MEASUREMENT OF BEDLOAD DISCHARGE IN NINE ILLINOIS STREAMS WITH THE HELLEY-SMITH SAMPLER

By Julia B. Graf

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply inch-pound units	By	To obtain SI units
inch (in.)	0.0254	meter (m)
	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per second squared (ft/s^2)	0.3048	meter per second squared (m/s^2)
square foot per second (ft^2/s)	0.09290	square meter per second (m^2/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per foot [(ft^3/s)/ft]	0.09290	cubic meter per second per meter [(m^3/s)/m]
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
pound (mass) per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter (kg/m^3)
pound (force) per square foot (lbf/ft^2)	47.88	pascal (Pa)
ton (short)	0.9072	megagram (Mg)
ton per day (ton/d)	0.9072	megagram per day (Mg/d)

GLOSSARY OF TERMS

Bedload is the sediment transported by rolling, sliding, or skipping along the streambed or very close to it; in this report, bedload is considered to be all sediment greater than 0.25 mm in size transported within 3 inches of the bed.

Bedload discharge is the quantity of sediment transported as bedload through a cross section of a stream channel in a given period of time.

Bedload-discharge rating curve is the relation between bedload discharge and water discharge, expressed graphically or as an equation.

Bedload sample is a representative portion of sediment moving within 3 inches of a streambed.

Bed material is the unconsolidated material of which a streambed is composed.

Bed-material characteristics are sizes within a sediment grain-size distribution which are used to describe that distribution, including the mean grain size, the median grain size, and the grain size at the 35th, 65th, and 90th percentiles (percent finer by weight).

Critical discharge is discharge at which bed material begins to move as bedload.

Cross section is a planar section across a stream channel which is described by the geometry of the bed and banks.

Discharge is the volume of water that passes a given point in a given period of time.

Effective width is the distance across a channel over which sediment is transported as bedload.

Energy slope is the slope of a line which represents the height of the total hydraulic head above a datum.

Gage height is the water-surface elevation referred to an arbitrary gage datum.

Gaging station is a particular site on a water body where systematic observations of hydrologic data are made.

Geometric mean is a measure of central tendency of a grain-size distribution, computed as the antilog of the quantity $[(\Sigma P_i \log d_i)/\Sigma P_i]$, where P_i is expressed as a percent, and the sums are computed over all grain-size fractions in the distribution.

Grain-size distribution is a frequency distribution of particle sizes in a sediment sample, described in terms of the weight of particles in each size fraction of the distribution.

Hydraulic radius is the area occupied by water at a stream cross section divided by the distance across the submerged channel bed at that section.

Indirect method is a theoretical or empirical relation used to compute bedload discharge from hydraulic and sediment characteristics.

Median grain size is the particle diameter which is larger than 50 percent of the diameters in a grain-size distribution and smaller than the other 50 percent.

River mile is the distance of a point on a stream upstream of the mouth of the stream.

Sampling site is a cross section at a gaging station at which bedload samples were collected.

Sampling point is a location in the cross section at a sampling site where a sample of bedload was collected.

Size fraction is a class of particle sizes identified by the grain sizes which form upper and lower boundaries of the class.

Suspended load is the sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Suspended-sediment sample is a representative sample of sediment moving above a point 3 inches from a streambed.

Unit bedload discharge is the bedload discharge per unit width of the cross section.

Unit discharge is the discharge per unit width of the cross section.

Water year is the period from October 1 of a given year to September 30 of the following year. The number of the year is the year in which it ends (year beginning October 1, 1980, and ending September 30, 1981, is the 1981 water year).

Width is the distance across the water surface at a cross section.

LIST OF SYMBOLS

d_i - Mean grain size of the ith fraction of a grain-size distribution (millimeters).

d_n - Grain size such that "n" percent of the sample is finer than the given size; in this report, n is equal to 35, 50, 65, or 90 (millimeters).

f - Darcy-Weisbach friction factor (dimensionless).

g - The gravitational constant (feet per second squared).

k/k' - A ratio used in the Meyer-Peter, Müller (1948) bedload equation to account for the effect of bedforms on bedload discharge.

P_i - Percent of the total weight of a sediment sample of sediment in the "ith" grain-size fraction (decimal).

q - Unit discharge (cubic feet per second per foot).

q_{icr} - Unit discharge required to move grains of a size d_i (cubic feet per second per foot).

q_b - Unit bedload discharge (pounds per second per foot).

q_{ib} - Unit bedload discharge of the ith grain-size fraction (pounds per second per foot).

Q - Discharge (cubic feet per second).

Q_b - Bedload discharge (tons per day).

R - Hydraulic radius of a stream channel (feet).

R' - That portion of the total hydraulic radius of the channel that is effective in bedload discharge (feet). Einstein (1950) called R' the hydraulic radius with respect to grains.

R'' - That portion of the total hydraulic radius of the channel that is not effective in bedload discharge (feet). Defined by Einstein (1950, p. 9).

S - Slope of the energy grade line (dimensionless).

$\overline{U}$ - Mean velocity at a given cross section of a stream (feet per second).

u_* - Shear velocity, $(SR_g)^{1/2}$ (feet per second).

ν - Kinematic viscosity (square feet per second).

ρ - Density of stream water (pounds per cubic foot).

ρ_s - Density of sediment (pounds per cubic foot).

τ - Mean bed shear stress [pounds (force) per square foot].

Ψ - A measure of flow intensity (dimensionless).

Φ - A measure of bedload-transport intensity (dimensionless).

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ABSTRACT

Samples collected with the Helley-Smith bedload sampler can provide useful information about transport of sand-size sediment in Illinois streams. Samples provide the basis for bedload-discharge rating curves for the Rock and Kaskaskia Rivers and Henderson Creek. Rock River data cover a wide range of flow conditions and yield a well-defined curve. Data from Henderson Creek cover a much narrower range of flow conditions and show wide scatter. Only three measurements define the Kaskaskia River rating curve, but these cover a range of flow conditions and fall on a straight line.

Comparison of measured bedload discharge with bedload discharge computed for selected flow conditions from channel characteristics allows the selection of an appropriate indirect method for determining bedload discharge for the Spoon, Kishwaukee, and Edwards Rivers. No one indirect method best represents bedload discharge in studied streams. No bedload-discharge rating curve was developed for the La Moine River, because the two measured bedload discharges are not sufficient for development of a rating curve and do not agree well with discharges computed by any of the three indirect methods.

The dominant size of bedload particles in all streams sampled is in the range from 0.25 to 0.50 millimeters. Sampler efficiency has not been determined for grains finer than 0.50 millimeters and bedload-discharge rating curves presented should be used with caution. Data from two of nine streams sampled give results which cannot be used at this time. Clogging of the sample-collection bag by fine sediment may have been significant in the Green River, and because the effect of clogging has not been defined, the data cannot be interpreted at this time. Samples collected in the Vermilion River were judged not to be representative of the true bedload transport, possibly because large bed material grains or high flow velocities interfered with the operation of the sampler.

INTRODUCTION

Erosion of soil from farmland and deposition of sediment in navigational channels and reservoirs are major environmental issues in Illinois. Accurate measurement of sediment transported by streams is critical to evaluation of these issues. Although there are well-established techniques and equipment for measuring suspended sediment, there is no widely accepted procedure for measuring bedload. The Helley-Smith sampler (Helley and Smith, 1971) is one instrument that has come into wide use for measurement of bedload, although tests on its sampling efficiency are still being conducted.

In 1978, the U.S. Geological Survey began sampling bedload in Illinois streams with the Helley-Smith sampler to provide data to estimate the volume of sand-size material entering the Mississippi River and its tributaries, the Rock and Illinois Rivers. The first sampling sites were on the Rock River, Henderson Creek, and the Green River. In 1980, sites on the Vermilion River and the Edwards River were added to the sampling program. In 1981, sites on four additional streams were added--the La Moine, Kaskaskia, Spoon, and Kishwaukee Rivers. All sampling sites are at long-term Geological Survey stream-gaging stations (fig. 1 and table 1).

Purpose and Scope

The purpose of the present study was to analyze the bedload discharge measurements, to develop bedload-discharge rating curves for those sites with sufficient record, to determine the usefulness of each sampling site for measurement of bedload discharge, and to evaluate the suitability of the Helley-Smith sampler to Illinois streams. Methods of extending the rating curves or developing curves for stations with few measurements also were to be investigated, using bedload discharges computed from channel geometry and bed material characteristics for selected flow conditions. Three available methods for such computations (indirect methods) were chosen: the Meyer-Peter, Müller equation (Meyer-Peter and Müller, 1948), the Einstein method (Einstein, 1950) and the Schoklitsch equation (Shulits, 1935).

In this report, a description of methods used to measure and compute bedload discharge is followed by the description and evaluation of each bedload sampling site. For each site, channel characteristics that relate to sediment transport are described, measured and computed bedload discharge are presented, suspended-sediment samples are discussed in relation to bedload samples, a bedload discharge-rating curve is presented if one was developed, and an evaluation of the site in terms of bedload sampling is given. A final section discusses the more important points brought out in the analysis.

Acknowledgments

The bedload sampling was done in cooperation with the U.S. Army Corps of Engineers, Rock Island and St. Louis Districts. Data analysis was carried out in cooperation with both the U.S. Army Corps of Engineers and the Illinois Department of Transportation, Division of Water Resources. The assistance of Charles W. Farnham, U.S. Army Corps of Engineers, Rock Island District, who provided unpublished data used to determine water surface slopes for the Rock River, is gratefully acknowledged. The thoughtful report review of Claude N. Strauser, U.S. Army Corps of Engineers, St. Louis District, was also appreciated.

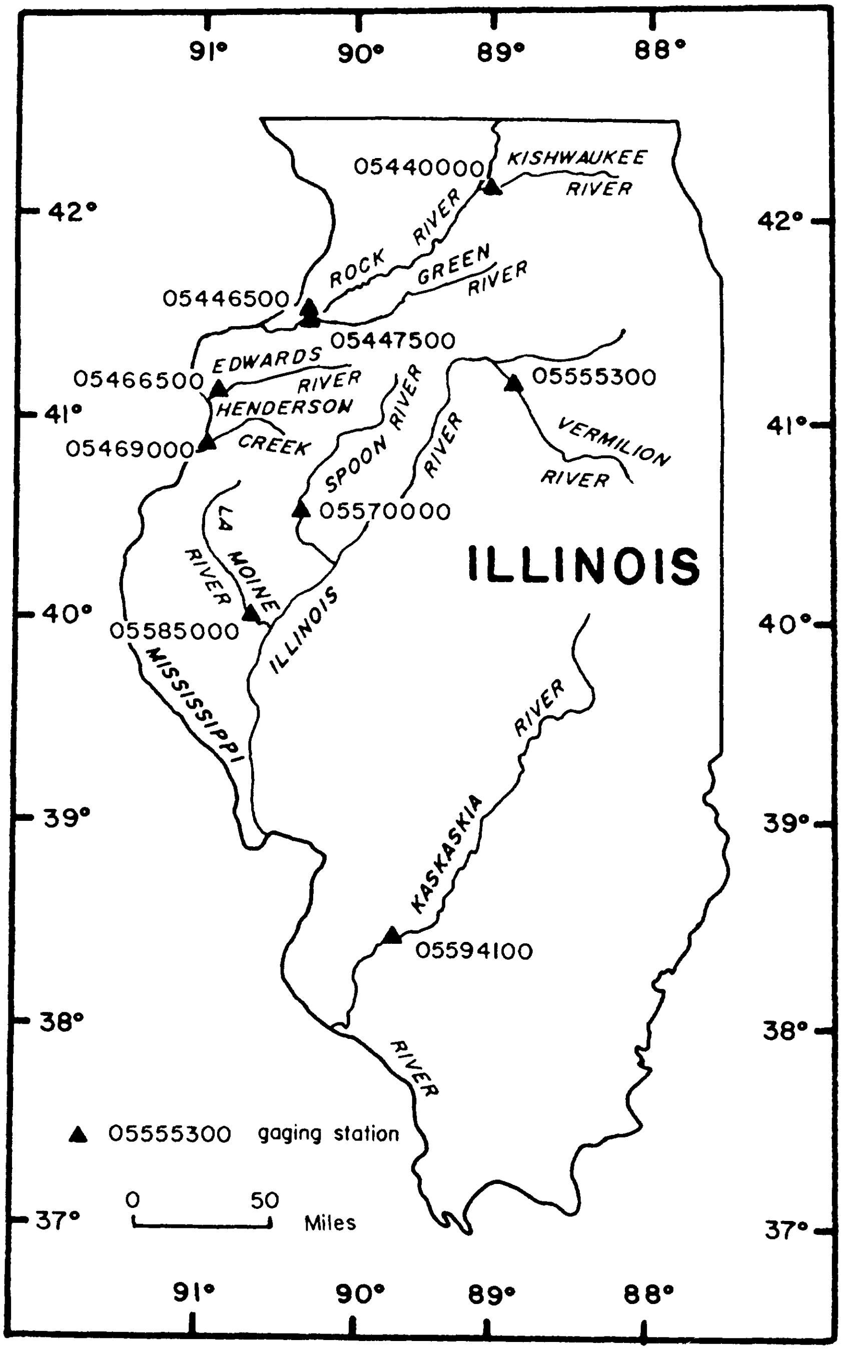

Figure 1.--Locations of bedload sampling sites in Illinois.

Table 1.--Bedload sampling sites in Illinois

[River mile is the distance of a point on a stream upstream from the stream mouth. Data from Healy, 1979a, 1979b]

Station number	Station name	River mile	Drainage area (mi^2)	Average discharge (ft^3/s)	Tributary to-- River	Tributary to-- At river mile
05440000	Kishwaukee River near Perryville	9.6	1,099	692	Rock	130.0
05446500	Rock River near Joslin	26.9	9,549	5,873	Mississippi	479.1
05447500	Green River near Geneseo	14.9	1,003	594	Rock	13.0
05466500	Edwards River near New Boston	4.6	445	272	Mississippi	431.2
05469000	Henderson Creek near Oquawka	20.8	432	278	do.	409.9
05555300	Vermilion River near Leonore	17.2	1,251	783	Illinois	226.3
05570000	Spoon River at Seville	39.2	1,636	1,026	do.	119.4
05585000	La Moine River at Ripley	12.3	1,293	774	do.	83.5
05594100	Kaskaskia River near Venedy Station	57.2	4,393	3,484	Mississippi	117.6

METHODS OF STUDY

Measured Bedload Discharge

The Helley-Smith bedload sampler (Helley and Smith, 1971) used in this study has a 3- by 3-inch-square nozzle and a collection bag of 0.25-mm mesh. Samples collected with this sampler therefore consist of material 0.25 mm and larger traveling in suspension or as bedload within 3 inches of the bed. Field calibration of the Helley-Smith sampler (Emmett, 1980) gave results which indicate that a significant fraction of trapped sediment may be suspended load, depending upon flow rate and the size of sediment available for transport. In this report, samples collected with the Helley-Smith sampler are considered to represent bedload even though they may contain a varying amount of material that actually moved in suspension.

The sampling efficiency of the Helley-Smith sampler has not yet been determined, and tests on its accuracy, precision, and applicability are still in progress. The U.S. Geological Survey has developed provisional guidelines for use of the sampler during the period of testing. The basic provisions of the provisional method are as follows:

(1) Two traverses should be made along a stream cross section.

(2) Each traverse should consist of at least 20 equally spaced sampling points, except for streams that are very wide or very narrow where more or fewer sampling points, respectively, are appropriate.

(3) The time that the sampler rests on the bottom should be the same at each sampling point, and that time should be about 30 to 60 seconds.

(4) For each traverse, individual sampling points may be analyzed or they may be composited for analysis.

(5) Bed-material and suspended-sediment samples should be collected.

Whenever possible, the provisional Geological Survey procedures described above were followed. Deviations from these procedures are noted in tables and text for each sampling site. In the discussion of bedload, the term "sample" will be used to refer to all measurements made at a given site on a given day at the same, or close to the same, flow condition. One or two traverses make up a "sample", and a "traverse" is made up of a number of sampling points along the cross section. From 1 to 2 hours usually was required to collect a sample composed of two traverses of 20 sampling points each.

The results of field calibration of the sampler (Emmett, 1980) indicate that sampling efficiency is almost 100 percent for bedload material from 0.5 to 8 mm in size. Because of the paucity of material in the range of 8 to 16 mm collected in the field-calibration tests, the efficiency of the sampler for grains in that size range is not yet defined. Therefore, the procedure is not recommended for streams in which the median diameter of the bed material (d_{50}) is greater than 8 mm, or for streams in which the bed material less than 0.25 mm accounts for more than 10-15 percent of the bed material. It is also not recommended for streams in which the bed materials or bed configuration interfere with a good fit of the sampler to the bed, or where a significant amount of fine sediment or organic material is present that may clog the collection bag.

Median diameters of bed materials sampled in this study range from 0.28 mm (Green River) to 3.65 mm (Vermilion River). Also, bed materials and hydraulic geometries are such that dune bedforms are likely to form when bedload discharge is significant. It was not possible to quantify the effects of bed-material size or bed configuration on bedload samples because bedload discharge could not be measured independently in these streams. Bedload and suspended sediment grain-size distributions and the comparison of measured bedload discharge to computed bedload discharge were used to make qualitative conclusions about the data.

Measured bedload discharge in tons per day is found by multiplying the dry mass of sample in grams by 86,400 to convert seconds to days and by 0.000001103 to convert grams to tons, and dividing by the total time on the bottom in seconds. The result is multiplied by 4 to convert bedload discharge in tons per day for the 3-inch width of the sampler to unit bedload discharge in tons per day per foot. The total bedload discharge through the measured cross section is obtained by multiplying unit bedload discharge by the effective width in feet. The effective width is that part of the cross section in which bedload discharge is occurring at the time of sampling and is determined in the field visually and by sampling. For many samples, the sediment from individual points in the cross section was analyzed separately or composited into subsamples which represented several points. For those samples, the computation described above was done separately for the subsamples and the bedload discharges from subsections were totaled.

Computed Bedload Discharge

Three indirect methods were used for computation of bedload discharge to compare with measurements. Each method is briefly described below. The types of data needed for computations are described following the description of all three methods.

Einstein Method

Einstein (1950) developed a method for estimating bedload discharge by considering the equilibrium between the rate of erosion of particles from the bed and the rate of deposition. The probability of erosion of a particle was assumed to depend upon the hydrodynamic lift on that particle and its weight. The method reduces to a relation between two dimensionless parameters;

$$\Psi = \frac{\rho_s - \rho}{\rho} \cdot \frac{d_i}{SR'} \qquad (1)$$

and

$$\Phi = \frac{q_b}{\rho_s g} \sqrt{\frac{\rho}{\rho_s - \rho} \cdot \frac{1}{g d_i{}^3}} \qquad (2)$$

Einstein called the first parameter (Ψ) flow intensity and the second parameter (Φ), the intensity of bedload transport. To find the bedload discharge for a grain-size fraction with mean size d_i, Ψ is calculated from measured or assumed values of the variables, which are defined in a list of symbols at the end of the report. Φ is found from an empirical relation between Ψ and Φ which is expressed graphically by Einstein (1950, fig. 10, p. 77). Bedload discharge is computed from equation 2 for each grain-size fraction of bed material. Unit bedload discharge is the sum of the discharges computed for all grain-size fractions.

Although the relations described above were derived from theoretical arguments, a number of coefficients determined from flume experiments are used to obtain Ψ. One of these is a hiding factor used to account for shielding of smaller grains by larger ones or by the laminar sublayer. Einstein (1950, p. 9) believed that shear stress transmitted to the bed grains will be effective in bedload transport, whereas shear stress transmitted by separation of flow at bedforms is not effective because turbulence remains a greater distance from bed grains. To take this into account in bedload calculations, Einstein conceptually divided the hydraulic radius into a fraction (R') due to grain roughness and a fraction due to form roughness (R").

Meyer-Peter, Müller Equation

Unlike the Einstein method, the equation developed by Meyer-Peter and Müller (1948) is based on an entirely empirical relation, derived from flume experimental data with sediment of several densities. Grain sizes ranged from 0.4 to 28.6 mm. The equation developed is:

$$q_b^{2/3} = \frac{\left(\frac{k}{k'}\right)^{3/2} \tau - 0.047\,(\rho_s-\rho) g\, d_{50}}{0.25\rho^{1/3}\left(g\,\frac{\rho_s-\rho}{\rho}\right)^{2/3}} \quad . \tag{3}$$

The ratio (k/k') is found from the relation

$$\frac{k}{k'} = \left(\frac{f}{8}\right)^{1/2} \frac{\bar{U}}{u_*} \tag{4}$$

for smooth flow ($d_{90}u_*/\nu$ less than 100), and from

$$\frac{k}{k'} = 0.0212\,\frac{\bar{U} d_{90}^{1/6}}{R^{2/3} S^{1/2}} \tag{5}$$

for rough flow ($d_{90}u_*/\nu$ equal to or greater than 100). Grain size is expressed in feet. Although obtained in different ways, the Meyer-Peter, Müller equation is very similar to that derived by Einstein (1950). The ratio k/k' accounts for the effect of bedforms in the same way as Einstein's hydraulic radius division (Vanoni, 1975).

Schoklitsch Equation

The equation developed by Schoklitsch (Shulits, 1935) is simpler than the Einstein and Meyer-Peter, Müller methods. It is based on the assumption that for each grain-size fraction of bed material there is a discharge below which bedload transport will not take place (the critical discharge). The critical unit discharge (q_{icr}, or critical discharge per foot of width) for a given grain-size fraction is given by:

$$q_{icr} = 0.0638 \frac{d_i}{S^{4/3}} \tag{6}$$

and the unit bedload discharge for that grain-size fraction, in pounds per second per foot, is given by

$$q_{ib} = P_i \frac{25.0}{d_i^{1/2}} S^{3/2} (q-q_{icr}) \,. \tag{7}$$

Total unit bedload discharge is found by summing all grain-size fractions. Grain size is expressed in feet.

Information Needs and Data Sources

Computations were made for each station using the three indirect methods for hydraulic conditions associated with each bedload sample. Where two traverses were made for one sample, the average of the hydraulic variables was used for the indirect methods of computing bedload discharge. In addition, gaging-station records were used to select 15 discharge measurements from which hydraulic variables over a wide range of streamflow conditions could be determined for computing bedload discharge. The date of each discharge measurement and the hydraulic variables used are tabulated and presented with each site description in tables 3, 6, 9, 12, 15, 18, 21, 24, and 27.

A sediment density of 165 lb/ft^3 (quartz density) and a gravitational constant of 32.16 feet per second squared were used in all computations. Hydraulic radius was assumed equal to the mean flow depth. Except for the Rock River, the energy slope was assumed equal to the slope of the channel in the vicinity of the gage and was determined from topographic map contours. Slope was computed from the closest contours upstream and downstream of the gage. Because the contour interval is 10 feet for most maps used, slope was determined from the distance over which the channel bed decreased 10 feet in elevation. For the Rock River, measurements of regional water-surface slope, provided by the U.S. Army Corps of Engineers, were used to develop a relation with discharge that was used to estimate slope for each computation.

Each indirect method requires some measure of the grain size of bed material. The percent of grains in each size fraction is used in the Einstein method and the Schoklitsch equation. In addition, Einstein uses d_{35} and d_{65} of the bed material, and the Meyer-Peter, Müller relation uses d_{90} and d_{50}. The number of bed-material samples and the grain-size distribution of bed material varied considerably from site to site. If a bed-material sample was collected at the time a bedload sample was collected or on the day a discharge measurement was made, then the grain-size distribution of that sample was used. If no bed material sample was available for a given day, then an average grain-size distribution of bed material was used. For some sites, the average was computed from all available samples. For other sites, averages were computed separately for each year. The averaging method depended on the number and variability of analyses.

Observed effective widths were used in computing bedload discharge by indirect methods for dates on which bedload samples were collected. For other dates, effective width was estimated from its relation to discharge. For the Green River, the Rock River, and Henderson Creek, the relation between effective width and discharge was developed from observed values. For the other sites, the relation was developed from observed values supplemented with effective widths estimated for a range of discharges from the distribution of near-bottom velocity (velocity at a depth equal to 80 percent of the total depth in a vertical). The distribution of these velocities during bedload sampling was examined in relation to the measured bedload at each sampling point to aid in determination of the velocity at which bedload transport begins at each site. Although no single velocity was used for all streams as a criterion for beginning of transport, near bottom velocities of less than about 1 ft/s were found to correspond to regions of no transport in many cases.

As a qualitative aid to interpretation of bedload data, relative stability of the channel bed was examined by plotting channel cross sections from data collected during discharge measurements made over the period of bedload sampling. Six to eight cross sections were plotted for each site. Changes in bed elevation are interpreted as being caused by scour and fill.

DESCRIPTION AND EVALUATION OF BEDLOAD SAMPLING SITES

The analysis of bedload-discharge measurements, the results of computations by indirect methods, and site evaluations are presented by sampling site. The Vermilion, Spoon, and La Moine Rivers, all tributaries to the Illinois River, are presented first. Rock River tributaries, the Kishwaukee and Green Rivers, are next, followed by streams that flow directly into the Mississippi River--the Rock, Edwards, and Kaskaskia Rivers, and Henderson Creek.

Illinois River Tributaries

Vermilion River near Leonore

Uplands in the drainage basin of the Vermilion River above the gage near Leonore (fig. 1, table 1) are covered by thick glacial deposits which form low, broad morainal ridges or very gently rolling areas (Leighton and others, 1948). The streambed in the vicinity of the gage is composed of sand, gravel, and bedrock. Channel slope in the vicinity of the gage is 0.000256 (1.35 ft/mi). The bed is fairly even, with low-amplitude gravel bars. Flow is confined within high banks and is affected by two bridge piers. Flow velocity was evenly distributed between the piers at medium and low stages during the period of study. Velocity was much lower between the piers and the banks than in the center of the section. At high stages, highest velocities were measured in the left half of the channel. Bed elevation differences of ±4 feet were found from cross sections plotted from discharge-measurement notes made over the last few years. These differences indicate that moderate scour and fill of the channel bed takes place.

Bed material has been sampled twice at the site. The two samples, which differ greatly in grain-size distribution (table 2), indicate that bed grains are larger and much more variable than in other streams. One sample had 85 percent of the total sample weight greater than 16 mm in size. The bed material sample taken on June 2, 1980, was taken at the same high flow during which bedload was sampled. The bed-material sample was collected from a bridge at the gage section using a sampler suspended from a cable. At one sampling point, no material was collected, and at another the material collected was muddy. The high flow velocity (mean velocity 5.0 ft/s) probably prevented optimum operation of the sampler. The bed material of September 3, 1980, was a shovel sample collected at a riffle section upstream of the gage; the material there was probably coarser than the bed material elsewhere in the channel. Also, the small number of points sampled across the channel (four points in June and three in September) is probably not adequate to sample material as variable as is found at this site. Because no other data were available, the average of the grain-size distributions of the two bed-material samples was used to compute bedload discharge by indirect methods (tables 2 and 4). The median grain size (d_{50}) for the average bed material was 1.75 mm.

Because of the inadequate description of bed material, material available for transport may be better represented by the bedload itself than by the bed-material samples. For dates on which bedload was sampled, bedload discharge was recomputed by indirect methods using the grain-size distribution of the bedload sample to represent the bed material. Results are given in table 4 for comparison with bedload discharge computed with average bed material.

Only two bedload samples were taken at this site (tables 2-4). Each sample consisted of one traverse of 19 sampling points composited into 4 and 5 subsamples. Time on the bottom was 60 seconds for one sample, and 3 minutes for the other. Highest bedload discharge was measured near the center of the channel during the two measurements. The grain-size distribution for the 1980 bedload sample (table 2) shows that the 8- and 16-mm size fractions are the largest fraction of the sample, whereas for the second bedload sample (April 16, 1981), most of the sample was in the 0.25 to 0.5 mm grain-size fraction. Both samples contain very little material less than 0.25 mm in size, suggesting that the collection bag was not clogging.

A suspended-sediment sample collected at the time of the 1980 bedload sample (table 2) contained particles which were all less than 0.25 mm. This is consistent with other suspended-sediment samples for which less detailed size-distribution data are available. Grains less than 0.062 mm typically make up greater than 90 percent of the sample.

Bedload discharges computed by the three indirect methods agree fairly well with each other for discharges greater than about 1,300 ft^3/s (tables 3 and 4, fig. 2). At lower discharges, the Schoklitsch equation (eq. 7) yields much smaller bedload discharges than the other two. Also, the scatter at lower discharges is much less for the Schoklitsch than for the Einstein and Meyer-Peter, Müller methods. Bedload discharges computed with the bedload size distribution as bed material for the measurement of April 16, 1981, are not much different from those made using the average bed material (table 4). However, for June 2, 1980, bedload discharges computed with the bedload representing the bed material are much smaller than those computed using average bed material. The smaller computed bedload discharges are caused by the greater amount of sediment in larger, less mobile, grain sizes in the bedload sample than in the bed material sample. Both measured bedload-discharge values plot (fig. 2) well below all computed values. Bedload discharges computed by the Schoklitsch equation plot along a slope very similar to the slope of a line drawn through the two measured bedload-discharge values.

Because bedload samples were so few and measured bedload discharges were much lower than any of the computed values, no bedload-discharge rating curve was developed for this station. Grain-size distributions of both bedload and suspended sediment suggest that clogging of the collection bag is not significant and that little, if any, of the trapped sediment was in fact suspended. Use of a larger nozzle on the sampler (6 by 6 inches) may show whether or not the lower than "expected" discharges are caused by the interference of large grains with the operation of the sampler. High flow velocities during one bedload measurement caused the sampler to drift downstream and may have prevented it from resting properly on the bed. Measurement at flows with lower velocity would help to determine if this affected results significantly. Low measured values relative to computed values also could be caused by a paucity of moveable sediment or by inaccurate estimates of grain-size distribution of bed material used in computations. Better descriptions of the bed material, including its thickness and areal extent, would help in evaluation of bedload discharge measurements.

Table 2.--Grain-size distribution of sediments, Vermilion River near Leonore

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
Bed material														
June 2, 1980	--	--	100	99	99	98	94	35	7	3	0	--	--	--
Sept. 3, 1980	100	15	4	2	1	1	0	--	--	--	--	--	--	--
Average	100	58	52	51	50	50	48	18	4	2	--	--	--	--
Bedload														
June 2, 1980	100	69	46	36	29	23	17	5	--	--	--	--	--	--
Apr. 16, 1981	100	87	76	74	69	63	53	7	--	--	--	--	--	--
Suspended sediment														
June 2, 1980	--	--	--	--	--	--	--	100	--	99	95	90	81	66

Table 3.--Data for bedload computations, Vermilion River near Leonore

[A slope of 0.000256 ft/ft was used for all calculations]

Date	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload sampled								
June 2, 1980	22.00	19,000	4,200	18.92	222	174	25.0	4.52
Apr. 16, 1981	12.78	6,590	1,830	9.73	188	139	11.5	3.60
Bedload not sampled								
Aug. 25, 1977	3.46	130	58.2	1.14	51	51	22.0	2.23
Sept. 12, 1978	2.84	17.0	14.4	.69	21	21	24.5	1.18
Mar. 5, 1979	23.20	21,300	4,680	20.89	224	179	0	4.55
Dec. 27, 1979	5.51	852	494	3.03	167	72	4.0	1.72
Mar. 11, 1980	8.12	2,500	778	4.66	159	107	.5	3.21
Apr. 24, 1980	5.52	972	439	3.82	115	76	6.5	2.21
June 4, 1980	20.72	17,100	3,380	15.94	212	171	21.0	5.06
July 16, 1980	3.94	279	140	1.28	109	109	21.0	1.99
Aug. 26, 1980	2.94	35.3	88.5	1.48	60	60	29.0	.40
Nov. 21, 1980	3.25	70.4	69.0	.95	72	72	3.0	1.02
Mar. 16, 1981	4.27	333	124	.95	131	124	8.0	2.68
Apr. 15, 1981	16.62	11,700	2,730	13.19	207	158	13.5	4.28
Do.	16.10	10,100	2,560	12.49	205	156	13.5	3.94
Apr. 30, 1981	10.13	4,220	1,460	7.93	184	123	13.0	2.89
July 23, 1981	5.71	1,080	581	4.37	133	80	23.0	1.85

Table 4.--Bed-material characteristics and measured and computed bedload discharge, Vermilion River near Leonore

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935). The second entry for each of the dates of bedload samples gives bedload discharge computed using bedload grain-size distribution to represent bed material grain-size distribution]

Date	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
	d35	*d50*	*d65*	*d90*	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled								
June 2, 1980	0.39	1.75	17.0	23.0	36.9	711	758	831
Do.	3.90	4.88	14.5	22.0	36.9	200	238	156
Apr. 16, 1981	.39	1.75	17.0	23.0	8.52	312	303	257
Do.	.39	1.23	1.30	18.0	8.52	267	326	338
Bedload not sampled								
Aug. 25, 1977						49.1	13.6	0.37
Sept. 12, 1978						1.62	0	0
Mar. 5, 1979						696	803	954
Dec. 27, 1979						25.2	.40	10.3
Mar. 11, 1980						300	157	79.4
Apr. 24, 1980						53.1	19.4	25.2
June 4, 1980						1,286	1,030	769
July 16, 1980	0.39	1.75	17.0	23.0	--	65.6	11.8	.85
Aug. 26, 1980						0	0	0
Nov. 21, 1980						1.49	0	0
Mar. 16, 1981						277	88.8	.85
Apr. 15, 1981						463	591	489
Do.						424	453	416
Apr. 30, 1981						396	121	142
July 23, 1981						25.4	3.39	25.0

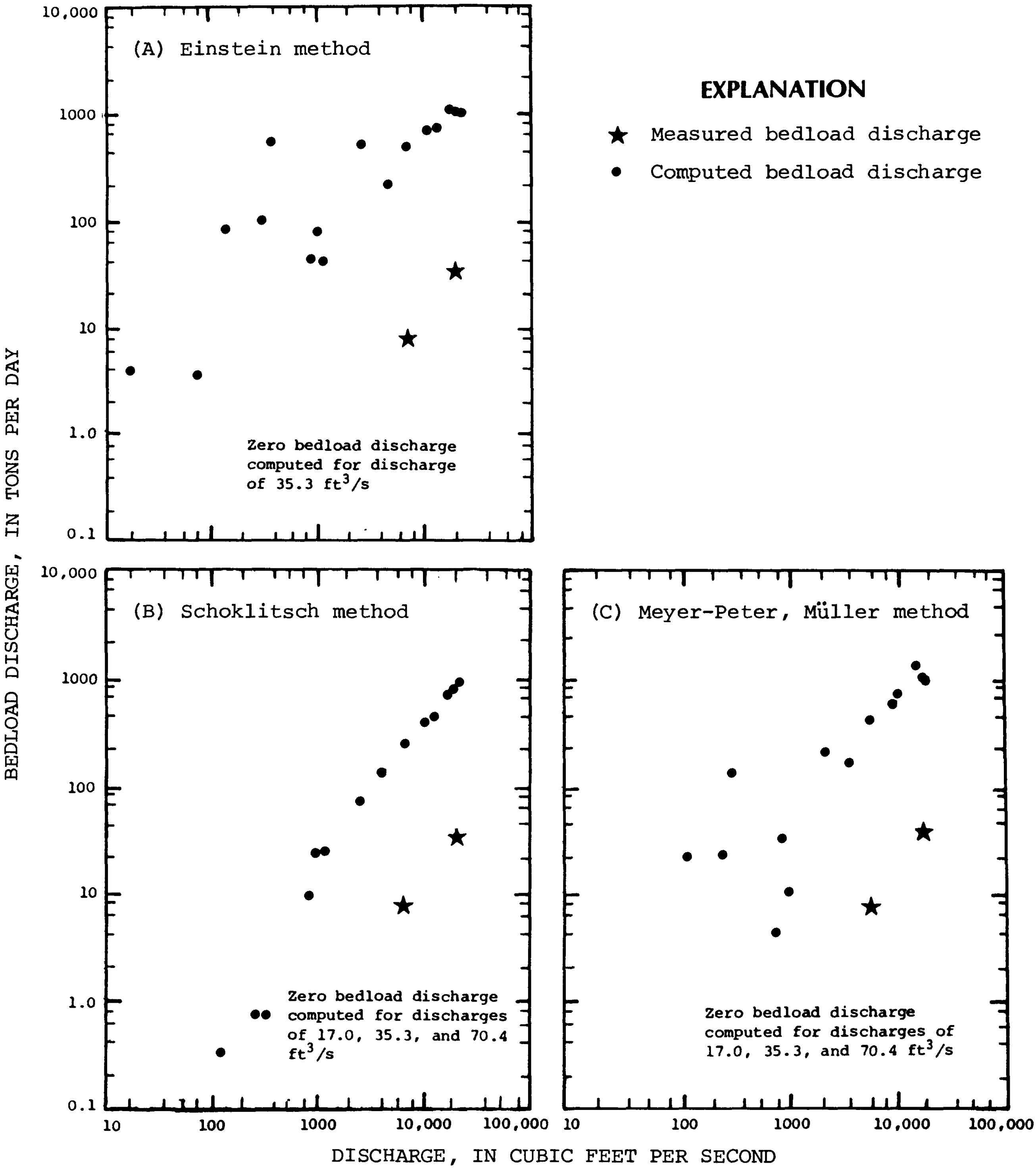

Figure 2.--Relation between discharge and measured and computed bedload discharge, Vermilion River near Leonore.

Spoon River at Seville

The Spoon River (fig. 1) drains a flat to gently undulating region with thick glacial deposits and more deeply incised valleys than other physiographic provinces in Illinois (Leighton and others, 1948). Channel slope in the vicinity of the gage at Seville (fig. 1, table 1) is 0.000129 (0.681 ft/mi). Some of the discharge measurements used to define the rating were made at a bridge about 1 mile downstream from the gage, the same location where the one bedload sample was taken. Channel geometry is very much the same at the two locations. The channel has a wide, flat bed and steep sides. At the downstream bridge, two piers located near the edges of the channel do not significantly affect flow. Plots of channel cross sections revealed bed elevation changes of up to 6 feet, suggesting considerable scour and fill. Flow velocity is distributed fairly evenly across the channel.

Two bed-material samples collected at the gage section had similar grain-size distributions (table 5). Bed material nearest the right bank was coarser than in the rest of the cross section, but the difference was not large. A bed-material sample collected on April 14, 1981, was used in computation of bedload discharge for that date by the indirect methods (table 5). For all other dates the average grain-size distribution of the two samples was used for the bed material (table 5). The median size of the average bed material is 0.56 mm, and 99 percent of the bed material is finer than 16 mm.

One bedload sample was taken at the Spoon River sampling site (tables 5-7). The sample was taken in two traverses of 10 and 12 sampling points each. Bottom time for the sampler was 30 seconds. Points from each traverse were composited into four subsamples, and the two traverses gave very similar results in both volume and lateral distribution of bedload discharge. Highest bedload discharge was measured near the left bank, where the water was deepest and had the highest velocities. The bedload sample (table 5) contained very little material less than 0.25 mm. Most of the bedload was in the 0.5 to 1.0 mm and 0.25 to 0.50 mm grain-size fractions.

One suspended-sediment sample, collected at the same time as the bedload sample (table 5), indicates that little, if any, of the suspended sediment is larger than 0.25 mm.

Each of the three indirect methods yield computed bedload discharge that plot against discharge (fig. 3) with very similar trends. The Einstein and Meyer-Peter, Müller methods compute very similar bedload discharges at high discharges, but the Einstein method yields lower bedload discharge at low discharges than does the Meyer-Peter, Müller equation. The Schoklitsch equation gives the lowest bedload discharges of the three at low discharges. Of the three, the Einstein method best estimates (table 7 and fig. 3) the one measured bedload discharge, although bedload discharge computed with that method is only about half the measured bedload discharge.

Because only one bedload sample was collected at this site, no bedload-discharge rating curve was developed from measured values. The relatively good agreement between that one sample and bedload discharge computed by the

Einstein method for the same flow condition indicates that the Einstein method could be used to estimate bedload discharge until a rating based on measured values can be developed. A curve visually positioned through the points of figure 3A is useful for these estimates. The one measured value suggests that this method would underestimate bedload discharge at this site.

Bedload and suspended sediment grain-size distributions suggest that the collection bag was not clogging and that very little of the trapped sediment was suspended load. The extensive scour and fill at the gage and bedload measuring section suggests that bedload transport is important at this site. The new bridge, with no piers to interfere with flow and sediment transport, makes it a good site for bedload sampling. The potential for taking meaningful samples at this site with the Helley-Smith sampler and for developing a bedload rating curve from measurements seems to be high.

Table 5.--Grain-size distribution of sediments, Spoon River at Seville

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
Bed material														
Oct. 23, 1980	100	97	90	83	76	67	46	9	0	--	--	--	--	--
Apr. 14, 1981	--	100	97	93	88	78	41	3	0	--	--	--	--	--
Average	100	99	94	89	83	73	44	6	0	--	--	--	--	--
Bedload														
Apr. 14, 1981	--	100	98	94	90	84	39	2	0	--	--	--	--	--
Suspended sediment														
Apr. 14, 1981	--	--	--	--	--	--	--	--	97	96	83	67	58	54

Table 6.--Data for bedload computations, Spoon River at Seville

[A slope of 0.000129 ft/ft was used for all calculations]

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload sampled									
Apr. 14, 1981	1	20.52	8,680	2,400	12.24	196	117	16.0	3.62
Do.	2	20.52	8,680	2,400	12.24	196	117	16.0	3.62
Bedload not sampled									
Sept. 21, 1977	--	12.54	3,400	1,260	7.16	176	125	18.0	2.68
Nov. 2, 1977	--	19.89	8,420	2,680	13.60	197	157	15.5	3.14
Apr. 12, 1978	--	21.01	8,860	3,350	9.03	371	158	11.0	2.65
Mar. 22, 1979	--	22.36	10,900	4,000	9.66	414	166	11.0	2.73
Nov. 27, 1979	--	4.78	140	151	1.64	92	20	5.0	.93
Mar. 17, 1980	--	10.47	2,120	792	5.82	136	108	4.0	2.68
June 4, 1980	--	27.20	20,500	5,800	12.89	450	188	21.0	3.53
Aug. 6, 1980	--	4.82	125	116	.94	123	20	27.0	1.08
Mar. 3, 1981	--	7.17	812	444	4.40	101	75	5.0	1.82
May 27, 1981	--	11.11	2,500	1,020	6.18	165	114	18.5	2.45
June 17, 1981	--	12.00	2,970	1,200	7.06	170	120	21.0	2.48
July 14, 1981	--	7.97	1,110	541	3.75	145	86	24.5	2.04
Aug. 17, 1981	--	19.45	7,260	2,090	14.03	149	151	20.0	3.47
Sept. 14, 1981	--	6.16	466	347	2.61	133	56	19.0	1.34
Dec. 3, 1981	--	6.98	648	438	3.13	140	67	1.5	1.48

Table 7.--Bed-material characteristics and measured and computed bedload discharge, Spoon River at Seville

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled									
Apr. 14, 1981	1	0.45	0.57	0.73	2.50	553	275	107	179
Do.	2					442	275	107	179
Bedload not sampled									
Sept. 21, 1977	--	0.44	0.56	0.79	4.50	--	56.5	63.1	52.3
Nov. 2, 1977							119	128	212
Apr. 12, 1978							85.7	77.3	93.0
Mar. 22, 1979							112	89.1	114
Nov. 27, 1979							0	0	0
Mar. 17, 1980							44.5	54.8	30.1
June 4, 1980							544	213	276
Aug. 6, 1980							0	0	0
Mar. 3, 1981							1.91	9.13	3.68
May 27, 1981							30.1	43.1	30.0
June 17, 1981							30.7	47.1	41.9
July 14, 1981							9.71	16.7	3.41
Aug. 17, 1981							157	163	241
Sept. 14, 1981							0	.86	0
Dec. 3, 1981							.21	3.01	0

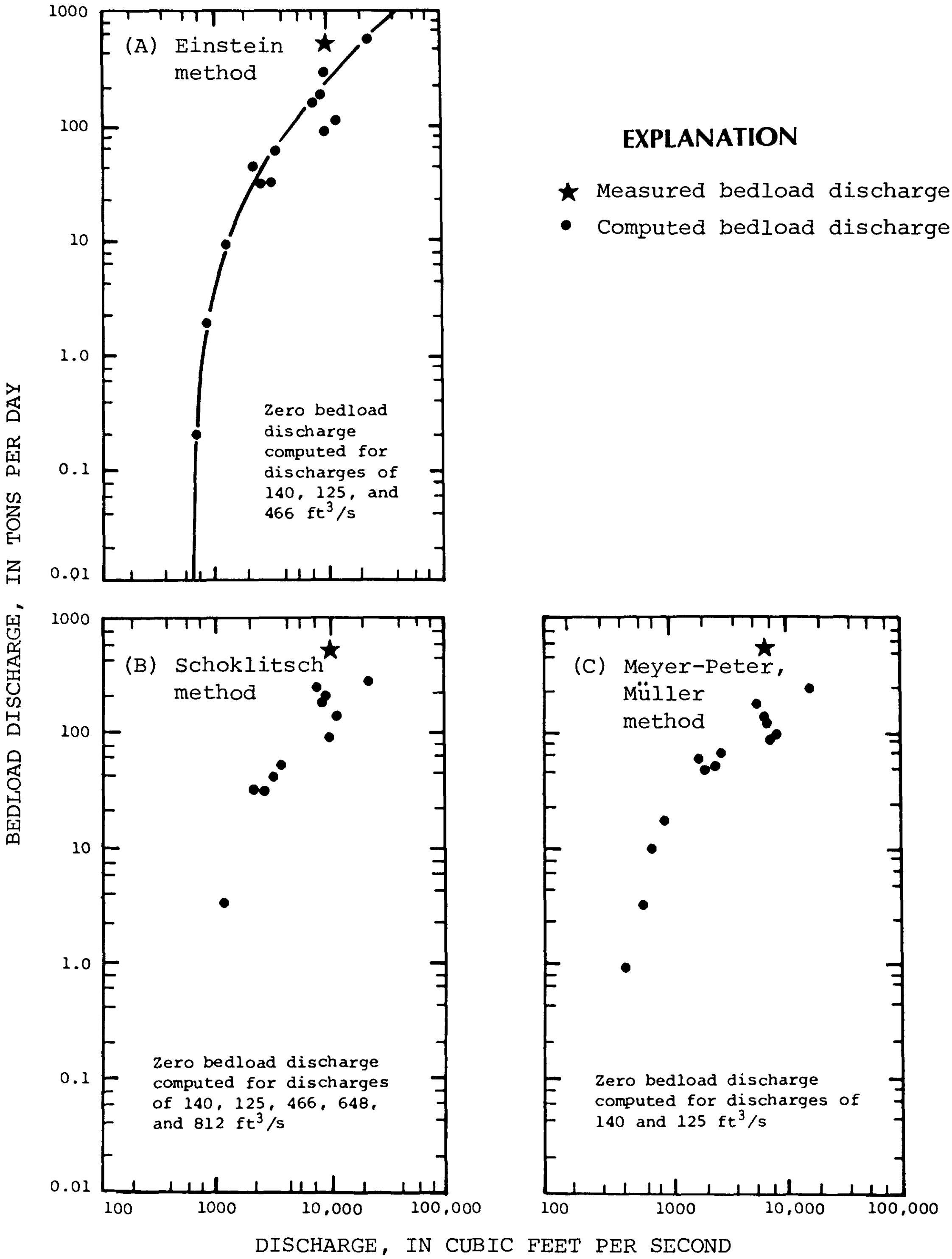

Figure 3.--Relation between discharge and measured and computed bedload discharge, Spoon River at Seville.

La Moine River at Ripley

The La Moine River (fig. 1) drains a region which is very similar to the Spoon River drainage basin. Channel slope in the vicinity of the gage at Ripley (fig. 1 and table 1) is 0.000186 (0.983 ft/mi). Channel geometry at the measuring cross section is very similar to that of the Spoon River, with steep sides and a wide, flat bed. Some discharge measurements and all bedload samples have been taken at a new bridge located about 0.1 mile above the gage. The sampling section and gage section are very much the same, except that the upstream bridge has no piers to interfere with the flow, and flow velocity is evenly distributed across the section. Bed elevation changes on the order of 3 feet are shown on plots of channel cross sections at the gage.

Two bed-material samples were collected in 1981 (table 8). Fifteen percent of the June 17, 1981, sample was less than 0.062 mm. The grain-size distribution was recomputed with the fraction less than 0.062 mm removed to make the sample more representative of bed material under bedload-transport conditions. The average grain-size distribution of the two samples, with a median size of 0.57 mm, was used for all computations (table 8). All of this bed material is less than 32 mm.

Two bedload samples were collected at this site (tables 8-10). The June 17, 1981, sample consisted of one traverse of 10 sampling points with a bottom time of 30 seconds each. The April 15, 1981, sample consisted of two traverses of 12 and 13 points and 30 seconds bottom time. For each traverse, samples from all points were composited. Grain-size distributions show that very little material less than 0.25 mm in size was trapped by the sampler (table 8) and that the highest percentage of the bedload is in the 0.25 to 0.50 mm range for the June sample and the 0.50 to 1.00 mm range for the April sample. The difference in bedload discharge measured by the two traverses of April 15, 1981, is large (68.0 and 361 tons/d).

Grain-size distributions are available for two suspended-sediment samples taken at the time of bedload sampling (table 8). These show that most of the suspended material is less than 0.25 mm.

Of the three indirect methods (table 10), the Schoklitsch equation most closely estimates one of the measured bedload discharge values (April 14, 1981), and the Meyer-Peter, Müller equation best estimates the other measurement (June 17, 1981). Bedload discharges computed with the Einstein method have a trend when plotted against discharge that best matches the trend of a line through the two measured values (fig. 4). The offset in the trend of bedload discharges computed with the Schoklitsch equation at a discharge about 7,000 ft^3/s is caused by an abrupt increase in channel width. That equation is more sensitive to channel geometry changes than are the other two methods.

Because only two measurements of bedload discharge are available, and no clear decision as to which indirect method is best is possible, no rating curve was developed for this site. Suspended sediment grain-size distributions suggest that some of the trapped sediment in the 0.25 to 0.50 mm fraction may have been in suspension, but it appears that this would be a small percent of the total. Like the Spoon River, the potential for collection of meaningful samples at this site appears good.

Table 8.--Grain-size distribution of sediments, La Moine River at Ripley

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
							Bed material							
Apr. 15, 1981	--	100	98	94	87	74	34	8	0	--	--	--	--	--
June 17, 1981	100	99	97	91	86	78	53	18	4	0	--	--	--	--
Average	100	99	97	92	86	75	43	13	2	0	--	--	--	--
							Bedload							
Apr. 15, 1981	--	100	99	96	88	76	27	2	--	--	--	--	--	--
June 17, 1981	--	--	100	98	93	83	44	0	--	--	--	--	--	--
							Suspended sediment							
Apr. 15, 1981	--	--	--	--	--	--	--	100	98	97	88	85	80	72
June 17, 1981	--	--	--	--	--	100	99	93	92	91	74	69	65	56

Table 9.--Data for bedload computations, La Moine River at Ripley

[A slope of 0.000186 ft/ft was used for all calculations]

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effec-tive width (ft)	Water temper-ature (°C)	Mean velocity (ft/s)
Bedload sampled									
Apr. 15, 1981	1	19.96	5,670	2,200	16.92	130	105	18.0	2.58
Do.	2	19.96	5,670	2,200	16.92	130	105	18.0	2.58
June 17, 1981	1	15.30	3,240	1,500	12.50	120	90	23.5	2.16
Bedload not sampled									
Sept. 19, 1977	--	12.48	1,900	906	8.55	106	89	20.4	2.10
Oct. 31, 1977	--	10.77	1,330	699	7.13	98	87	14.0	1.90
Mar. 21, 1978	--	21.68	6,830	2,520	7.61	331	110	14.0	2.71
Apr. 18, 1978	--	17.31	4,090	1,580	12.95	122	98	11.5	2.59
May 30, 1979	--	6.63	249	112	1.72	65	65	20.5	2.22
Nov. 7, 1979	--	4.39	16.8	13.5	.45	30	30	4.5	1.24
Apr. 29, 1980	--	5.73	149	100	1.52	66	66	13.8	1.49
June 5, 1980	--	24.87	13,300	3,800	10.92	348	138	19.5	3.51
Sept. 11, 1980	--	6.34	214	132	1.71	77	77	22.0	1.62
Dec. 17, 1980	--	7.64	467	512	4.97	103	82	1.5	.91
Feb. 26, 1981	--	9.09	863	626	6.59	95	84	3.0	1.38
Apr. 21, 1981	--	14.97	2,900	1,220	10.61	115	93	13.4	2.38
May 19, 1981	--	23.72	9,470	2,700	7.94	340	122	12.5	3.50
June 17, 1981	--	15.50	3,130	1,350	11.44	118	94	23.5	2.32
July 28, 1981	--	23.24	8,390	2,790	7.34	380	116	21.5	3.00

Table 10.--Bed-material characteristics and measured and computed bedload discharge, La Moine River at Ripley

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled									
Apr. 14, 1981	1					361	17.8	46.3	256
Do.	2	0.44	0.57	0.76	3.10	68.0	17.8	46.3	256
June 17, 1981	1					25.1	4.80	21.3	120
Bedload not sampled									
Sept. 19, 1977							4.26	19.0	64.9
Oct. 31, 1977							1.78	12.4	42.0
Mar. 21, 1978							101	57.0	102
Apr. 18, 1978							19.7	43.9	173
May 30, 1979							15.1	19.0	.29
Nov. 7, 1979							.08	.13	0
Apr. 29, 1980							.31	2.61	0
June 5, 1980	--	0.44	0.57	0.76	3.10	--	436	152	287
Sept. 11, 1980							1.23	4.91	0
Dec. 17, 1980							0	0	2.28
Feb. 26, 1981							0	1.63	18.6
Apr. 21, 1981							11.6	31.4	114
May 19, 1981							485	134	170
June 17, 1981							9.57	28.9	123
July 28, 1981							258	81.5	119

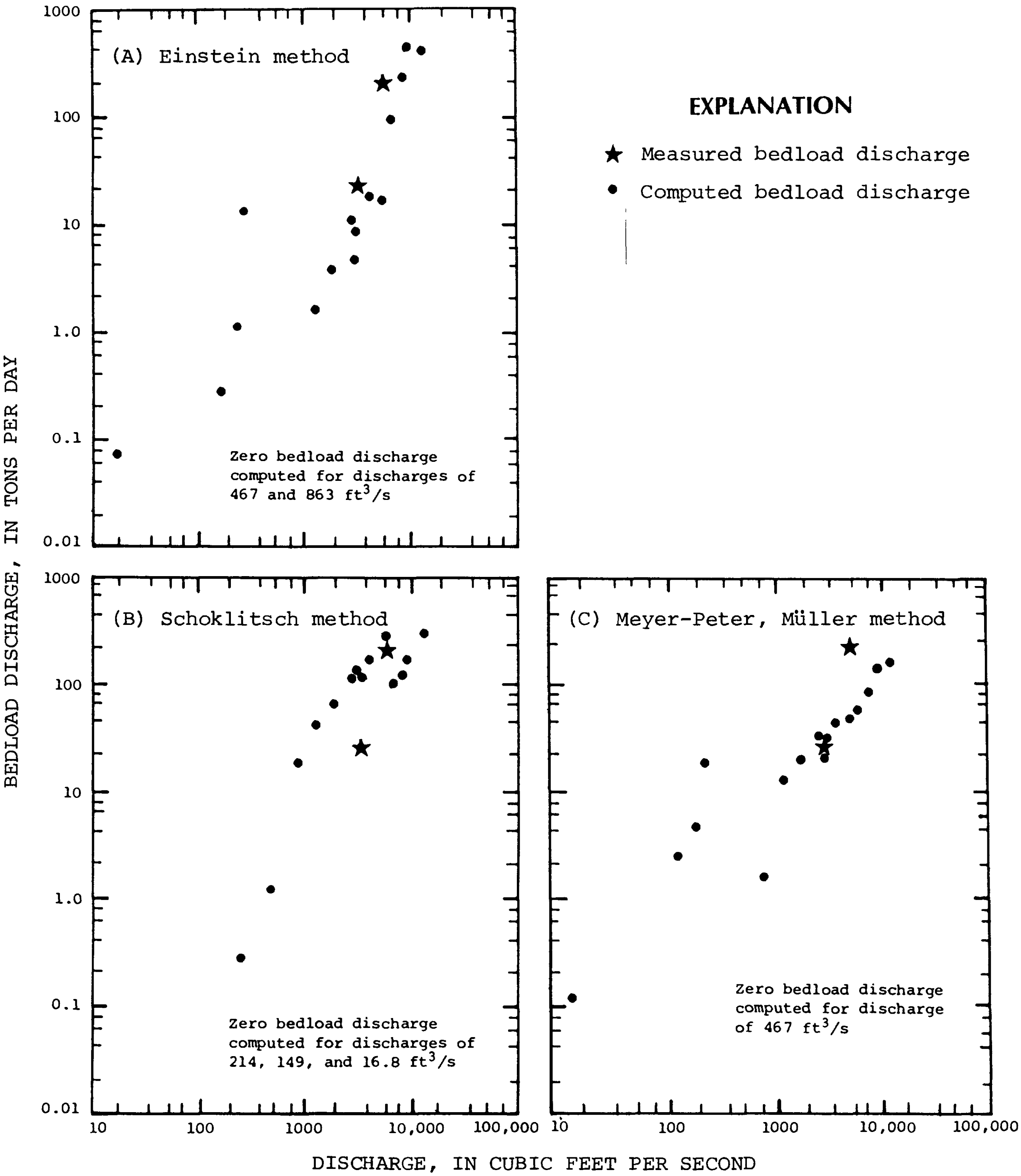

Figure 4.--Relation between discharge and measured and computed bedload discharge, La Moine River at Ripley.

Rock River Tributaries

Kishwaukee River near Perryville

The Kishwaukee River (fig. 1) drains an area characterized by rolling hills and thin glacial drift over bedrock (Leighton and others, 1948). Slope of the channel bed in the vicinity of the gage near Perryville (fig. 1, table 1) is 0.000375 (1.98 ft/mi). At the gage the channel is wide and shallow. Three piers affect flow and bed configuration within about 10 feet of the piers. Flow velocity is lowest near these piers, otherwise flow velocity is fairly evenly distributed across the section. Plots of channel cross sections at the gage indicate that scour and fill is on the order of 2 to 3 feet.

Bed material was sampled four times at this section (table 11). The four samples are very much the same and show that bed materials at this section are coarse relative to those of most of the other streams. Median grain size of the average grain-size distribution of the four samples is 0.76 mm. The sample collected on June 15, 1981, was used to compute bedload discharge for that date. For all other computations, the average grain-size distribution of the four samples was used. Almost all of the bed material is finer than 16 mm (table 11).

One bedload sample has been collected (tables 11-13). The sample consisted of one traverse of nine sampling points, each with a bottom time of 60 seconds. None of the trapped sediment was finer than the 0.25 mm mesh of the collection bag. Most of the collected sediment was in the 0.25 to 0.50 mm size fraction (table 11). Sediment from all nine points was composited.

A sample of suspended sediment taken at the time of bedload sampling (table 11) contains very fine sediment (63 percent clay size).

All three indirect methods compute bedload discharges close to the one measured value (tables 12 and 13, fig. 5). Bedload discharge computed with the Einstein method is almost equal to the measured value and the bedload discharge computed with the Meyer-Peter, Müller equation for the same hydraulic condition is very close to the measured bedload discharge. When plotted against discharge (fig. 5), the trends of values computed by all three methods are similar. As in the other streams, bedload discharge computed with the Einstein and Meyer-Peter, Müller methods are very similar at high discharges (above 3,000 ft^3/s), but at low discharges the Einstein method yields lower bedload discharges than the Meyer-Peter, Müller equation.

Because only one measured bedload discharge is available, no bedload-discharge rating curve was developed from measured values for this site. The excellent agreement between the one measured bedload discharge and values computed by the indirect methods is encouraging, but more measured bedload discharges are needed to verify the agreement. Until additional measurements are made and a rating developed, either the Einstein or Meyer-Peter, Müller methods could be used to estimate bedload discharge. A curve drawn through the points of figure 5A is useful for these estimates. Although bed material is generally finer than that recommended for use of the Helley-Smith sampler, samples collected appear to be meaningful. Collection bag clogging does not seem to be significant and sediment carried in suspension is very fine grained.

Table 11.--Grain-size distribution of sediments, Kishwaukee River near Perryville

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
Bed material														
July 31, 1980	100	96	87	78	70	62	42	23	12	9	--	--	--	--
Sept. 9, 1980	--	100	90	85	79	73	54	32	25	22	--	--	--	--
June 1, 1981	--	100	97	87	80	43	22	6	1	0	--	--	--	--
June 15, 1981	--	100	91	84	69	50	40	7	1	0	--	--	--	--
Average	100	99	91	83	74	57	39	17	10	8	--	--	--	--
Bedload														
June 15, 1981	--	100	98	93	88	82	71	18	--	--	--	--	--	--
Suspended sediment														
June 15, 1981	--	--	--	--	--	--	--	--	94	--	81	--	63	47

Table 12.--Data for bedload computations, Kishwaukee River near Perryville

[A slope of 0.000375 ft/ft was used for all calculations]

Date	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload sampled								
June 15, 1981	9.38	3,120	1,142	5.12	223	174	23.0	2.72
Bedload not sampled								
Apr. 4, 1978	7.34	1,290	704	3.30	213	128	8.0	1.84
May 10, 1978	6.49	693	344	2.21	156	98	12.0	2.01
July 3, 1978	18.25	12,900	3,520	14.61	241	216	22.0	3.67
Sept. 19, 1978	8.88	2,440	1,060	4.88	217	159	21.0	2.30
Mar. 8, 1979	10.20	3,920	1,390	6.07	229	182	.5	2.82
Mar. 20, 1979	20.16	16,200	3,840	16.13	238	216	3.5	4.21
June 25, 1979	6.15	466	287	1.86	154	78	20.5	1.62
Aug. 19, 1979	8.42	2,180	932	4.18	223	154	22.0	2.34
Oct. 1, 1979	6.85	1,010	410	2.65	155	117	16.5	2.46
Nov. 29, 1979	6.27	611	318	2.07	154	92	2.0	1.92
Mar. 17, 1980	7.14	1,340	677	3.15	215	130	1.0	1.98
Apr. 23, 1980	6.76	941	395	2.55	155	113	16.5	2.38
June 7, 1980	9.73	3,280	1,205	5.60	215	174	24.5	2.72
July 8, 1980	5.55	302	216	1.43	151	60	26.5	1.40
Mar. 19, 1981	5.95	514	281	1.84	153	84	4.0	1.83

Table 13.--Bed-material characteristics and measured and computed bedload discharge, Kishwaukee River near Perryville

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
	d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
				Bedload sampled				
June 15, 1981	0.44	1.00	1.75	7.00	161	167	141	321
				Bedload not sampled				
May 10, 1978						19.6	36.0	14.0
July 3, 1978						417	502	1,308
Sept. 19, 1978						43.2	93.3	125
Mar. 8, 1979						137	204	269
Mar. 20, 1979						712	726	1,718
June 25, 1979						3.75	11.3	3.23
Aug. 19, 1979						54.9	95.6	98.1
Oct. 1, 1979	0.45	0.76	1.38	7.40	--	74.2	85.8	36.4
Nov. 29, 1979						13.0	28.4	9.99
Mar. 17, 1980						15.9	45.2	36.8
Apr. 23, 1980						61.1	74.5	30.2
June 7, 1980						123	173	218
July 8, 1980						.88	3.63	.73
Mar. 19, 1981						9.64	21.4	5.47
Apr. 4, 1981						8.31	33.3	34.0

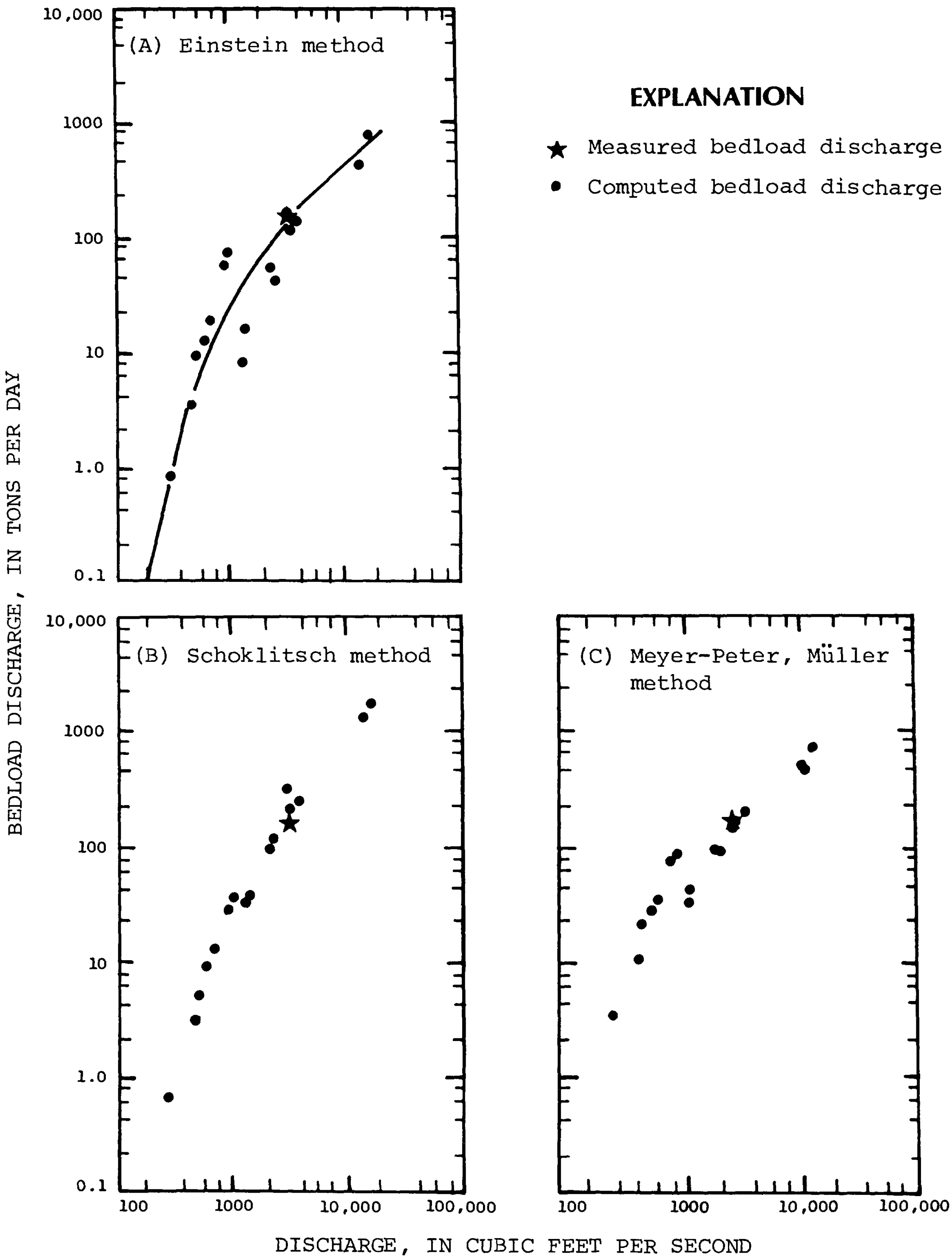

Figure 5.--Relation between discharge and measured and computed bedload discharge, Kishwaukee River near Perryville.

Green River near Geneseo

The Green River (fig. 1) flows through a poorly drained plain covered with glacial outwash deposits and sand ridges (Leighton and others, 1948). Channel slope in the vicinity of the gage near Geneseo (fig. 1, table 1) is 0.000237 (1.25 ft/mi). The Green River is a channelized stream with very high, steep banks of the natural surficial materials. The high banks confine the flow even at very high stages, width changes very little with stage, and flow velocities are generally high. The channel at the gage is V-shaped. A pier located at the deepest point of the channel and another near the left bank locally affect flow velocity. Channel cross sections plotted from discharge measurement notes made in 1979-81, show that scour and fill is on the order of 2 to 6 feet in the area between the two piers.

Bed material at this site is defined by nine samples collected over 4 years of bedload sampling (table 14). Coarsest sediment was found in the deepest portion of the channel. Bed material remained fairly constant in grain-size distribution over the 4 years of sampling, with the median size ranging from 0.26 to 0.37 mm. Most bed material is finer than 8 mm. Bed-material samples taken at the time of bedload sampling (table 14) were used for computations by indirect methods for those dates. For computations for other dates, average bed material grain-size distribution for the year was computed and used (table 14). For computations for 1977, average 1978 bed material was used.

This is one of the earliest established bedload sampling sites, and seven samples have been collected (tables 14-16). Each of the two 1978 samples consisted of one traverse with 21 sampling points and 60 and 120 seconds bottom times. Three samples of two traverses each were collected in 1979, with each traverse consisting of 15 to 22 sampling points, each with 60 second bottom times. The sample collected on March 19, 1979, was taken about 2½ hours after the peak discharge of the 1979 water year, which was very close to the peak discharge of record. Only one sample was collected in 1980, and that consisted of one traverse of 22 sampling points, each with 120 seconds on the bottom. In 1981, two samples of one traverse each were collected. One traverse consisted of 10 sampling points and the other of 9. All points were sampled with a bottom time of 60 seconds. Sediments from the sampling points in each traverse were composited into from one to nine subsamples.

Grain-size distributions of sediment collected by the bedload sampler (table 14) indicate that very large amounts of material finer than the mesh size of the bag were trapped. This suggests that the collection bag may have been clogging. The dominant size of material trapped is 0.25 to 0.50 mm. Grain-size distributions of suspended sediment (table 14) show that at extremely high flows such as that of March 19, 1979, as much as 20 percent of the sediment in suspension above 3 inches from the bed may be coarser than 0.25 mm, but that at lower flows the amount larger than 0.25 mm is probably not significant. However, it may be that the size distribution of bedload was affected by the coarse suspended sediment--that is, bedload particles smaller than 0.25 mm actually entered the sampler as suspended sediment.

Because of the simple channel geometry at this section, bedload discharges computed with all three of the indirect methods show well-defined trends when plotted against discharge (fig. 6). Measured bedload discharges (fig. 6A) show a less well defined trend. Bedload discharges computed with the Einstein and Meyer-Peter, Müller methods agree reasonably well with measured bedload discharges at the highest discharges (table 16).

No bedload-discharge rating curve was developed for this site because it was not possible to determine the effect of possible collection bag clogging nor of suspended sediment on the bedload sample collected. Bag clogging probably interferes with both hydraulic and sampling efficiency of the sampler. Bed-material samples show that this site does not meet Geological Survey guidelines for use of the sampler. Until the effects of clogging can be documented, and the part of measured bedload that is actually suspended load can be evaluated, use of the Helley-Smith sampler at this site should be done only for investigation of the clogging problem. Any additional bedload sampling should be accompanied by detailed suspended-sediment sampling.

Table 14.--Grain-size distribution of sediments, Green River near Geneseo

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
						Bed material								
May 5, 1978	--	--	--	100	98	97	97	30	1	0	--	--	--	--
Sept. 15, 1978	--	--	100	99	99	98	93	15	1	0	--	--	--	--
Mar. 19, 1979	100	97	95	93	91	89	87	22	1	0	--	--	--	--
Apr. 13, 1979	--	--	--	--	100	99	99	40	1	0	--	--	--	--
Aug. 21, 1979	--	--	100	99	99	99	98	39	1	0	--	--	--	--
June 5, 1980	--	100	99	97	96	95	90	34	3	1	--	--	--	--
Sept. 3, 1980	--	100	95	93	88	82	69	22	2	1	--	--	--	--
Mar. 18, 1981	100	99	95	92	92	91	80	29	2	1	--	--	--	--
June 19, 1981	--	--	--	100	99	98	96	42	3	1	--	--	--	--
Average 1978	--	--	--	100	99	99	95	22	1	0	--	--	--	--
Average 1979	100	99	99	97	97	96	94	33	1	0	--	--	--	--
Average 1980	--	100	97	95	92	88	79	28	2	1	--	--	--	--
Average 1981	100	99	98	96	95	94	88	35	2	1	--	--	--	--
						Bedload								
Sept. 15, 1978	--	--	--	100	99	98	97	54	--	--	--	--	--	--
Mar. 19, 1979	100	91	91	90	89	88	86	32	--	--	--	--	--	--
Apr. 13, 1979	--	--	100	99	98	97	94	25	--	--	--	--	--	--
Aug. 21, 1979	--	100	99	99	97	96	90	20	--	--	--	--	--	--
Aug. 19, 1980	--	--	--	--	100	99	96	39	--	--	--	--	--	--
Apr. 14, 1981	--	100	98	97	96	95	89	36	--	--	--	--	--	--
June 13, 1981	--	--	100	99	99	98	94	0	--	--	--	--	--	--
						Suspended sediment								
Sept. 15, 1978	--	--	--	--	--	--	100	98	93	90	71	55	49	42
Mar. 19, 1979	--	--	--	--	--	--	100	80	--	71	48	36	33	30
Apr. 13, 1979	--	--	--	--	--	--	100	98	83	78	53	45	42	39
Aug. 21, 1979	--	--	--	--	--	100	99	70	40	37	29	25	24	21

Table 15.--Data for bedload computations, Green River near Geneseo

[A slope of 0.000237 ft/ft was used for all calculations]

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload sampled									
Sept. 15, 1978	1	3.71	803	448	3.73	120	82	22.0	1.78
Do.	2	3.65	780	440	3.67	120	82	22.0	1.78
Mar. 19, 1979	1	15.88	10,400	2,300	16.67	138	120	6.0	4.52
Do.	2	15.88	10,400	2,300	16.67	138	120	6.0	4.52
Apr. 13, 1979	1	9.50	3,700	1,210	8.64	140	100	11.0	3.09
Do.	2	9.41	3,640	1,170	8.36	140	100	11.0	3.09
Aug. 21, 1979	1	13.04	6,950	1,950	14.44	135	113	20.5	3.91
Do.	2	12.93	6,830	1,935	14.33	135	113	20.5	3.91
Aug. 19, 1980	1	6.68	2,130	830	6.80	122	111	22.0	2.57
Apr. 14, 1981	1	12.60	6,480	1,690	12.61	134	116	13.5	3.83
June 13, 1981	1	7.69	2,620	945	7.16	132	88	24.0	2.77
Bedload not sampled									
Oct. 13, 1977	--	4.00	907	474	4.16	114	80	16.0	1.91
Nov. 11, 1977	--	5.30	1,470	640	5.52	116	86	9.5	2.30
May 22, 1978	--	5.03	1,380	545	4.58	119	85	15.0	2.53
July 5, 1978	--	6.14	1,790	750	6.00	125	89	28.0	2.39
July 11, 1978	--	3.41	701	325	3.01	108	76	24.0	2.16
Aug. 31, 1978	--	1.66	179	212	2.06	103	58	24.0	.84
Mar. 20, 1979	--	13.44	8,970	1,920	14.33	134	110	4.0	4.68
Apr. 16, 1979	--	6.29	1,990	806	6.45	125	90	13.0	2.47
Nov. 19, 1979	--	1.79	189	167	1.40	119	59	13.5	1.13
Dec. 28, 1979	--	4.48	1,120	550	4.51	122	82	2.0	2.03
Apr. 25, 1980	--	3.48	820	443	3.75	118	78	19.5	1.85
Oct. 8, 1980	--	2.55	400	275	2.27	121	69	13.5	1.45
Apr. 28, 1981	--	4.12	1,050	517	4.54	114	82	18.0	2.03
June 10, 1981	--	3.04	644	350	2.94	119	75	23.0	1.83
Aug. 15, 1981	--	13.76	7,700	1,910	14.47	132	108	23.5	3.88

Table 16.--Bed-material characteristics and measured and computed bedload discharge, Green River near Geneseo

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled									
Sept. 15, 1978	1	0.30	0.33	0.36	0.46	37.0	4.27	12.1	16.4
Do.	2					27.4	4.27	12.1	16.4
Mar. 19, 1979	1	.28	.32	.37	1.50	157	307	237	928
Do.	2					70.0	307	237	928
Apr. 13, 1979	1	.25	.26	.28	.34	34.9	106	83.3	260
Do.	2					37.4	106	83.3	260
Aug. 21, 1979	1	.20	.27	.30	.39	189	297	180	673
Do.	2					170	297	180	673
Aug. 19, 1980	1	.27	.32	.37	1.45	13.4	44.3	49.5	150
Apr. 14, 1981	1	.25	.29	.33	.54	374	207	200	597
June 13, 1981	1	.24	.26	.29	.38	73.2	68.9	57.6	174

	Bedload not sampled								
Oct. 13, 1977							8.63	16.5	31.7
Nov. 11, 1977							24.6	32.3	81.7
May 22, 1978	--	0.27	0.29	0.30	0.39	--	47.6	40.3	69.9
July 5, 1978							30.0	36.8	102
July 11, 1978							20.0	20.6	17.2
Aug. 13, 1978							0	.018	0
Mar. 20, 1979							352	294	748
Apr. 16, 1979	--	.25	.28	.30	.42	--	39.0	43.4	136
Nov. 19, 1979							.21	1.32	0
Dec. 28, 1979	--	.25	.32	.37	1.45	--	15.8	22.8	48.9
Apr. 25, 1980	--	.27	.32	.37	1.45	--	7.50	18.1	20.8
Oct. 8, 1980							1.74	8.01	1.76
Apr. 28, 1981							13.1	22.2	46.9
June 10, 1981	--	.25	.29	.33	.54	--	9.15	13.1	10.8
Aug. 15, 1981							236	193	682

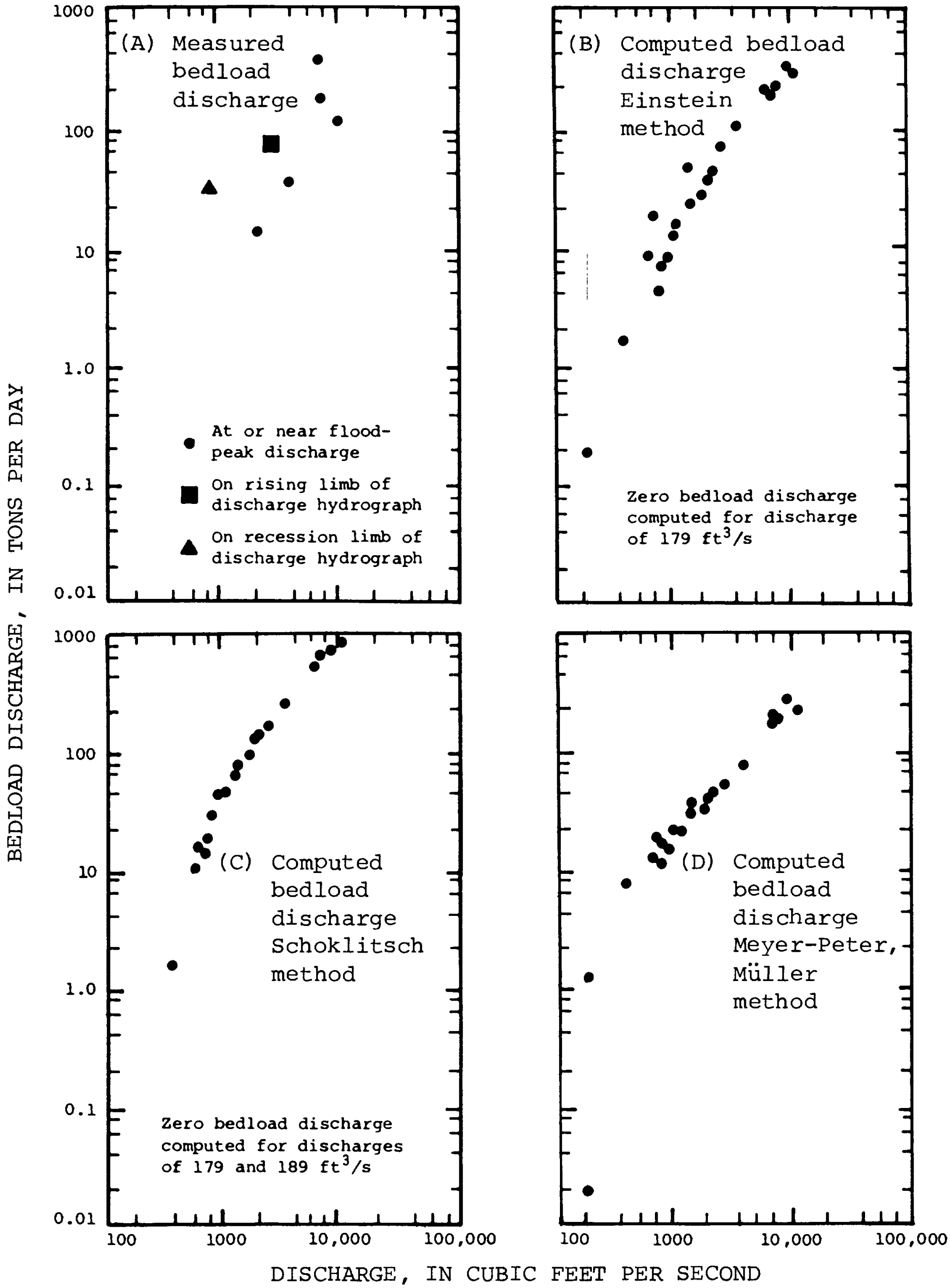

Figure 6.--Relation between discharge and measured and computed bedload discharge, Green River near Geneseo.

Mississippi River Tributaries

Rock River near Joslin

The Rock River flows through both areas of rolling hills with thin glacial drift and of more poorly drained plain with outwash deposits and sand ridges (Leighton and others, 1948) above the gage near Joslin (fig. 1, table 1). Low-head dams have been constructed at Rockford, at Dixon, and at Rock Falls. The gage near Joslin is 46.7 miles below the lower dam. Channel slope in the vicinity of the gage determined from topographic maps is 0.000136 (0.72 ft/mi). This is at about the midpoint of the range of estimated water surface slopes (table 18). Seven piers support the bridge across the channel at the gage, and five of these affect the flow. Channel bed and flow-velocity distribution were relatively stable over the period of bedload sampling. Plots of channel cross sections made from discharge measurements show that moderate scour and fill occurs at this site (2 to 3 feet).

Seven samples of bed material were collected from 1978 through 1981 (table 17). One of these, collected on March 11, 1981, included separate analyses for each of four points across the channel. No significant differences in grain-size distribution across the channel were found from those samples. The median size of the bed material ranged from 0.42 to 0.92 mm, and a trend toward coarser bed material from 1978 to 1981 is shown by the samples. Because of the trend, average bed material for each year of sampling was computed and used for computations with the indirect methods for dates on which no bed-material sample was collected (table 17). All bed material is finer than 16 mm.

This is one of the first established bedload-sampling sites and, with 10 samples, is the most frequently sampled (tables 17-19). Two samples were collected in 1978. Each sample consists of two traverses of 20 or 21 sampling points each and bottom time of 120 seconds. The sample of July 5, 1978, was collected just before the peak discharge of that water year. Three samples were collected in 1979. Two (March 23 and April 17, 1979) consisted of two traverses of 20 to 22 sampling points each with bottom time of 60 seconds. The March 23, 1979, sample was taken at about the peak discharge for the 1979 water year, which was not far below the peak discharge of record (46,200 ft^3/s). A sample collected on August 21, 1979, consisted of one traverse of 20 points and 60 seconds bottom time. The three samples taken in 1980 each have only one traverse, one with with 3 sampling points, one with 20, and the last with 10. Bottom times were 300, 120, and 180 seconds. Two samples of one traverse each were collected in 1981. Each had 10 sampling points and one had a bottom time of 90 seconds, the other of 180 seconds.

Samples at this site are composed of from 4 to 11 subsamples each. Subsamples of the March 23, 1979, sample indicate that bedload discharge was fairly even across the channel between the five central piers. Zones with measured bedload discharge two or three times that of other zones were found. The position of these zones of higher bedload discharge changed from sample to sample.

Grain-size distribution of bedload samples (table 17) shows that the largest amount trapped is in the 0.25 to 0.50 mm fraction. The amount of material less than 0.25 mm trapped by the sampler is often significant (up to 15 percent) but less than that found in the Green River samples.

Available suspended-sediment samples (table 17) show that suspended sediment here is very fine (greater than 90 percent less than 0.062 mm).

A line was fitted to the measured values of figure 7A using least-squares linear regression on the logarithms of bedload-discharge and water-discharge values. The equation of the line is

$$Q_b = 6.55 \times 10^{-7} Q^{2.0} . \qquad (8)$$

The correlation coefficient is 0.91. Equation 8 defines an acceptable bedload rating curve for this site.

Bedload discharges computed with the Schoklitsch equation agree best with measured values. However, there seems to be little value in using any of the indirect methods to modify or extend equation 8, because the equation is well defined and based on values which cover a wide range of discharges. Bedload and suspended-sediment samples suggest that the collection bag may be clogging at this site, but that very little of the sediment 0.25 mm and larger trapped by the sampler was carried in suspension. The reasons for, and effects of, the relatively large amount of sediment less than 0.25 mm collected by the sampler should be investigated more thoroughly before equation 8 is considered a fully verified bedload-discharge rating curve.

Table 17.--Grain-size distribution of sediments, Rock River near Joslin

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
Bed material														
May 16, 1978	--	100	99	97	96	92	64	5	0	--	--	--	--	--
July 5, 1978	--	100	90	88	85	80	65	7	1	0	--	--	--	--
Mar. 23, 1979	--	100	98	95	88	77	53	9	0	--	--	--	--	--
May 28, 1980	--	100	91	80	72	63	43	14	2	1	--	--	--	--
Sept. 3, 1980	--	100	89	80	73	66	32	3	1	0	--	--	--	--
Mar. 11, 1981	--	100	99	97	94	58	6	0	--	--	--	--	--	--
June 23, 1981	--	100	98	95	91	82	57	12	1	0	--	--	--	--
Average 1978	--	100	94	92	90	86	64	6	0	--	--	--	--	--
Average 1979	--	100	98	95	88	77	53	9	0	--	--	--	--	--
Average 1980	--	100	90	80	72	65	37	8	1	0	--	--	--	--
Bedload														
May 16, 1978	--	--	100	98	96	90	69	5	--	--	--	--	--	--
July 5, 1978	--	100	98	96	93	87	68	6	--	--	--	--	--	--
Mar. 23, 1979	--	100	99	98	96	90	67	9	--	--	--	--	--	--
Apr. 17, 1979	--	--	100	98	97	91	54	12	--	--	--	--	--	--
Aug. 21, 1979	--	100	99	98	92	83	59	5	--	--	--	--	--	--
May 28, 1980	--	--	100	99	98	96	72	11	--	--	--	--	--	--
June 20, 1980	--	--	--	100	99	98	89	15	--	--	--	--	--	--
Sept. 11, 1980	--	100	99	98	96	94	84	14	--	--	--	--	--	--
Apr. 14, 1981	--	--	--	100	99	98	69	7	--	--	--	--	--	--
Aug. 17, 1981	--	--	100	99	97	89	44	0	--	--	--	--	--	--
Suspended sediment														
May 16, 1978	--	--	--	--	--	--	--	--	--	93	--	--	--	--
Apr. 17, 1979	--	--	--	--	--	--	--	--	--	93	--	--	--	--
Apr. 14, 1981	--	--	--	--	--	--	--	--	--	97	--	--	--	--

Table 18.--Data for bedload computations, Rock River near Joslin

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Slope (ft/ft)	Mean velocity (ft/s)
Bedload sampled										
May 16, 1978	1	12.26	18,960	7,810	7.50	1,042	594	13.0	0.000167	2.38
Do.	2	12.26	18,960	7,810	7.50	1,042	594	13.0	.000167	2.38
July 5, 1978	1	15.48	31,060	11,100	10.48	1,059	595	25.0	.000147	2.62
Do.	2	15.50	31,140	11,100	10.48	1,059	595	25.0	.000147	2.88
Mar. 23, 1979	1	17.74	41,250	14,300	13.23	1,081	595	6.5	.000146	2.88
Do.	2	17.74	41,250	14,300	13.23	1,081	595	6.5	.000146	2.88
Apr. 17, 1979	1	13.56	23,510	9,040	9.62	1,040	675	22.0	.000135	2.45
Do.	2	13.52	23,360	9,040	9.62	1,040	675	22.0	.000135	2.45
Aug. 21, 1979	1	11.35	16,500	6,830	9.97	685	594	26.0	.000117	2.49
May 28, 1980	1	5.28	4,355	2,840	4.54	626	565	24.5	.000102	1.65
June 20, 1980	1	7.38	7,610	5,300	5.82	662	594	24.0	.000133	2.06
Sept. 11, 1980	1	9.49	12,200	5,600	7.45	700	605	16.8	.000131	2.32
Apr. 14, 1981	1	8.85	10,900	4,750	6.85	693	588	15.0	.000126	2.29
Aug. 17, 1981	1	7.12	7,425	3,760	5.62	669	588	24.0	.000121	1.95

				Bedload not sampled						
Sept. 29, 1977	--	4.68	3,520	1,960	3.16	620	565	17.0	0.000114	1.80
Mar. 8, 1978	--	6.38	2,380	1,930	3.42	565	565	0	.000119	1.23
Oct. 26, 1978	--	5.66	4,940	2,620	4.13	635	565	11.0	.000117	1.89
Nov. 3, 1978	--	9.32	12,400	5,000	7.06	708	605	14.0	.000128	2.49
June 13, 1978	--	6.60	6,430	3,090	4.50	687	565	24.0	.000120	2.08
Sept. 26, 1978	--	8.28	9,450	4,500	6.62	680	605	18.0	.000125	2.10
Apr. 11, 1979	--	13.82	25,000	10,200	9.62	1,060	675	5.0	.000142	2.45
June 20, 1979	--	6.97	6,910	3,930	5.96	690	565	26.0	.000121	1.75
Aug. 13, 1979	--	7.60	8,910	4,320	6.49	666	565	23.0	.000123	2.06
Nov. 20, 1980	--	4.97	3,780	2,470	3.98	620	565	7.0	.000114	1.53
Feb. 28, 1980	--	9.06	6,880	3,260	5.26	620	590	0	.000123	2.11
Mar. 21, 1980	--	7.84	8,830	4,660	6.87	678	590	1.0	.000123	1.89
Mar. 28, 1980	--	6.42	5,850	3,690	5.68	650	565	5.1	.000119	1.59
Apr. 11, 1980	--	8.44	10,400	5,430	7.97	681	605	7.0	.000125	1.92
Oct. 8, 1980	--	7.91	9,000	4,255	6.30	675	605	14.0	.000123	2.12

Table 19.--Bed-material characteristics and measured and computed bedload discharge, Rock River near Joslin

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled									
May 16, 1978	1	0.35	0.43	0.51	0.91	216	223	331	569
Do.	2					800	223	331	569
July 5, 1978	1	.35	.42	.52	8.50	391	388	462	757
Do.	2					968	388	462	757
Mar. 23, 1979	1					1,433	646	306	1,005
Do.	2					2,318	646	306	1,005
Apr. 17, 1979	1	.38	.48	.70	2.25	213	135	199	432
Do.	2					224	135	199	432
Aug. 21, 1979	1					610	112	170	308
May 28, 1980	1	.42	.62	1.15	7.60	11.9	2.14	43.7	0
June 20, 1980	1	.48	.65	1.02	8.30	39.8	19.6	155	66.1
Sept. 11, 1980	1	.55	.86	1.45	8.60	61.7	74.5	187	184
Apr. 14, 1981	1	.80	.92	1.07	1.62	303	6.11	75.9	65.4
Aug. 17, 1981	1	.76	.92	1.15	3.50	63.1	2.27	17.1	17.6

Bedload not sampled									
Sept. 29, 1977							20.7	63.2	0
Mar. 8, 1978							0	44.6	0
Oct. 26, 1978	--	0.36	0.42	0.51	1.70	--	25.7	86.3	16.8
Nov. 3, 1978							147	263	287
June 13, 1978							58.6	120	51.7
Sept. 26, 1978							46.9	150	172
Apr. 11, 1979							182	322	520
June 20, 1979	--	.38	.48	.70	2.25	--	7.13	39.9	86.8
Aug. 13, 1979							43.4	83.8	107
Nov. 20, 1979							2.71	29.7	0
Feb. 28, 1980							31.1	165	53.0
Mar. 21, 1980	--	.48	.65	1.02	8.30	--	9.66	104	69.1
Mar. 28, 1980							.78	40.4	21.4
Apr. 11, 1980							9.78	115	116
Oct. 8, 1980	--	.36	.42	.51	1.70	--	32.0	169	76.2

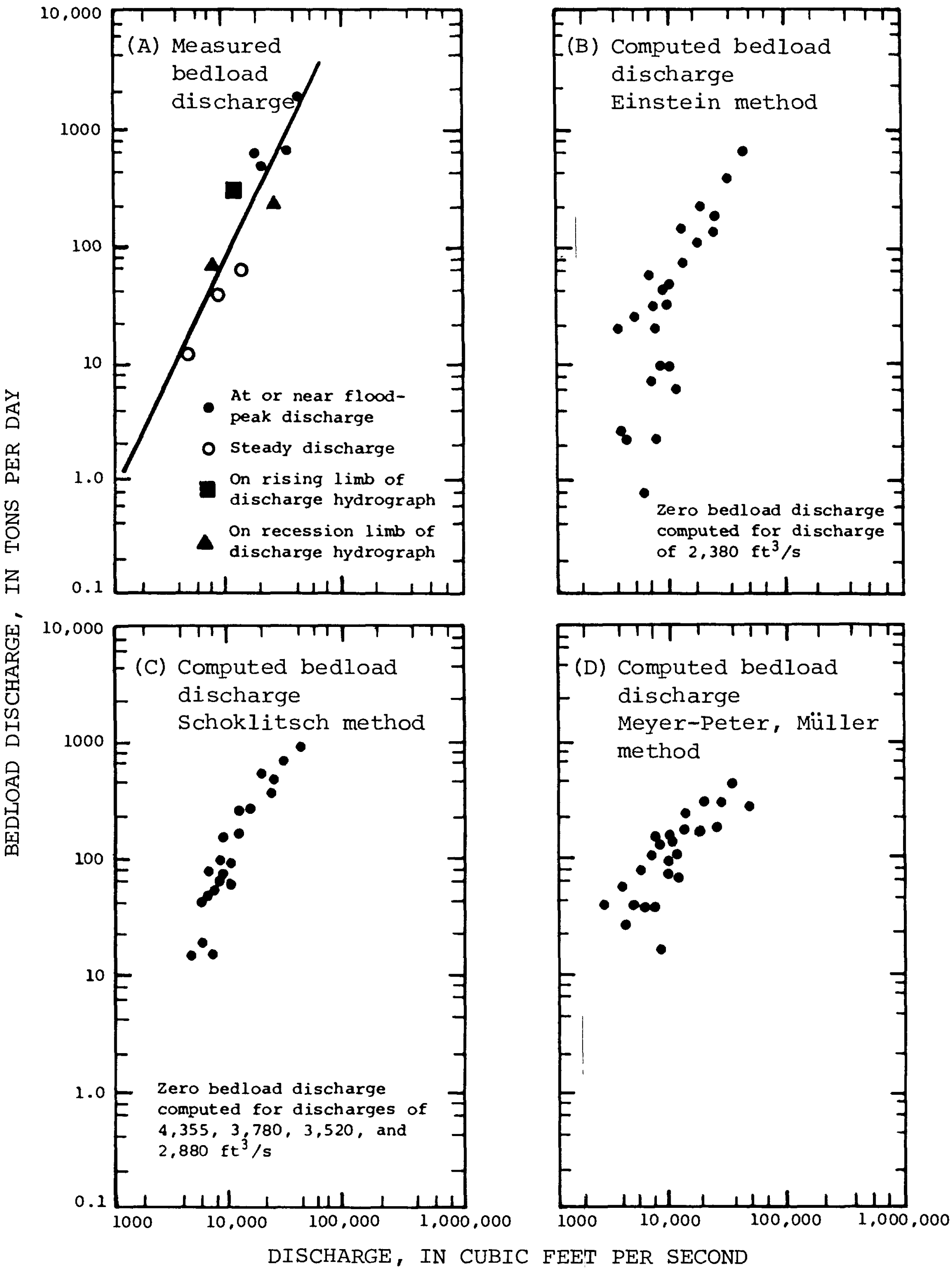

Figure 7.--Relation between discharge and measured and computed bedload discharge, Rock River near Joslin.

Edwards River near New Boston

The Edwards River (fig. 1) flows through flat to gently undulating countryside with thick glacial deposits (Leighton and others, 1948). Channel slope in the vicinity of the gage near New Boston (fig. 1, table 1) is 0.000453 (2.39 ft/mi). The channel cross section at the gage has an asymmetrical "V" shape with two piers which affect the flow. Flow velocity is much lower between the banks and piers than between the piers. High banks confine the flow at high stages. At high stages, backwater from the Mississippi River is observed at the gage. Plots of channel cross sections from 1979 to 1981 indicate that less scour and fill occurs here than other streams studied (1 to 2 feet).

Eleven samples of bed material were collected from 1979 through 1981 (table 20). Lateral variation in bed material could not be described because samples were composited into one bag for analysis. Bed material is less than 16 mm in size. Bed material samples taken in 1981 are coarser than those taken in previous years. The median size for samples from 1979 and 1980 are 0.47 and 0.48 mm, respectively, whereas that for 1981 is 0.63 mm. Yearly average grain-size distribution of bed material was computed and used for computations with indirect methods (table 20). For all computations for dates before 1979, the 1979 average bed material was used. A bed-material sample taken on June 2, 1980, was used for computations for that date (table 20).

Only one bedload sample has been collected at this site (tables 20-22), and that sample consisted of one traverse of four sampling points with 30 seconds bottom time each. Sediment from all sampling points was composited into one bag. Most sediment collected was in the 0.25 to 0.50 mm size fraction. A small amount of sediment finer than 0.25 mm was also trapped by the bedload sampler (table 20).

The grain-size distribution of a suspended-sediment sample (table 20) taken at the time of bedload sampling shows that little of the sampled bedload is likely to be suspended sediment.

All three of the indirect methods yield estimates of bedload discharge that are much lower than the measured value (fig. 8, tables 21 and 22). The Schoklitsch equation gives the best estimate of the measured bedload discharge. Bedload discharges computed by both the Einstein and Meyer-Peter, Müller methods show much more scatter when plotted against discharge for this stream than they do for any of the others, and both methods underestimate the measured value by more than an order of magnitude (fig. 8).

No bedload-discharge rating curve was developed for this site because only one measurement is available. The Schoklitsch equation could be used to estimate bedload discharge, but additional measurements are needed to establish the validity of its application to this site. A line computed with least-squares regression techniques from the logarithms of the discharge and bedload-discharge values computed with the Schoklitsch equation is drawn on figure 8C. The one point on figure 8C which lies well away from the others is assumed to represent backwater conditions and was not used to compute the line. The equation

$$Q_b = 7.0 \times 10^{-3} Q^{1.5} \tag{9}$$

has a correlation coefficient of 0.98.

Even though bed material is often finer than recommended, there appears to be good potential for collecting meaningful samples with the Helley-Smith sampler at this site. Collection bag clogging by fine sediment may be significant, but additional sampling is needed to define the extent of the problem.

Table 20.--Grain-size distribution of sediments, Edwards River near New Boston

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
							Bed material							
Mar. 21, 1979	--	100	99	98	94	80	36	11	0	--	--	--	--	--
June 20, 1979	--	--	--	100	99	96	79	23	1	0	--	--	--	--
Sept. 11, 1979	--	--	100	99	98	91	56	8	2	2	--	--	--	--
Nov. 29, 1979	--	--	100	99	97	92	46	4	0	--	--	--	--	--
June 2, 1980	--	--	100	98	96	91	69	10	1	0	--	--	--	--
July 31, 1980	--	--	100	98	95	89	61	17	2	1	--	--	--	--
Dec. 3, 1980	--	100	98	95	90	79	36	16	10	6	--	--	--	--
Jan. 15, 1981	--	100	99	97	95	88	27	3	0	--	--	--	--	--
Apr. 9, 1981	--	100	99	96	88	70	34	8	2	1	--	--	--	--
Apr. 14, 1981	--	100	99	95	86	70	53	6	0	--	--	--	--	--
Oct. 23, 1981	--	100	98	95	90	76	22	3	1	0	--	--	--	--
Average 1979	--	--	100	99	97	90	54	11	0	--	--	--	--	--
Average 1980	--	100	99	97	94	86	55	14	4	2	--	--	--	--
Average 1981	--	100	99	96	90	76	34	5	1	0	--	--	--	--
							Bedload							
June 2, 1980	--	--	100	99	97	90	57	6	--	--	--	--	--	--
							Suspended sediment							
June 2, 1980	--	--	--	--	--	--	100	97	--	96	79	64	61	45

Table 21.--Data for bedload computations, Edwards River near New Boston

[A slope of 0.000453 ft/ft was used for all calculations]

Date	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
				Bedload sampled				
June 2, 1980	18.92	1,810	615	6.68	92	70	25.0	2.94
				Bedload not sampled				
Aug. 9, 1977	17.39	1,090	508	5.77	88	67	23.0	2.15
Aug. 17, 1977	14.44	405	185	2.64	70	62	21.5	2.19
Sept. 27, 1977	13.25	275	179	2.30	78	59	17.5	1.61
Nov. 29, 1977	17.30	1,130	680	8.10	84	67	12.0	1.54
Dec. 22, 1977	14.44	399	246	3.51	70	62	0	1.62
May 10, 1978	15.28	678	307	4.15	74	64	9.0	2.21
June 2, 1978	13.70	306	180	2.65	68	60	21.5	1.70
July 13, 1978	12.54	170	117	1.77	66	57	21.0	1.44
July 19, 1978	12.18	122	93.6	1.33	70.5	55	26.0	1.28
Mar. 21, 1979	21.06	4,520	1,680	2.96	567	74	5.0	2.79
May 16, 1979	14.80	536	244	3.54	69	63	19.0	2.12
June 20, 1979	13.09	194	153	1.91	80	58	29.0	1.25
June 20, 1980	13.78	363	204	2.76	74	61	22.5	1.78
Feb. 26, 1981	13.69	294	157	2.24	70	60	3.0	1.87
June 17, 1981	16.16	821	341	4.87	70	65	25.0	2.41

Table 22.--Bed-material characteristics and measured and computed bedload discharge, Edwards River near New Boston

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
	d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled								
June 2, 1980	0.36	0.40	0.47	0.94	852	57.8	46.3	415
Bedload not sampled								
Aug. 9, 1977						7.71	26.4	217
Aug. 17, 1977						12.1	22.4	76.8
Sept. 27, 1977						.56	6.89	33.6
Nov. 19, 1977						.34	9.78	239
Dec. 22, 1977						.77	8.98	75.2
May 10, 1978	0.39	0.48	0.54	1.00	--	10.1	27.1	145
June 2, 1978						1.42	9.12	51.0
July 13, 1978						.32	3.74	16.9
July 19, 1978						.08	1.60	5.98
Mar. 21, 1979						344	58.3	141
May 16, 1979						9.74	22.1	116
June 20, 1979						0	1.67	14.7
June 20, 1980	.39	.47	.54	1.30	--	2.23	12.4	55.1
Feb. 26, 1980	.51	.63	.79	2.00	--	2.51	13.0	37.1
June 17, 1981						12.3	27.1	176

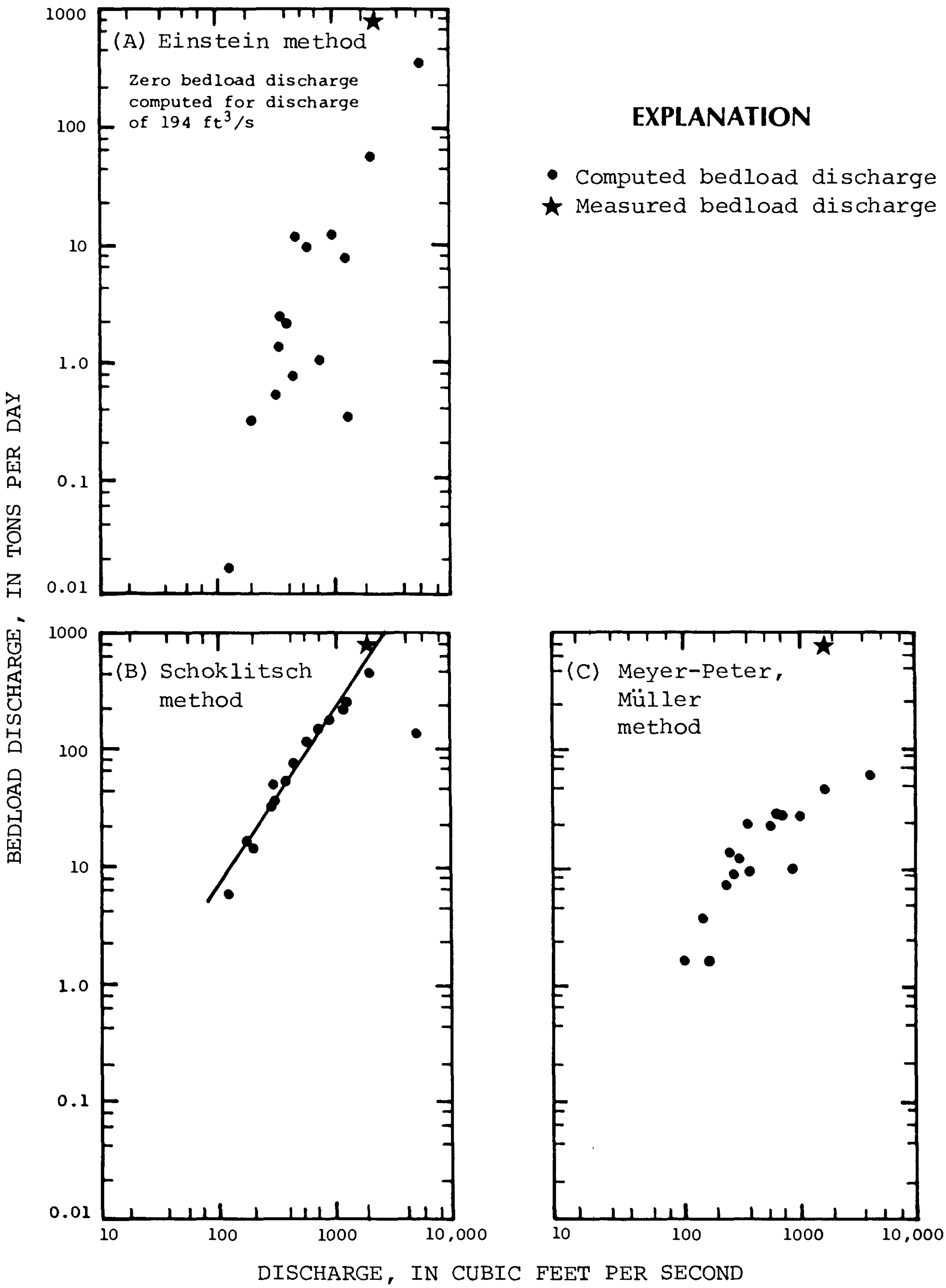

Figure 8.--Relation between discharge and measured and computed bedload discharge, Edwards River near New Boston.

Henderson Creek near Oquawka

The Henderson Creek drainage basin is very similar to that of the Edwards River, having low relief and thick glacial deposits. Channel slope in the vicinity of the gage near Oquawka (fig. 1, table 1) is 0.000369 (1.95 ft/mi). The main channel is V-shaped with one pier toward the left bank which affects flow locally. At discharges above about 1,700 ft^3/s, flow overflows the main channel. The overflow sections are wide, shallow areas covered with grasses or row crops. Because bedload discharge was assumed to be negligible in these sections and was not measured, a main-channel rating was developed for stages above overflow for use in this study. Hydraulic variables needed for computations (cross-sectional area, mean depth, and mean velocity of flow) were obtained from hydraulic-geometry relations developed from discharge-measurement notes for the main channel only. Cross-section plots made from discharge-measurement notes show that scour and fill is on the order of 3 to 4 feet.

Bed material at the gage cross section is defined by 17 samples collected from 1978 through 1981 (table 23). Median size of bed material ranged from 0.30 mm in 1978 to 0.45 mm in 1981. Because of the trend in median size, yearly average grain-size distribution of bed material was computed and used for computations for dates on which samples were not collected (table 23). The samples contain a very small amount of sediment larger than 8 mm.

This is one of the earliest bedload-sampling sites, and nine samples have been collected (tables 23-25). The two samples collected in 1978 each consisted of two traverses of 12 or 15 sampling points each. Bottom times were 300 and 120 seconds. In 1979, two samples with two traverses each were collected. Sampling points ranged from 15 to 16 and bottom time was 60 seconds for all points. The three samples taken in 1980 each had 4 to 6 sampling points across the section with bottom times of 10 or 30 seconds. The June 3, 1980, sample consisted of two traverses, whereas the other two had only one. Two samples of two traverses each and 9 to 10 sampling points were collected in 1981. Bottom times for these were 30 to 120 seconds.

Bedload samples from 1978 and 1979 (table 23) indicate that 12 to 41 percent of sediment trapped was finer than the 0.25 mm mesh of the sampler bag. Samples collected in 1980 and 1981 have a much smaller amount of material finer than 0.25 mm (0 to 13 percent). The abrupt and consistent change suggests a change in sampler bag mesh, but no such change was recorded. The change could also have been caused by a change in character of the sediment supplied to the stream, or by a change in channel conditions. However, no indication was found of changes within the watershed or the channel which would have caused a change in the character of the sediment.

Four suspended-sediment samples were taken at the time of bedload sampling (table 23). The suspended sediment is a little coarser here than the other streams sampled, with as much as 9 percent of the suspended-sediment sample in the 0.25 to 0.50 mm size fraction. The amount of material trapped in the bedload sampler which was traveling in suspension may be significant, especially at high flows.

None of the three indirect methods yields bedload discharges that are very close to the measured values for the same flow conditions (fig. 9, tables 24 and 25). Bedload discharge computed with the Schoklitsch equation agrees best with measurements at high discharge, and agrees very closely with the measurement of April 14, 1981. The Schoklitsch equation, however, greatly overestimates the bedload discharge for hydraulic conditions of June 16, 1981. Therefore, measured values have a steeper trend when plotted against discharge (fig. 9) than do the values computed with the Schoklitsch equation.

Bedload samples were collected over a relatively narrow range of discharge (fig. 9). Although the discharge peak of the water year was sampled in 1979, that discharge was well below the 16,500 ft^3/s peak discharge of record. The scatter of measured bedload discharge over this narrow discharge range is quite large (fig. 9), giving a very steep trend when plotted against discharge. A line was computed using least-squares linear regression of the logarithms of bedload discharge and discharge. The equation of the line is

$$Q_b = 7.1 \times 10^{-10} Q^{3.3} , \qquad (10)$$

with a correlation coefficient of 0.64.

Bedload grain-size distributions indicate that collection bag clogging may have been significant during the 1978 and 1979 sampling, but probably was not significant in the later years. The effect of the clogging on measured values, and therefore on equation 10, cannot be evaluated with the data available, and the equation should be used with caution. Because values computed with the Schoklitsch equation agree fairly well with measured values from samples collected in 1980 and 1981, that equation may be useful for estimating bedload discharge at this site. Additional sampling over a wider range of discharge is needed to obtain a reliable bedload-discharge rating curve. Additional samples should be carefully examined to determine the extent of collection bag clogging. Suspended samples should be taken to determine whether a significant part of that sampled bedload was moving in suspension.

Table 23.--Grain-size distribution of sediments, Henderson Creek near Oquawka

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
						Bed material								
Apr. 25, 1978	--	--	--	100	99	96	76	13	1	1	--	--	--	--
May 8, 1978	100	99	99	99	99	98	96	45	2	1	--	--	--	--
May 9, 1978	100	98	94	89	87	85	84	35	3	2	--	--	--	--
June 13, 1978	--	--	--	--	100	99	91	17	0	--	--	--	--	--
June 30, 1978	--	--	--	--	100	99	89	13	0	--	--	--	--	--
Mar. 20, 1979	--	100	97	95	91	86	81	30	11	7	--	--	--	--
Apr. 13, 1979	--	--	--	--	100	99	86	24	2	0	--	--	--	--
Sept. 12, 1979	--	--	--	--	100	98	83	21	12	10	--	--	--	--
Nov. 28, 1979	--	--	--	100	95	88	73	31	18	13	--	--	--	--
May 5, 1980	--	100	99	98	96	94	84	24	1	1	--	--	--	--
June 1, 1980	--	--	--	100	99	98	90	24	3	2	--	--	--	--
July 30, 1980	--	--	100	98	97	93	74	11	1	1	--	--	--	--
Sept. 2, 1980	--	--	100	99	98	92	54	6	0	--	--	--	--	--
Sept. 10, 1980	--	--	--	--	--	100	93	15	2	1	--	--	--	--
Oct. 22, 1980	--	--	--	--	100	84	38	4	0	--	--	--	--	--
Apr. 8, 1981	--	--	--	--	100	97	54	7	3	2	--	--	--	--
Apr. 14, 1981	--	100	99	96	87	74	61	11	1	--	--	--	--	--
Average 1978	100	99	99	98	97	96	87	25	1	1	--	--	--	--
Average 1979	--	100	99	99	96	92	80	26	11	8	--	--	--	--
Average 1980	--	--	100	99	97	94	72	14	1	1	--	--	--	--
Average 1981	--	--	100	98	93	86	57	9	1	1	--	--	--	--
						Bedload								
May 8, 1978	--	100	99	97	92	82	71	33	--	--	--	--	--	--
July 10, 1978	--	--	100	99	98	95	88	22	--	--	--	--	--	--
Mar. 20, 1979	--	--	100	99	98	94	76	15	--	--	--	--	--	--
Apr. 13, 1979	--	--	100	99	98	93	75	18	--	--	--	--	--	--
June 2, 1980	--	--	--	100	99	97	75	7	--	--	--	--	--	--

Table 23.--Grain-size distribution of sediments, Henderson Creek near Oquawka--Continued

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
							Bedload--Continued							
June 3, 1980	--	--	100	99	97	93	60	8	--	--	--	--	--	--
Sept. 2, 1980	--	100	99	97	94	85	34	1	--	--	--	--	--	--
Apr. 14, 1981	--	--	100	97	90	83	63	12	--	--	--	--	--	--
June 16, 1981	--	100	99	94	83	67	38	0	--	--	--	--	--	--
							Suspended sediment							
Feb. 8, 1978	--	--	--	--	--	--	100	99	95	92	50	37	32	24
Mar. 20, 1979	--	--	--	--	--	--	100	91	76	73	60	--	50	45
Apr. 13, 1979	--	--	--	--	--	--	100	96	88	84	62	--	47	42
June 3, 1980	--	--	--	--	--	--	--	100	--	90	84	78	72	58

Table 24.--Data for bedload computations, Henderson Creek near Oquawka

[A slope of 0.000369 ft/ft was used for all calculations]

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
				Bedload sampled					
May 8, 1978	1	21.67	1,600	590	8.31	71	48	15.0	2.71
Do.	2	21.59	1,530	570	8.26	69	48	15.0	2.68
July 10, 1978	1	23.86	2,430	780	9.18	85	56	23.0	3.12
Do.	2	23.66	2,330	760	9.16	83	56	23.0	3.07
Mar. 20, 1979	1	25.02	3,010	911	9.69	94	85	3.8	3.30
Do.	2	25.02	3,010	911	9.69	94	85	3.8	3.30
Apr. 13, 1979	1	24.23	2,630	820	9.32	88	73	9.0	3.21
Do.	2	24.15	2,580	810	9.20	88	72	9.0	3.19
June 2, 1980	1	24.55	2,830	860	9.35	92	75	20.5	3.29
June 3, 1980	1	24.73	2,950	880	9.26	95	75	20.5	3.35
Do.	2	24.73	2,950	880	9.26	95	75	20.5	3.35
Sept. 2, 1980	1	25.46	2,230	730	9.01	81	61	22.5	3.05
Apr. 14, 1981	1	24.63	2,770	875	9.83	89	50	13.0	3.17
Do.	2	24.63	2,770	875	9.63	89	50	13.0	3.17
June 16, 1981	1	21.14	1,390	535	7.99	67	50	17.0	2.59
Do.	2	20.97	1,340	515	7.80	66	45	17.0	2.60

Table 24.--Data for bedload computations, Henderson Creek near Oquawka--Continued

Date	Cross section	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload not sampled									
Sept. 28, 1977	--	15.89	353	240	4.29	56	20	15.0	1.46
Nov. 8, 1977	--	20.44	1,190	529	8.27	64	40	14.0	2.25
Dec. 22, 1977	--	16.08	459	309	5.24	59	20	0	1.49
July 18, 1978	--	15.18	253	167	3.04	55	15	24.5	.66
Aug. 31, 1978	--	12.95	53.8	54.9	1.06	52	10	23.5	.98
Oct. 3, 1978	--	13.16	72.4	63.5	1.20	53	10	14.5	1.11
Apr. 9, 1979	--	17.70	698	353	5.88	60	25	6.5	1.98
May 10, 1979	--	16.74	532	259	4.71	55	25	24.0	2.05
June 20, 1979	--	14.60	193	134	2.23	60	15	23.5	1.44
June 19, 1980	--	15.34	320	192	3.69	52	15	20.5	1.67
Sept. 10, 1980	--	15.77	317	192	3.49	55	20	24.0	1.65
Jan. 14, 1981	--	14.67	169	146	2.81	52	15	.3	1.16
Feb. 25, 1981	--	16.14	399	244	4.28	57	20	3.0	1.64
July 29, 1981	--	15.46	293	217	4.02	54	15	19.0	1.35
Sept. 10, 1981	--	13.63	108	86.3	1.69	51	10	20.0	1.25

Table 25.--Bed-material characteristics and measured and computed bedload discharge, Henderson Creek near Oquawka

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled									
May 8, 1978	1	0.25	0.29	0.33	4.70	14.0	34.3	52.9	240
Do.	2					10.5	34.3	52.9	240
July 10, 1978	1	.27	.30	.34	.57	33.0	68.6	65.5	321
Do.	2					13.2	68.6	65.5	321
Mar. 20, 1979	1	.26	.31	.36	1.12	60.0	89.9	133	459
Do.	2					166	89.9	133	459
Apr. 13, 1979	1	.28	.33	.38	.52	88.7	89.9	112	440
Do.	2					146	89.9	112	440
June 2, 1980	1					706	108	101	464
June 3, 1980	1	.25	.28	.33	.51	723	119	103	469
Do.	2					472	119	103	469
Sept. 2, 1980	1	.44	.49	.53	.91	647	42.7	64.9	268
Apr. 14, 1980	1	.34	.41	.53	2.40	264	69.2	56.4	243
Do.	2					195	69.2	56.4	243
June 16, 1981	1	.37	.45	.57	1.38	44.1	19.6	22.7	140
Do.	2					41.4	19.6	22.7	140

Table 25.--Bed-material characteristics and measured and computed bedload discharge, Henderson Creek near Oquawka--Continued

Date	Cross section	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
		d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload not sampled									
Sept. 28, 1977							0.54	2.01	16.3
Nov. 7, 1977							9.66	19.8	142
Dec. 22, 1977							.70	2.87	22.8
July 18, 1978	--	0.27	0.30	0.34	0.57	--	.81	0	6.77
Aug. 31, 1978							0	.11	0
Oct. 3, 1978							.08	.26	0
Apr. 9, 1979							4.49	8.22	40.6
May 10, 1979	--	.29	.34	.40	.78	--	5.64	8.47	31.5
June 20, 1979							.63	1.39	1.71
June 19, 1980	--	.32	.37	.45	.78	--	1.22	2.40	8.97
Sept. 10, 1980	--	.30	.32	.34	.44	--	1.11	2.96	13.0
Jan. 14, 1981							0	.39	1.06
Feb. 25, 1981	--	.37	.45	.57	1.38	--	.70	3.15	12.0
July 29, 1981							.02	.99	5.27
Sept. 10, 1981							.03	.33	.14

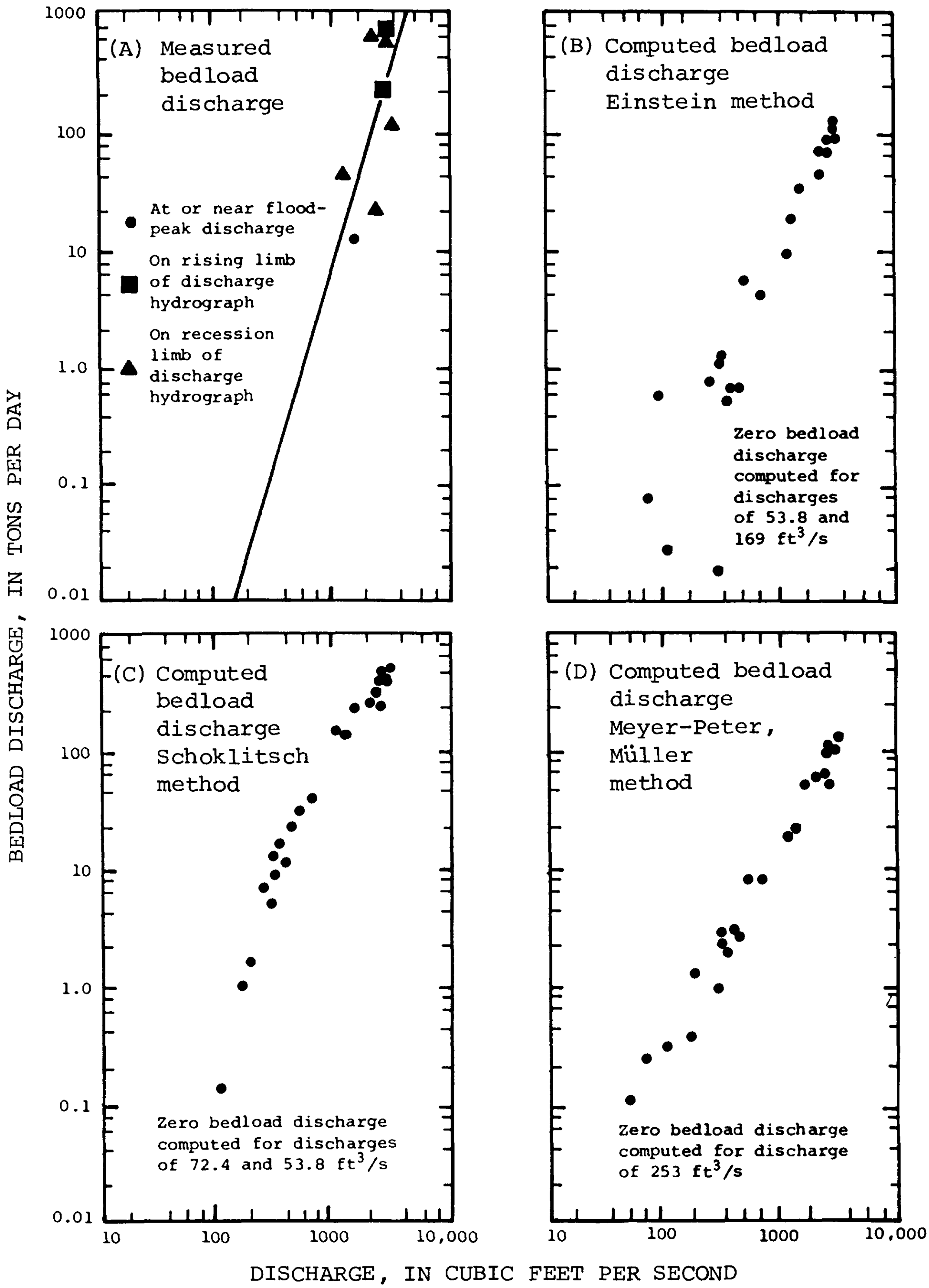

Figure 9.--Relation between discharge and measured and computed bedload discharge, Henderson Creek near Oquawka.

Kaskaskia River near Venedy Station

The Kaskaskia River (fig. 1) flows through countryside characterized by ridges of glacial materials and well-developed drainage systems (Leighton and others, 1948). Two large reservoirs have been constructed in the reach above the gage. The dam for the lowermost one is 30.6 miles above the gage near Venedy Station. Between the gage and the dam, one large creek (Shoal Creek) and three smaller creeks flow into the Kaskaskia River. Channel slope in the vicinity of the gage is 0.000311 (1.64 ft/mi). The channel cross section at the gage is W-shaped, with a pier in the center of the channel. A large log jam at the pier has caused deposition of sediment in that area. Highest flow velocities occur to the right of the central pier. Cross-section plots from discharge-measurement notes show the bottom to be more stable than most of the other streams sampled, although changes of up to 6 feet were noted.

Only one sample of bed material was collected, and that sample contained a large amount of sediment less than 0.125 mm in size. For use in the computations, that size fraction was removed and the grain-size distribution recomputed. The recomputed distribution was used in computations (table 26).

Three bedload samples were collected in 1981 (tables 26-28). The samples consisted of one traverse of 22 to 28 points each, with bottom times of 90 seconds for two traverses and 180 for the other. Sediment from all sampling points in a traverse was composited into one bag. The amount of sediment less than 0.25 mm trapped was insignificant (table 26). A very large amount of the trapped sediment was in the 0.25 to 0.50 mm size fraction.

Grain-size distributions of two suspended-sediment samples taken at the time of bedload sampling show that here, too, suspended sediment is extremely fine-grained (table 26).

Measured bedload-discharge values fall on a straight line when plotted against discharge (fig. 10). The equation of a line drawn through the measured points is

$$Q_b = 6.1 \times 10^{-11} Q^{3.0} . \qquad (11)$$

All three indirect methods overestimate bedload discharge as compared to measured values by at least an order of magnitude (fig. 10, table 28). The Einstein method yields values which are closest to the measured ones, and the trend of values computed with that method on figure 10 is very much the same as that of the line through the measured values.

Equation 11 represents a bedload-discharge rating curve for the Kaskaskia River at this site. However, the fact that the points fall on a straight line is probably due to chance. The much lower than estimated bedload discharge may be caused by reduced supply of sediment trapped in the reservoir upstream. Collection bag clogging is not a problem here in spite of the fine bed materials and very fine sediment in suspension. Additional samples would probably be meaningful and would serve to verify equation 11.

Table 26.--Grain-size distribution of sediments, Kaskaskia River near Venedy Station

Date	Percentage finer than indicated size, in millimeters													
	32	16	8	4	2	1	0.5	0.25	0.125	0.062	0.016	0.008	0.004	0.002
						Bed material								
June 29, 1981	--	--	--	100	98	92	75	42	0	--	--	--	--	--
						Bedload								
Apr. 30, 1981	--	--	--	100	89	84	64	0	--	--	--	--	--	--
June 2, 1981	--	--	100	99	97	89	63	0	--	--	--	--	--	--
June 29, 1981	--	100	99	98	98	97	87	0	--	--	--	--	--	--
						Suspended sediment								
June 2, 1981	--	--	--	--	--	100	99	98	--	97	--	--	38	--
June 29, 1981	--	--	--	--	--	--	--	--	--	--	68	51	46	43

Table 27.--Data for bedload computations, Kaskaskia River near Venedy Station

[A slope of 0.000311 ft/ft was used for all calculations]

Date	Gage height (ft)	Discharge (ft^3/s)	Area (ft^2)	Mean depth (ft)	Width (ft)	Effective width (ft)	Water temperature (°C)	Mean velocity (ft/s)
Bedload sampled								
Apr. 30, 1981	5.81	1,140	780	6.50	120	80	10.0	1.46
June 2, 1981	14.03	5,040	1,880	12.05	156	118	27.0	2.68
June 29, 1981	9.39	2,560	1,250	9.77	128	101	26.0	2.05
Bedload not sampled								
Mar. 16, 1977	19.50	8,030	2,640	16.20	166	130	11.0	3.05
Dec. 7, 1977	19.40	8,060	2,640	16.20	163	130	1.0	3.05
Mar. 17, 1978	22.03	9,750	3,202	18.62	172	134	2.5	3.04
May 22, 1978	15.64	4,910	2,060	13.83	149	118	18.0	2.38
Mar. 5, 1979	23.04	13,300	3,331	17.08	195	142	4.5	3.99
May 9, 1979	20.96	7,890	2,810	16.43	171	130	20.5	2.81
June 12, 1979	9.92	2,350	1,210	9.03	134	98	22.0	1.94
Aug. 7, 1979	13.19	4,100	1,670	11.28	148	112	27.0	2.46
Apr. 14, 1980	17.08	6,770	2,340	15.00	156	125	0	2.89
Nov. 3, 1980	5.16	854	622	5.18	120	73	10.7	1.37
Dec. 1, 1980	4.45	648	534	4.77	112	66	6.0	1.21
May 5, 1981	3.13	391	398	3.97	101	53	18.5	.96
July 21, 1981	13.73	4,950	1,770	11.49	154	118	26.5	2.80
Sept. 1, 1981	10.40	3,050	1,220	8.78	139	105	24.5	2.40
Nov. 23, 1981	5.93	1,210	760	6.55	116	81	7.0	1.59

Table 28.--Bed-material characteristics and measured and computed bedload discharge, Kaskaskia River near Venedy Station

[Computed bedload discharges were determined using the methods of Einstein (1950), Meyer-Peter and Müller (1948), and Schoklitsch (Shulits, 1935)]

Date	Bed-material characteristics, in millimeters				Bedload discharge, in tons per day			
	d_{35}	d_{50}	d_{65}	d_{90}	Measured	Einstein method	Meyer-Peter, Müller equation	Schoklitsch equation
Bedload sampled								
Apr. 30, 1981					0.086	1.14	7.69	62.7
June 2, 1981	0.24	0.29	0.40	0.88	7.36	72.8	70.3	405
June 29, 1981					.89	12.6	27.6	202
Bedload not sampled								
Mar. 16, 1977						118	117	689
Dec. 7, 1977						131	125	702
Mar. 17, 1978						127	129	1,322
May 22, 1978						33.1	54.7	369
Mar. 5, 1979						424	256	1,080
May 9, 1979						89.0	93.4	655
June 12, 1979						9.65	23.0	168
Aug. 7, 1979	0.24	0.29	0.40	0.88	--	43.6	52.2	324
Apr. 14, 1980						102	104	590
Nov. 3, 1980						.75	5.12	37.4
Dec. 1, 1980						.14	2.89	24.3
May 5, 1981						.37	.47	8.63
July 21, 1981						90.5	76.2	402
Sept. 1, 1981						51.1	43.5	233
Nov. 23, 1981						2.48	10.6	72.1

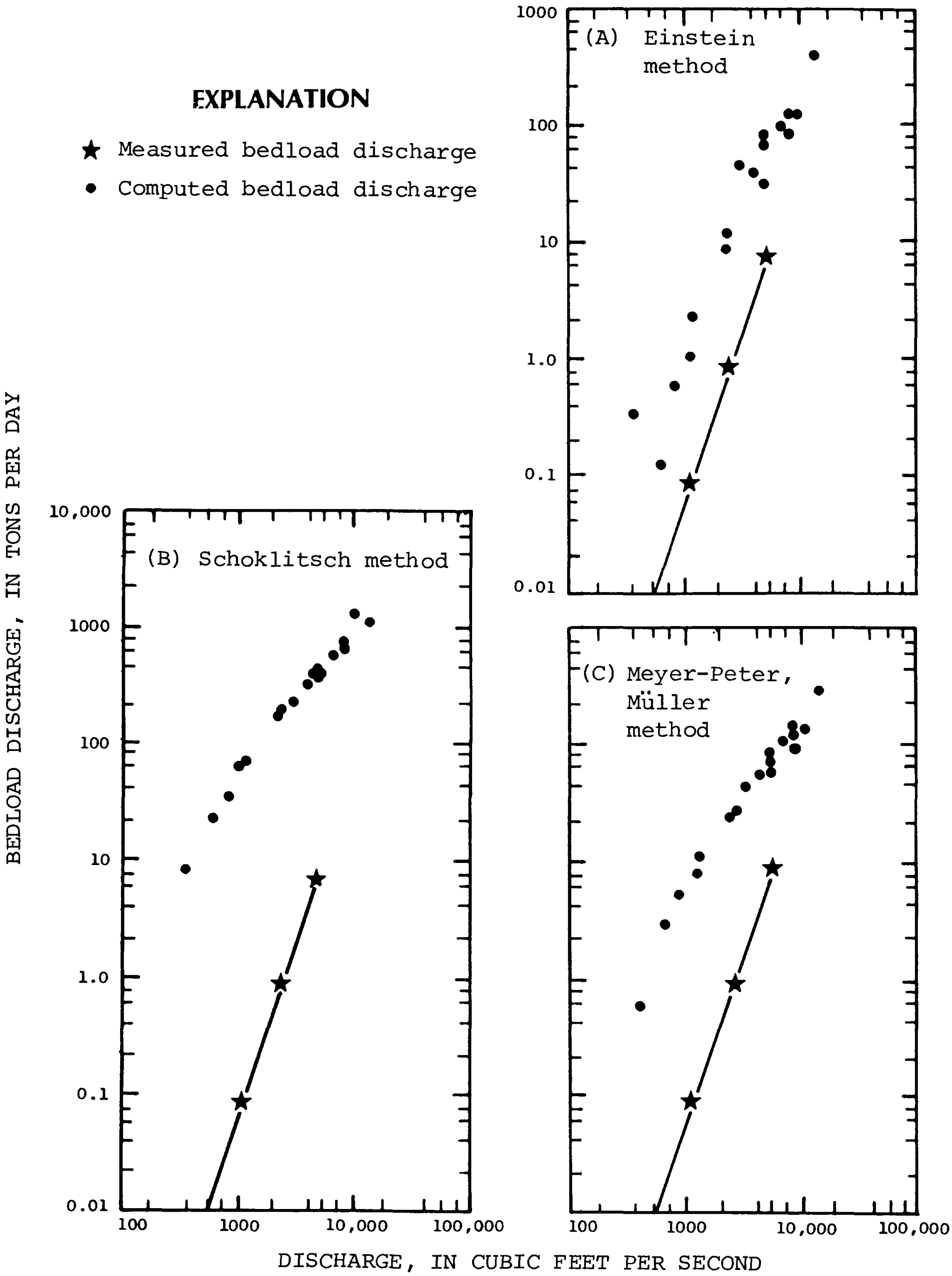

Figure 10.--Relation between discharge and measured and computed bedload discharge, Kaskaskia River near Venedy Station.

SUMMARY AND CONCLUSIONS

Much of the data collected with the Helley-Smith bedload sampler in Illinois provides useful information about sediment transport in sampled streams, despite some bed materials finer than recommended and some bedload grain sizes smaller than that for which sampling efficiency has been defined. If the amount of trapped sediment finer than the collection bag mesh is used as an indication of the extent of clogging, size-distribution analyses suggest that clogging may be a severe problem only in the Green River. Clogging may affect the sampling at some flow conditions in the Rock and Edwards Rivers and in Henderson Creek, but clogging appears to be less severe in those streams than in the Green River. Because bed materials generally contained some sediment smaller than 0.25 mm, part of the bedload smaller than 0.25 mm may have been retained in the collection bag for reasons other than clogging.

Although the dominant size of bedload sampled is small (0.25 to 0.50 mm), suspended sediment probably is a small portion of the total trapped sediment. Suspended sediment in all streams sampled is composed predominantly of silt- and clay-sized particles (less than 0.062 mm), with only several percent of the sample being larger than the sampler bag mesh of 0.25 mm. Additional suspended-sediment sampling, with detailed analyses of the grain-size distribution, would better define the importance of the suspended load in samples collected with the Helley-Smith sampler. In particular, the La Moine, Rock, and Edwards Rivers and Henderson Creek require additional sampling to verify the conclusion that no significant suspended load is measured with the Helley-Smith sampler in those streams. Additional samples in the Green River would help to determine the cause of the large amount of fine material trapped by the Helley-Smith sampler.

The time that the sampler rested on the stream bottom was often longer than the recommended time of 30 to 60 seconds for bedload samples discussed in this report. Sampling times up to 300 seconds were recorded. Long sampling times, required by low bedload discharge, increase the possibility of scour around the sampler or of settling of the sampler into the bed. The effects of these processes on the samples discussed in this report are unknown.

For some sites, the number of sampling points that make up a sample varied considerably. For example, at Henderson Creek the number of sampling points ranged from 4 to 15. All samples collected have been used in this analysis, regardless of the number of sampling points. Comparison of samples composed of different numbers of sampling points introduces an error that cannot be quantified, but which may be one cause of the lack of consistency in the Henderson Creek data.

Bedload discharge at a sampling point was found to vary up to 4 times the mean rate at that point at a constant discharge (Hubbell and others, 1981). Therefore, many samples are needed to define consistent lateral variations in bedload discharge. Descriptions of lateral differences in bedload discharge given in this report are intended only to report the results of the individual measurements discussed, and should not be interpreted as consistent patterns of transport.

Although bed materials and flow conditions in the streams studied favor the formation of bedforms, especially dunes, little information is available on the presence and movement of bedforms in Illinois streams. No observations on bedforms were made at the time of collection of the bedload samples.

Although many of the samples were collected at or very near discharge peaks or at nearly steady flow conditions, some were collected when discharge was increasing or decreasing. The position of each sample relative to the discharge hydrograph is indicated on figures 6, 7, and 9 which accompany the discussion of the Green River, the Rock River, and Henderson Creek. No pattern of bedload discharge with respect to increasing or decreasing discharge could be identified. Additional sampling on rising and recession limbs of the discharge hydrographs might reveal such a pattern.

Three commonly-accepted, theoretical and empirical equations have been used to compute bedload discharge for comparison to measured bedload discharge. As noted above, computed values from these equations often differ from each other by several orders of magnitude. These results are not unique to the present study, but illustrate a common problem which arises from application of indirect methods to a particular situation (for example, see Graf, 1971, p. 221). Although the measured data show some inconsistency, the discrepancy in computed values causes as much doubt about their meaning as does any shortcoming in the measured data. In addition, all the indirect methods give the maximum capacity of the stream to transport bedload, and do not consider conditions in individual streams that could cause transport to be below capacity. Therefore, the effects of dams (as in the Rock River and the Kaskaskia River) or large areas of bedrock in the stream channel (as possibly in the Vermilion River) would not be reflected in the computations. Uncertainty in the applicability of indirect methods probably is responsible for the growing acceptance of bedload data collected with the Helley-Smith sampler. No indirect method can reliably replace data from measurements in a real situation.

Curves or equations relating bedload discharge to discharge were developed for Henderson Creek, and the Rock, Kaskaskia, Kishwaukee, Spoon, and Edwards Rivers. Bedload discharge measurements are the basis of the first three, and bedload discharges computed with indirect methods are the basis for the last three. Of all rating curves developed, the curve for the Rock River is the only one which can be considered to be well defined. The Rock River curve incorporates reasonably consistent bedload-discharge measurements over a wide range of discharges. The other five curves all require verification by additional sampling and should be used with caution.

The following conclusions are drawn on the basis of the presented analysis:

1) The rating curve developed for the Rock River (equation 8) can be used to estimate bedload discharge. It should be remembered when using equation 8 that the effect of clogging of the sample bag and the amount of suspended sediment included are not known, but are assumed to be insignificant.

2) Rating curves or equations presented for Henderson Creek, and the Kaskaskia, Edwards, Kishwaukee, and Spoon Rivers should be used with care. Measurements upon which the Henderson Creek curve is based cover a narrow discharge range and scatter widely, and the other ratings are based on very few measurements.

3) Additional samples are needed to verify the ratings developed for Henderson Creek and the Kaskaskia, Edwards, Kishwaukee, and Spoon Rivers and to develop a rating for the La Moine River. Suspended-sediment samples should be taken at the time of bedload sampling to allow an estimate of the significance of the suspended load in the samples. The potential for collecting meaningful samples at these sites is good.

4) Clogging of the collection bag at the Green River site makes it difficult to interpret these samples. An independent study of the effects of clogging on sampler efficiency may provide a means of analyzing such samples.

5) Samples at the Vermilion River indicate that the large grain size of the bed material and high flow velocities may have interfered with the operation of the sampler. Determination of sampler efficiency for large grains will help in data evaluation at this site. Better descriptions of bed materials are needed to determine if the low measured bedload discharge could be caused by a paucity of mobile bed material.

6) Bed material should be better defined at all sites for which continued sampling would be useful. Variation in grain size across the channel, upstream of the gage section, and with time should be defined.

7) Observations on bedform movement should be made at the time of sampling. A recording fathometer could be used during sampling to provide information on size and rate of movement of bedforms, which might provide insight as to their influence on the Helley-Smith sampler.

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