1\gamma S(Q_w - Q_o)$. Hence, if the bed-load discharge is proportional to the work, G_b is equal to $C\gamma S(Q_w - Q_o)$. The constant, C, is a function of the slope and the particle size. The final equation for the unigranular material is—

$$g_b = 43.2\left[\frac{86.7}{\sqrt{D}}S^{3/2}(Q_w - wq_0)\right]$$

in which—

D is the mean particle size, in inches, and in this report it is used as the geometric mean.

Q_w is the instantaneous water discharge, in cubic feet per second.

q_o is the water discharge per foot of width just sufficient to move bed material. It is the critical water discharge per foot of width and equals $0.00532\ D/S^{4/3}$.

For sand mixtures, the bed-load discharge, in tons per day, of each size range, is computed according to the above equation, and the bed-load discharge for all size ranges is a weighted summation of each individual range. The weighting factor for the load in each range is the fraction of the total bed mixture which that range represents.

Seventeen computations of the bed-load discharge at section E were made with the Schoklitsch equation for sand mixtures. The results of these computations are given in table 9. Computed discharges tend to increase slightly as both the total sediment discharge and the unmeasured sediment discharge increase; however, five of the computations gave bed-load discharges greater than comparable unmeasured sediment discharges. In general, computed discharges were higher than those computed with the other bed-load formulas. The different hydraulic conditions produced a fairly wide range of computed discharges, but the discharges did not vary consistently with any of the hydraulic parameters that were examined.

Figure 30 shows that computed discharges tend to increase as the concentrations of measured suspended sediment coarser than 0.125 millimeter increase. These computations seem to indicate that computed discharges include the bed-load discharge and a part of the suspended-sediment discharge.

MEYER-PETER AND MÜLLER EQUATION

Meyer-Peter and Müller (1948) have presented an equation for computing the bed-load discharge in natural streams. The equation is based on tests that were made in laboratory flumes of various scales and in the region of fully developed turbulence. The shearing stress was shown to be an important factor in bed-load transport by these tests, which were made throughout wide ranges of slope, particle size, water depth, water discharge, and specific gravity of sediment. For wide channels, the equation can be written—

$$\gamma \left(\frac{k_t}{k_r}\right)^{3/2} dS = \underline{E}\underline{\gamma_g} D_m + \underline{F} \left(\frac{\gamma}{g}\right)^{1/3} \underline{g_s}^{2/3}$$

in which—

γ is the specific weight of water and equals 1 metric ton per cubic meter (1 gram per cubic centimeter). This parameter is called specific gravity with the units indicated by Meyer-Peter and Müller and is designated γ_w.

k_r is the coefficient of particle friction with a smooth bed and is equal to $26/D_{90}^{1/6}$.

k_t is the coefficient of roughness, given by Meyer-Peter and Müller as k_s and is equal to $\bar{u}/d^{2/3}S^{1/2}$.

d is the mean depth of water, in meters, and is given by Meyer-Peter and Müller as h.

$\underline{E}$ is a constant that equals 0.047 and is given by Meyer-Peter and Müller as A″.

$\underline{\gamma_g}$ is the specific weight of the sediment under water and equals 1.65 metric tons per cubic meter (1.65 grams per cubic centimeter) for this report. This parameter is called the specific gravity under water by Meyer-Peter and Müller with the units indicated above and is designated as γ_s.

D_m is the "effective diameter" of the bed-material mixture, in meters, and is equal to $\Sigma D i_b$.

$\underline{F}$ is a constant that equals 0.25 and is given by Meyer-Peter and Müller as B''.

g is the gravity constant and equals 9.815 meters per second per second.

$\underline{g_s}$ is the bed-load discharge per meter of width, in metric tons per meter per second (1×10^6 grams per meter per second), as measured under water.

where—

D_{90} is the particle size, in meters, at which 90 percent of the bed material by weight is finer.

$\bar{u}$ is the mean velocity of flow, in meters per second.

D is the geometric mean size, in meters, of a size fraction.

Seventeen bed-load discharges for section E that were computed with the Meyer-Peter and Müller equation are given in table 9. Computed discharges compare reasonably with total sediment discharges and unmeasured sediment discharges. The different hydraulic conditions produced a relatively wide range of bed-load discharges, and the discharges varied progressively with progressive changes in several hydraulic parameters that were examined—particularly mean velocity. Figure 30 shows that the computed bed-load discharges increase as the concentrations of measured suspended sediment coarser than 0.125 millimeter increase. On the basis of these computations, bed-load discharges computed with the Meyer-Peter and Müller equation seem to be accurate measures of the actual bed-load discharge.

SIZE DISTRIBUTION OF BED MATERIAL

In alluvial streams, such as the Middle Loup River, the size distribution of bed material varies both laterally and vertically. The variations have been studied from regular and special samples from section E. Piston-type samplers that obtain cores about 2 inches in diameter and about 6 inches in length were used for all the sampling.

Because the size distribution of bed material varies laterally across a section (fig. 31), the size distributions of sample composites from only a few points have less possibility of being representative of the whole cross section than the size distributions of composites from many points. Data on April 26 and March 30, 1951, show the results when different numbers of samples are composited (table 4, section E). For April 26 the composite of 3 samples has a distinctly coarser distribution than the composite of 29 samples, and for March 30 the composite of 3 samples collected at centers of maximum discharge sections has a coarser distribution than the composite of 7 samples. On the basis of data from section E, at least five samples, but preferably more, should be collected for a composite to define adequately the bed-material size distribution at a cross section.

An example of the vertical variation in the size distribution of bed material for one time and station is given in figure 32. Size analyses of the top 0.5 inch of 6-inch cores (table 4, section E) and size analyses from station 77 on May 6, 1952, (fig. 32) indicate that, in general, the material near the surface of the bed is somewhat finer than that for an entire 6-inch core. However, at any station

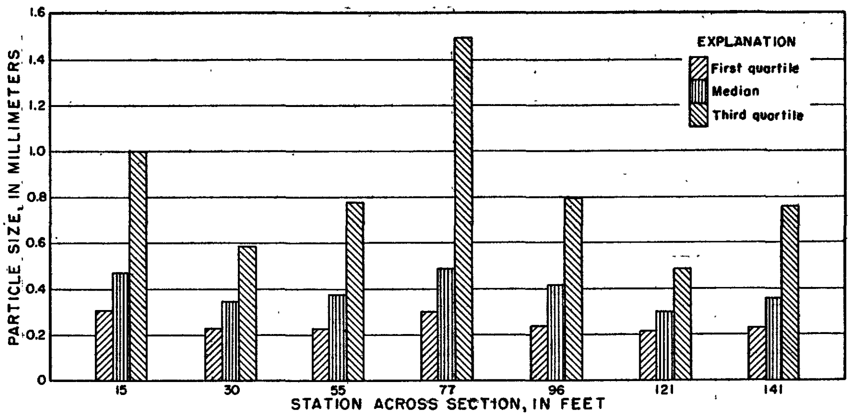


FIGURE 31.—Lateral variation of the size distribution of bed material, section E, May 6, 1952.

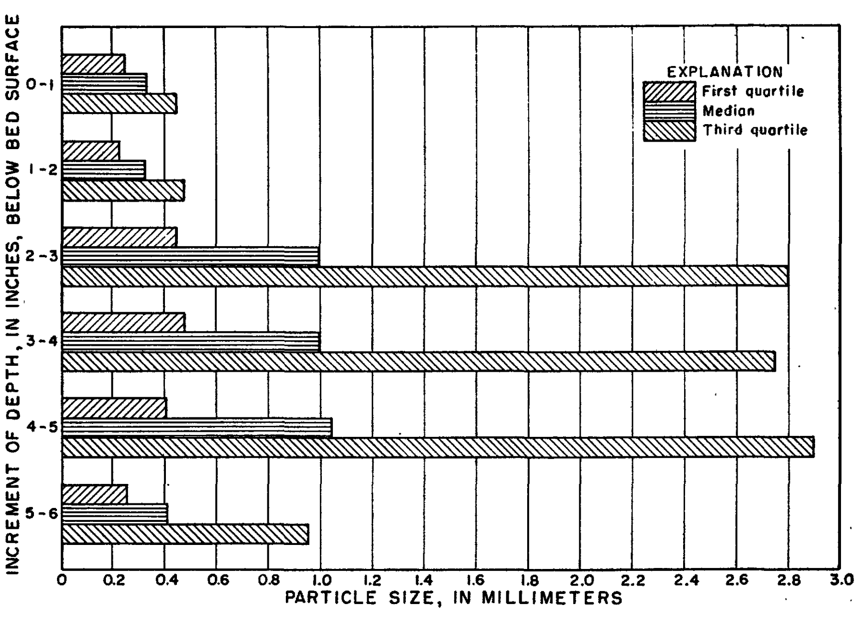


FIGURE 32.—Vertical variation of the size distribution of bed material, section E, station 77, May 6, 1952.

the vertical size distribution is continually changing as dunes move through the section.

The median particle size of bed material at sections A, C_2, and E, determined from 6-inch core samples, seems to have no direct relation with either the water discharge or the water temperature (fig. 33). First- and third-quartile particle sizes at section A also showed no such relation.

On streams such as the Middle Loup River, where sediment is relatively coarse and unlimited in supply and where the size dis-

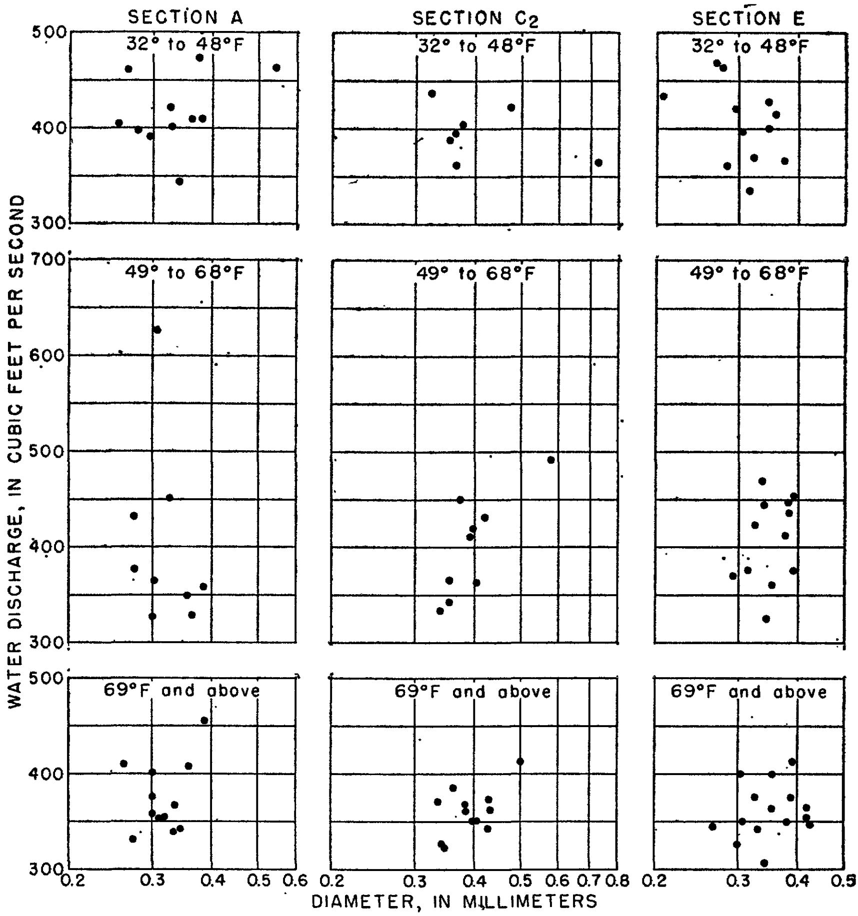


FIGURE 33.—Variation of median particle size of bed material with water temperature and discharge

tribution is evidently unrelated to water discharge and water temperature, the most representative size distribution can probably be determined from an average of all available samples.

VARIATIONS IN z_1

The equation for the vertical distribution of suspended sediment has been recapitulated by Einstein (1950, equation 29) as—

$$\frac{c_y}{c_a}=\left(\frac{d-y}{y}\,\frac{a}{d-a}\right)^z$$

in which—

z equals V_s/ku_*.

where—

k is the Von Karman coefficient for turbulent exchange. Anderson (1942), Vanoni (1941), and others have found that the exponential form of this equation is satisfactory but that z should be replaced by z_1, the exponent that fits the measured data. Vanoni (1941) has proposed that differences in z and z_1 for fine particle sizes result from the derivation of z when the sediment transfer coefficient and the momentum transfer coefficient are assumed to be equal. Einstein and Ning Chien (1954) developed formulas for z_1 on the assumptions that mixing lengths are of variable distance in all directions and that the concentration changes along the mixing length. Colby and Hembree (1955) demonstrated that z_1 varies, on the average, with about the 0.7 power of the fall velocity when fall velocities are based on Rubey's equation.

For Nebraska sandhill streams, a z_1 less than about 0.7 is generally larger than an associated z that is computed with a V_s from figure 34, a k from velocities determined from the point-integrated samples used to define the z_1, and a u_* from $\sqrt{dSg}$. (See fig. 35.) However, for flumes and relatively deep streams, other investigators have found that a z_1 less than 1.0 is about equal to an associated z. The difference in the z_1 versus z relationship is because values of k for sandhill streams are larger than those for flumes and relatively deep streams.

Flume experiments and measurements in relatively deep streams indicate that k is generally less than 0.4 and that k decreases as sediment concentration increases. However, for the Niobrara River, Colby and Hembree (1955) found that k varies markedly; investigations for other Nebraska sandhill streams show that k varies from about 0.4 to 4.00. This range is for k's that are averages of the k's at sampled verticals in a cross section; each k at a vertical was determined from the velocity profile that was defined by point-integrated samples at 3 or 4 points in the vertical, sampling verticals were not consistent with respect to their position on the dune, and the relative roughness of the bed in the vicinity of the sampling verticals varied widely and was often very great. Because the theory of velocity distribution probably is invalid where the relative roughness is extremely great, the significance of a k determined from these samples is unknown.

For sandhill streams that have a range of k from 0.4 to 4.00, z_1 varies inversely with about the 0.6 power of k. (See fig. 36.) Throughout this range of k, the relation seems to be continuous.

For these same streams, z_1 can be expressed as a power of z. Figure 37, which includes some of the data used by Colby and Hembree (1955), shows that z_1 varies with about the 0.6 power of z. The fall velocities for this graph are based on data from figure 34. If fall

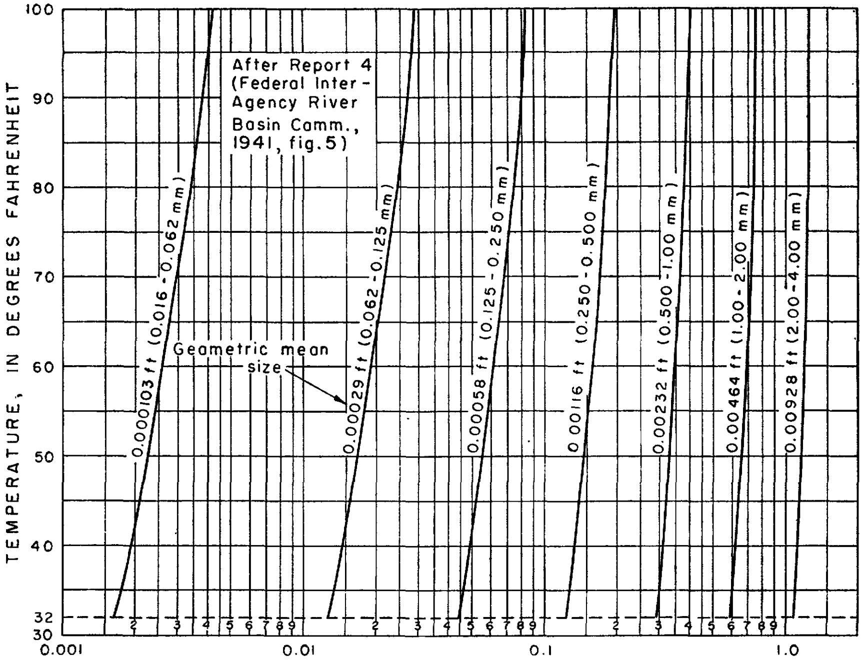


FIGURE 34.—Fall velocity of quartz spheres in water.

velocities (fig. 38) are based on Rubey's equation (1933), a graph similar to figure 37 can be developed by plotting z_1 against $z^{0.7}$. Data obtained by Anderson (1942) and data from the Mississippi River at St. Louis generally plot within the limits of the scatter in figure 37; however, these data have been omitted in order to avoid any implication that the relationships have any known theoretical basis or will be representative of all streams.

CONCLUSIONS

For the normal ranges of water discharge of the Middle Loup River at Dunning, Nebr., about 75–80 percent of the measured suspended sediment at the 6 selected river sections is coarser than 0.062 millimeter, and about 40 percent is in the 0.125- to 0.25-millimeter size fraction. Also, the median diameter of bed material is in the 0.25- to 0.50-millimeter range.

Vertical distributions indicate slightly more turbulence at section C than at the selected river sections. Also, about 88 percent of the measured suspended sediment entering the flume at section C is coarser than 0.062 millimeter, and about half of the total sand is in the 0.125- to 0.25-millimeter size fraction, although the median bed-

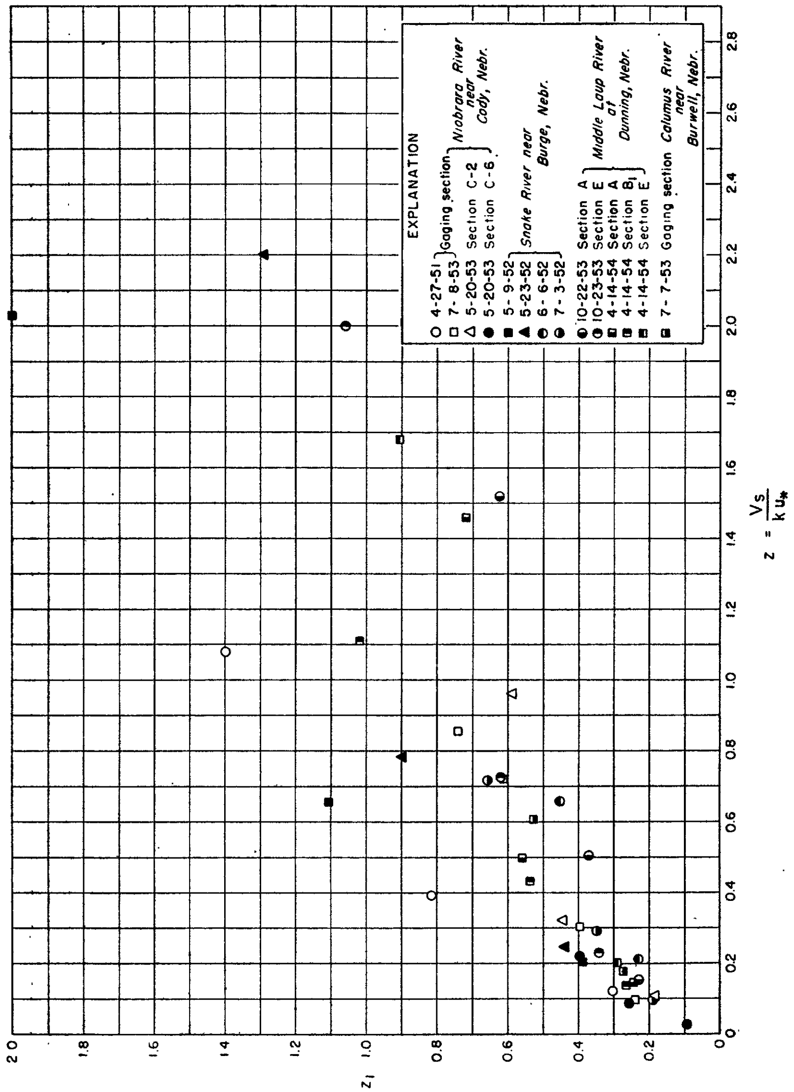


FIGURE 35.—z_1 plotted against z.

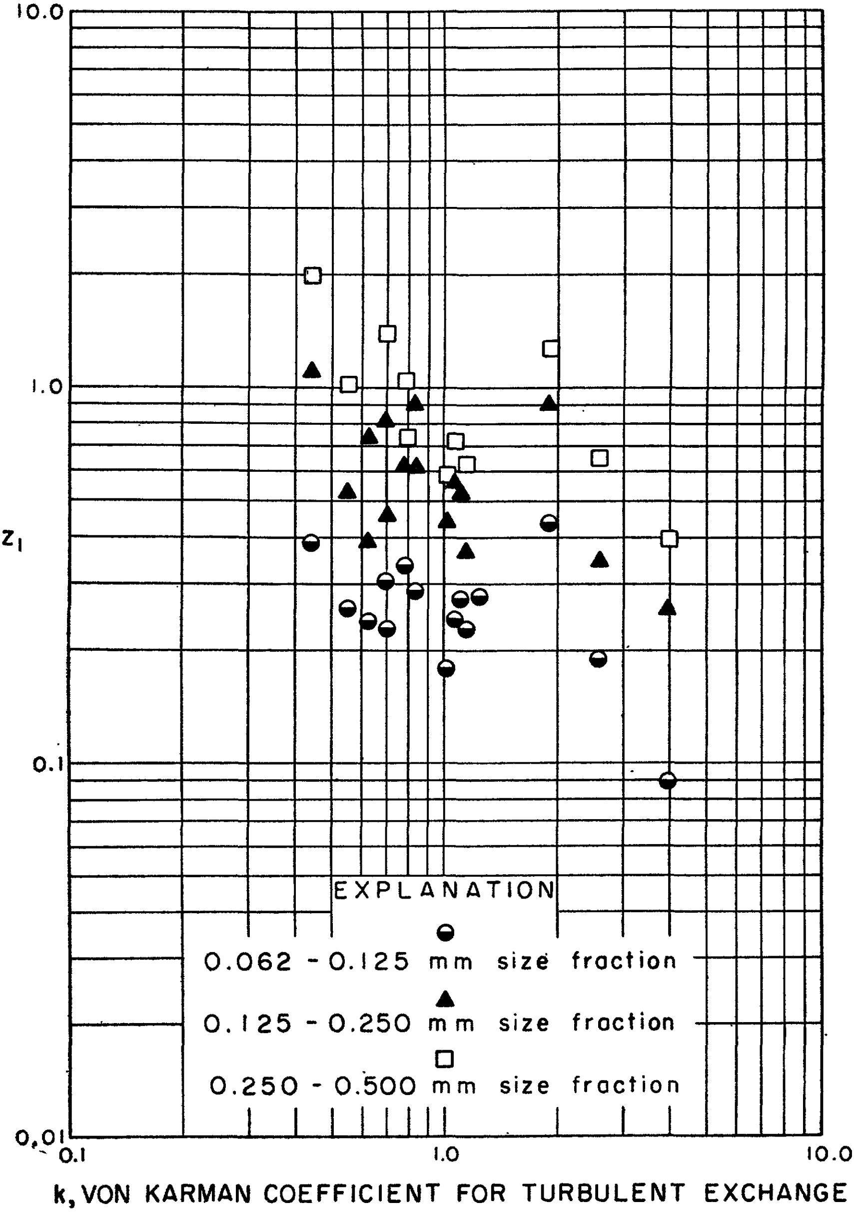


FIGURE 36.—z_1 plotted against k for some Nebraska sandhill streams.

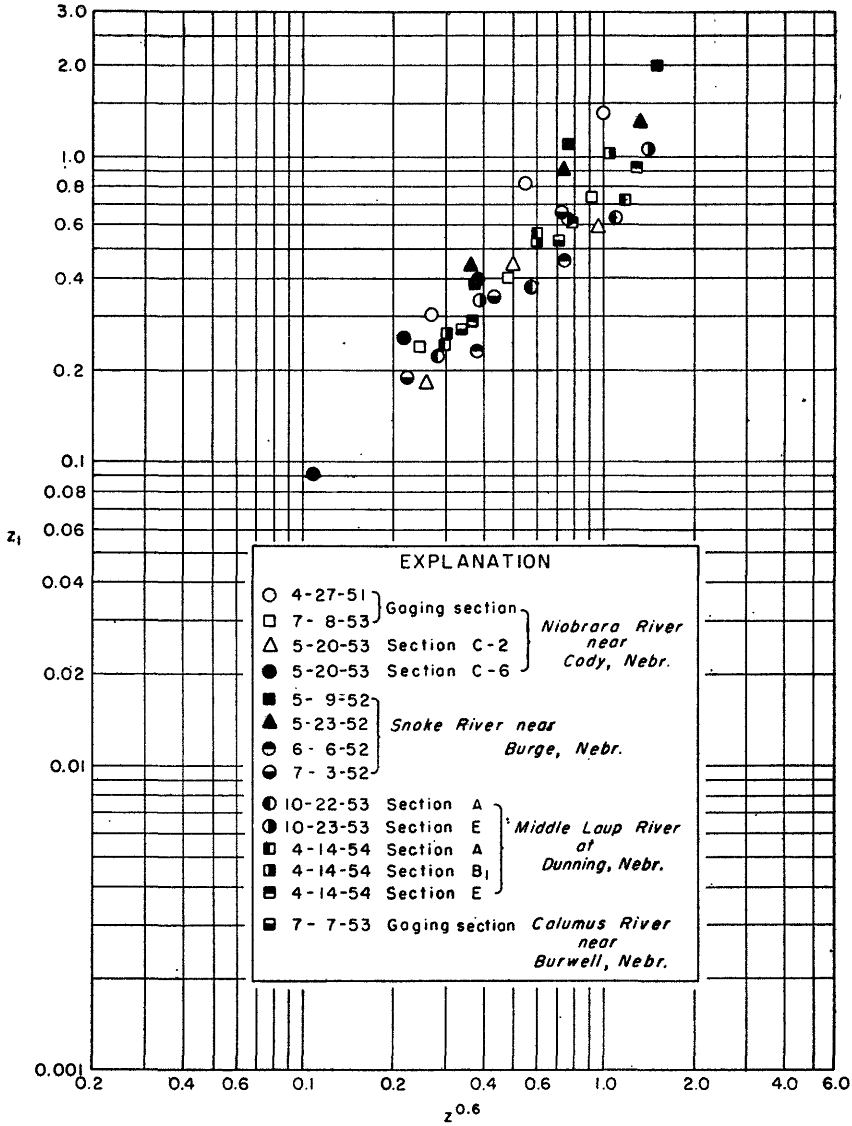


FIGURE 37.—z_1 expressed as a power of z.

material size just upstream from section C is about the same as that at the river sections.

About 90 percent of the measured total sediment discharge at section D is coarser than 0.062 millimeter, and about 35 percent is in the 0.125- to 0.25-millimeter size fraction.

The total sediment discharge varies about as the cube of the water discharge; however, the relationship is not well defined.

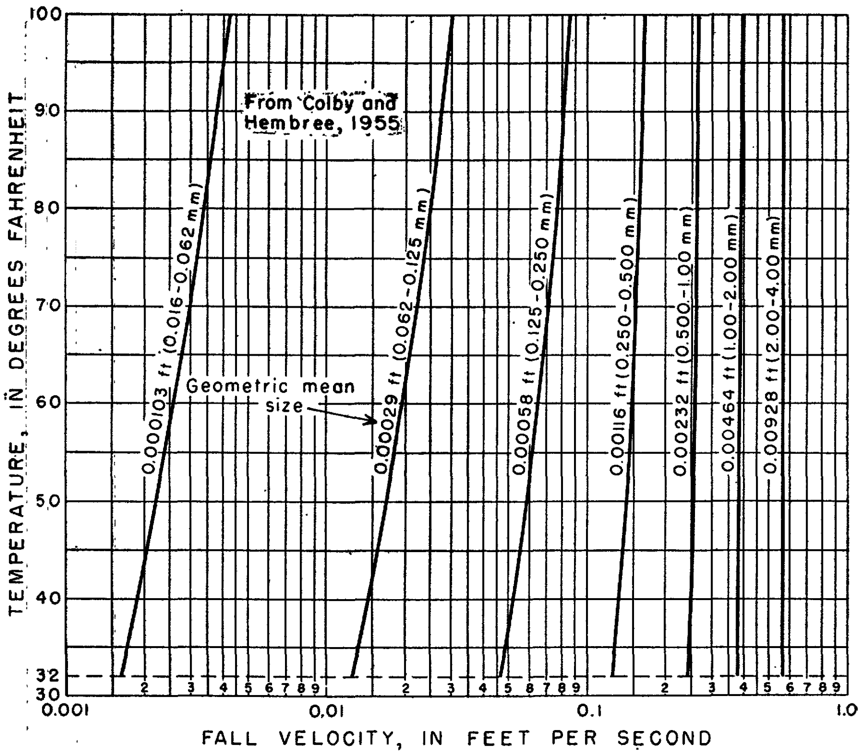


FIGURE 38.—Variation of fall velocity with temperature from the Rubey equation.

Forty-four determinations of the ratio of daily sample concentrations to cross-section concentrations at section D averaged 1.03 and ranged from 0.72 to 1.61. Fluctuations of this ratio cannot be explained by any of the common flow parameters.

Computations by the Einstein procedure indicate that accurate sediment discharges can be obtained only if the computed cross section is representative of the reach that is being studied. For the Dunning reach, when the computed cross section was narrower and deeper than a representative cross section, computed loads were high; and when the computed cross section was wider and shallower than a representative cross section, computed loads were low. However, when section E, which is probably nearly representative of the Dunning reach, was used as the cross section, computed total loads (computed discharge of sediment coarser than 0.125 millimeter plus the discharge of measured sediment finer than 0.125 millimeter) averaged 115 percent and ranged from 31 to 240 percent (standard deviation, 94 percent) of measured total loads. The accuracy of the Einstein procedure cannot be evaluated because only a limited number of cross sections were measured for this investigation and the computations did not include as many sections as recommended by

Einstein to define adequately the representative cross section. However, of the various combinations of sections that were available, the four-section combination of section A, B (or B_1 or 25 feet upstream from B), C_2, and E gave the best average results. Computed total loads averaged 81 percent and ranged from 26 to 150 percent (standard deviation, 49 percent) of the measured total loads. Computed loads larger than 0.125 millimeter were less accurate than computed total loads. Also, in most computations, the largest part of the total load was in the 0.25- to 0.50-millimeter size fraction; however, the largest part of the measured total load was usually in the 0.125- to 0.25-millimeter size fraction.

Computations of total sediment discharge by the modified Einstein procedure averaged 112 percent and ranged from 64 to 166 percent (standard deviation, 22 percent) of measured total loads. Also, computed loads by size ranges agreed fairly closely with comparable measured loads. On the basis of these computations, the procedure appears to be satisfactory for use on streams similar to the Middle Loup River. Although the procedure is satisfactory for any section, best results are obtained for sections where the lateral distributions of stream depth, stream velocity, and measured suspended-sediment concentrations are relatively uniform.

Computations of sediment discharge for section E by the Straub equation averaged about twice the measured total sediment loads. The equation seems to be more suitable for deep streams or shallow streams that have flat gradients than for streams that have hydraulic characteristics like those of the Middle Loup River.

Computations for section E by the Kalinske equation indicate that the equation gives bed-load discharges in the proper order of magnitude. However, computed discharges are relatively constant for the range of hydraulic conditions that exist at the Middle Loup River at Dunning; low computed discharges are associated with high total sediment discharges, high unmeasured sediment discharges, and high concentrations of measured suspended sediment coarser than 0.125 millimeter; and high computed discharges are associated with low total sediment discharges, low unmeasured sediment discharges, and low concentrations of measured suspended sediment coarser than 0.125 millimeter.

Computations for section E by the Schoklitsch equation gave bed-load discharges that seem somewhat high; about one-third of the computed loads were slightly higher than comparable unmeasured loads. In general, high computed discharges were associated with high total sediment discharges, high unmeasured sediment discharges, and high concentrations of measured suspended sediment coarser than 0.125 millimeter; low computed discharges were associated with low total sediment discharges, low unmeasured sediment discharges, and low

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concentrations of measured suspended sediment coarser than 0.125 millimeter. However, the trend was not progressively consistent.

Computations for section E by the Meyer-Peter and Müller equation gave bed-load discharges that seem to be accurate measures of the the actual bed-load discharges. Computed loads varied progressively with changes in several hydraulic parameters, compared reasonably with total and unmeasured sediment discharges, and increased fairly consistently as the concentrations of measured suspended sediment coarser than 0.125 millimeter increased.

Size analyses indicated that the bed material varies both laterally and vertically. On the basis of samples collected at section E, at least five samples, but preferably more, seem to be necessary for an adequate determination of the bed-material size distribution at a cross section. The size distribution for the top 1 inch or so of the bed is generally finer than that for the top 6 inches. For 6-inch cores, the median and the first- and third-quartile particle sizes seem to have no direct relation with either water discharge or water temperature. As a result, on streams similar to the Middle Loup River the most representative bed-material size distribution from 6-inch cores can probably be determined from an average of all available samples.

For Nebraska sandhill streams, a z_1, from point-integrated samples, that is less than about 0.7 is generally larger than a comparable z from V_s/ku_*, where the V_s is based on the fall velocity of quartz spheres in water. Throughout a range for the Von Karman coefficient, k, of 0.4–4.00, z_1 varies inversely with about the 0.6 power of k. In addition, z_1 can be expressed roughly as a power of z; the power depends on which system of fall velocities is used.

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SYMBOLS

Symbol	Definition	Page
′	Single prime mark on *A*, *J*, or *Q* designates association with the sampling depth	48
″	Double prime mark on *A*, *J*, *I*, or *Q* designates association with the total depth through which suspended sediment is discharged	48
‴	Triple prime mark on *Q* designates association with the total sediment discharge	51
a	Distance above the stream bed	47
A	Distance of the lower limit of integration above the stream bed divided by d	47
A_f	Cross-sectional area of flow	66
A_o	Cross-sectional area when flow is just sufficient to move bed material	66
c_1	A proportionality constant	66
c_a	Concentration of sediment particles of a size fraction at distance, a, above the stream bed	47
c_y	Concentration of sediment particles of a size fraction at distance, y, above the stream bed	48
C	A proportionality constant	66
C_1	A constant	20
Conc	Measured suspended-sediment concentration	42
$Conc_u$	Mean concentration of the suspended-sediment discharge in the unsampled zone	42
d	Mean depth of water	47
d_n	Distance from the bottom of the sampled zone to the stream bed	54
d_o	Minimum depth at which bed sediment will move	61

		Page
d_s	Average depth at the sampling verticals	53
D	Geometric mean size of a size fraction	51
D_{35}	Particle size at which 35 percent of the bed material by weight is finer	52
D_{65}	Particle size at which 65 percent of the bed material by weight is finer	47
D_{90}	Particle size at which 90 percent of the bed material by weight is finer	68
D_m	Effective diameter of the bed-material mixture	67
$\underline{E}$	A constant	67
$\underline{F}$	A constant	67
g	The gravity constant	47
g_b	Bed-load discharge of a size fraction	63
$\underline{g_s}$	Bed-load discharge per meter of width as measured under water	67
G	Sediment discharge from the Straub equation	61
G_b	Bed-load discharge	41
i_b	Fraction by weight of bed material in a size range	55
$i_B q_B$	Sediment discharge per unit width through the bed layer of particles of a size fraction	55
$i_B Q_B$	Sediment discharge through the bed layer of particles of a size fraction	49
I_1	A mathematical abbreviation that contains J_1	49
I_2	A mathematical abbreviation that contains J_2	49
J_1	An integral	48
J_2	An integral	48
k	Von Karman coefficient for turbulent exchange	71
k_r	Coefficient of particle friction with a smooth bed	67
k_s	Roughness diameter, the same as D_{65}	47
k_t	Coefficient of roughness	67
K	A constant	48
K_1	A constant	49
K_o	A constant	42
K_{oo}	Fraction of flow in the unsampled zone	42
m	Summation of all values of i_b/D of a bed mixture	63
p	Part of the bed area taking shear	63
p_i	Part of the bed area occupied by the particles in a size range	63
P	A parameter	48
q_o	Critical water discharge per foot of width	66
Q_o	Critical water discharge	66
Q_s	Suspended-sediment discharge of a size range	47
Q_{sM}	Measured suspended-sediment discharge	41
Q_{ts}	Total sediment discharge in the cross section	20
Q_{ts}'	Sediment discharge in the sampled zone	54
Q_{uM}	Unmeasured sediment discharge	41
Q_{usM}	Unmeasured suspended-sediment discharge	41
Q_w	Water discharge	20
r	Relative intensity of turbulence	63
R	Ratio of the mean concentration in the unsampled zone to that in the sampled zone	42
$(RS)_m$	Quantity obtained by solving equation a for $(RS)_m$	47
S	Slope of the energy gradient and in this report is considered to be equal to the slope of the water surface	61

		Page
S_s	Specific gravity of sediment	52
Temp	Water temperature	53
u_m	Shear velocity for the modified procedure	47
$\bar{u}$	Mean velocity of flow	47
u_*	Shear velocity	47
$\bar{U}$	Mean velocity of flow at the grain level	63
$\bar{U}_s$	Mean speed of movement of the particles of a size range	63
V_s	Fall velocity of sediment particles	49
V_{sr}	Fall velocity of the geometric mean size of the reference range	56
V_{su}	Fall velocity of the geometric mean size of the range requiring a z_2	56
w	Width of the stream channel	47
x	Dimensionless transition parameter	47
X	Characteristic grain size of the bed mixture	51
y	Distance above the stream bed	48
Y	Pressure correction in the transition from smooth to rough flow	51
z	Theoretical exponent of the equation that describes the vertical distribution of suspended sediment of a size range	47
z_1	Exponent for the actual distribution of suspended sediment of a size range determined from a logarithmic plot of concentration in a size range versus $(d-y)/y$	49
z_2	Exponent for a size range that will determine values of I and J to satisfy equation f or an exponent determined by proportion from an exponent determined in the above manner	51
z_{2r}	z_2 for the reference range	56
z_{2u}	Unknown and required z_2 for a size range	56
z_3	Exponent for a size range that will determine values of I and J to satisfy equation h or an exponent determined by proportion from an exponent determined in the above manner	51
z_4	Exponent determined from an empirical equation	51
z_m	Exponent computed from $V_s/0.4u_m$	49
z_x	Represents either z_1, z_3, or z_4	58
β	Log_{10} (10.6)	51
β_x	Log_{10} $(10.6X\, x/k_s)$	51
γ	Specific weight of water	61
γ_s	Specific weight of sediment particles	63
$\underline{\gamma_s}$	Specific weight of sediment particles under water	67
δ	Thickness of the laminar sublayer	47
θ	Transportation characteristic and corresponds to Straub's Ψ	61
ν	Kinematic viscosity	47
ξ	Hiding factor of grains in a mixture	51
ρ_s	Mass density of sediment	55
τ_c	Critical tractive force	61
τ_o	Total shear or tractive force at the bed	63
Φ_*	Intensity of bed-load transport from Einstein	53
$\Phi_*/2$	Intensity of bed-load transport from the modified procedure	53
Ψ	Function for correlating the effect of flow with the intensity of bed-load transport	51
Ψ_m	Flow intensity from the modified procedure	52
Ψ_*	Flow intensity from Einstein	53
43.2	Constant for converting pounds per second to tons per day	55
7.3	Constant in the Kalinske equation	63

TABLES OF BASIC DATA

TABLE 1.—*Water and suspended-sediment discharge measurements*

[Mean gage heights are from water-stage recorder at gaging station]

Date	Water discharge measurement: Mean time	Water discharge measurement: Mean gage height (ft)	Water discharge measurement: Discharge (cfs)	Water discharge measurement: Effective width (ft)	Water discharge measurement: Effective area (sq ft)	Water discharge measurement: Mean velocity (fps)	Suspended-sediment discharge measurement: Mean time	Suspended-sediment discharge measurement: Mean gage height (ft)	Suspended-sediment discharge measurement: Rated water discharge (cfs)	Suspended-sediment discharge measurement: Mean concentration (ppm)	Suspended-sediment discharge measurement: Discharge (tons per day)	Water-surface slope (ft per mile): Local	Water-surface slope (ft per mile): Reach	Water temperature (°F)
Section A [1]														
1949														
Aug. 17	11:20 a. m.	3.37	382	307	225	1.70	2:00 p. m.	3.44	385	274	285	7.1		
23	9:05 a. m.	3.35	314	303	188	1.67	10:00 a. m.	3.31	341	250	230	7.8		
25	9:25 a. m.	3.24	312	281	188	1.66	11:00 a. m.	3.24	341	206	190	7.8		
30	9:05 a. m.	3.28	374	273	194	1.93	10:00 a. m.	3.29	350	298	282	6.8		64
31	8:25 a. m.	3.34	424	272	229	1.85	9:15 a. m.	3.33	379	314	321	6.7		
Sept. 7	9:00 a. m.	3.29	379	279	213	1.78	10:00 a. m.	3.31	400	370	400	6.6		61
9	8:50 a. m.	3.25	399	275	221	1.81	10:00 a. m.	3.24	385	408	424	6.9		59
13	8:50 a. m.		419	258	187	2.24	10:00 a. m.	3.17	376	516	524	7.7		
1950														
Mar. 1	10:10 a. m.	3.12	426	299	168	2.54	11:00 a. m.	3.17	[2] 472	1,430	1,820	7.7		35
21	9:45 a. m.	3.30	430	230	190	2.26	11:00 a. m.	3.32	[2] 463	1,040	1,300	6.6		35
Apr. 12	9:30 a. m.	3.17	432	229	172	2.51	10:00 a. m.	3.14	[2] 421	804	914	8.3		40
25	10:20 a. m.	3.18	426	285	194	2.20	11:00 a. m.	3.17	[2] 460	796	989	7.5		41
May 9	10:05 a. m.	3.26	477	325	197	2.42	11:00 a. m.	3.26	[2] 450	794	965	7.0		50
23	10:15 a. m.	3.35	391	236	171	2.29	11:30 a. m.	3.36	[2] 409	334	369	8.2		70
June 6	10:30 a. m.	3.30	356	244	178	2.00	11:00 a. m.	3.24	[2] 358	356	344	7.0		70
20	4:45 p. m.	3.27	339	325	213	1.59	5:15 p. m.	3.28	[2] 406	363	398	8.3		80
July 6	7:40 a. m.	3.27	366	266	196	1.87	9:00 a. m.	3.28	[2] 364	296	291	7.3		66
18	7:40 a. m.	3.27	402	318	221	1.82	9:00 a. m.	3.28	[2] 376	343	348	6.6		64
Aug. 1	11:15 a. m.	3.22	364	320	198	1.84	12:30 p. m.	3.21	[2] 364	834	820			70
25	5:00 p. m.	3.18	317	289	167	1.90	6:10 p. m.	3.20	330	272	242			74
Oct. 4	9:20 a. m.	3.13	380	[3] 260	[3] 190	2.00	10:30 a. m.	3.17	344	516	479			44
Nov. 7	1:45 p. m.	3.17	399	330	191	2.09	2:50 p. m.	3.17	397	365	391	7.0		48
29	4:20 p. m.	3.11	405	256	162	2.50	5:10 p. m.	3.11	391	770	813		7.0	38
1951														
Jan. 23	3:05 p. m.	3.22	406	205	156	2.60	4:50 p. m.	3.26	400	1,790	1,930			32
Feb. 19	3:30 p. m.	3.30	427	276	183	2.33	4:45 p. m.	3.22	[2] 403	1,050	1,140	8.0		38
Mar. 13	4:15 p. m.	3.06	404	160	135	2.99	5:30 p. m.	3.08	[2] 409	1,560	1,720			32
Apr. 25	10:42 a. m.	3.44	452	282	190	2.38	11:45 a. m.	3.48	[2] 409	512	565		6.9	48
May 21	2:27 p. m.	3.67	575	296	223	2.58	4:00 p. m.	3.70	[2] 626	566	957	6.2	6.7	56
June 4	9:02 a. m.	3.39	476	332	229	2.08							6.9	
25	2:32 p. m.	3.39	391	288	198	1.97	5:55 p. m.	3.59	453	320	391	6.6	6.8	78

July 27	9:30 a. m.	3.34	403	323	230	1.75						6.6	7.0	81
Aug. 15	6:12 p. m.	3.21	350	336	210	1.67	7:30 p. m.	3.22	338	300	274		7.0	72
29	9:18 a. m.	3.34	341	329	196	1.74	10:40 a. m.	3.34	400	302	326		7.0	73
Sept. 20	12:02 p. m.	3.19	417	256	199	2.10	1:10 p. m.	3.13	358	454	439	7.5		67
Dec. 4	9:45 a. m.	3.03	452	330	213	2.12							7.2	35
1952														
May 6							12:15 p. m.	3.21	361	407	397		7.0	
21							2:40 p. m.	3.25	431	500	582		7.0	65
June 3							3:20 p. m.	3.27	364	276	271		7.0	
July 18							1:15 p. m.	3.17	352	212	201	7.7	7.1	85
30							9:20 a. m.	3.09	327	318	281	7.9	7.1	68
Aug. 13							9:25 a. m.	3.19	373	387	390	7.8	7.1	72
26							10:35 a. m.	3.17	[2] 352	369	351	7.4	7.1	77
Sept. 11							9:22 a. m.	3.16	[2] 347	338	317	7.6	7.2	64
24							9:35 a. m.	3.11	[2] 376	339	344	8.0	7.1	57

Section B_1

1950														
Dec. 14	10:22 a. m.	3.90	415	112	162	2.56	11:30 a. m.	3.92	496	724	970			32
1951														
June 4	11:28 a. m.	3.38	428	91	159	2.69	12:10 p. m.	3.38	[2] 434	552	647		6.9	61
26	9:30 a. m.	3.46	429	95	169	2.54	10:45 a. m.	3.46	424	544	623			72
July 25	3:25 p. m.	3.23	357	94	157	2.27	5:00 p. m.	3.21	[2] 352	561	533		7.0	85
Aug. 16	9:40 a. m.	3.23	379	94	149	2.54	10:55 a. m.	3.19	[2] 350	332	314		7.0	70
Oct. 30	11:30 a. m.	3.18	442	93	150	2.95	1:15 p. m.	3.18	437	1,060	1,250		7.1	41
Dec. 4	1:50 p. m.	3.02	414	92	116	3.57	2:50 p. m.	3.02	[2] 415	707	792		7.2	38
1952														
May 6	12:07 p. m.	3.23	368	97	137	2.69	2:00 p. m.	3.24	370	509	508		7.0	68
21	2:40 p. m.	3.25	418	96	174	2.40	4:55 p. m.	3.24	[2] 412	715	795		7.0	65
June 3							4:40 p. m.	3.26	361	455	443		7.0	74
18							10:55 a. m.	3.12	325	474	416		7.0	70
July 6							1:50 p. m.	3.12	[2] 341	367	338		7.0	76
18							2:15 p. m.	3.16	350	363	343		7.1	86
30							11:50 a. m.	3.09	327	332	293		7.1	72
Aug. 26							3:00 p. m.	3.16	[2] 350	283	267		7.1	80
Sept. 11							10:40 a. m.	3.15	[2] 344	363	337		7.2	66
24							11:15 a. m.	3.08	[2] 367	485	481		7.1	59

See footnotes at end of table.

TABLE 1.—*Water and suspended-sediment discharge measurements*—Continued

[Mean gage heights are from water-stage recorder at gaging station]

Date	Water discharge measurement						Suspended-sediment discharge measurement					Water-surface slope (ft per mile)		Water temperature (°F)
	Mean time	Mean gage height (ft)	Discharge (cfs)	Effective width (ft)	Effective area (sq ft)	Mean velocity (fps)	Mean time	Mean gage height (ft)	Rated water discharge (cfs)	Mean concentration (ppm)	Discharge (tons per day)	Local	Reach	
Section B														
1948														
Oct. 6							9:40 a. m.	3.31	370	594	593			
19	10:05 a. m.	3.13	368	[4] 62	[4] 116	3.17	12:00 m.	3.07	350	908	858			45
Nov. 2							6:15 p. m.	3.17	379	634	649			
16	12:00 m.	3.23	423	61	134	3.16	2:15 p. m.	3.28	440	640	760			
Dec. 1							4:00 p. m.	3.18	412	976	1,090			
1949														
Jan. 13							2:35 p. m.	6.10	380	162	166			
Mar. 7	2:50 p. m.	3.22	459	61	142	3.23	2:00 p. m.	3.20	450	1,230	1,490			48
8							11:50 a. m.	3.21	453	1,040	1,270			
22							11:20 a. m.	3.25	466	1,040	1,310			
Apr. 4	2:20 p. m.	3.71	454	58	164	2.77	12:30 p. m.	3.72	456	772	950			56
9							1:15 p. m.	3.96	530	1,300	1,860			
19							9:30 a. m.	3.66	391	932	984			
May 6							12:40 p. m.	3.77	456	961	1,180			
17							12:10 p. m.	3.55	431	508	591			
June 1							9:45 a. m.	3.53	397	581	623			
4							1:45 p. m.	3.37	350	571	540			
14							11:30 a. m.	3.52	424	754	863			
19							9:10 a. m.	3.35	370	464	464			
21	1:35 p. m.	3.38	383	65	145	2.64	3:30 p. m.	3.38	379	411	421			80
28							12:55 p. m.	3.37	352	382	363			
28							2:20 p. m.	3.33	341	345	318			
July 12							9:45 a. m.	3.37	347	471	441			
15	11:10 a. m.	3.29	376	65	129	2.91	1:45 p. m.	3.31	364	325	319			78
26							12:30 p. m.	3.24	350	510	482			
Aug. 4	9:20 a. m.	3.26	339	64	122	2.78	10:00 a. m.	3.23	330	446	397			
9							5:00 p. m.	3.26	333	338	304			
10							10:40 a. m.	3.46	391	370	391			
17	12:15 p. m.	3.39	[5] 372	62	135	2.76	1:25 p. m.	3.42	379	373	382			
23	9:40 a. m.	3.33	339	61	140	2.42	11:20 a. m.	3.32	344	456	424			72
25	9:05 a. m.	3.24	345	63	129	2.67	10:15 a. m.	3.22	336	508	461			
30	9:15 a. m.	3.28	394	64	139	2.83	11:15 a. m.	3.27	344	408	379			64
31	8:45 a. m.	3.33	390	62	140	2.79	10:00 a. m.	3.30	370	475	475			

Sept. 7	9:00 a. m.	3.29	404	63	150	2.69	9:50 a. m.	3.28	391	463	489			61
9	9:00 a. m.	3.25	386	63	128	3.02	10:15 a. m.	3.23	382	522	538			59
13	10:40 a. m.	3.19	425	63	139	3.06	12:05 p. m.	3.18	379	586	600			53
20							4:10 p. m.	3.21	344	458	425			
Oct. 5							1:45 p. m.	3.27	361	382	372			65
12	9:35 a. m.	3.18	431	61	129	3.34	11:15 a. m.	3.16	[2] 394	836	889			49
18							3:45 p. m.	3.22	347	617	578			60
18							4:00 p. m.	3.23	350	602	569			60
Nov. 1							11:30 a. m.	3.18	347	634	594			47
5	9:30 a. m.	3.24	399	61	131	3.05	11:10 a. m.	3.26	388	1,050	1,100			45
15							12:45 p. m.	3.23	412	880	979			42
30							12:00 m.	3.14	364	934	918			39
Dec. 9	8:55 a. m.	3.16	370	60	111	3.33	11:00 a. m.	3.22	388	1,060	1,110			32
14							10:15 a. m.	5.58	210	255	145			32
21							12:30 p. m.	4.14	290	136	107			32
29							11:00 a. m.	4.45	390	212	223			32
1950														
Jan. 11	2:40 p. m.	4.72	450	62	217	2.07	4:30 p. m.	4.75	460	198	246			32
24	1:00 p. m.	4.70	406	57	200	2.03	2:00 p. m.	4.78	420	242	274			32
Feb. 6	3:30 p. m.	4.98	443	54	192	2.31	4:55 p. m.	4.98	440	247	293			32
14	3:00 p. m.	4.08	255	54	180	1.42	4:00 p. m.	4.07	250	178	120			32
22							1:30 p. m.	3.20	400	1,470	1,590			36
Mar. 1	9:50 a. m.	3.11	500	62	126	3.97	11:20 a. m.	3.17	[2] 472	1,280	1,630			34
8	12:20 p. m.	5.80	214	67	182	1.18	2:15 p. m.	5.76	210	1,660	941			32
21	9:10 a m.	3.27	492	62	140	3.51	10:30 a. m.	3.28	[2] 450	1,820	2,210			34
Apr. 12	12:00 m.	3.12	457	62	137	3.34	1:00 p. m.	3.14	[2] 421	1,090	1,240			41
25	9:20 a. m.	3.19	492	65	136	3.62	10:45 a. m.	3.18	[2] 463	1,090	1,360			40
May 9							8:25 a. m.	3.24	[2] 444	1,230	1,470			43
23							8:20 a. m.	3.35	[2] 406	801	878			62
June 6							8:45 a. m.	3.35	[2] 391	747	789			65
20	7:40 a. m.	3.27	430	64	149	2.89	8:45 a. m.	3.25	[2] 397	524	562			64
July 6							7:55 a. m.	3.27	[2] 361	629	613			64
18							8:50 a. m.	3.28	[2] 376	526	534			64
Aug. 1							9:00 a. m.	3.25	[2] 376	871	884			62
26	8:10 a. m.	3.51	498	64	162	3.07	9:10 a. m.	3.49	[2] 479	550	711			64
Oct. 4	12:22 p. m.	3.14	419	65	153	2.74	1:30 p. m.	3.17	344	635	590			47
Nov. 8	8:47 a. m.	3.24	434	59	139	3.12	10:00 a. m.	3.27	[2] 453	1,280	1,570			39
30 [6]	10:00 a. m.	3.10	407	71	129	3.16	10:40 a. m.	3.08	382	925	954			35
1951														
Jan. 24							10:40 a. m.	3.18	376	1,650	1,680			32
Feb. 20	10:40 a. m.	3.35	442	59.5	154	2.87	12:05 p. m.	3.36	[2] 364	1,670	1,640			37
Mar. 14 [6]	10:15 a. m.	3.25	360	71	115	3.13	11:00 a. m.	3.21	361	1,090	1,060			32
Apr. 25	2:07 p. m.	3.45	417	57	131	3.18	3:10 p. m.	3.44	[2] 397	621	666		6.9	61
May 21	5:40 p. m.	3.67	613	59	190	3.23	6:45 p. m.	3.65	[2] 608	1,040	1,710			57
Aug. 29	12:20 p. m.	3.32	415	57	139	2.99	1:20 p. m.	3.32	394	390	415		7.0	77
Sept. 20 [6]	3:40 p. m.	3.16	361	77	137	2.64	4:40 p. m.	3.16	367	384	381			69
1952														
Jan. 28	2:28 p. m.	5.26	586	59	255	2.30	4:00 p. m.	5.33	[2] 609	462	760			32

See footnotes at end of table.

TABLE 1.—*Water and suspended-sediment discharge measurements*—Continued

[Mean gage heights are from water-stage recorder at gaging station]

Date	Water discharge measurement						Suspended-sediment discharge measurement					Water-surface slope (ft per mile)		Water temperature (°F)
	Mean time	Mean gage height (ft)	Discharge (cfs)	Effective width (ft)	Effective area (sq ft)	Mean velocity (fps)	Mean time	Mean gage height (ft)	Rated water discharge (cfs)	Mean concentration (ppm)	Discharge (tons per day)	Local	Reach	
Section C_3														
1950														
Oct. 4	3:35 p. m.	3.16	335	80	132	2.54	4:20 p. m.	3.17	344	635	590			52
Nov. 8	11:52 a. m.	3.26	448	76	147	3.05	12:50 p. m.	3.24	[2] 444	976	1,170	6.6		39
30	12:05 p. m.	3.13	378	78	120	3.15	1:15 p. m.	3.15	403	815	887			36
Dec. 14	2:02 p. m.	3.95	506	81	170	2.98	3:30 p. m.	3.88	485	1,160	1,520	5.7		32
1951														
Jan. 24	11:28 a. m.	3.21	369	79	108	3.42	12:00 m.	3.22	388	1,420	1,490			32
Feb. 20	11:47 a. m.	3.36	366	76	122	3.00	1:10 p. m.	3.36	[2] 364	795	781	7.6		40
Mar. 14	11:00 a. m.	3.22	365	83	106	3.44	11:45 a. m.	3.21	361	1,100	1,070			32
Apr. 25	4:12 p. m.	3.40	368	82	139	2.65							6.9	
May 22	9:42 a. m.	3.51	499	84	172	2.90	12:15 p. m.	3.48	[2] 492	726	964	6.7		61
June 4	2:10 p. m.	3.32	411	84	156	2.63	3:05 p. m.	3.31	[2] 412	600	667		6.9	63
26	12:12 p. m.	3.42	431	83	174	2.48	1:20 p. m.	3.42	412	526	585			78
July 26	10:30 a. m.	3.34	367	83	164	2.24	12:30 p. m.	3.33	361	405	395	7.3		78
Aug. 16	12:22 p. m.	3.23	361	84	155	2.33	1:20 p. m.	3.23	[2] 361	506	493		7.0	75
29	6:20 p. m.	3.29	340	81	154	2.21							7.0	78
Sept. 20	5:58 p. m.	3.15	365	82	152	2.40	6:40 p. m.	3.15	364	410	403	6.7		67
Oct. 30	3:17 p. m.	3.15	419	82	162	2.59	5:45 p. m.	3.13	421	904	1,030		7.2	40
Dec. 4	4:12 p. m.	2.99	407	82	127	3.20	5:40 p. m.	2.95	[2] 394	956	1,020		7.1	38
1952														
Feb. 11	1:45 p. m.	3.12	428	81	123	3.48	2:40 p. m.	3.15	437	932	1,100			44
Mar. 10	3:15 p. m.	3.18	414	82	126	3.29	4:30 p. m.	3.24	431	812	944			50
26	2:32 p. m.	3.27	460	86	156	2.95	4:20 p. m.	3.24	[2] 450	1,200	1,460			49
May 6	3:35 p. m.	3.23	338	85	139	2.43	5:00 p. m.	3.23	367	500	495		7.0	69
21	4:52 p. m.	3.24	405	84	165	2.45	6:25 p. m.	3.27	[2] 421	638	725		7.0	65
June 3	3:47 p. m.	3.27	351	84	164	2.14	5:50 p. m.	3.26	[2] 370	399	399		7.0	74
18							11:40 a. m.	3.13	327	376	332		7.0	71
July 6							5:00 p. m.	3.12	[2] 341	388	357		7.0	74
18							3:00 p. m.	3.16	350	340	321	5.1	7.0	86
30							2:15 p. m.	3.07	322	334	290	5.3	7.1	81
Aug. 13							12:05 p. m.	3.19	373	438	441	5.5	7.1	75
26							3:45 p. m.	3.16	[2] 350	329	311	5.4	7.1	80
Sept. 11							11:40 a. m.	3.12	[2] 336	415	376	5.7	7.2	66
24							12:15 p. m.	3.08	[2] 367	405	401	5.5	7.1	64

Section C1														
1950														
May 9							2:20 p. m.	3.26	[2] 450	837	1,020	5.7		59
23							11:30 a. m.	3.36	[2] 409	436	481			70
July 18	6:50 p. m.	3.42	410	86	150	2.73	7:20 p. m.	3.40	[2] 412	519	577	4.5		64
Aug. 1	11:40 a. m.	3.22	372	87	156	2.38	12:00 m.	3.23	[2] 370	516	515	4.1		69
27 [7]	2:50 p. m.	3.28	386	81	156	2.47	3:20 p. m.	3.28	[2] 385	358	372	6.1		74
Section C														
1949														
June 4							2:55 p. m.	3.36	347	556	521			
21	7:35 p. m.	3.37	368	80	148	2.49	5:05 p. m.	3.36	373	388	390			77
July 15	9:10 p. m.	3.32	351	80	147	2.39	4:50 p. m.	3.33	370	365	365			
Aug. 17	3:45 p. m.	3.45	387	80	144	2.69	5:30 p. m.	3.44	385	539	560			
23	1:25 p. m.	3.27	339	80	146	2.32	2:55 p. m.	3.27	330	334	298			
25	1:35 p. m.	3.23	330	80	136	2.43	2:35 p. m.	3.23	338	335	306			
30	1:20 p. m.	3.27	354	80	147	2.41	3:50 p. m.	3.29	350	366	346			73
31	10:45 a. m.	3.34	373	80	143	2.61	12:40 p. m.	3.32	376	453	460			
Sept. 3							3:30 p. m.	3.24	370	892	891			
7	11:40 a. m.	3.27	403	80	138	2.92	1:30 p. m.	3.29	394	383	407			
9	11:10 a. m.	3.23	399	80	142	2.81	1:00 p. m.	3.28	397	530	568			60
13	2:45 p. m.	3.19	366	80	139	2.63	4:15 p. m.	3.20	385	490	509			62
Oct. 12	5:10 p. m.	3.14	357	80	138	2.59	1:14 p. m.	3.17	[2] 397	619	664			59
Nov. 5	2:45 p. m.	3.24	374	80	136	2.75	3:55 p. m.	3.21	373	591	595			53
Dec. 9	1:35 p. m.	3.23	413	78	111	3.72	3:15 p. m.	3.23	391	1,650	1,740			32
1950														
Mar. 1	2:00 p. m.	3.16	479	80	131	3.66	3:00 p. m.	3.17	[2] 472	1,270	1,620			39
21	10:10 a. m.	3.28	460	80	122	3.77	11:20 a. m.	3.33	[2] 466	1,460	1,840			37
Apr. 12	3:15 p. m.	3.14	417	82	139	3.00	4:00 p. m.	3.14	[2] 421	891	1,010			43
25	12:30 p. m.	3.17	458	82	136	3.37	2:00 p. m.	3.10	[2] 437	1,220	1,440			49
May 9	10:05 a. m.	3.26	503	81	173	2.91	11:40 a. m.	3.28	[2] 456	912	1,120			52
23	9:35 a. m.	3.36	425	81	149	2.85	10:20 a. m.	3.32	[2] 397	548	587			66
June 6	10:15 a. m.	3.34	380	84	150	2.53	11:30 a. m.	3.26	[2] 364	349	343			71
20	2:55 p. m.	3.25	380	83	153	2.48	4:15 p. m.	3.26	[2] 400	394	426			79
July 6	9:30 a. m.	3.28	358	81	153	2.34	10:50 a. m.	3.25	[2] 355	458	439			69
18							11:40 a. m.	3.28	[2] 376	383	389			64
Aug. 1							2:45 p. m.	3.21	[2] 364	868	853			73
26							7:25 p. m.	3.39	[2] 447	651	786			69
Oct. 4							3:00 p. m.	3.14	336	570	517			51
Nov. 8							2:30 p. m.	3.22	[2] 437	955	1,130			39
30							2:10 p. m.	3.16	406	930	1,020			38
1951														
Feb. 20							6:15 p. m.	3.37	[2] 367	1,080	1,070			45
Mar. 14							2:30 p. m.	3.17	350	1,250	1,180			32

See footnotes at end of table.

TABLE 1.—*Water and suspended-sediment discharge measurements*—Continued

[Mean gage heights are from water-stage recorder at gaging station]

Date	Water discharge measurement						Suspended-sediment discharge measurement					Water-surface slope (ft per mile)		Water temperature (°F)
	Mean time	Mean gage height (ft)	Discharge (cfs)	Effective width (ft)	Effective area (sq ft)	Mean velocity (fps)	Mean time	Mean gage height (ft)	Rated water discharge (cfs)	Mean concentration (ppm)	Discharge (tons per day)	Local	Reach	
Section D														
1949														
June 4							4:05 p. m.	3.35	344	763	709			
21							5:54 p. m.	3.38	379	1,170	1,200			
July 15							4:54 p. m.	3.32	367	743	736			
Aug. 17							5:45 p. m.	3.47	394	1,090	1,160			
23							2:50 p. m.	3.26	327	613	541			
25	1:25 p. m.	3.24	351	[8] 80	[8] 125	2.81	2:45 p. m.	3.24	341	768	707			
30	1:35 p. m.	3.27	339	[8] 80	[8] 125	2.71	3:50 p. m.	3.29	350	740	699			73
31	10:35 a. m.	3.34	370	[8] 80	[8] 126	2.94	1:15 p. m.	3.31	373	855	861			
Sept. 7	11:35 a. m.	3.27	378	[8] 80	[8] 133	2.84	1:45 p. m.	3.24	379	835	854			
9	11:05 a. m.	3.25	398	[8] 80	[8] 124	3.21	1:30 p. m.	3.27	394	902	960			60
13	2:05 p. m.	3.18	390	[8] 80	[8] 123	3.17	4:55 p. m.	3.17	376	813	825			62
Oct. 12							3:10 p. m.	3.15	[2] 391	912	963			
Nov. 5							4:20 p. m.	3.20	370	972	971			53
Dec. 9							3:15 p. m.	3.23	391	3,150	3,320			32
1950														
Mar. 1	1:50 p. m.	3.16	461	[8] 81	[8] 113	4.08	3:00 p. m.	3.17	[2] 472	2,310	2,940			39
21							11:25 a. m.	3.33	[2] 466	2,440	3,070			37
Apr. 12							4:10 p. m.	3.14	[2] 421	1,500	1,710			44
25							2:00 p. m.	3.10	[2] 437	1,480	1,750			49
May 9							11:15 a. m.	3.25	[2] 447	1,340	1,620			50
23							10:20 a. m.	3.32	[2] 397	750	804			66
June 6							11:30 a. m.	3.26	[2] 364	632	621			71
20							4:15 p. m.	3.26	[2] 400	553	597			79
July 6							10:50 a. m.	3.25	[2] 355	687	658			69
18							11:40 a. m.	3.28	[2] 376	539	547			64
Aug. 1							2:45 p. m.	3.21	[2] 364	576	566			73
26							7:25 p. m.	3.39	[2] 447	1,300	1,570			69
Oct. 4							3:00 p. m.	3.14	336	990	898			51
Nov. 8							2:30 p. m.	3.22	[2] 437	1,420	1,680			39
30							2:10 p. m.	3.16	406	1,560	1,710			38
Dec. 14							2:50 p. m.	3.92	497	1,800	2,420			32
1951														
Jan. 24							1:30 p. m.	3.15	367	2,600	2,580			33
Feb. 20							6:15 p. m.	3.37	[2] 367	1,260	1,250			45
Mar. 14	1:25 p. m.	3 24	336	[8] 81	[8] 119	2.82	3:00 p. m.	3.16	347	1,660	1,560			32
14							4:00 p. m.	3.17	350	1,860	1,760			32
20							7:00 p. m.	3.22	[2] 367	1,410	1,400			46

Apr. 25							7:00 p. m.	3.43	[2] 394	902	960			59
May 11							6:20 p. m.	3.25	330	748	666			70
22							8:55 a. m.	3.50	[2] 499	2,100	2,830			56
June 4							4:30 p. m.	3.31	[2] 412	935	1,040			61
26							4:25 p. m.	3.41	409	652	720			82
July 26							7:15 p. m.	3.27	341	548	505			85
Aug. 16							4:15 p. m.	3.25	[2] 367	654	648			80
30							12:00 m.	3.34	[2] 376	716	727			77
Oct. 31							3:00 p. m.	3.06	[2] 424	1,640	1,880			40
Dec. 5							2:00 p. m.	2.98	364	2,020	1,990			36
1952														
Jan. 7							5:45 p. m.	5.19		287				32
28							5:35 p. m.	5.38		704				32
Feb. 11							4:00 p. m.	3.17	444	1,900	2,280			
Mar. 10							6:10 p. m.	3.27	440	1,440	1,710			48
26							5:40 p. m.	3.19	[2] 434	2,000	2,340			48
May 6							7:00 p. m.	3.22	364	971	954			67
22							10:20 a. m.	3.29	450	1,450	1,760			64
June 4							9:10 a. m.	3.35	388	1,010	1,060			66
18							3:05 p. m.	3.10	320	672	581			77
July 6							6:10 p. m.	3.12	[2] 341	816	751			73
18							8:25 p. m.	3.13	341	852	784			80
30							5:10 p. m.	3.04	314	762	646			81
Aug. 13							4:25 p. m.	3.17	367	686	680			84
26							7:05 p. m.	3.14	[2] 344	[9] 1,260	[9] 1,170			
Sept. 11							2:30 p. m.	3.12	[2] 336	[9] 1,040	[9] 943			67
24							2:10 p. m.	3.10	[2] 373	1,020	1,030			68
Section E														
1949														
Aug. 17	6:10 p. m.	3.47	388	154	183	2.12	7:15 p. m.	3.51	406	370	406	6.3		
23	1:30 p. m.	3.27	331	152	159	2.08	2:30 p. m.	3.27	330	298	266	6.4		
25	2:45 p. m.	3.23	331	152	158	2.09	3:45 p. m.	3.24	341	269	248	6.6		
30	2:50 p. m.	3.29	348	150	157	2.22	3:45 p. m.	3.29	350	359	339	7.4		
31	12:40 p. m.	3.32	386	148	173	2.23	1:15 p. m.	3.31	373	329	331	7.6		
Sept. 7	12:55 p. m.	3.27	369	148	165	2.24	1:45 p. m.	3.23	376	369	375	7.8		
9	12:50 p. m.	3.26	377	152	175	2.15	1:30 p. m.	3.27	394	307	327	6.9		
13	3:10 p. m.	3.20	361	150	163	2.21	4:00 p. m.	3.20	385	336	349	7.9		
1950														
Mar. 1	3:00 p. m.	3.16	432	144	140	3.09	4:00 p. m.	3.16	[2] 469	1,230	1,560	4.9		39
21	2:45 p. m.	3.31	410	141	135	3.04	12:30 p. m.	3.32	[2] 463	1,050	1,310	7.6		40
Apr. 12	2:00 p. m.	3.15	386	145	150	2.57	3:00 p. m.	3.14	[2] 421	891	1,010	7.0		43
25	1:45 p. m.	3.09	414	145	144	2.88	3:00 p. m.	3.06	[2] 424	759	869	5.4		51
May 9	1:50 p. m.	3.27	399	145	163	2.45	3:00 p. m.	3.25	[2] 447	596	719	6.6		61
23	12:35 p. m.	3.35	392	145	154	2.55	2:00 p. m.	3.33	[2] 400	348	376	6.3		75
June 6	1:40 p. m.	3.24	364	144	152	2.39	2:30 p. m.	3.21	[2] 350	308	291	7.7		76
20	11:10 a. m.	3.24	381	144	162	2.35	12:00 m.	3.26	[2] 400	406	438	6.1		70
July 6	10:05 a. m.	3.27	369	142	166	2.22	11:30 a. m.	3.22	[2] 347	384	360	6.6		71
18	1:00 p. m.	3.26	377	147	183	2.06	2:00 p. m.	3.28	[2] 376	476	483	6.4		68
Aug. 1	3:40 p. m.	3.18	349	148	160	2.18	4:30 p. m.	3.17	[2] 352	510	485			76
26	4:30 p. m.	3.40	441	148	200	2.20	5:30 p. m.	3.38	[2] 444	478	573			68

See footnotes at end of table.

TABLE 1.—*Water and suspended-sediment discharge measurements*—Continued

[Mean gage heights are from water-stage recorder at gaging station]

Date	Water discharge measurement						Suspended-sediment discharge measurement					Water-surface slope (ft per mile)		Water temperature (°F)
	Mean time	Mean gage height (ft)	Discharge (cfs)	Effective width (ft)	Effective area (sq ft)	Mean velocity (fps)	Mean time	Mean gage height (ft)	Rated water discharge (cfs)	Mean concentration (ppm)	Discharge (tons per day)	Local	Reach	
Section E—Continued														
1950—Continued														
Oct. 4	5:45 p. m.	3.16	339	148	157	2.16	6:20 p. m.	3.14	336	464	421			48
Nov. 8	4:02 p. m.	3.21	443	148	120	3.69	4:50 p. m.	3.21	[2] 434	786	921	7.1		37
30	3:20 p. m.	3.15	400	147	146	2.74	4:15 p. m.	3.13	397	774	830			37
Dec. 14	3:20 p. m.	3.91	481	131	148	3.25	4:25 p. m.	3.87	482	1,080	1,410	6.6		32
1951														
Jan. 24	2:02 p. m.	3.13	388	152	135	2.87	3:30 p. m.	3.15	367	1,170	1,160			32
Feb. 20	4:15 p. m.	3.40	374	145	141	2.65	5:15 p. m.	3.38	[2] 370	739	738	8.3		45
Mar. 14	4:22 p. m.	3.18	395	142	145	2.72	5:30 p. m.	3.21	361	1,510	1,470			32
30	4:52 p. m.	3.20	361	145	158	2.28	5:30 p. m.	3.20	[2] 361	562	548	7.1		50
Apr. 26	9:20 a. m.	3.42	416	146	155	2.68	10:45 a. m.	3.42	[2] 415	618	692		6.9	48
May 22	12:35 p. m.	3.46	488	148	205	2.38	2:15 p. m.	3.41	[2] 469	1,120	1,420	6.6	6.8	64
June 4	4:40 p. m.	3.31	417	148	179	2.33							6.9	61
26	4:32 p. m.	3.42	418	145	179	2.34	6:00 p. m.	3.42	412	348	387		6.9	82
July 26	3:20 p. m.	3.30	367	147	180	2.04	5:05 p. m.	3.30	350	248	234	6.8	7.0	88
Aug. 16	4:08 p. m.	3.25	346	142	164	2.11	6:30 p. m.	3.24	[2] 364	268	263		7.1	78
30	9:45 a. m.	3.35	378	146	173	2.18	10:50 a. m.	3.34	[2] 376	383	389		7.0	76
Sept. 21	3:02 p. m.	3.21	442	143	163	2.71	3:50 p. m.	3.19	[2] 437	472	557	6.9		55
Oct. 31	10:38 a. m.	3.00	427	152	157	2.72	11:50 a. m.	3.07	[2] 428	766	885	6.9	7.1	39
Dec. 5	9:50 a. m.	3.09	399	123	132	3.02	10:50 a. m.	3.10	400	996	1,080	6.2		34
1952														
May 6	7:15 p. m.	3.22	366	142	168	2.18	9:15 p. m.	3.26	376	518	526		7.0	65
22	10:48 a. m.	3.29	454	143	189	2.40	12:00 m.	3.30	453	530	648		7.0	66
June 3	5:50 p. m.	3.26	394	149	178	2.21	6:40 p. m.	3.27	364	314	309		7.0	74
18	2:38 p. m.	3.10	329	150	150	2.19	12:40 p. m.	3.12	325	317	278		7.1	72
July 6	5:25 p. m.	3.12	355	153	168	2.11							7.0	73
18	11:00 a. m.	3.14	330	147	161	2.05	4:00 p. m.	3.14	344	291	270	7.5	7.1	87
30	5:25 p. m.	3.03	319	153	164	1.95						7.0	7.1	78
Aug. 13	11:40 a. m.	3.19	386	148	160	2.41	1:05 p. m.	3.20	376	341	346	7.0	7.1	79
26	12:08 p. m.	3.16	362	153	174	2.08							7.1	80
Sept. 11	3:00 p. m.	3.11	334	149	152	2.20	4:00 p. m.	3.08	[2] 325	286	251	6.8	7.2	68
24	11:58 a. m.	3.08	366	148	161	2.27	1:55 p. m.	3.09	[2] 370	471	471	6.9	7.1	65

Gaging sections [10]

1948														
Nov. 2	1:08 p. m.	3.18	383	[8] 68	[8] 120	3.26	...	...	...	...	...	...	...	51
1949														
Jan. 13	1:40 p. m.	6.11	383	[8] 65	[8] 183	2.09	...	...	...	...	...	...	...	32
May 17	1:12 p. m.	3.54	427	[8] 71	[8] 144	2.96	...	...	...	...	...	...	...	69
June 28	1:35 p. m.	3.36	350	[8] 67	[8] 134	2.61	...	...	...	...	...	...	...	83
July 12	8:48 a. m.	3.37	347	[8] 65	[8] 128	2.71	...	...	...	...	...	...	...	68
26	1:25 p. m.	3 24	349	[8] 69	[8] 132	2.62	...	...	...	...	...	...	...	73
Aug. 9	3:55 p. m.	3.24	328	[8] 65	[8] 126	2.60	...	...	...	...	...	...	...	82
23	9:52 a. m.	3.33	347	[8] 71	[8] 132	2.63	...	...	...	...	...	...	...	72
Sept. 20	6:25 p. m.	3.22	348	[8] 69	[8] 135	2.58	...	...	...	...	...	...	...	66
Oct. 5	11:58 a. m.	3.26	349	[8] 64	[8] 129	2.71	...	...	...	...	...	...	...	65
18	2:55 p. m.	3.22	352	[8] 64	[8] 115	3.06	...	...	...	...	...	...	...	...
Nov. 15	11:48 a. m.	3.23	411	[8] 64	[8] 128	3.21	...	...	...	...	...	...	...	39
30	10:42 a. m.	3.17	373	[8] 64	[8] 122	3.06	...	...	...	...	...	...	...	36
Dec. 21	11:15 a. m.	4.08	280	[8] 71	[8] 153	1.83	...	...	...	...	...	...	...	32
29	9:40 a. m.	4.47	391	[8] 60	[8] 164	2.38	...	...	...	...	...	...	...	32
1950														
Feb. 22	12:18 p. m.	3.19	398	[8] 69	[8] 126	3.16	...	...	...	...	...	...	...	33
Nov. 29	2:15 p. m.	3.12	391	[8] 69	[8] 109	3.59	...	...	...	...	...	...	...	37
1951														
July 25	12:12 p. m.	3.28	345	[8] 54	[8] 125	2.76	...	...	...	...	...	...	...	...
Oct. 31	10:10 a. m.	3.02	390	[8] 75	[8] 138	2.83	...	...	...	...	...	...	...	...
1952														
June 18	4:47 p. m.	3.07	318	[8] 55	[8] 113	2.81	...	...	...	...	...	...	...	77
July 6	12:00 m.	3.11	323	[8] 66	[8] 129	2.51	...	...	...	...	...	...	...	77
18	9:10 a. m.	3.15	343	[8] 58	[8] 117	2.92	...	...	...	...	...	...	...	74
30	11:45 a. m.	3.09	322	[8] 67	[8] 126	2.55	...	...	...	...	...	...	...	68
Aug. 13	9:38 a. m.	3.18	369	[8] 59	[8] 124	2.98	...	...	...	...	...	...	...	70
26	9:48 a. m.	3.17	340	[8] 67	[8] 138	2.48	...	...	...	...	...	...	...	73
Sept. 11	11:12 a. m.	3.14	342	[8] 68	[8] 129	2.65	...	...	...	...	...	...	...	66
24	9:50 a. m.	3.12	377	[8] 58	[8] 126	2.99	...	...	...	...	...	...	...	57

[1] Under this spanner mean gage heights for sediment measurements have been corrected for time of travel from section A to gaging station.
[2] Based on shift determined from all available measurements made on this day.
[3] Does not include width and area of no flow (45 ft and 4.5 sq ft, respectively).
[4] Includes width and area of upstream flow (7.0 ft and 9.1 sq ft, respectively).
[5] Revised.
[6] Measurement made 25 ft upstream from section B.
[7] Measurement made 300 ft upstream from section C.
[8] Not effective, but as measured.
[9] May be in error.
[10] Includes only those water-discharge measurements that were made on days when sediment-discharge measurements were made.

TABLE 2.—*Cross-section soundings*

Date	Section	Time	Mean gage height (ft)	Width (ft)	Area (sq ft)
1952					
Sept. 11	A			298	162
Do	B_1	11:08 a. m.	3.13	95	143
Do	C_2	12:15 p. m.	3.13	77	129
Sept. 24	A	9:35 a. m.	3.10	335	228
Do	B_1	11:15 a. m.	3.08	93	135
Do	C_2	12:25 p. m.	3.08	83	143

TABLE 3.—*Particle-size analyses of measured suspended sediment, depth-integrated samples*

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; W, in distilled water; S, sieve; C, chemically dispersed M, mechanically dispersed ;and P, pipette]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment: Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	Methods of analysis
Section A																	
1949																	
Aug. 25	11:00 a. m.	341	--	206	1,910	--	--	--	8	14	27	57	--	--	--	--	BN
Sept. 13	10:00 a. m.	376	--	516	4,950	--	--	--	3	5	11	37	--	--	--	--	BW
1950																	
Mar. 1	11:00 a. m.	[1] 472	35	1,430	--	--	--	--	--	--	23	54	94	100	--	--	SWCM
21	11:00 a. m.	[1] 463	35	1,040	--	--	--	--	--	--	19	51	96	99	100	--	SWCM
Apr. 12	10:00 a. m.	[1] 421	40	804	--	--	--	--	--	--	13	47	94	100	--	--	SWCM
25	11:00 a. m.	[1] 460	41	796	--	--	--	--	--	--	17	49	96	100	--	--	SWCM
May 9	11:00 a. m.	[1] 450	50	794	--	--	--	--	--	--	23	43	91	99	100	--	SWCM
23	11:30 a. m.	[1] 409	70	334	--	--	--	--	--	--	23	52	89	97	100	--	SWCM
June 6	11:00 a. m.	[1] 358	70	356	--	--	--	--	--	--	19	49	92	100	--	--	SW
20	5:15 p. m.	[1] 406	80	363	--	--	--	--	--	--	27	54	83	99	100	--	SW
July 18	9:00 a. m.	[1] 376	64	343	--	--	--	--	--	--	19	48	84	93	94	95	S
Aug. 1	12:30 p. m.	[1] 364	70	834	--	--	--	--	--	--	15	30	68	96	99	100	S
25	6:10 p. m.	330	74	272	--	--	--	--	--	--	30	62	95	100	--	--	S
Oct. 4	10:30 a. m.	344	44	516	--	--	--	--	--	--	13	46	93	--	--	--	S
Nov. 7	2:50 p. m.	397	48	365	--	--	--	--	--	--	17	53	94	100	--	--	S
29	5:10 p. m.	391	38	770	--	--	--	--	--	--	11	36	83	99	--	--	S
1951																	
Jan. 23	4:50 p. m.	400	32	1,790	--	--	--	--	--	--	7	30	88	99	--	--	S
Feb. 19	4:45 p. m.	[1] 403	38	1,050	--	--	--	--	--	--	14	44	89	--	--	--	S
Mar. 13	5:30 p. m.	[1] 409	32	1,560	--	--	--	--	--	--	10	36	89	--	--	--	S
Apr. 25	11:45 a. m.	[1] 409	48	512	--	--	--	--	--	--	18	57	96	--	--	--	S
May 21	4:00 p. m.	[1] 626	56	566	--	--	--	--	--	--	30	63	98	--	--	--	S
Aug. 15	7:30 p. m.	338	72	300	--	--	--	--	--	--	28	58	96	--	--	--	S
29	10:40 a. m.	400	73	302	--	--	--	--	--	--	25	60	95	--	--	--	S
Sept. 20	1:10 p. m.	358	67	454	--	--	--	--	--	--	47	68	96	100	--	--	S

See footnotes at end of table.

TABLE 3.—*Particle-size analyses of measured suspended sediment, depth-integrated samples*—Continued

[Method of analysis: B, bottom-withdrawal tube; N, in native water; W, in distilled water; S, sieve; C, chemically dispersed; M, mechanically dispersed; and P, pipette]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment													Methods of analysis
				Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
						0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section A—Continued																	
1952																	
May 6	12:15 p. m.	361		407							22	51	86	99	100		S
21	2:40 p. m.	431	65	500							27	52	90	100			S
June 3	3:20 p. m.	364		276							27	54	93	100			S
July 18	1:15 p. m.	352	85	212							41	70	95	100			S
30	9:20 a. m.	327	68	318							25	54	90	100			S
Aug. 13	9:25 a. m.	373	72	387							25	57	94	100			S
26	10:35 a. m.	[1] 352	77	369							21	49	92	100			S
Sept. 11	9:22 a. m.	[1] 347	64	338							19	47	89	100			S
24	9:35 a. m.	[1] 376	57	339							29	59	91	100			S
Section B₁																	
1950																	
Dec. 14	11:30 a. m.	496	32	724							9	29	84	99			S
1951																	
June 4	12:10 p. m.	[1] 434	61	552							23	55					S
26	10:45 a. m.	424	72	544							44	48					S
Aug. 16	10:55 a. m.	[1] 350	70	332							23	58	95				S
Oct. 30	1:15 p. m.	437	41	1,060							10	37	92	100			S
Dec. 4	2:50 p. m.	[1] 415	38	707							13	45	94	100			S
1952																	
May 6	2:00 p. m.	370	68	509							19	49	92	100			S
21	4:55 p. m.	[1] 412	65	715							19	49	88	100			S
June 3	4:40 p. m.	361	74	455							19	42	88	100			S
18	10:55 a. m.	325	70	474	633			5	6	9	20	48	93	100			SPWCM
July 6	1:50 p. m.	[1] 341	76	367							27	47	90	100			S
18	2:15 p. m.	350	86	363							24	48	89	100			S
30	11:50 a. m.	327	72	332							25	51	89	99	100		S
Aug. 26	3:00 p. m.	[1] 350	80	283							26	56	92	100			S
Sept. 11	10:40 a. m.	[1] 344	66	363							18	47	91	100			S
24	11:15 a. m.	[1] 367	59	485							13	41	88	100			S

Section B

1948																	
Oct. 15	12:45 p. m.	367								2	4	14	79	99			BN
15	4:20 p. m.	370								4	9	27	97	100			BN
19	12:00 m.	350	45	908	1,740				4	4	8	18	74	96			BN
Nov. 2	6:15 p. m.	379		634	1,340				6	6	10	22	81	94			BN
Dec. 1	4:00 p. m.	412		976	1,780				4	5	11	26	78	98			BN
1949																	
Jan. 13	2:35 p. m.	380		162	335				7	12	21	38	63	86			BN
Mar. 22	11:20 a. m.	466		1,040	1,890				12	15	21	46					BW
May 17	12:10 p. m.	431		508	1,120				6	8	14	29	94	100			BW
June 4	1:45 p. m.	350		571	988					7	11	32					BN
14	11:30 a. m.	424		754	1,540				20	24	33	48					BW
28	12:55 p. m.	352		382	809					24	31	45					BW
July 15	1:45 p. m.	364	78	325						17	24	35					BN
Aug. 4	10:00 a. m.	330		446	1,170				6	8	16	38	100				BN
9	5:00 p. m.	333		338	1,140				14	18	28	36					BW
25	10:15 a. m.	336		508	1,430				7	9	18	34					BN
Sept. 13	12:05 p. m.	379	53	586	1,840				4	5	10	24					BW
20	4:10 p. m.	344		458	812							30					BW
Oct 5	1:45 p. m.	361	65	382							9	31	75	98			S
12	11:15 a. m.	[1] 394	49	836	2,680						9	30	74	96			BW
18	3:45 p. m.	347	60	617							6	26	78	99			S
Nov. 1	11:30 a. m.	347	47	634							16	47	95	100			SWCM
15	12:45 p. m.	412	42	880							8	30	89	100			SWCM
30	12:00 m.	364	39	934							8	32	83	99			SWCM
Dec. 9	11:00 a. m.	388	32	1,060							7	24	86	99			SWCM
1950																	
Jan. 11	4:30 p. m.	460	32	198							18	34	83	99			SWCM
Feb. 22	1:30 p. m.	400	36	1,470							22	50	94	100			SWCM
Mar 1	11:20 a. m.	[1] 472	34	1,280							26	52	93	99			SWCM
8	2:15 p. m.	210	32	1,660							5	22	79	97			SWCM
8	2:15 p. m.	210	32	1,660	1,410					5	8	25					BN
21	10:30 a. m.	[1] 450	34	1,820							12	39	88	99			SWCM
Apr. 12	1:00 p. m.	[1] 421	41	1,090							11	40	90	99			SWCM
25	10:45 a. m.	[1] 463	40	1,090							13	40	94	100			SWCM
May 9	8:25 a. m.	[1] 444	43	1,230							13	46	91	98			SWCM
23	8:20 a. m.	[1] 406	62	801							13	34	80	95			SWCM
June 6	8:45 a. m.	[1] 391	65	747							10	26	64	91	97	99	S
20	8:45 a. m.	[1] 397	64	524							16	41	83	98			S
July 6	7:55 a. m.	[1] 361	64	629							13	37	78	93	98		S
18	8:50 a. m.	[1] 376	64	526							13	39	83	99			S
Aug 1	9:00 a. m.	[1] 376	62	871							22	38	76	97	100		S
26	9:10 a. m.	[1] 479	64	550							27	60	94				S
Oct. 4	1:30 p. m.	344	47	635							10	39	88	100			S
Nov. 8	10:00 a. m.	[1] 453	39	1,280							6	24	66	89	99		S
30 [2]	10:40 a. m.	382	35	925							11	38	84	99			S

See footnotes at end of table.

TABLE 3.—*Particle-size analyses of measured suspended sediment, depth-integrated samples*—Continued

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; W, in distilled water; S, sieve; C, chemically dispersed; M, mechonically dispersed; and P, pipette]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment													Methods of analysis
				Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
						0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section B—Continued																	
1951																	
Jan. 24	10:40 a. m.	376	32	1,650							3	19	74	98			S
Feb. 20	12:05 p. m.	[1] 364	37	1,670							10	30	66	90			S
Mar. 14 [2]	11:00 a. m.	361	32	1,090							7	36	95				S
Apr. 25	3:10 p. m.	[1] 397	61	621							15	48	94	100			S
May 21	6:45 p. m.	[1] 608	57	1,040							21	47	88	95			S
Aug. 29	1:20 p. m.	394	77	390							17	40	86				S
Sept. 20 [2]	4:40 p. m.	367	69	384							20	50	91				S
1952																	
Jan. 28	4:00 p. m.	[1] 609	32	462							9	22	77	98	100		S
Section C₂																	
1950																	
Nov. 8	12:50 p. m.	[1] 444	39	976							9	36	84	100			S
30	1:15 p. m.	403	36	815							11	38	84	99			S
Dec. 14	3:30 p. m.	485	32	1,160							11	30	84	99			S
1951																	
Jan. 24	12:00 m.	388	32	1,420							4	25	91	100			S
Feb. 20	1:10 p. m.	[1] 364	40	795							16	48	85	99			S
Mar. 14	11:45 a. m.	361	32	1,100							8	36	92	100			S
May 22	12:15 p. m.	[1] 492	61	726							27	54	90	99	100		S
June 4	3:05 p. m.	[1] 412	63	600							19	53					S
26	1:20 p. m.	412	78	526							23	47					S
Aug. 16	1:20 p. m.	[1] 361	75	506							15	39	87	99			S
Sept. 20	6:40 p. m.	364	67	410							19	49	90	100			S
Oct. 30	5:45 p. m.	421	40	904							9	36	86	100			S
Dec. 4	5:40 p. m.	[1] 394	38	956							10	37	91	100			S
1952																	
Mar. 10	4:30 p. m.	431	50	812							18	50	91	99	100		S
26	4:20 p. m.	[1] 450	49	1,200							25	68	95	99	100		S

May 6	5:00 p. m.	367	69	500	----	----	----	----	----	----	17	46	88	100	----	----	S
21	6:25 p. m.	[1] 421	65	638	----	----	----	----	----	----	23	56	95	100	----	----	S
June 3	5:50 p. m.	[1] 370	74	399	----	----	----	----	----	----	20	46	89	100	----	----	S
18	11:40 a. m.	327	71	376	578	5	6	6	9	12	22	50	90	100	----	----	SPWCM
July 6	5:00 p. m.	[1] 341	74	388	----	----	----	----	----	----	27	48	90	100	----	----	S
18	3:00 p. m.	350	86	340	----	----	----	----	----	----	27	52	92	100	----	----	S
Aug. 13	12:05 p. m.	373	75	438	----	----	----	----	----	----	22	49	90	99	100	----	S
26	3:45 p. m.	[1] 350	80	329	----	----	----	----	----	----	22	48	81	94	98	100	S
Sept. 11	11:40 a. m.	[1] 336	66	415	----	----	----	----	----	----	19	46	88	100	----	----	S
24	12:15 p. m.	[1] 367	64	405	----	----	----	----	----	----	16	45	91	100	----	----	S

Section C_1

1950																	
May 9	2:20 p. m.	[1] 450	59	837	----	----	----	----	----	----	17	51	92	100	----	----	SWCM
23	11:30 a. m.	[1] 409	70	436	----	----	----	----	----	----	12	47	93	98	----	----	SWCM
July 18	7:20 p. m.	[1] 412	64	519	----	----	----	----	----	----	20	46	90	99	100	----	S
Aug. 1	12:00 m.	[1] 370	69	516	----	----	----	----	----	----	30	52	89	----	----	----	S
27 [3]	3:20 p. m.	[1] 385	74	358	----	----	----	----	----	----	23	53	88	99	----	----	S

Section C

1949																	
June 4	2:55 p. m.	347	----	556	----	----	----	----	----	4	10	32	----	----	----	----	BN
July 15	4:50 p. m.	370	----	365	----	----	----	----	14	16	24	39	78	92	----	----	BN
Aug. 25	2:35 p. m.	338	----	335	2,830	----	----	----	3	6	14	36	----	----	----	----	BN
Sept. 13	4:15 p. m.	385	62	490	6,400	----	----	----	----	3	7	18	90	98	----	----	BW
1950																	
Mar. 21	11:20 a. m.	[1] 466	37	1,460	----	----	----	----	----	----	15	42	83	96	100	----	SWCM
Apr. 12	4:00 p. m.	[1] 421	43	891	----	----	----	----	----	----	13	40	82	96	97	99	SWCM
25	2:00 p. m.	[1] 437	49	1,220	----	----	----	----	----	----	10	30	75	95	98	----	SWCM
May 9	11:40 a. m.	[1] 456	52	912	----	----	----	----	----	----	13	46	91	99	----	----	SWCM
23	10:20 a. m.	[1] 397	66	548	----	----	----	----	----	----	17	46	92	100	----	----	SWCM
June 6	11:30 a. m.	[1] 364	71	349	----	----	----	----	----	----	18	45	88	99	----	----	S
20	4:15 p. m.	[1] 400	79	394	----	----	----	----	----	----	19	43	83	98	----	----	S
July 6	10:50 a. m.	[1] 355	69	458	----	----	----	----	----	----	16	43	87	99	----	----	S
18	11:40 a. m.	[1] 376	64	383	----	----	----	----	----	----	15	42	86	99	----	----	S
Aug. 1	2:45 p. m.	[1] 364	73	868	----	----	----	----	----	----	19	34	60	93	98	99	S
26	7:25 p. m.	[1] 447	69	651	----	----	----	----	----	----	14	34	70	92	97	----	S
Oct. 4	3:00 p. m.	336	51	570	----	----	----	----	----	----	11	38	88	100	----	----	S
Nov. 8	2:30 p. m.	[1] 437	39	955	----	----	----	----	----	----	11	38	89	99	----	----	S
30	2:10 p. m.	406	38	930	----	----	----	----	----	----	11	36	86	99	----	----	S
1951																	
Feb. 20	6:15 p. m.	[1] 367	45	1,080	----	----	----	----	----	----	12	38	75	92	----	----	S
Mar. 14	2:30 p. m.	350	32	1,250	----	----	----	----	----	----	10	39	91	100	----	----	S

See footnotes at end of table.

TABLE 3.—*Particle-size analyses of measured suspended sediment, depth-integrated samples*—Continued

[Methods of analysis: B, bottom-withbrawal tube; N, in natiqe water; W, in distilled water; S, sieve; C, chemically dispersed; M, mechanically dispersed; and P, pipette]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment													Methods of analysis
				Concentration (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
						0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section D																	
1949																	
June 4	4:05 p. m.	344		763							6	23					BN
21	5:54 p. m.	379		1,170						7	10	17	65	94			BN
July 15	4:54 p. m.	367		743						7	11	19	63	100			BN
Aug. 25	2:45 p. m.	341		768	8,740				4	4	7	16	66	90			BN
Sept. 13	4:55 p. m.	376	62	813	2,140				2	4	8	18					BW
1950																	
Mar. 1	3:00 p. m.	[1] 472	39	2,310							14	30	67	90	96	99	SWCM
21	11:25 a. m.	[1] 466	37	2,440							7	25	63	92	98		SWCM
30 [4]	6:55 p. m.	421		2,320							6	19	55	86	96	99	SWCM
Apr. 10 [4]	8:15 a. m.	370		1,930							7	22	65	91	98		SWCM
12	4:10 p. m.	[1] 421	44	1,500							8	27	68	95			SWCM
20 [4]	7:40 a. m.	307		1,850							6	26	73	91	97		SWCM
25	2:00 p. m.	[1] 437	49	1,480							7	25	70	93	98		SWCM
May 1 [4]	7:15 a. m.	421		2,790							4	16	46	78	89	95	S
9	11:15 a. m.	[1] 447	50	1,340							9	35	74	91	98		SWCM
10 [4]	7:20 a. m.	370		1,680							8	33	72	93	99		S
20 [4]	7:00 a. m.	364		1,250							7	29	74	94	98		S
23	10:20 a. m.	[1] 397	66	750							12	33	77	97			SWCM
June 1 [4]	7:00 a. m.	344		856							10	32	70	91	96	98	S
6	11:30 a. m.	[1] 364	71	632							10	28	65	93	98		S
14 [4]	7:05 a. m.	391		877							15	33	72	95	99		S
20	4:15 p. m.	[1] 400	79	553							14	32	71	94	98		S
24 [4]	6:30 a. m.	350		649							13	32	76	96	99		S
July 6 [4]	7:00 a. m.	[1] 370	69	966							12	28	63	96	100		S
6	10:50 a. m.	[1] 355	69	687							10	30	65	88	95	98	S
16 [4]	7:30 a. m.	361		1,040							10	23	51	83	91	96	S
25 [4]	7:05 a. m.	364		1,070							14	32	65	94	99		S
Aug. 1	2:45 p. m.	[1] 364	73	576							24	42	77	96	99		S
10 [4]	7:00 a. m.	456		1,560			29		34		48	63	86	96	98		SPWCM
20 [4]	7:20 a. m.	344		1,030							10	26	64	94	99		S
26	7:25 p. m.	[1] 447	69	1,300							8	21	46	96	100		S
30 [4]	7:00 a. m.	379		757							14	36	70	88	92	93	S

Sept. 13[4]	7:15 a. m.	358		931							10	32	74	94	98		S
Oct. 4	3:00 p. m.	336	51	990							7	24	64	91	97		S
Nov. 8	2:30 p. m.	[1] 437	39	1,420							8	28	69	92	99		S
30	2:10 p. m.	406	38	1,560							6	23	60	89	96	100	S
Dec. 14	2:50 p. m.	497	32	1,800							6	19	68	92	98		S
1951																	
Jan. 24	1:30 p. m.	367	33	2,600							4	16	65	94			S
Feb. 20	6:15 p. m.	[1] 367	45	1,260							10	30	71	94			S
Mar. 14	3:00 p. m.	347	32	1,660							8	29	72	94	99	100	S
14	4:00 p. m.	350	32	1,860							7	27	72	95	99	99	S
30	7:00 p. m.	[1] 367	46	1,410							9	26	66	90	97		S
Apr. 25	7:00 p. m.	[1] 394	59	902							9	27	66	94	99		S
May 11	6:20 p. m.	330	70	748							9	31	64	90	96	98	S
June 4	4:30 p. m.	[1] 412	61	935							13	36	73	94			S
26	4:25 p. m.	409	82	652							18	37	68	88	94	96	S
July 26	7:15 p. m.	341	85	548							12	25	61	91	98		S
Aug. 16	4:15 p. m.	[1] 367	80	654							10	28	62	86	94	98	S
30	12:00 m.	[1] 376	77	716							10	23	58	89	96		S
Oct. 31	3:00 p. m.	[1] 424	40	1,640							4	18	56	81	91	97	S
Dec. 5	2:00 p. m.	364	36	2,020							4	19	62	87	95	99	S
1952																	
Jan. 7	5:45 p. m.		32	287							12	28	74	99	100		S
28	5:35 p. m.		32	704							21	35	69	97			S
Feb. 11	4:00 p. m.	444		1,900							8	28	62	88	95	99	S
Mar. 10	6:10 p. m.	440	48	1,440							9	26	59	85	92	97	S
26	5:40 p. m.	[1] 434	48	2,000							13	42	71	93	97	100	S
May 6	7:00 p. m.	364	67	971							9	28	65	90	97		S
22	10:20 a. m.	450	64	1,450							10	28	64	90	96	98	S
June 4	9:10 a. m.	388	66	1,010							12	27	60	88	96	99	S
18	3:05 p. m.	320	77	672							13	32	68	90	96	100	S
July 6	6:10 p. m.	[1] 341	73	816							12	23	58	89	97		S
18	8:25 p. m.	341	80	852							10	24	58	84	93	98	S
30	5:10 p. m.	314	81	762							10	24	54	83	94	99	S
Aug. 13	4:25 p. m.	367	84	686							12	28	60	87	96		S
26	7:05 p. m.	[1] 344		1,260							6	13	34	63	84	99	S
Sept. 11	2:30 p. m.	[1] 336	67	1,040							5	15	40	76	88	97	S
24	2:10 p. m.	[1] 373	68	1,020							6	20	51	84	93	98	S

Section E

1949																	
Aug. 25	3:45 p. m.	341		269	1,770				5	8	19	42					BN
Sept. 13	4:00 p. m.	385		336	2,370				5	8	15	30	84	98			BW
1950																	
Mar. 1	4:00 p. m.	[1] 469	39	1,230							26	55	97	100			SWCM
21	1:00 p. m.	[1] 463	40	1,050							21	56	96	100			SWCM
Apr. 12	3:00 p. m.	[1] 421	43	891							14	45	90	99			SWCM
25	3:00 p. m.	[1] 424	51	759							16	49	96	100			SWCM
May 9	3:00 p. m.	[1] 447	61	596							21	57	91	100			SWCM
23	2:00 p. m.	[1] 400	75	348							34	58	94	100			SWCM

See footnotes at end of table.

TABLE 3.—*Particle-size analyses of measured suspended sediment, depth-integrated samples*—Continued

[Methods of analysis; B, bottom-withdrawal tube; N, in native water; W, in distilled water; S, sieve; C, chemically dispersed; M, mechanically dispersed; and P, pipette]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Suspended sediment: Concentration (ppm)	Suspended sediment: Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters: 0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	Methods of analysis
Section E—Continued																	
1950—Continued																	
June 6	2:30 p. m.	[1] 350	76	308							18	48	88	97			S
July 6	11:30 a. m.	[1] 347	71	384							20	53	92	100			S
18	2:00 p. m.	[1] 376	68	476							20	49	88	98			S
Aug. 1	4:30 p. m.	[1] 352	76	510							27	46	89				S
26	5:30 p. m.	[1] 444	68	478							27	59	91	99			S
Oct. 4	6:20 p. m.	336	48	464							14	42	85	99			S
Nov. 8	4:50 p. m.	[1] 434	37	786							12	42	90	98			S
30	4:15 p. m.	397	37	774							10	38	90	99			S
Dec. 14	4:25 p. m.	482	32	1,080							11	31	87				S
1951																	
Feb. 20	5:15 p. m.	[1] 370	45	739							17	49	91				S
Mar. 14	5:30 p. m.	361	32	1,510							12	45	96				S
30	5:30 p. m.	[1] 361	50	562							21	57	93				S
Apr. 26	10:45 a. m.	[1] 415	48	618							16	51	96				S
June 26	6:00 p. m.	412	82	348							28						S
July 26	5:05 p. m.	350	88	248							26	50	88	99			S
Aug. 16	6:30 p. m.	[1] 364	78	268							56	57	95				S
30	10:50 a. m.	[1] 376	76	383							21	46	89				S
Sept. 21	3:50 p. m.	[1] 437	55	472							18	55	94				S
Oct. 31	11:50 a. m.	[1] 428	39	766							9	36	89	100			S
Dec. 5	10:50 a. m.	400	34	996							10	38	94	100			S
1952																	
May 6	9:15 p. m.	376	65	518							18	52	93	100			S
22	12:00 m.	453	66	530							27	60	96	100			S
June 3	6:40 p. m.	364	74	314							26	55	94	100			S
18	12:40 p. m.	325	72	317	586	6	7	8	9	13	26	57	92	100			SPWCM
July 18	4:00 p. m.	344	87	291							28	55	91	100			S
Aug. 13	1:05 p. m.	376	79	341							26	57	94	100			S
Sept. 11	4:00 p. m.	[1] 325	68	286							21	55	93	100			S
24	1:55 p. m.	[1] 370	65	471							14	38	77	96	100		S

[1] Based on shift determined from all available measurements made on this day.
[2] Measurement made 25 ft upstream from section B.
[3] Measurement made 300 ft upstream from section C.
[4] Daily samples.

TABLE 4.—*Particle-size analyses of bed material*

[Method of analysis, sieve]

Date	Number of sampling points	Bed material: Percent finer than indicated size, in millimeters							Remarks
		0.062	0.125	0.25	0.50	1.0	2.0	4.0	
Section A									
1949									
Sept. 13	3	------	1	29	76	91	95	98	
1950									
Mar. 1	3	------	3	28	66	84	91	96	
21	3	------	1	9	47	72	86	95	
Apr. 12	3	------	2	29	82	95	98	99	
25	3	------	3	46	91	97	98	99	
May 9	3	------	4	33	76	89	93	96	
23	3	------	3	47	87	97	99	100	
June 6	3	------	2	38	81	94	98	100	
20	3	------	2	26	73	90	95	98	
July 6	3	------	2	35	85	95	98	99	
18	3	------	2	43	85	94	97	99	
Aug. 1	3	------	2	29	78	92	97	99	
25	3	------	9	45	82	92	97	99	
Oct. 4	3	2	10	32	72	90	97	100	
Nov. 7	3	1	3	43	83	95	98	99	
29	3	0	4	40	79	89	93	96	
1951									
Jan. 23	3	0	1	26	83	94	97	99	
Feb. 19	3	0	4	49	93	98	99	100	
Mar. 13	3	0	3	25	67	86	93	98	
Apr. 25	[1] 3	0	2	25	73	89	94	98	
May 21	3	0	3	37	80	92	96	99	
June 4	3	0	2	24	78	93	97	99	
25	[1] 3	0	1	22	67	79	86	93	
July 27	[1] 3	1	3	34	76	88	92	96	
Aug. 15	[1] 7	1	3	33	75	90	96	99	
29	7	0	2	37	82	93	96	98	
Sept. 20	[1] 7	0	3	23	66	83	90	96	
Dec. 4	3	0	3	31	74	88	94	97	
1952									
May 6	4	0	1	22	70	86	92	96	
21	3	0	5	44	81	93	97	98	
June 3	3	0	4	36	75	89	93	95	
18	3	0	2	37	82	92	96	98	
July 6	3	0	3	28	75	91	96	98	
18	3	0	1	31	82	91	94	96	
30	3	0	3	28	68	85	93	98	
Aug. 13	3	1	7	38	80	93	96	99	
26	3	0	2	36	77	89	94	98	
Sept. 11	3	0	1	25	73	92	96	99	
Total or weighted mean	127	0	3	32	77	90	95	98	

See footnotes at end of table.

TABLE 4.—*Particle-size analyses of bed material*—Continued

[Method of analysis, sieve]

Date	Number of sampling points	Bed material: Percent finer than indicated size, in millimeters							Remarks
		0.062	0.125	0.25	0.50	1.0	2.0	4.0	
Section B1									
1950									
Dec. 14	3	0	2	46	95	98	99	99	
1951									
June 4	[1] 3	0	1	30	72	88	94	97	
26	[1] 3	1	2	24	65	80	88	95	
July 25	[1] 3	2	4	28	68	78	87	95	
Aug. 16	[1] 5	1	2	26	65	84	92	96	
Oct. 30	[1] 3	0	1	20	65	85	93	97	
Dec. 4	[1] 3	1	2	34	86	96	98	99	
1952									
May 6	[1] 2	0	3	39	78	86	89	92	
21	[1] 3	0	1	23	72	91	96	97	
June 3	[1] 3	0	2	37	87	95	98	99	
18	3	0	1	17	45	65	78	91	
July 6	3	1	5	39	79	93	96	98	
18	3	0	1	20	76	92	95	97	
30	3	0	1	17	52	77	90	97	
Aug. 13	3	0	2	25	84	91	95	97	
26	3	0	2	32	75	87	93	98	
Sept. 11	3	0	3	37	81	94	97	99	
24	3	0	2	26	75	92	96	99	
Total or weighted mean	55	0	2	29	73	87	93	97	
Section B									
1949									
Sept. 13	3	------	1	19	75	91	95	98	
1950									
June 20	3	------	1	25	79	95	98	99	25 ft upstream from sec. B.
July 6	3	------	1	18	55	73	84	93	Do.
18	3	------	1	30	92	99	99	100	Do.
Aug. 1	3	------	1	27	71	87	95	99	Do.
26	3	------	1	22	88	97	99	100	Do.
Oct. 4	3	0	1	20	74	93	98	100	
Nov. 8	3	0	2	32	76	83	90	97	
30	[1] 3	0	1	20	81	94	96	98	Do.
1951									
Jan. 24	3	0	2	42	88	97	98	99	
Feb. 20	3	------	0	9	37	80	89	95	
Mar. 14	[1] 3	0	2	38	80	94	98	99	Do.
Apr. 25	[1] 3	0	1	26	49	70	83	92	
May 21	3	0	1	20	75	92	96	97	
Aug. 29	[1] 5	1	2	17	58	80	91	96	
Sept. 20	[1] 3	2	4	20	63	85	94	98	Do.
1952									
Jan. 28	[1] 3	0	1	40	92	97	98	98	
Total or weighted mean [2]	53	0	1	25	72	88	94	97	
Do. [3]	24	0	2	25	76	90	95	98	

See footnotes at end of table.

TABLE 4.—*Particle-size analyses of bed material*—Continued

[Method of analysis, sieve]

Date	Number of sampling points	Bed material: Percent finer than indicated size, in millimeters							Remarks
		0.062	0.125	0.25	0.50	1.0	2.0	4.0	
Section C_2									
1950									
Oct. 4	3	0	1	19	81	91	95	98	
Nov. 30	3	0	1	18	73	90	95	98	
1951									
Jan. 24	3	0	1	28	72	90	96	99	
Feb. 20	3	1	1	7	33	65	84	93	
Mar. 14	[1] 3	0	1	23	73	88	94	99	
Apr. 25	3	0	1	12	44	59	72	87	
May 22	[1] 3	0	1	10	45	68	85	94	
June 4	[1] 3	0	4	17	70	84	89	94	
26	[1] 3	0	1	13	50	72	83	91	
July 26	[1] 3	0	1	16	60	79	90	97	
Aug. 16	[1] 7	0	2	24	66	85	92	97	
29	[1] 7	0	1	23	74	88	94	97	
Sept. 20	[1] 5	0	1	20	65	86	94	98	
Oct. 30	[1] 3	0	1	12	54	80	91	96	
Dec. 4	[1] 3	0	1	26	71	87	93	96	
1952									
Feb. 11	3	1	8	30	81	92	96	99	
Mar. 10	3	1	1	20	61	84	94	97	
26	3	0	2	24	70	89	92	97	
May 6	[1] 3	0	1	23	67	81	88	94	
21	[1] 3	0	1	24	64	80	87	94	
June 3	3	0	1	25	80	91	94	97	
18	3	0	6	26	78	91	95	97	
July 6	3	0	1	21	60	77	86	94	
18	3	0	4	24	63	81	91	96	
30	3	0	2	24	78	84	91	97	
Aug. 13	3	0	1	20	59	79	87	94	
26	3	0	1	19	66	83	92	97	
Sept. 11	3	0	2	25	80	92	96	99	
24	3	0	1	27	73	89	94	98	
Total or weighted mean	97	0	2	21	66	83	91	96	
Section C_1									
1949									
Dec. 9	3	------	1	39	90	97	98	99	95 ft downstream from sec. C_1.
1950									
May 9	3	------	4	35	92	98	99	99	
23	3	------	2	29	75	89	94	97	
June 6	3	------	1	21	70	86	92	98	
20	3	------	1	35	89	96	97	99	
July 6	3	------	2	29	75	92	96	98	
18	3	------	1	32	87	96	98	99	
Aug. 1	3	------	1	27	76	90	95	98	
27	3	------	1	26	85	96	98	100	105 ft upstream from sec. C_1.
Total or weighted mean [4]	21	------	2	30	81	92	96	98	

See footnotes at end of table.

TABLE 4.—*Particle-size analyses of bed material*—Continued

[Method of analysis, sieve]

Date	Number of sampling points	Bed material: Percent finer than indicated size, in millimeters							Remarks
		0.062	0.125	0.25	0.50	1.0	2.0	4.0	
Section C									
1949									
June 4	3	------	1	16	58	80	89	96	
21	3	------	2	34	73	87	94	98	
Aug. 30	6	------	1	28	82	95	98	99	
Sept. 13	3	------	2	32	75	89	96	99	20 ft upstream from sec. C.
Nov. 5	3	------	1	30	78	90	96	98	
1950									
Mar. 1	3	------	1	18	70	91	96	98	
22	3	------	1	16	68	90	95	97	25 ft upstream from sec. C.
Apr. 25	3	------	1	18	67	86	93	97	Do.
June 20	3	------	2	34	85	96	98	99	Do.
July 6	3	------	2	32	78	91	95	98	Do.
18	3	------	1	23	73	90	94	96	Do.
Aug. 1	3	------	1	25	76	93	97	99	Do.
26	3	------	2	41	90	98	99	100	Do.
Section D									
1950									
Aug. 15	2	------	1	22	60	72	81	92	Stations 62 and 64 at measuring sill.
Section E									
1949									
Sept. 13	3	------	1	29	81	93	96	99	
1950									
Mar. 1	3	------	2	44	90	97	99	99	
21	3	------	4	42	87	96	98	99	
Apr. 12	3	------	5	40	77	89	95	98	
25	3	------	2	32	77	92	96	98	
May 9	2	------	2	21	70	90	94	96	
23	3	------	2	35	84	95	97	99	
June 6	3	------	2	36	80	90	95	99	
20	3	------	2	27	73	90	94	98	
July 6	3	------	1	17	61	80	88	94	
18	3	------	2	32	83	96	98	99	
Aug. 1	3	------	1	20	61	80	88	95	
26	3	------	3	30	74	91	96	99	
Oct. 4	3	0	2	32	81	93	97	99	
Nov. 8	3	1	11	66	94	97	98	100	
30	3	0	2	30	89	98	99	100	
1951									
Jan. 24	3	0	1	20	71	87	93	98	
Feb. 20	3	0	2	31	79	93	97	100	
Mar. 14	3	0	2	40	89	96	98	99	
30	3	0	2	25	75	90	95	99	
30	3	0	1	16	68	86	91	95	At centers of maximum Q_w sections.
30	[1] 7	0	2	29	79	94	98	99	
Apr. 26	[1] 3	0	1	20	55	75	86	96	
26	29	0	2	27	73	87	93	97	
May 22	[1] 3	0	3	32	73	87	93	97	
June 4	[1] 3	0	2	23	69	86	91	96	
26	[1] 3	0	2	23	66	82	89	95	
July 26	[1] 3	1	2	22	69	83	90	96	
Aug. 16	[1] 7	0	3	24	60	77	86	94	
30	[1] 7	0	2	25	65	80	88	95	

See footnotes at end of table.

TABLE 4.—*Particle-size analyses of bed material*—Continued

[Method of analysis, sieve]

Date	Number of sampling points	Bed material							Remarks
		Percent finer than indicated size, in millimeters							
		0.062	0.125	0.25	0.50	1.0	2.0	4.0	
Section E—Continued									
1951—Continued									
Sept. 20	36	1	2	26	68	82	89	94	At 4-ft intervals across section.
21	[1] 5	1	2	24	67	83	90	96	
Oct. 31	[1] 3	0	1	25	77	92	96	99	
Dec. 5	[1] 3	0	1	27	75	92	97	99	
1952									
May 6	1	0	1	25	82	96	98	99	Station 77, 0-1 in. below bed surface.
6	1	0	2	31	78	92	96	97	Station 77, 1-2 in. below bed surface.
6	1	0	1	8	29	50	63	82	Station 77, 2-3 in. below bed surface.
6	1	------	0	6	27	50	68	80	Station 77, 3-4 in. below bed surface.
6	1	1	1	13	31	49	63	81	Station 77, 4-5 in. below bed surface.
6	1	0	2	23	60	76	87	93	Station 77, 5-6 in. below bed surface.
6	[1] 7	0	2	27	63	80	88	94	
6	[1] 7	0	2	29	74	88	93	96	Top one-half inch of 6-in. core.
22	[1] 3	0	2	21	66	84	92	96	
22	[1] 3	0	2	26	76	92	97	98	Do.
June 3	[1] 3	0	2	29	71	86	92	98	
3	[1] 3	0	2	27	76	92	96	98	Do.
18	[1] 3	0	2	38	80	93	97	99	
18	[1] 3	0	6	61	90	98	99	100	Do.
July 6	[1] 3	0	1	30	78	90	95	98	
6	[1] 3	0	1	36	85	96	99	100	Do.
18	[1] 3	0	5	46	84	94	97	98	
18	[1] 3	0	3	43	83	94	97	99	Do.
30	[1] 3	0	2	33	70	83	90	94	
30	[1] 3	0	2	39	83	93	96	99	Do.
Aug. 13	[1] 3	0	2	33	76	89	94	97	
13	[1] 3	0	2	42	82	89	93	95	Do.
26	[1] 3	0	2	28	65	82	88	94	
26	[1] 3	0	2	33	75	89	93	97	Do.
Sept. 11	[1] 3	0	2	29	74	87	94	98	
11	[1] 3	0	1	26	72	86	92	97	Do.
24	[1] 3	0	2	36	89	97	98	99	
24	[1] 3	0	2	45	90	96	98	100	Do.
Total or weighted mean [5]	208	0	2	29	73	87	93	97	

[1] Sampling points at centers of equal segments of water discharge.
[2] For all samples.
[3] For samples 25 ft upstream from sec. B.
[4] For samples at sec. C_1.
[5] For all samples except at centers of maximum water discharge sections, station 77 on May 6, 1952, and top one-half inch of 6-in. core.

TABLE 5.—*Particle-size analyses of measured suspended sediment, point-integrated samples*

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; S, sieve; W, in distilled water; C, chemically dispersed; and M, mechanically dispersed. Samples collected with a P-46 sampler]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Sampling station	Total depth (ft)	Suspended sediment: Sampling point			Suspended sediment: Percent finer than indicated size, in millimeters								Methods of analysis
						Velocity (fps)	Depth (ft)	Concentration (ppm)	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section B																	
1948 Oct. 15	3:05 p. m.	361		24	3.7	3.28	0.4	440			21	44					BN
	3:00 p. m.	355		24	3.7	3.39	1.4	1,140	8	9	11	28					BN
	3:00 p. m.	355		24	3.7	3.14	2.5	1,520		6	8	20					BN
	2:50 p. m.	355		24	3.7	1.92	3.2	4,230									
	3:10 p. m.	367		42	1.4	3.20	.1	730	11	12	15	32	89	99			BN
	3:10 p. m.	367		42	1.4	3.46	.4	1,220	9	10	13	27	73	96			BN
	3:15 p. m.	367		42	1.4	3.34	.6	2,300	3	4	5	15	52	94			BN
	3:20 p. m.	367		42	1.4	3.76	.9	1,170	4	5	7	17	66	94			BN
	3:25 p. m.	364		60	1.4	3.10	.1	260	18	22	31	50	90	99			BN
	3:55 p. m.	367		60	1.4	3.30	.4	470	12	14	19	38	89	99			BN
	3:50 p. m.	367		60	1.4	3.60	.6	550	9	10	16	30	89	99			BN
	3:40 p. m.	367		60	1.4	3.41	.9	740	9	10	16	31	87	99			BN
1950 Mar. 21	3:30 p. m.	[1] 450	46	20	3.6	4.96	1.0	820			23	54	92	99			SWCM
	3:35 p. m.	[1] 450	46	20	3.6	4.00	2.5	1,100			18	48	91	100			SWCM
	3:40 p. m.	[1] 450	46	20	3.6	3.47	3.1	2,120			10	28	69	98			SWCM
	3:45 p. m.	[1] 450	46	40	2.0	3.48	.5	1,210			18	56	97	100			SWCM
	3:50 p. m.	[1] 450	47	40	2.0	3.60	1.0	1,690			15	50	96	100			SWCM
	3:55 p. m.	[1] 450	47	40	2.0	2.97	1.5	2,890			9	37	89	100			SWCM
	4:00 p. m.	[1] 450	47	60	1.6	3.88	.4	680			31	74	98	100			SWCM
	4:05 p. m.	[1] 450	47	60	1.6	4.10	.8	690			31	77	99	100			SWCM
	4:10 p. m.	[1] 450	47	60	1.6	3.66	1.1	1,130			20	60	94	100			SWCM
June 20	11:40 a. m.	[1] 397	70	17	4.3	3.38	.8	180									
	11:33 a. m.	[1] 397	70	17	4.3	3.34	2.0	300									
	11:30 a. m.	[1] 397	70	17	4.3	2.68	3.0	440									
	11:15 a. m.	[1] 397	70	17	4.3	1.74	3.9	430									
	12:07 p. m.	[1] 400	70	23	4.1	3.96	.7	260									
	12:10 p. m.	[1] 400	70	23	4.1	3.72	1.7	370									
	11:55 a. m.	[1] 397	70	23	4.1	3.22	2.7	600									
	11:45 a. m.	[1] 397	70	23	4.1	2.61	3.7	1,150									

	12:18 p. m.	[1]400	70	30	3.1	3.42	.5	190	------	------	------	------	------	------	------	------
	12:15 p. m.	[1]400	70	30	3.1	3.04	1.7	460	------	------	------	------	------	------	------	------
	12:10 p. m.	[1]400	70	30	3.1	2.62	2.7	600	------	------	------	------	------	------	------	------
	12:30 p. m.	[1]400	71	41	2.4	2.96	.5	510	------	------	------	------	------	------	------	------
	12:28 p. m.	[1]400	71	41	2.4	2.88	1.5	570	------	------	------	------	------	------	------	------
	12:20 p. m.	[1]400	71	41	2.4	.92	2.0	360	------	------	------	------	------	------	------	------
	12:40 p. m.	[1]400	71	59	1.3	3.06	.5	890	------	------	------	------	------	------	------	------
	12:35 p. m.	[1]400	71	59	1.3	3.07	.9	1,110	------	------	------	------	------	------	------	------
July 18	9:38 a. m.	[1]376	65	18	3.9	4.07	1.0	220	------	------	36	70	97	99	------	------
	9:34 a. m.	[1]376	65	18	3.9	3.05	2.5	470	------	------	18	52	98	------	------	------
	9:32 a. m.	[1]376	65	18	3.9	1.96	3.4	600	------	------	18	47	95	99	------	------
	10:01 a. m.	[1]376	65	27	3.8	3.90	1.0	220	------	------	33	67	93	------	------	------
	9:55 a. m.	[1]376	65	27	3.8	3.07	2.5	540	------	------	15	48	86	98	------	------
	9:48 a. m.	[1]376	65	27	3.8	1.05	3.3	3,200	------	------	3	11	46	94	99	------
	10:12 a. m.	[1]379	65	36	2.5	3.58	.5	300	------	------	27	55	88	------	------	------
	10:09 a. m.	[1]376	65	36	2.5	3.57	1.4	430	------	------	21	49	87	99	------	------
	10:05 a. m.	[1]376	65	36	2.5	3.20	2.0	600	------	------	13	40	85	100	------	------
	10:23 a. m.	[1]373	65	45	2.1	3.48	.4	310	------	------	24	58	96	------	------	------
	10:20 a. m.	[1]376	65	45	2.1	3 55	1.1	530	------	------	16	43	92	99	100	------
	10:17 a. m.	[1]376	65	45	2.1	3.20	1.6	940	------	------	8	32	86	99	------	------
	10:30 a. m.	[1]373	65	58	1.1	3.04	.2	580	------	------	16	25	66	96	------	------
	10:27 a. m.	[1]373	65	58	1.1	3.44	.6	800	------	------	11	26	77	------	------	------
Aug. 27	8:10 a. m.	[1]409	61	18	3.7	2.64	.8	330	------	------	32	68	------	------	------	------
	8:06 a. m.	[1]409	61	18	3.7	2.63	2.0	420	------	------	26	60	98	------	------	------
	7:59 a. m.	[1]409	61	18	3.7	2.38	3.2	710	------	------	16	45	96	------	------	------
	8:23 a. m.	[1]409	61	25	3.7	2.96	.8	360	------	------	30	66	95	99	------	------
	8:19 a. m.	[1]409	61	25	3.7	2.83	2.0	540	------	------	19	56	93	100	------	------
	8:13 a. m.	[1]409	61	25	3.7	2.33	3.2	1,490	------	------	10	33	84	100	------	------
	8:39 a. m.	[1]406	61	34	2.8	3.03	.6	420	------	------	27	65	96	100	------	------
	8:35 a. m.	[1]409	61	34	2.8	2.46	1.5	720	------	------	20	54	91	100	------	------
	8:31 a. m.	[1]409	61	34	2.8	2.10	2.3	990	------	------	12	42	84	99	------	------
	8:48 a. m.	[1]406	61	47	1.5	2.75	.5	1,140	------	------	12	33	77	99	------	------
	8:44 a. m.	[1]406	61	47	1.5	2.60	1.0	1,700	------	------	8	25	74	98	------	------
	8:57 a. m.	[1]406	61	59	2.3	3.03	.8	580	------	------	22	51	88	100	------	------
	8:54 a. m.	[1]406	61	59	2.3	2.81	1.8	870	------	------	14	36	77	98	------	------
1951																
Apr. 25	4:06 p. m.	[1]391	60	17	3.3	3.34	.5	185	------	------	40	75	96	------	------	------
	4.02 p. m.	[1]391	60	17	3.3	3.42	1.4	284	------	------	28	62	94	------	------	------
	3:50 p. m.	[1]394	60	17	3.3	2.67	2.8	408	------	------	23	55	86	99	------	------
	4:28 p. m.	[1]388	60	27	2.8	4.14	.5	344	------	------	27	58	------	------	------	------
	4:21 p. m.	[1]388	60	27	2.8	4.14	1.2	428	------	------	43	49	94	------	------	------
	4:14 p. m.	[1]391	60	27	2.8	2.42	2.3	1,310	------	------	8	26	77	97	------	------
	4:38 p. m.	[1]385	61	38	2.3	4.04	.5	302	------	------	20	------	------	------	------	------
	4:36 p. m.	[1]385	61	38	2.3	4.19	.9	426	------	------	23	59	100	------	------	------
	4:34 p. m.	[1]388	61	38	2.3	3.60	1.8	835	------	------	12	34	88	------	------	------
	5:12 p. m.	[1]385	61	47	1.7	4.34	.5	553	------	------	25	69	------	------	------	------
	5:09 p. m.	[1]385	61	47	1.7	4.14	.8	885	------	------	14	54	99	------	------	------
	5:04 p. m.	[1]382	61	47	1.7	3.48	1.2	1,650	------	------	12	41	------	------	------	------
	5:50 p. m.	[1]385	61	60	1.7	4.32	.5	366	------	------	59	61	------	------	------	------
	5:56 p. m.	[1]385	61	60	1.7	4.28	.8	707	------	------	14	49	------	------	------	------
	5:53 p. m.	[1]385	61	60	1.7	3.32	1.2	2,880	------	------	6	22	92	------	------	------

See footnotes at end of table.

TABLE 5.—*Particle-size analyses of measured suspended sediment, point-integrated samples*—Continued

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; S, sieve; W, in distilled water; C, chemically dispersed; and M, mechanically dispersed. Samples collected with a P-46 sampler]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Sampling station	Total depth (ft)	Suspended sediment											Methods of analysis
						Sampling point			Percent finer than indicated size, in millimeters								
						Velocity (fps)	Depth (ft)	Concentration (ppm)	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section B—Continued																	
1951—Continued																	
Aug. 29	1:35 p. m.	394	74	17	2.1	4.06	0.5	161			43	70	95				
	2:16 p. m.	382	76	17	2.1		1.0	164			39	68	94				
	2:10 p. m.	385	76	17	2.1	4.09	1.6	242			27	53	90				
	2.25 p. m.	382	76	31	2.5	3.86	.5	293			23	51	91				
	2:35 p. m.	382	76	31	2.5	3.53	1.2	401			16	39	83				
	2:30 p. m.	382	76	31	2.5	3.84	2.0	561			13	33	81				
	2:38 p. m.	382	77	40	3.3	3.60	.5	231			31	66					S
	2:49 p. m.	382	77	40	3.3	3.96	1.5	317			25	57	96				S
	2:45 p. m.	382	77	40	3.3	3.38	2.8	625			12	41	92				S
	2:51 p. m.	382	77	48	3.1	3.50	.5	246			27	58					S
	3:06 p. m.	385	77	48	3.1	3.56	1.5	389			23	54	93				S
	3:01 p. m.	382	77	48	3.1	3.88	2.6	598			12	33	81				S
	3:10 p. m.	385	78	57	2.2	3.74	.5	77			56						S
	3:20 p. m.	382	78	57	2.2	6.62	1.1	130			52	80	96				S
	3:14 p. m.	385	78	57	2.2	3.56	1.7	172			32	65					S
Section C																	
1950																	
Mar. 21	6:30 p. m.	[1] 450	45	10	1.5	3.22	0.3	860			22	56	93	100			SWCM
	6:30 p. m.	[1] 450	45	10	1.5	3.48	.7	1,000			19	52	92	100			SWCM
	6:35 p. m.	[1] 450	45	10	1.5	3.41	1.0	1,100			17	49	92	100			SWCM
	6:40 p. m.	[1] 450	45	30	1.8	3.24	.4	800			24	61	95	99			SWCM
	6:40 p. m.	[1] 450	45	30	1.8	2.56	1.0	1,860			11	38	85	99			SWCM
	6:45 p. m.	[1] 450	45	30	1.8	2.30	1.3	2,190			10	33	83	99			SWCM
	6:50 p. m.	[1] 450	44	50	1.5	3.96	.3	1,050			21	56	92	100			SWCM
	6:50 p. m.	[1] 450	44	50	1.5	4.00	.8	1,680			16	45	88	100			SWCM
	6:55 p. m.	[1] 450	44	50	1.5	3.84	1.0	1,830			12	41	86	100			SWCM
	7:00 p. m.	[1] 447	44	70	1.7	4.05	.3	1,120			17	52	94	100			SWCM

	7:00 p. m.	[1] 447	44	70	1.7	4.68	.9	1,470			14	44	93	100			SWCM
	7:05 p. m.	[1] 447	44	70	1.7	4.47	1.2	1,800			12	41	92	100			SWCM
June 20	7:57 p. m.	[1] 403	76	10	2.3	3.08	.5	210									
	7:55 p. m.	[1] 403	76	10	2.3	2.91	1.3	340									
	7:52 p. m.	[1] 403	76	10	2.3	1.94	1.9	410									
	8:04 p. m.	[1] 406	76	20	2.0	4.23	.5	190									
	8:02 p. m.	[1] 406	76	20	2.0	2.84	1.1	430									
	8:01 p. m.	[1] 406	76	20	2.0	1.91	1.6	630									
	8:14 p. m.	[1] 406	76	35	1.9	2.86	.5	250									
	8:12 p. m.	[1] 406	76	35	1.9	3.02	1.0	420									
	8:10 p. m.	[1] 406	76	35	1.9	2.39	1.5	450									
	8:25 p. m.	[1] 403	76	50	1.2	2.46	.4	400									
	8:18 p. m.	[1] 406	76	50	1.2	2.52	.8	530									
	8:45 p. m.	[1] 406	75	62	1.6	3 04	.5	470									
	8:43 p. m.	[1] 406	75	62	1.6	1.84	1.2	1,130									
	8:53 p. m.	[1] 406	75	73	1.7	3.01	.6	350									
	8:50 p. m.	[1] 406	75	73	1.7	2.18	1.3	490									
July 18	4:37 p. m.	[1] 412	66	10	2.6	3.61	.5	190			50	76	98				S
	4:33 p. m.	[1] 412	66	10	2.6	3.96	1.5	300			32	61	95				S
	4:30 p. m.	[1] 412	66	10	2.6	2.11	2.1	1,960			6	18	71	99			S
	4:47 p. m.	[1] 415	66	20	2.5	3.37	.5	440			23	52	95				S
	4:44 p. m.	[1] 412	66	20	2.5	3.31	1.5	680			15	44	94				S
	4:41 p. m.	[1] 412	66	20	2.5	1.67	2.0	1,400			9	29	87	99			S
	5:05 p. m.	[1] 415	65	30	2.3	3.27	.5	460			33	61	96				S
	4:58 p. m.	[1] 415	65	30	2.3	2.53	1.3	510			22	53	96				S
	4:53 p. m.	[1] 415	65	30	2.3	2.34	1.8	660			18	46	88	98			S
	5:14 p. m.	[1] 415	65	50	1.9	2.75	.5	730			17	44	91	99			S
	5:09 p. m.	[1] 415	65	50	1.9	1.93	1.4	1,380			9	31	84	99			S
	5:22 p. m.	[1] 415	65	60	1.5	3.37	.5	610			19	43	87	100			S
	5:19 p. m.	[1] 415	65	60	1.5	3.36	1.0	920			12	32	81	100			S
	5:38 p. m.	[1] 415	65	72	1.7	3.22	.5	600			19	39	75	98			S
	5:34 p. m.	[1] 415	65	72	1.7	2.95	1.2	750			15	35	73	99			S
Aug. 27	10:50 a. m.	[1] 406	66	10	2.0	2.84	.5	420			22	49	87	99			S
	10:53 a. m.	[1] 406	66	10	2.0	2.12	1.5	1,340			9	24	70	98			S
	11:11 a. m.	[1] 406	66	25	1.6	2.30	.5	790			17	44	87	100			S
	11:05 a. m.	[1] 406	66	25	1.6	2.93	1.1	680			18	45	88	100			S
	12:30 p. m.	[1] 397	69	40	2.4	2.73	.5	430			23	56	94	100			S
	11:25 a. m.	[1] 406	67	40	2.4	2.60	1.2	890			14	37	80	98			S
	11:17 a. m.	[1] 406	67	40	2.4	2.26	1.9	970			11	35	78	98			S
	12:42 p. m.	[1] 394	69	55	1.7	2.71	.3	420			25	60	95	100			S
	12:40 p. m.	[1] 397	69	55	1.7	2.92	1.2	670			18	50	94	100			S
	1:17 p. m.	[1] 382	69	70	2.7	2.55	.3	300			38	71	98				S
	1:06 p. m.	[1] 385	69	70	2.7	2.71	1.2	520			23	53	93				S
	12:50 p. m.	[1] 388	69	70	2.7	2.16	2.2	790			11	43	87				S

See footnotes at end of table.

TABLE 5.—*Particle-size analyses of measured suspended sediment, point-integrated samples*—Continued

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; S, sieve; W, in distilled water; C, chemically dispersed; and M, mechanically dispersed. Samples collected with a P-46 sampler]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Sampling station	Total depth (ft)	Suspended sediment											Methods of analysis
						Sampling point			Percent finer than indicated size, in millimeters								
						Velocity (fps)	Depth (ft)	Concentration (ppm)	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section D																	
1950 Mar. 21	6:15 p. m.	[1] 447	44	10	1.8	3.16	0.4	2,580	------	------	7	20	42	86	------	------	SWCM
	6:10 p. m.	[1] 447	46	10	1.8	2.82	.9	------	------	------	------	------	------	------	------	------	S
	6:05 p. m.	[1] 447	46	10	1.8	2.76	1.3	------	------	------	------	------	------	------	------	------	S
	6:00 p. m.	[1] 447	46	30	1.7	4.38	.4	1,380	------	------	14	41	76	97	------	------	SWCM
	5:55 p. m.	[1] 447	46	30	1.7	4.16	.9	1,640	------	------	12	36	72	96	------	------	SWCM
	5:50 p. m.	[1] 447	46	30	1.7	3.00	1.2	2,470	------	------	7	25	61	92	------	------	SWCM
	5:45 p. m.	[1] 447	46	50	1.8	3.86	.3	1,460	------	------	16	46	84	98	------	------	SWCM
	5:40 p. m.	[1] 447	46	50	1.8	3.33	.6	1,940	------	------	12	36	73	91	97	------	SWCM
	5:35 p. m.	[1] 447	46	50	1.8	3.02	1.0	2,180	------	------	10	34	70	90	98	------	SWCM
	5:30 p. m.	[1] 447	46	50	1.8	3.09	1.3	2,630	------	------	9	28	65	89	95	98	SWCM
	5:25 p. m.	[1] 447	46	70	2.0	3.81	.4	2,450	------	------	9	30	73	96	100	------	SWCM
	5:20 p. m.	[1] 447	46	70	2.0	4.22	.8	2,470	------	------	11	32	75	96	100	------	SWCM
	5:15 p. m.	[1] 447	46	70	2.0	3.66	1.2	2,320	------	------	11	33	74	94	100	------	SWCM
	5:10 p. m.	[1] 447	46	70	2.0	3.21	1.5	2,320	------	------	9	28	67	91	98	99	SWCM
June 20	7:27 p. m.	[1] 403	79	10	2.3	3.07	.5	370	------	------	27	47	75	92	------	------	S
	7:26 p. m.	[1] 403	79	10	2.3	2.36	1.3	600	------	------	14	28	56	82	------	------	S
	7:23 p. m.	[1] 403	79	10	2.3	1.83	1.8	740	------	------	14	22	38	65	85	------	S
	7:17 p. m.	[1] 403	79	20	2.1	3.29	.5	470	------	------	19	40	71	92	------	------	S
	7:15 p. m.	[1] 403	79	20	2.1	2.90	1.2	660	------	------	14	31	63	88	------	------	S
	7:14 p. m.	[1] 403	79	20	2.1	2.50	1.6	610	------	------	15	32	63	88	------	------	S
	7:10 p. m.	[1] 403	79	35	2.3	3.15	.5	500	------	------	17	38	84	98	------	------	S
	7:07 p. m.	[1] 403	79	35	2.3	2.37	1.3	950	------	------	9	25	72	95	------	------	S
	7:05 p. m.	[1] 403	80	35	2.3	1.73	1.8	810	------	------	11	26	65	90	------	------	S
	6:58 p. m.	[1] 403	80	47	2.2	3.07	.5	620	------	------	16	38	82	98	------	------	S
	6:55 p. m.	[1] 403	80	47	2.2	1.98	1.2	1,390	------	------	8	25	74	96	------	------	S
	6:52 p. m.	[1] 403	80	47	2.2	1.18	1.7	680	------	------	16	36	76	94	------	------	S
	6:46 p. m.	[1] 403	80	65	2.2	3.23	.5	440	------	------	21	46	83	96	------	------	S
	6:45 p. m.	[1] 403	80	65	2.2	2.92	1.2	590	------	------	16	37	73	95	------	------	S
	6:41 p. m.	[1] 403	80	65	2.2	2.41	1.7	670	------	------	13	28	67	97	------	------	S
	6:35 p. m.	[1] 406	80	75	1.7	2.65	.3	270	------	------	29	58	92	------	------	------	S
	6:30 p. m.	[1] 406	80	75	1.7	2.52	.8	330	------	------	26	52	88	------	------	------	S
	6:25 p. m.	[1] 406	80	75	1.7	2.23	1.2	450	------	------	21	44	81	------	------	------	S

July 18	3:35 p. m.	[1]406	66	10	2.2	3.77	.5	590	------	------	17	33	68	90	93	------	S
	3:33 p. m.	[1]406	66	10	2.2	3.50	1.2	630	------	------	16	31	68	95	------	------	S
	3:27 p. m.	[1]406	66	10	2.2	2.51	1.7	1,380	------	------	7	17	53	79	86	89	S
	3:24 p. m.	[1]406	66	20	2.1	3.47	.5	790	------	------	13	34	83	97	------	------	S
	3:19 p. m.	[1]406	66	20	2.1	2.82	1.2	1,020	------	------	11	28	76	96	------	------	S
	3:14 p. m.	[1]406	66	20	2.1	2.01	1.6	1,390	------	------	8	23	65	88	96	------	S
	3:07 p. m.	[1]406	67	35	2.1	3.73	.5	680	------	------	16	37	77	98	------	------	S
	3:04 p. m.	[1]406	67	35	2.1	3.29	1.2	920	------	------	12	32	70	89	93	------	S
	3:01 p. m.	[1]406	67	35	2.1	2.55	1.6	1,150	------	------	11	28	70	93	------	------	S
	2:55 p. m.	[1]406	67	50	2.1	3.57	.5	850	------	------	13	32	76	99	------	------	S
	2:52 p. m.	[1]406	67	50	2.1	2.92	1.2	1,160	------	------	10	24	63	91	96	------	S
	2:40 p. m.	[1]409	66	50	2.1	2.67	1.6	1,510	------	------	6	20	62	91	98	------	S
	2:34 p. m.	[1]409	66	65	1.9	2.93	.5	630	------	------	15	39	79	99	------	------	S
	2:32 p. m.	[1]409	66	65	1.9	2.14	1.4	1,670	------	------	6	18	52	91	99	------	S
	1:37 p. m.	[1]370	66	75	1.8	2.63	.5	590	------	------	15	34	78	100	------	------	S
	1:35 p. m.	[1]370	66	75	1.8	2.58	1.3	940	------	------	9	22	63	98	------	------	S
Aug. 27	10:44 a. m.	[1]409	66	10	1.8	3.81	.5	520	------	------	20	44	84	98	------	------	S
	10:41 a. m.	[1]409	66	10	1.8	3.13	1.0	650	------	------	17	38	77	93	------	------	S
	10:39 a. m.	[1]412	66	10	1.8	2.23	1.8	850	------	------	13	30	69	92	96	------	S
	10:33 a. m.	[1]412	66	25	1.7	2.65	.5	1,380	------	------	9	26	66	96	------	------	S
	10:30 a. m.	[1]412	66	25	1.7	2.33	1.0	1.470	------	------	9	23	58	92	98	------	S
	10:25 a. m.	[1]412	66	25	1.7	2.12	1.7	1,250	------	------	10	27	63	94	99	------	S
	10:20 a. m.	[1]412	66	40	1.7	3.35	.5	1,490	------	------	8	23	63	94	99	------	S
	10:17 a. m.	[1]409	66	40	1.7	3.48	1.0	1,940	------	------	7	18	53	91	98	------	S
	10:14 a. m.	[1]409	66	40	1.7	2.46	1.7	3,960	------	------	3	11	49	91	99	------	S
	10:08 a. m.	[1]406	66	55	1.8	2.91	.4	980	------	------	14	37	77	99	------	------	S
	10:05 a. m.	[1]406	66	55	1.8	3.24	1.0	1,520	------	------	9	26	67	98	------	------	S
	10:02 a. m.	[1]406	66	55	1.8	1.81	1.8	4,210	------	------	3	12	44	89	98	------	S
	9:55 a. m.	[1]403	66	70	1.9	1.86	.8	1,360	------	------	9	23	56	96	------	------	S
	9:50 a. m.	[1]403	66	70	1.9	1.24	1.9	2,140	------	------	6	16	44	94	------	------	S
1951																	
Apr. 26	11:22 a. m.	[1]415	48	10	1.8	3.85	.5	930	------	------	9	25	50	95	------	------	S
	11:18 a. m.	[1]415	48	10	1.8	3.70	.9	1,220	------	------	8	21	41	92	------	------	S
	11:13 a. m.	[1]415	47	10	1.8	2.98	1.3	1,420	------	------	6	18	37	88	98	------	S
	11:07 a. m.	[1]415	47	25	1.8	1.26	.5	1,360	------	------	9	27	57	------	------	------	S
	11:00 a. m.	[1]415	47	25	1.8	1.66	.9	1,710	------	------	6	20	50	95	------	------	S
	10:24 a. m.	[1]409	46	25	1.8	1.78	1.3	2,150	------	------	5	18	43	89	99	------	S
	9:48 a. m.	[1]418	46	40	1.8	2.86	.5	1,700	------	------	6	26	66	93	------	------	S
	9:42 a. m.	[1]421	46	40	1.8	2.70	.9	1,820	------	------	7	28	63	88	97	------	S
	9:30 a. m.	[1]428	46	40	1.8	2.46	1.3	1,720	------	------	7	28	63	88	------	------	S
	9:12 a. m.	[1]428	46	55	2.0	3.00	.5	1,520	------	------	9	33	82	------	------	------	S
	9:20 a. m.	[1]428	46	55	2.0	3.46	1.0	2,000	------	------	7	24	70	------	------	------	S
	9:16 a. m.	[1]431	46	55	2.0	3.75	1.5	2,890	------	------	4	21	62	94	------	------	S
	8:54 a. m.	[1]412	46	70	1.9	3.27	.5	1,920	------	------	31	48	87	------	------	------	S
	9:06 a. m.	[1]418	46	70	1.9	3.52	.9	2,700	------	------	5	22	73	------	------	------	S
	9:00 a. m.	[1]412	46	70	1.9	2.84	1.4	4,680	------	------	2	16	64	93	98	99	S
Aug. 30	5:12 p. m.	[1]361	82	10	1.6	3.99	.5	533	------	------	13	25	62	96	------	------	S
	5:20 p. m.	[1]361	82	10	1.6	3.61	.9	722	------	------	12	22	54	90	------	------	S
	5:16 p. m.	[1]361	82	10	1.6	3.07	1.2	916	------	------	10	19	51	90	------	------	S
	5:23 p. m.	[1]361	82	10	1.6	2.08	1.6	1,710	------	------	5	12	39	81	------	------	S
	4:50 p. m.	[1]364	82	20	1.7	3.07	.5	580	------	------	12	26	57	84	------	------	S

See footnotes at end of table.

TABLE 5.—*Particle-size analyses of measured suspended sediment, point-integrated samples*—Continued

[Methods of analysis: B, bottom-withdrawal tube; N, in native water· S, sieve; W, in distilled water; C, chemically dispersed; and M, mechanically dispersed. Samples collected with a P-46 sampler]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Sampling station	Total depth (ft)	Suspended sediment: Sampling point: Velocity (fps)	Sampling point: Depth (ft)	Concentration (ppm)	Percent finer than indicated size, in millimeters: 0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	Methods of analysis
Section D—Continued																	
1951—Continued																	
Aug. 30—Continued	4:58 p. m.	[1] 364	82	20	1.7	3.02	0.9	625	--	--	12	26	61	94	--	--	S
	4:54 p. m.	[1] 364	82	20	1.7	2.58	1.2	628	--	--	11	24	57	91	--	--	S
	5:08 p. m.	[1] 364	82	20	1.7	3.04	1.7	770	--	--	9	20	58	92	--	--	S
	4:30 p. m.	[1] 367	82	30	1.5	3.31	.5	628	--	--	11	26	74	--	--	--	S
	4:36 p. m.	[1] 367	82	30	1.5	2.98	.9	801	--	--	10	25	73	--	--	--	S
	4:33 p. m.	[1] 367	82	30	1.5	3.48	1.2	745	--	--	9	24	71	92	98	--	S
	4:42 p. m.	[1] 367	82	30	1.5	3.54	1.5	765	--	--	10	25	75	100	--	--	S
	4:07 p. m.	[1] 370	82	40	1.5	3.35	.5	419	--	--	16	38	78	--	--	--	S
	4:18 p. m.	[1] 370	82	40	1.5	3.50	.8	369	--	--	19	41	79	--	--	--	S
	4:14 p. m.	[1] 370	82	40	1.5	3.26	1.1	461	--	--	15	36	76	--	--	--	S
	4:22 p. m.	[1] 370	82	40	1.5	2.34	1.5	629	--	--	11	28	72	95	--	--	S
	3:47 p. m.	[1] 370	82	50	1.5	2.83	.5	878	--	--	9	23	74	97	--	--	S
	3:55 p. m.	[1] 370	82	50	1.5	2.94	.9	1,310	--	--	6	18	64	97	--	--	S
	3:50 p. m.	[1] 370	82	50	1.5	2.38	1.2	1,290	--	--	7	18	63	96	--	--	S
	4:01 p. m.	[1] 370	82	50	1.5	2.38	1.5	2,000	--	--	4	12	51	93	99	--	S
	3:08 p. m.	[1] 373	82	60	1.7	2.74	.5	473	--	--	18	40	77	--	--	--	S
	3:18 p. m.	[1] 373	82	60	1.7	3.28	.9	580	--	--	14	30	60	--	--	--	S
	3:12 p. m.	[1] 373	82	60	1.7	2.72	1.3	907	--	--	11	24	53	82	--	--	S
	3:24 p. m.	[1] 373	82	60	1.7	2.43	1.7	918	--	--	9	22	51	79	92	--	S
	2:38 p. m.	[1] 373	82	70	1.6	3.34	.5	499	--	--	15	36	74	--	--	--	S
	2:46 p. m.	[1] 373	82	70	1.6	3.94	.8	477	--	--	17	35	73	--	--	--	S
	2:54 p. m.	[1] 373	82	70	1.6	3.78	1.5	550	--	--	14	31	67	--	--	--	S
	3:02 p. m.	[1] 373	82	70	1.6	2.37	1.6	732	--	--	11	25	62	--	--	--	S
Nov. 29 [2]	5:00 p. m.	421	45	10	1.6	--	0	579	--	--	16	38	77	98	100	--	S
	5:00 p. m.	421	45	10	1.6	--	.5	1,050	--	--	9	22	54	92	98	100	S
	5:00 p. m.	421	45	10	1.6	--	1.1	1,090	--	--	13	26	59	94	100	--	S
	5:00 p. m.	421	45	10	1.6	--	1.6	986	--	--	10	23	54	87	99	100	S
	5:25 p. m.	421	45	30	1.5	--	0	719	--	--	14	34	71	98	100	--	S
	5:25 p. m.	421	45	30	1.5	--	.5	807	--	--	11	32	73	98	100	--	S
	5:25 p. m.	421	45	30	1.5	--	1.0	862	--	--	12	32	72	99	100	--	S
	5:25 p. m.	421	45	30	1.5	--	1.5	1,860	--	--	5	17	48	90	98	100	S
	5:35 p. m.	421	45	50	1.5	--	0	1,600	--	--	6	26	67	88	97	100	S
	5:35 p. m.	421	45	50	1.5	--	.5	1,040	--	--	10	35	80	96	99	100	S
	5:35 p. m.	421	45	50	1.5	--	1.0	2,220	--	--	5	19	54	73	85	92	S
	5:35 p. m.	421	45	50	1.5	--	1.5	4,440	--	--	3	11	35	60	77	87	S

	5:50 p. m.	415	45	70	1.5	----------	0	1,920	------	------	5	20	70	99	100	------	S
	5:50 p. m.	415	45	70	1.5	----------	.5	2,510	------	------	4	17	62	98	100	------	S
	5:50 p. m.	415	45	70	1.5	----------	1.0	2,340	------	------	4	17	65	99	100	------	S
	5:50 p. m.	415	45	70	1.5	----------	1.5	3,210	------	------	3	15	60	98	100	------	S
1952																	
May 22	4:06 p. m.	453	72	10	1.6	4.23	.4	591	------	------	27	59	87	98	100	------	S
	4:03 p. m.	453	72	10	1.6	4.24	.8	625	------	------	26	57	86	100	------	------	S
	4:00 p. m.	453	72	10	1.6	3.45	1.2	757	------	------	23	49	81	94	100	------	S
	3:56 p. m.	453	72	10	1.6	2.08	1.6	1,690	------	------	11	28	52	68	80	94	S
	3:47 p. m.	453	72	30	1.4	3.30	.4	634	------	------	27	62	95	100	------	------	S
	3:44 p. m.	453	72	30	1.4	3.56	.8	650	------	------	26	59	93	100	------	------	S
	3:41 p. m.	453	72	30	1.4	3.64	1.1	636	------	------	26	60	94	100	------	------	S
	3:35 p. m.	456	72	30	1.4	2.74	1.4	798	------	------	21	52	88	95	100	------	S
	3:28 p. m.	456	72	50	1.6	3.52	.4	1,230	------	------	14	36	82	98	100	------	S
	3:26 p. m.	456	72	50	1.6	3.47	.8	1,250	------	------	12	34	79	97	100	------	S
	3:21 p. m.	456	72	50	1.6	2.58	1.2	1,700	------	------	11	30	75	96	100	------	S
	3:16 p. m.	456	72	50	1.6	2.30	1.6	2,920	------	------	6	20	63	91	95	98	S
	3:10 p. m.	456	72	70	1.8	3.51	.4	938	------	------	16	33	69	95	100	------	S
	3:08 p. m.	456	72	70	1.8	3.24	.9	1,330	------	------	10	23	57	92	100	------	S
	3:02 p. m.	456	72	70	1.8	2.63	1.4	1,500	------	------	10	22	52	88	97	100	S
	2:56 p. m.	456	72	70	1.8	2.09	1.8	4,990	------	------	3	8	29	74	92	98	S
July 7	12:06 p. m.	370	67	10	1.5	3.36	.5	482	------	------	23	38	70	96	100	------	S
	12:04 p. m.	370	67	10	1.5	3.31	1.0	513	------	------	22	35	66	93	97	100	S
	12:01 p. m.	370	67	10	1.5	2.16	1.5	1,260	------	------	9	17	41	73	83	96	S
	11:50 a. m.	370	67	30	1.3	2.86	.5	541	------	------	24	42	78	96	100	------	S
	11:12 a. m.	367	67	30	1.3	3.20	.9	541	------	------	23	46	87	100	------	------	S
	11:06 a. m.	367	67	30	1.3	2.62	1.3	752	------	------	17	34	77	97	100	------	S
	10:53 a. m.	367	67	50	1.5	2.89	.5	1,040	------	------	13	33	80	97	100	------	S
	10:48 a. m.	367	67	50	1.5	1.98	1.0	1,200	------	------	12	30	80	96	100	------	S
	10:42 a. m.	367	67	50	1.5	2.08	1.5	1,670	------	------	8	24	76	93	98	100	S
	10:28 a. m.	367	67	70	1.7	3.18	.5	1,530	------	------	8	18	54	94	100	------	S
	10:26 a. m.	367	67	70	1.7	3.00	.9	1,650	------	------	8	17	49	90	98	100	S
	10:20 a. m.	367	67	70	1.7	1.90	1.7	3,290	------	------	4	10	37	85	98	100	S
July 18	7:08 p. m.	338	82	10	1.6	9.08	.5	448	------	------	21	38	78	98	100	------	S
	7:00 p. m.	338	82	10	1.6	2.93	1.0	606	------	------	19	34	73	96	100	------	S
	6:45 p. m.	336	82	10	1.6	3.12	1.6	5,150	------	------	1	20	65	93	96	100	S
	6:38 p. m.	338	83	30	1.5	9.95	.5	350	------	------	27	50	85	100	------	------	S
	6:30 p. m.	338	83	30	1.5	6.22	1.0	521	------	------	19	41	81	98	100	------	S
	6:26 p. m.	338	83	30	1.5	3.96	1.5	1,980	------	------	7	27	77	98	99	100	S
	6:17 p. m.	341	83	50	1.5	5.85	.5	380	------	------	25	45	82	97	100	------	S
	6:06 p. m.	341	84	50	1.5	5.75	1.0	753	------	------	14	30	68	85	89	89	S
	6:00 p. m.	341	84	50	1.5	3.90	1.5	1,060	------	------	11	29	72	93	98	100	S
	5:56 p. m.	341	84	70	1.5	3.33	.5	422	------	------	23	42	80	100	------	------	S
	5:48 p. m.	341	84	70	1.5	2.49	1.0	639	------	------	16	35	72	95	100	------	S
	5:44 p. m.	341	84	70	1.5	2.70	1.5	712	------	------	16	30	70	97	100	------	S
Aug. 13	6:12 p. m.	358	84	10	1.5	3.24	.5	521	------	------	20	39	77	96	100	------	S
	6:10 p. m.	355	84	10	1.5	3.10	1.0	735	------	------	16	32	66	92	100	------	S
	6:08 p. m.	355	84	10	1.5	2.71	1.5	1,740	------	------	8	15	40	70	84	94	S
	6:04 p. m.	352	84	20	1.5	2.72	.5	618	------	------	19	37	77	95	100	------	S
	6:02 p. m.	352	84	20	1.5	2.43	1.0	743	------	------	16	32	72	88	100	------	S
	6:00 p. m.	352	84	20	1.5	2.45	1.5	796	------	------	16	32	71	95	100	------	S
	5:56 p. m.	352	84	30	1.3	4.06	.5	601	------	------	18	40	77	90	91	91	S
	5:54 p. m.	355	84	30	1.3	3.05	.9	565	------	------	20	42	84	98	100	------	S
	5:50 p. m.	355	84	30	1.3	2.76	1.3	723	------	------	16	37	79	97	100	------	S
	5:46 p. m.	358	85	40	1.4	3.72	.5	543	------	------	23	47	88	100	------	------	S
	5:44 p. m.	358	85	40	1.4	3.39	1.0	617	------	------	19	44	85	97	100	------	S

See footnotes at end of table.

TABLE 5.—*Particle-size analyses of measured suspended sediment, point-integrated samples*—Continued

[Methods of analysis: B, bottom-withdrawal tube; N, in native water; S, sieve; W, in distilled water; C, chemically dispersed; and M, mechanically dispersed. Samples collected with a P-46 sampler]

Date	Time	Water discharge (cfs)	Water temperature (°F)	Sampling station	Total depth (ft)	Suspended sediment: Sampling point			Suspended sediment: Percent finer than indicated size, in millimeters								Methods of analysis
						Velocity (fps)	Depth (ft)	Concentration (ppm)	0.016	0.031	0.062	0.125	0.25	0.50	1.0	2.0	
Section D—Continued																	
1952—Continued																	
Aug. 13—Continued	5:40 p. m.	358	85	40	1.4	2.00	1.4	1,330	------	------	12	30	72	94	100	------	S
	5:36 p. m.	358	85	50	1.4	2.61	.5	476	------	------	24	51	86	98	100	------	S
	5:34 p. m.	358	85	50	1.4	2.12	1.0	599	------	------	21	44	80	96	100	------	S
	5:32 p. m.	358	85	50	1.4	2.73	1.4	660	------	------	20	42	81	95	100	------	S
	5:28 p. m.	361	85	60	1.4	2.86	.5	414	------	------	26	49	81	97	100	------	S
	5:26 p. m.	361	85	60	1.4	2.68	1.0	463	------	------	22	42	74	94	100	------	S
	5:24 p. m.	361	85	60	1.4	3.44	1.4	516	------	------	18	35	66	92	98	100	S
	5:17 p. m.	364	85	70	1.5	3.24	.5	576	------	------	17	33	65	96	100	------	S
	5:14 p. m.	364	85	70	1.5	3.42	1.0	737	------	------	15	29	61	95	100	------	S
	5:11 p. m.	367	85	70	1.5	2.72	1.5	1,390	------	------	8	18	46	88	96	100	S
Sept. 10	5:00 p. m.	338	69	10	1.1	2.11	.1	481	------	------	15	36	67	95	100	------	S
	5:00 p. m.	338	69	10	1.1	2.58	.5	669	------	------	11	29	58	91	100	------	S
	5:00 p. m.	338	69	10	1.1	3.13	.8	605	------	------	12	30	62	95	100	------	S
	5:00 p. m.	338	69	10	1.1	2.80	1.1	1,290	------	------	6	16	44	88	97	100	S
	5:00 p. m.	338	69	30	1.2	3.11	.1	346	------	------	18	50	88	98	100	------	S
	5:00 p. m.	338	69	30	1.2	3.22	.5	339	------	------	20	50	87	98	100	------	S
	5:00 p. m.	338	69	30	1.2	3.40	.9	397	------	------	18	48	84	96	100	------	S
	5:00 p. m.	338	69	30	1.2	3.53	1.2	561	------	------	13	38	76	88	90	100	S
	5:00 p. m.	338	69	50	1.2	2.54	.1	560	------	------	12	34	73	96	100	------	S
	5:00 p. m.	338	69	50	1.2	2.62	.5	784	------	------	10	26	65	90	94	100	S
	5:00 p. m.	338	69	50	1.2	2.60	.9	852	------	------	7	24	62	88	96	100	S
	5:00 p. m.	338	69	50	1.2	2.22	1.2	1,370	------	------	7	21	60	89	95	100	S
	5:00 p. m.	338	69	70	1.3	3.04	.1	375	------	------	15	40	76	99	100	------	S
	5:00 p. m.	338	69	70	1.3	3.24	.5	418	------	------	16	40	76	98	100	------	S
	5:00 p. m.	338	69	70	1.3	3.07	.9	467	------	------	14	37	75	98	100	------	S
	5:00 p. m.	338	69	70	1.3	2.82	1.3	472	------	------	15	41	79	97	100	------	S

[1] Based on shift determined from all available measurements made this day.
[2] Tait-Binckley sampler used for collecting all samples on this date.

TABLE 6.—*Monthly and annual summary of water and total sediment discharges, section D*

Month	Water discharge (cfs-days)	Runoff (acre-feet)	Suspended sediment					
			Load (tons)	Daily load (tons)			Concentration (ppm)	
				Mean	Maximum	Minimum	Weighted mean	Maximum daily
1950								
Mar. 22-31	4,527	8,980	28,970	2,900	4,000	1,820	2,370	3,140
April	11,112	22,040	57,260	1,910	3,370	1,310	1,910	3,290
May	11,774	23,350	47,600	1,540	3,270	800	1,500	2,860
June	10,329	20,490	21,410	710	910	490	770	930
July	11,014	21,850	24,830	800	1,580	520	830	1,410
August	10,994	21,810	25,760	830	2,100	540	870	----------
September	10,701	21,230	26,520	880	1,430	520	920	1,400
Mar. 22 to Sept. 30	70,451	139,800	232,400	1,200	4,000	490	1,220	3,290
October	10,727	21,280	29,900	960	1,410	690	1,030	1,660
November	11,507	22,820	48,490	1,620	2,460	730	1,560	2,240
December	12,181	24,160	49,667	1,600	3,360	57	1,510	3,110
1951								
January	11,499	22,810	60,460	1,950	----------	----------	1,950	----------
February	12,095	23,990	21,070	750	1,970	79	650	1,770
March	11,696	23,200	48,550	1,570	2,130	980	1,540	2,020
April	10,006	19,850	36,680	1,220	1,610	760	1,360	1,830
May	12,655	25,100	39,830	1,280	1,970	870	1,170	1,540
June	12,202	24,200	36,970	1,230	2,340	890	1,120	1,850
July	11,777	23,360	29,390	950	2,120	650	920	1,890
August	11,365	22,540	25,550	820	1,080	640	830	1,010
September	11,957	23,720	42,630	1,420	3,000	940	1,320	2,100
Water year 1950-51	139,667	277,000	469,187	1,290	3,360	----------	1,240	3,110
October	12,040	23,880	48,580	1,570	2,140	1,010	1,490	1,910
November	11,560	22,930	52,100	1,740	2,350	1,340	1,670	2,280
December	12,013	23,830	30,314	978	2,200	125	934	2,140
1952								
January	11,782	23,370	8,835	285	582	21	278	501
February	11,730	23,270	65,900	2,270	3,860	1,030	2,080	3,800
March	13,541	26,860	66,406	2,142	5,160	850	1,820	3,300
April	12,988	25,760	58,010	1,930	3,370	1,110	1,650	2,890
May	12,671	25,130	65,590	2,120	3,420	1,010	1,920	3,420
June	10,662	21,150	35,505	1,180	2,330	731	1,230	2,350
July	10,834	21,490	26,929	869	2,020	556	921	2,040
August	11,287	22,390	26,559	857	1,200	512	872	1,210
September	10,305	20,440	27,923	931	1,520	717	1,000	1,530
Water year 1951-52	141,413	280,500	512,651	1,400	5,160	21	1,340	3,800

TABLE 7.—*Sediment discharge computed with the Einstein procedure for the selected river sections and the comparable measured sediment discharge at section D*

[Figures are in tons per day except as indicated]

Date	Section	Sediment discharge										
		Finer than 0.062 mm	0.062 to 0.125 mm	0.125 to 0.25 mm	0.25 to 0.50 mm	0.50 to 1.0 mm	1.0 to 2.0 mm	2.0 to 4.0 mm	Larger than 0.125 mm		All particle sizes	
									Tons per day	Percent of measured	Tons per day	Percent of measured
1950												
Nov. 29–30	[1] A, B, C_2, E	[2] 94	[3] 233	0	22	127	42	5	196	13	523	26
	D	120	342	744	583	141	80	0	1,548		[3] 2,010	
Nov. 30	[1] B, C_2, E	[2] 95	[2] 243	88	448	270	77	23	906	65	1,244	69
	D	108	308	670	525	127	72	0	1,394		[3] 1,810	
	C_2	[2] 98	[2] 239	571	897	389	149	40	2,046	155	2,383	139
	D	102	291	633	496	120	68	0	1,317		1,710	
	E	[2] 83	[2] 232	0	28	130	43	6	207	16	522	31
	D	100	284	618	484	117	67	0	1,286		1,670	
1951												
May 21–22	A, B, C_2, E	[2] 302	[2] 340	573	1,049	370	96	20	2,108	160	2,750	150
	D	165	348	695	457	110	55	0	1,317		[3] 1,830	
June 4	A, B_1, C_2, E	[2] 138	[2] 216	14	321	143	22	2	502	65	856	71
	D	157	278	448	254	61	12	0	775		[3] 1,210	
June 25–26	A, B_1, C_2, E	[2] 122	[2] 140	121	530	172	29	3	855	108	1,117	89
	D	227	239	391	252	76	25	50	794		[3] 1,260	
June 26	B_1, C_2, E	[2] 122	[2] 140	2,919	2,154	613	222	98	6,006	756	6,268	497
	D	227	239	391	252	76	25	50	794		[3] 1,260	
	C_2	[2] 135	[2] 140	4,168	3,369	1,004	478	227	9,246	1,748	9,521	1,241
	D	100	138	276	192	38	23	0	529		767	
	E	[2] 108	[2] 140	445	803	225	50	7	1,530	299	1,778	240
	D	96	134	260	193	37	22	0	512		742	
July 25–27	[4] A, B_1, C_2, E, G	[2] 61	[2] 56	310	688	204	39	5	1,246	232	1,363	190
	D	87	93	258	215	50	14	0	537		[3] 717	
	A, B_1, C_2, E	[2] 61	[2] 56	137	562	165	28	3	895	167	1,012	141
	D	87	93	258	215	50	14	0	537		[3] 717	
1952												
May 6	B_1, C_2, E	[2] 92	[2] 158	849	984	298	80	22	2,233	209	2,483	168
	D	133	281	548	370	104	44	0	1,066		[3] 1,480	
	C_2	[2] 84	[2] 144	1,403	1,392	462	184	54	3,495	462	3,723	355
	D	94	200	388	262	74	32	0	756		1,050	
	E	[2] 95	[2] 179	118	577	198	41	6	940	145	1,214	134
	D	81	172	334	226	63	27	0	650		903	
Sept. 11	A, B_1, C_2, E	[2] 61	[2] 93	1	116	68	8	0	193	30	347	46
	D	38	76	190	274	92	69	23	648		[3] 762	
	B_1, C_2, E	[2] 62	[2] 95	400	746	236	57	14	1,453	224	1,610	211

	D	38	76	190	274	92	69	23	648		[3] 762	
	C_2	[2] 71	[2] 101	1,775	1,495	469	195	62	3,996	480	4,168	425
	D	49	98	245	353	118	88	29	833		980	
	E	[2] 53	[2] 85	8	230	87	12	1	338	46	476	55
	D	43	87	217	313	104	78	26	738		868	
Sept. 24	A, B_1, C_2, E	[2] 73	[2] 117	3	182	115	14	1	315	32	505	41
	D	74	172	381	406	111	61	25	984		[3] 1,230	
Average (five sections)										232		190
Average (four sections)										82		81
Average (three sections)										314		236
Average (sec. C_2)										711		540
Average (sec. E)										126		115

[1] B refers to 25 ft upstream from sec. B.
[2] Average of the measured sediment discharges from each section included in the computation.
[3] Daily mean.
[4] G refers to gaging section.

TABLE 8.—*Sediment discharge computed with the modified Einstein procedure for the selected river sections and the comparable measured sediment discharge at section D*

Date	Section	Sediment discharge, in tons per day: Finer than 0.062 mm	0.062 to 0.125 mm	0.125 to 0.25 mm	0.25 to 0.50 mm	0.50 to 1.00 mm	1.00 to 2.00 mm	2.00 to 4.00 mm	Total	Percentage of measured sediment discharge at section D
1949										
Aug. 25	A	51	75	186	142	45	4	0	503	67
	D	52	67	373	179	75	0	0	746	-----------
1950										
Mar. 1	A	372	645	1,361	733	240	55	13	3,419	116
	D	412	471	1,088	676	176	88	29	2,940	-----------
	B	427	512	1,199	562	212	57	14	2,983	101
	D	412	471	1,088	676	176	88	29	2,940	-----------
	E	407	555	1,481	832	295	62	10	3,642	124
	D	410	469	1,084	674	176	88	29	2,930	-----------
Mar. 21	A	247	520	1,164	564	167	26	3	2,691	88
	D	214	549	1,159	884	183	61	0	3,050	-----------
	B	264	669	1,573	689	201	37	5	3,438	114
	D	211	542	1,144	873	180	60	0	3,010	-----------
	E	282	543	1,011	585	291	53	9	2,774	92
	D	210	540	1,140	870	180	60	0	3,000	-----------
Apr. 12	A	125	402	945	549	197	33	4	2,255	119
	D	151	359	775	510	95	0	0	1,890	-----------
	B	139	417	989	481	158	29	3	2,216	127
	D	140	332	718	472	70	18	0	1,750	-----------
	E	143	366	762	431	155	22	2	1,881	109
	D	138	329	709	467	87	0	0	1,730	-----------
Apr. 25	A	155	374	989	616	191	22	2	2,349	106
	D	155	398	994	508	111	44	0	2,210	-----------
	B	176	424	1,255	603	215	45	8	2,726	114
	D	168	432	1,080	552	120	48	0	2,400	-----------
	E	142	362	979	634	245	44	6	2,412	145
	D	116	299	747	382	83	33	0	1,660	-----------
May 9	A	235	252	1,038	615	204	44	10	2,398	150
	D	144	416	624	272	112	32	0	1,600	-----------
	E	154	327	507	339	130	16	1	1,474	105
	D	127	366	550	240	99	28	0	1,410	-----------
May 23	A	81	134	349	299	110	13	1	987	129
	D	92	161	338	153	23	0	0	767	-----------
	E	130	121	360	306	132	20	2	1,071	148
	D	87	152	318	145	22	0	0	724	-----------
June 6	E	54	118	291	236	104	13	1	817	163
	D	50	90	186	140	25	10	0	501	-----------
June 20	A	108	139	222	191	45	1	0	706	117
	D	84	109	235	139	24	12	0	603	-----------
	B	90	162	383	253	95	13	1	997	111
	D	126	162	351	207	36	18	0	900	-----------
July 6	E	74	151	292	208	78	8	0	811	131
	D	62	124	216	142	43	19	12	618	-----------
Aug. 26	B	195	274	441	295	113	17	2	1,337	80
	D	135	218	420	840	67	0	0	1,680	-----------
	E	156	216	322	214	79	7	0	994	64
	D	124	201	388	775	62	0	0	1,550	-----------
Oct. 4	A	63	208	516	315	91	7	0	1,200	125
	D	67	163	383	259	57	29	0	958	-----------
	B	65	195	469	236	80	9	1	1,055	115
	D	65	156	368	248	55	28	0	920	-----------
	C_2	101	193	376	292	98	15	1	1,076	117
	D	64	157	368	248	55	28	0	920	-----------
	E	60	144	335	198	70	6	0	813	91
	D	62	152	358	241	54	27	0	894	-----------
Nov. 8	B	103	321	963	431	128	19	2	1,967	124
	D	126	316	648	363	111	16	0	1,580	-----------
	C_2	105	354	810	475	159	35	4	1,942	116
	D	133	334	685	384	117	17	0	1,670	-----------
	E	111	345	1,108	747	380	128	37	2,856	166
	D	138	344	705	396	120	17	0	1,720	-----------
Nov. 30	[1] B	106	291	743	406	123	20	3	1,692	100
	D	101	287	626	490	118	68	0	1,690	-----------
	C_2	98	284	682	419	167	43	7	1,700	99
	D	102	291	633	496	120	68	0	1,710	-----------
	E	83	284	846	473	176	30	4	1,896	114
	D	100	284	618	484	117	67	0	1,670	-----------

[1] 25 ft upstream from section B.

TABLE 8.—*Sediment discharge computed with the modified Einstein procedure for the selected river sections and the comparable measured sediment discharge at section D*—Continued

Date	Section	Sediment discharge, in tons per day								Percentage of measured sediment discharge at section D
		Finer than 0.062 mm	0.062 to 0.125 mm	0.125 to 0.25 mm	0.25 to 0.50 mm	0.50 to 1.00 mm	1.00 to 2.00 mm	2.00 to 4.00 mm	Total	
1950—Continued										
Dec. 14	B_1	87	220	850	361	109	13	1	1,641	85
	D	116	252	951	466	116	39	0	1,940	--
	C_2	168	312	1,086	614	174	34	4	2,392	104
	D	138	299	1,127	552	138	46	0	2,300	--
	E	156	331	1,466	689	267	63	13	2,985	135
	D	133	287	1,083	530	133	44	0	2,210	--
1951										
Jan. 24	C_2	60	362	1,443	928	291	80	16	3,180	123
	D	103	310	1,264	748	103	52	0	2,580	--
Feb. 20	B	167	367	864	363	100	12	1	1,874	146
	D	128	256	525	294	64	13	0	1,280	--
	C_2	127	292	485	312	127	31	4	1,378	108
	D	127	254	521	292	63	13	0	1,270	--
	E	133	272	588	364	147	25	3	1,532	123
	D	125	250	512	288	75	0	0	1,250	--
Mar. 30	E	119	246	403	246	89	9	0	1,112	82
	D	122	230	540	324	94	40	0	1,350	--
June 4	B_1	110	214	521	310	104	14	1	1,274	97
	D	170	301	485	275	79	0	0	1,310	--
	C_2	122	223	423	342	120	19	1	1,250	115
	D	142	251	403	229	65	0	0	1,090	--
June 26	C_2	112	190	343	306	103	14	1	1,069	139
	D	100	138	276	192	38	23	0	767	--
	E	89	136	327	259	98	11	0	920	124
	D	96	134	260	193	37	22	0	742	--
July 26	E	62	70	177	148	55	4	0	516	90
	D	69	75	207	173	40	12	0	576	--
Aug. 16	B_1	72	143	253	178	74	10	1	731	101
	D	72	130	246	174	58	29	15	724	--
	C_2	74	133	330	337	101	11	0	986	142
	D	69	125	235	166	55	28	14	692	--
	E	66	88	210	161	62	5	0	592	91
	D	65	118	222	157	52	26	13	653	--
Aug. 30	E	84	128	328	241	85	8	0	874	121
	D	72	94	252	224	50	29	0	721	--
Oct. 31	E	81	291	910	495	182	30	4	1,993	105
	D	76	266	722	475	190	114	57	1,900	--
Dec. 5	E	108	367	1,171	608	213	43	7	2,517	115
	D	87	327	938	545	174	87	22	2,180	--
1952										
Mar. 10	C_2	171	351	656	513	214	59	10	1,974	114
	D	156	294	571	450	121	86	52	1,730	--
Mar. 26	C_2	369	716	605	442	159	33	4	2,328	92
	D	327	731	731	554	101	76	0	2,520	--
May 6	B_1	97	188	444	311	108	16	2	1,166	99
	D	106	224	437	295	83	35	0	1,180	--
	C_2	84	163	302	282	97	13	1	942	90
	D	94	200	388	262	74	32	0	1,050	--
	E	97	219	387	271	85	7	0	1,066	118
	D	81	172	334	226	63	27	0	903	--
May 22	E	176	251	435	291	114	12	1	1,280	74
	D	175	313	626	452	104	35	35	1,740	--
June 18	E	76	116	243	200	79	8	0	722	125
	D	75	110	209	127	35	23	0	579	--
July 18	E	77	96	214	178	66	5	0	636	83
	D	76	107	259	198	69	38	15	762	--
Aug. 13	E	91	147	337	277	116	15	1	984	127
	D	93	124	247	208	69	31	0	772	--
Sept. 24	B_1	63	167	456	288	109	15	2	1,100	114
	D	58	135	298	317	86	48	19	961	--
	C_2	65	136	308	271	99	16	1	896	91
	D	59	137	304	324	88	49	20	981	--
Unweighted average	--	--	--	--	--	--	--	--	--	112
Weighted average, in percent	--	105	106	114	104	157	73	65	111	--

TABLE 9.—*Sediment discharges computed with several formulas and data for comparison*

Date	Sediment discharge, in tons per day						Ratio of mean concentration in unsampled zone to that in sampled zone			
	Computed for section E				Unmeas at section E	Measured at section D				
	Straub	Kalinske	Schoklitsch	Meyer-Peter and Müller			Straub	Kalinske	Schoklitsch	Meyer-Peter and Müller
1949										
Aug. 17	2,722	330	411	149	784	1,190	--------	6.33	5.38	8.45
25	2,510	302	360	141	443	691	--------	3.37	2.39	6.08
Sept. 13	4,324	360	590	192	493	842	--------	2.66	--------	4.75
1950										
Mar. 1	1,013	206	317	404	1,370	2,930	--------	3.77	3.50	3.29
21	3,810	296	689	462	1,690	3,000	--------	4.94	3.86	4.47
Apr. 12	3,742	301	534	279	720	1,730	--------	2.66	1.74	2.74
25	1,719	230	333	350	791	1,660	--------	3.48	3.02	2.95
June 6	3,677	331	507	233	210	501	--------	--------	--------	--------
Dec. 14	3,288	278	572	488	800	2,210	--------	2.68	1.73	2.00
1951										
Feb. 20	5,583	330	613	337	512	1,250	--------	1.91	--------	1.88
Mar. 30	2,846	317	449	192	802	1,350	--------	4.85	3.80	5.84
July 26	4,129	342	400	130	342	576	--------	--------	--------	5.53
Oct. 31	3,229	312	525	346	1,015	1,900	--------	4.18	3.22	4.02
Dec. 5	1,962	236	413	359	1,100	2,180	--------	4.33	3.65	3.86
1952										
July 18	4,831	337	468	138	492	762	--------	3.50	1.39	6.70
Aug. 13	4,376	318	463	231	426	772	--------	2.36	--------	3.45
Sept. 24	3,694	318	441	189	549	1,020	--------	3.13	2.00	4.33

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