RELATIONSHIP OF SUSPENDED SEDIMENT TO STREAMFLOW IN THE GREEN RIVER BASIN, WYOMING

by Bruce H. Ringen

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CONVERSION FACTORS

The following factors may be used to convert the inch-pound units used in this report to metric units:

Multiply	By	To obtain
cubic foot per second	0.02832	cubic meter per second
foot	.3048	meter
square mile	2.590	square kilometer
ton (short)	.9072	megagram
ton (short) per day	.9072	megagram per day
ton (short) per square mile	.3503	megagram per square kilometer

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ABSTRACT

The report describes the relationship between the concentration of suspended sediment and the quantity of water transporting it in selected streams in the Green River basin of Wyoming, and shows by example, how this relation can be used to determine suspended-sediment discharge.

A regression analysis was performed on sediment and streamflow data collected at 33 sediment-sampling stations and 2 miscellaneous sites. The number of coincident suspended-sediment concentration and water-discharge values available for regression analysis at the 35 stations and sites ranged from 6 to 98. Computed standard error of estimates were greater than +100 for 32 of the 35 stations and correlation coefficients were less than 0.80 for 25 of the 35 stations. Large standard errors and small correlation coefficients were not unexpected. However, as shown by example in the report, the regression equation is useful in the calculation of daily suspended-sediment discharges which can be summed to obtain estimates of monthly and annual suspended-sediment discharge.

Daily suspended-sediment discharge was computed by the "sediment-transport-curve" method described in this report and compared with values computed by the traditional "temporal-concentration-graph" method for four stations. Annual sediment yields, in tons per square mile of drainage area, were compared in like manner. For those stations examined, values computed by the "sediment-transport-curve" method were within 58 percent of those computed by "temporal-concentration-graph" method when only one year of record was used, but were within 12 to 21 percent when 2 to 4 years of record were averaged.

INTRODUCTION

Erosion and the transport and deposition of sediment are natural processes that result from interactions between the climate and the environment. As a result of these natural processes, the land surface and stream-channel environments can be altered in a negative manner. Gulleys can be formed and aquatic habitats can be modified or destroyed. Also, surface-water-reservoir capacity can be reduced over time as sediment is trapped and accumulated in the reservoir.

The natural processes of erosion and sediment transport and deposition can be, and often are, accelerated by man's activities. A typical example of such activities is the surface mining of coal. As the surface is disturbed and reclaimed there is a potential for increased erosion, sediment transport, and deposition.

A particular basin in Wyoming where significant coal mining is occurring is the Green River basin. Because of the mining activity, there is expressed interest in determining the amount of sediment being transported by streams in the basin.

The purpose of the report is to describe the relation between the concentration of suspended sediment and the quantity of water transporting .it in selected streams in the Green River basin in Wyoming, and to show, by example, how this relation can be used to determine daily suspended-sediment discharge. Summation of daily suspended-sediment discharges provides estimates of monthly or annual suspended-sediment discharge which can be useful in the evaluation of alternative development plans and in the design of reservoirs and sediment-control structures.

DATA ANALYZED

Suspended-sediment concentration and streamflow data from 33 suspended-sediment sampling stations and 2 miscellaneous sites are used in this report. The sampling stations (fig. 1) are identified by a U.S. Geological Survey 8-digit station number, such as 09196500. The first two digits designate the major drainage basin in which the stream is located. The digits "09" refer to the Colorado River basin. The remaining six digits refer to individual stations with numbers increasing in the downstream direction. The 2 miscellaneous sites referred to in the report are identified by a 15-digit number. The first six digits identify the site by degrees, minutes, and seconds north latitude. The next seven digits identify the site by degrees, minutes, and seconds west longitude. The last two digits are a sequential number assigned to distinguish sites having the same latitude and longitude. Station and site numbers, names, and the period of record for which data were analyzed are presented in table 1. The station and site names listed in the table are the same as those presented in the U.S. Geological Survey annual publications of water-resources data for Wyoming (for example, see U.S. Geological Survey, 1978). Site selection was based on areal distribution and availability of streamflow records.

Techniques described by Guy and Norman (1970) were used to sample the suspended sediment transported in the zone between the water surface and a point 0.3 foot above the streambed. Samples were collected monthly and during periods of high flow. Streamflow was measured during each sample collection. Samples were analyzed at the Geological Survey laboratory in Worland, Wyo., using methods described by Guy (1969).

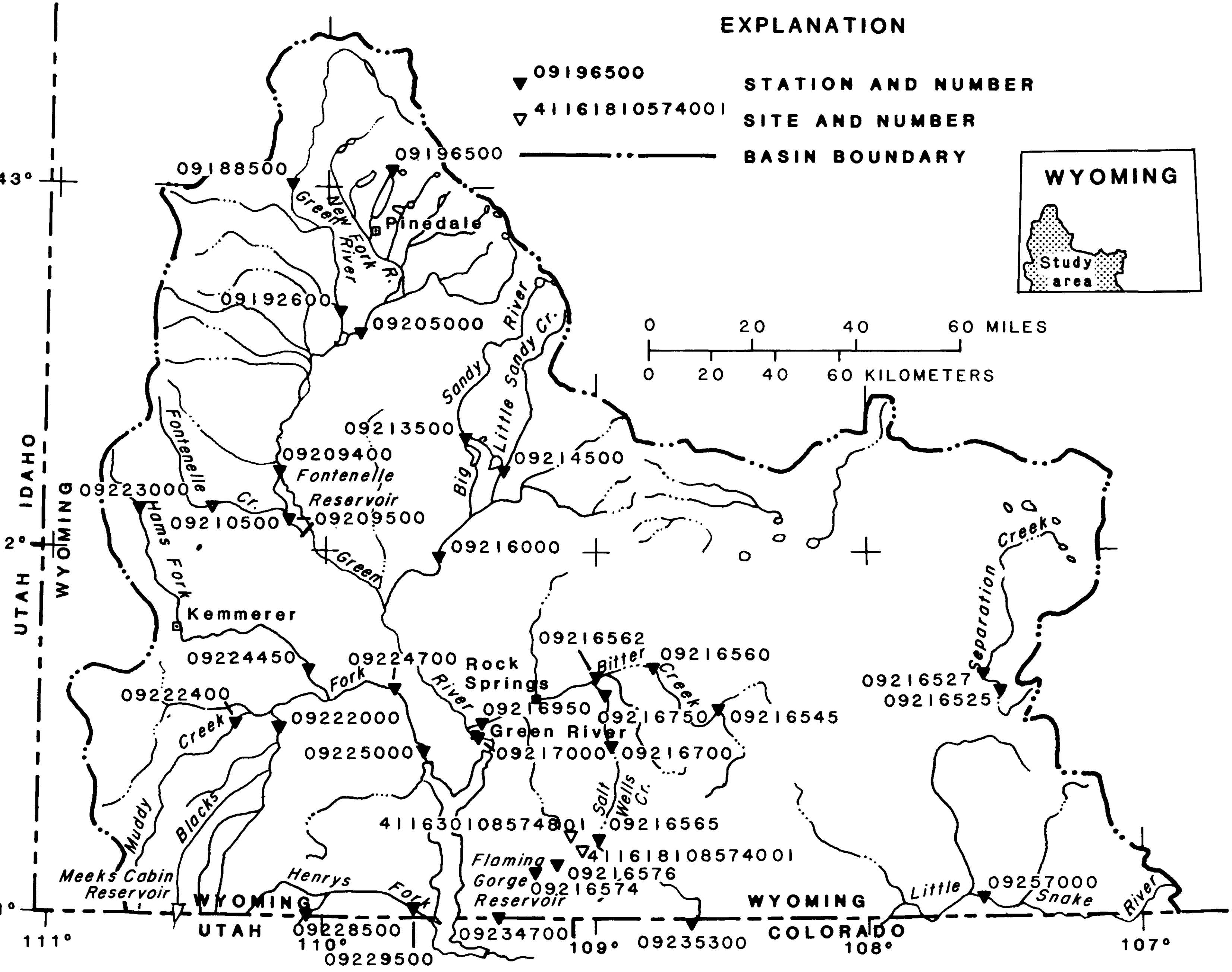

Figure 1.--Location of suspended-sediment sampling stations and sites, Green River basin.

Table 1.--Suspended-sediment sampling stations and sites

Station or site number	Station or site name	Period of record (water years)
09188500	Green River at Warren Bridge, near Daniel, Wyo.	1975-77
09192600	Green River near Big Piney, Wyo.	1975-77
09196500	Pine Creek above Fremont Lake, Wyo.	1975-77
09205000	New Fork River near Big Piney, Wyo.	1975-77
09209400	Green River near La Barge, Wyo.	1975-77
09209500	Green River near Fontenelle, Wyo.	1954-55
09210500	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.	1975-77
09213500	Big Sandy River near Farson, Wyo.	1972-77
09214500	Little Sandy Creek above Eden, Wyo.	1975-77
09216000	Big Sandy River below Eden, Wyo.	1972-77
09216525	Separation Creek at upper station, near Riner, Wyo.	1975-76
09216527	Separation Creek near Riner, Wyo.	1976-77
09216545	Bitter Creek near Bitter Creek, Wyo.	1975-77
09216560	Bitter Creek near Point of Rocks, Wyo.	1975-76
09216562	Bitter Creek above Salt Wells Creek, near Salt Wells, Wyo.	1976-77
09216565	Salt Wells Creek near South Baxter, Wyo.	1975-77
411618108574001	Salt Wells Creek above Gap Creek, near South Baxter, Wyo.	1976
09216574	Beans Spring Creek near South Baxter, Wyo.	1976
09216576	Gap Creek below Beans Spring Creek, near South Baxter, Wyo.	1976
411630108574801	Gap Creek above Salt Wells Creek, near South Baxter, Wyo.	1976
09216700	Salt Wells Creek near Rock Springs, Wyo.	1975-76
09216750	Salt Wells Creek near Salt Wells, Wyo.	1976-77
09216950	Bitter Creek near Green River, Wyo.	1966-72
09217000	Green River near Green River, Wyo.	1966, 1970-77
09222000	Blacks Fork near Lyman, Wyo.	1972-77
09222400	Muddy Creek near Hampton, Wyo.	1976-77
09223000	Hams Fork below Pole Creek, near Frontier, Wyo.	1976-77
09224450	Hams Fork near Granger, Wyo.	1971-77
09224700	Blacks Fork near Little America, Wyo.	1968-77
09225000	Blacks Fork near Green River, Wyo.	1956-58
09228500	Burnt Fork near Burntfork, Wyo.	1975-77
09229500	Henrys Fork near Manila, Utah	1975-77
09234700	Red Creek near Dutch John, Utah	1971-76
09235300	Vermillion Creek near Hiawatha, Colo.	1976-77
09257000	Little Snake River near Dixon, Wyo.	1972-77

METHODS OF ANALYSIS

Suspended-Sediment Concentration

Suspended-sediment concentration is generally related to water discharge; the larger the streamflow, the larger the concentration of sediment carried. This concentration is one of the basic components in the computation of suspended-sediment discharge records. Traditionally, the concentration is determined by graphically averaging, for a time period, a manually drawn temporal-concentration graph. This may be called the "temporal-concentration-graph" method. As this graph is based on appropiately collected samples and reflects actual stream condtions, it may be used as a standard against which other methods of concentration definition may be compared.

Another method of concentration determination is illustrated in this report. This method is based on a two-variable linear regression model using instantaneous suspended-sediment concentration as the dependent variable and instantaneous water discharge as the independent variable. This analysis results in the equation:

$$C_s = aQ_w^b \qquad (1)$$

where C_s = instantaneous suspended-sediment concentration, in milligrams per liter;
Q_w = instantaneous water discharge, in cubic feet per second; and
a and b = regression constants.

Examples of this relation are shown in figures 2-4. Although the primary quest is the definition of the regression constants, concentration may be defined with them if the water discharge is known. Determining suspended-sediment concentration this way may be called the "sediment-transport-curve" method.

Regression analyses were performed on data from 33 sediment sampling stations and 2 miscellaneous sites. The number of paired data values for each location ranged from 6 to 98. Values of standard error of estimate, correlation coefficients, and the regression constants for each analysis are listed in table 2.

The standard error of estimates are large (table 2) for most of the stations. It ranged from -43 to -84 and from +74 to +513 with 32 of the 35 stations having values greater than +100. Such large values may be expected, because the major factors affecting a fluvial system (geology, topography, climate, soils, vegetation, and land use) interact in complex ways, making a simple and exact correlation between suspended-sediment concentration and water discharge virtually impossible. The effects of these other factors were not evaluated in this study.

Regression constants are not shown in table 2 for stations where the computed correlation coefficient is less than 0.70. The median value of correlation coefficients for the 35 locations is about 0.70. The range in values is from 0.45 at stations 09196500 and 09217000 to 0.96 at site 411618108574001 with 15 of the 35 stations having values less than 0.70.

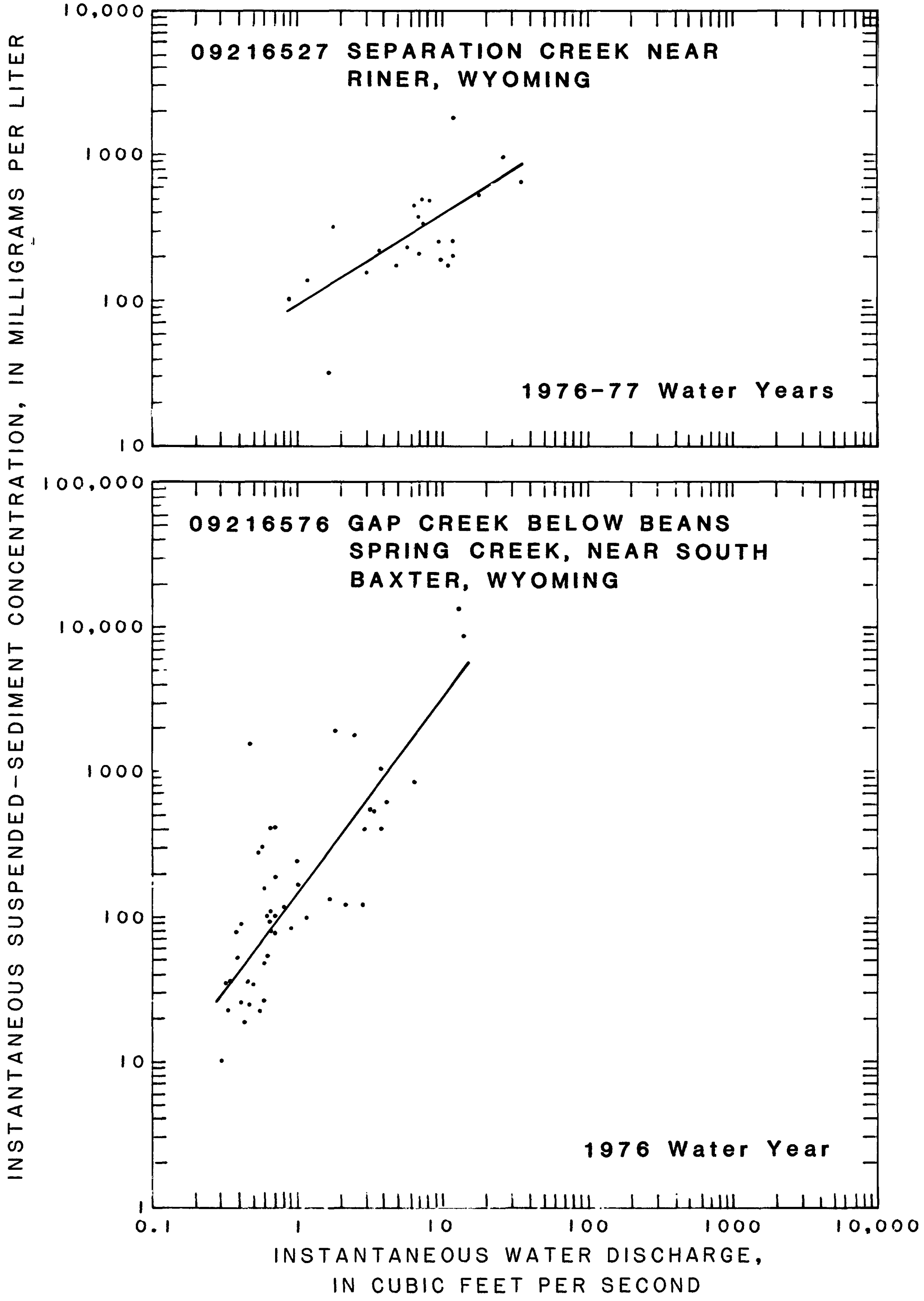

Figure 2.--Relation between instantaneous suspended-sediment concentration and instantaneous water discharge for stations 09216527, Separation Creek near Riner, Wyoming, and 09216576, Gap Creek below Beans Spring Creek, near South Baxter, Wyoming.

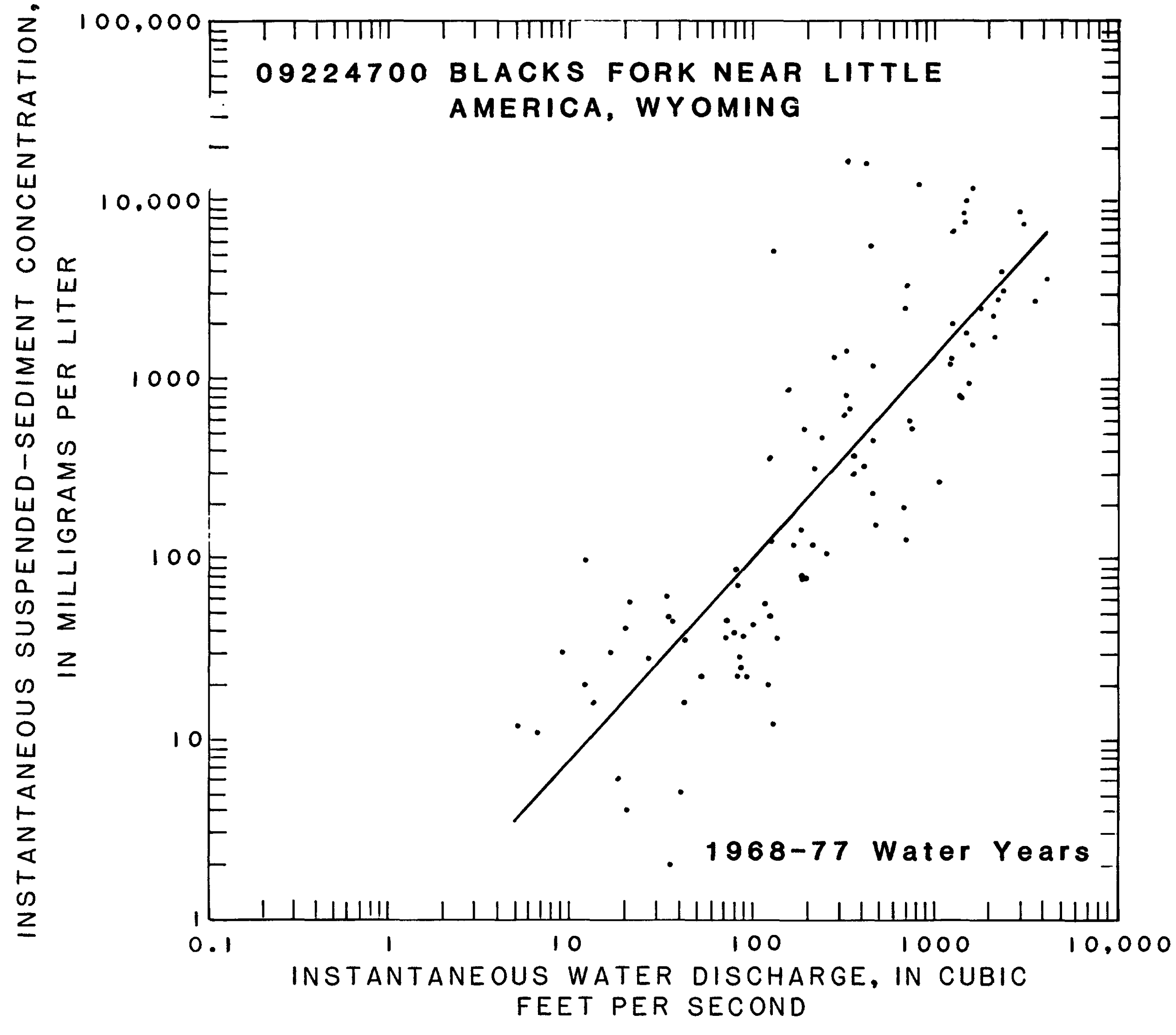

Figure 3.--Relation between instantaneous suspended-sediment concentration and instantaneous water discharge for station 09224700, Blacks Fork near Little America, Wyoming.

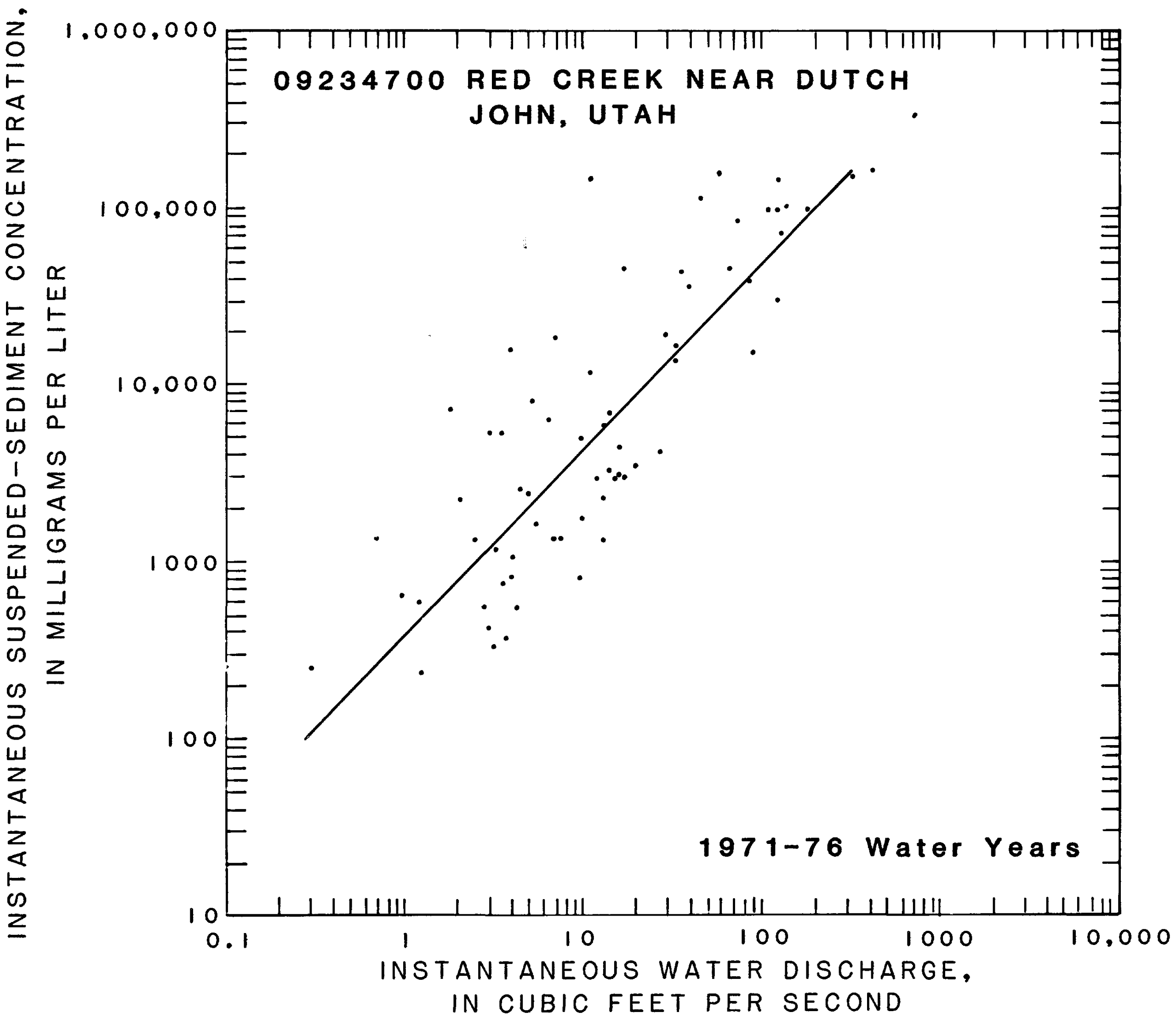

Figure 4.--Relation between instantaneous suspended-sediment concentration and instantaneous water discharge for station 09234700, Red Creek near Dutch John, Utah.

Table 2.--Statistical values for regression equation relating instantaneous suspended-sediment concentration to instantaneous water discharge at 35 stations and sites

[Regression constants are not shown where correlation coefficient is less than 0.70]

Station or site number	Number of samples	Standard error of estimate (percent)		Correlation coefficient	Regression constants	
		+	-		a	b
09188500	Green River at Warren Bridge, near Daniel, Wyo.					
	38	144	59	0.63	--	--
09192600	Green River near Big Piney, Wyo.					
	32	185	65	.60	--	--
09196500	Pine Creek above Fremont Lake, Wyo.					
	31	95	49	.45	--	--
09205000	New Fork River near Big Piney, Wyo.					
	36	194	66	.50	--	--
09209400	Green River near La Barge, Wyo.					
	40	186	65	.59	--	--
09209500	Green River near Fontenelle, Wyo.					
	44	183	64	.51	--	--
09210500	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.					
	35	154	61	.72	0.66	0.85
09213500	Big Sandy River near Farson, Wyo.					
	71	131	57	.77	3.7	.77
09214500	Little Sandy Creek above Eden, Wyo.					
	41	160	61	.78	6.4	.71
09216000	Big Sandy River below Eden, Wyo.					
	80	192	66	.58	--	--
09216525	Separation Creek at upper station, near Riner, Wyo.					
	13	143	59	.84	170	.73
09216527	Separation Creek near Riner, Wyo.					
	25	95	49	.70	91	.63
09216545	Bitter Creek near Bitter Creek, Wyo.					
	38	117	54	.83	210	.97
09216560	Bitter Creek near Point of Rocks, Wyo.					
	6	229	70	.80	179	.96
09216562	Bitter Creek above Salt Wells Creek, near Salt Wells, Wyo.					
	23	273	73	.82	210	.87
09216565	Salt Wells Creek near South Baxter, Wyo.					
	48	444	82	.59	--	--
411618108574001	Salt Wells Creek above Gap Creek, near South Baxter, Wyo.					
	12	118	54	.96	390	.71

Table 2.--Statistical values for regression equation relating instantaneous suspended-sediment concentration to instantaneous water discharge at 35 stations and sites --Continued

Station or site number	Number of samples	Standard error of estimate (percent)		Correlation coefficient	Regression constants	
		+	-		a	b
09216574	Beans Spring Creek near South Baxter, Wyo.					
	11	185	65	.65	--	--
09216576	Gap Creek below Beans Spring Creek, near South Baxter, Wyo.					
	49	129	56	.85	140	.85
411630108574801	Gap Creek above Salt Wells Creek, near South Baxter, Wyo.					
	11	291	74	.78	400	.69
09216700	Salt Wells Creek near Rock Springs, Wyo.					
	12	74	43	.94	260	1.21
09216750	Salt Wells Creek near Salt Wells, Wyo.					
	22	194	66	.80	1,300	.62
09216950	Bitter Creek near Green River, Wyo.					
	21	346	77	.73	55	1.16
09217000	Green River near Green River, Wyo.					
	38	513	84	.46	--	--
09222000	Blacks Fork near Lyman, Wyo.					
	77	258	72	.70	3.0	.82
09222400	Muddy Creek near Hampton, Wyo.					
	34	104	51	.91	11	1.05
09223000	Hams Fork below Pole Creek, near Frontier, Wyo.					
	35	169	63	.52	--	--
09224450	Hams Fork near Granger, Wyo.					
	70	213	68	.54	--	--
09224700	Blacks Fork near Little America, Wyo.					
	98	287	74	.79	.59	1.12
09225000	Blacks Fork near Green River, Wyo.					
	23	200	67	.79	6.9	.78
09228500	Burnt Fork near Burntfork, Wyo.					
	10	209	68	.55	--	--
09229500	Henrys Fork near Manila, Utah					
	37	261	72	.59	--	--
09234700	Red Creek near Dutch John, Utah					
	69	252	72	.80	365	1.05
09235300	Vermillion Creek near Hiawatha, Colo.					
	40	179	64	.74	200	.99
09257000	Little Snake River near Dixon, Colo.					
	48	234	70	.64	--	--

Because of the complexity of the flow system, the relatively small degree of correlation between suspended-sediment concentration (C_s) and water discharge (Q_w), as indicated by the large standard errors and small correlation coefficients, was not unexpected. However, the regression equations are useful if one keeps in mind their intended use and one realizes that critical evaluation of the suspended-sediment concentration estimated by the equation is necessary (Walling, 1977). In other words, haphazard use of the regression equation can complicate sediment analysis problems, while cautious use can add much needed insight.

Suspended-Sediment Discharge

Records of suspended-sediment discharge are usually computed on a daily basis using the equation:

$$Q_s = 0.0027 Q_w C_s \tag{2}$$

where Q_s = suspended-sediment discharge, in tons per day;
Q_w = water discharge, in cubic feet per second; and
C_s = suspended-sediment concentration, in milligrams per liter.

The daily values are then summed to monthly and annual totals.

Computation of suspended-sediment discharge records using a temporal-concentration graph requires considerable handwork and is time-consuming and expensive. Computation of these records using a sediment-transport curve is less accurate, but may be done with a digital computer; hence it is much faster and less expensive. Colby (1956, p. 164-169) states that annual values of sediment discharge computed using concentration values derived from a sediment-transport curve may be of sufficient accuracy for some purposes.

Computing suspended-sediment discharge records using a sediment-transport curve involves substituting equation (1) in equation (2) and simplifying to:

$$Q_s = 0.0027 a Q_w^{b+1} \tag{3}$$

As before, the daily discharges are computed and summed to monthly and annual totals, but the work may be done with a computer. Glover (1978) wrote a program that retrieves daily water discharges from computer storage, converts them to daily suspended-sediment discharge by applying the regression coefficients, and then summing these daily values to monthly and annual totals. This was done for stations 092216527 (1976-77 water years), 09216576 (1976 water year), 09224700 (1968-71 water years), and 09234700 (1973-76 water years). Values obtained were compared with values previously published in Water-Resources Data for Wyoming, a U.S. Geological Survey water-data report, for the appropriate years. This comparison is shown in table 3.

Suspended-sediment yields (usually given in tons per square mile per year) for the drainage areas above the sampling points also were computed from values of suspended-sediment discharge obtained by both methods of computation, as given in this report for the example stations. The yields also are listed in table 3.

Table 3.--Comparison of suspended-sediment discharges computed by sediment-transport curve method with discharges computed by the traditional temporal-concentration graph method

[a, sediment-transport-curve method; b, temporal-concentration-graph method]

Water year and method	Suspended-sediment discharge													Suspended-sediment yield (tons per square mile per year)
	Tons per month												Tons per year	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.		
09216527 Separation Creek near Riner, Wyo. (drainage area, 55.3 square miles)														
1976a	0	0	0	0	2.15	159	348	223	98.5	72.1	0	0	902	16.3
1976b	0	0	0	0	2.62	209	485	330	115	1.61	0	0	1,176	20.7
1977a	0	0	0	0	0	2.70	21.2	4.86	0	19.9	99.6	0	148	2.67
1977b	0	0	0	0	0	1.45	16.4	2.18	0	32.8	0.39	0	53.2	.96
09216576 Gap Creek below Beans Spring Creek, near South Baxter, Wyo. (drainage area, 35.9 square miles)														
1976a	1.40	20.6	3.64	2.22	6.71	258	1,331	27.4	5.11	1.55	2,570	1.00	4,212	117
1976b	3.94	6.29	4.24	1.63	3.58	64.8	688	53.9	5.79	2.72	1,821	.69	2,656	74.0
09224700 Blacks Fork near Little America, Wyo. (drainage area, 3,100 square miles)														
1968a	117	524	98.5	46.5	1,682	9,619	27,800	38,160	289,500	1,822	2,440	3,184	372,127	120
1968b	291	366	165	113	695	2,370	7,010	15,500	365,000	4,630	1,260	480	397,600	128
1969a	130	454	413	433	224	19,209	139,470	48,434	54,710	1,006	1,391	40.1	265,915	85.8
1969b	517	686	460	874	363	2,190	117,000	133,000	29,900	2,060	341	26.2	286,900	92.5
1970a	5,212	675	154	475	1,161	9,012	48,319	176,593	206,292	2,476	44.7	36,507	496,923	157
1970b	279	163	104	112	1,010	1,610	53,700	106,000	171,000	3,090	156	1,280	290,100	
1971a	2,220	2,783	1,083	8,816	9,538	151,777	209,498	154,230	62,789	7,665	401	145	610,946	197
1971b	518	1,040	447	27,600	11,000	40,300	165,000	514,000	312,000	29,700	678	517	1,102,800	356
09234700 Red Creek near Dutch John, Utah (drainage area, 140 square miles)														
1973a	5,670	825	43.6	2.58	12.0	10,488	32,587	16,823	2,213	9,567	961	7,803	86,997	621
1973b	1,480	93.0	55.0	9.55	39.1	9,200	15,100	29,800	4,370	2,970	327	3,180	66,650	476
1974a	237	417	122	59.8	120	13,073	13,498	10,054	2,146	191	85.4	24.4	40,027	286
1974b	239	319	188	126	338	16,300	16,100	22,400	3,090	797	281	34.2	60,100	429
1975a	313	640	42	3.00	103	2,360	2,370	56,070	9,510	13,340	527	3,560	88,840	635
1975b	730	767	112	3.05	251	1,700	3,170	133,000	18,000	9,060	264	5,100	172,100	1,229

SUMMARY AND CONCLUSIONS

A description and examples of the relationship between instantaneous suspended-sediment concentration and instantaneous water discharge are given in this report. The regression analyses were performed on sediment and streamflow data collected at 33 sediment-sampling stations and 2 miscellaneous sites. Results of the regression analyses were used to compute daily mean suspended-sediment discharges, which were summed to obtain monthly and annual totals for the four example stations.

Regression equations, such as those for the stations listed in table 2 must be used with caution, as the standard errors of the equations for some stations are large and the correlation coefficients for others are small. For these reasons, daily suspended-sediment discharges computed using the "sediment-transport-curve" method should be regarded as only estimates. Also, the results are based on suspended-sediment data collected in a defined range of flow rates during a calender time period. Thus, the sediment-transport curve represents only that range of water discharge during that particular time period, and therefore should be used for only within those limits.

Besides the insight that the values determined from the regression equations give as to the magnitude of suspended-sediment concentrations and discharges, two other applications of the results should be noted. First, the daily suspended-sediment discharges can be summed to obtain estimates of monthly and annual suspended-sediment discharges. The values of monthly discharges indicate the times of year when large sediment discharges can be expected. In the case of the stations used as examples, the largest monthly sediment discharges usually occurred in May or June.

Suspended-sediment discharges determined by regression analysis, like discharges determined by the "temporal-concentration-graph" method, may be used to calculate suspended-sediment yields. The variation in suspended-sediment yields can be used to compare discharges from different areas for equivalent time periods on a unit basis (usually tons per square mile per year). It is apparent that yields in the Green River basin vary considerably; therefore, it may be assumed that erosion rates are much greater in some areas than in others.

Sediment discharges computed by the "sediment-transport-curve" method described in this report were compared with values obtained by using the traditional "temporal-concentration-graph" method. For those stations examined, values computed by the "sediment-transport-curve" method were within 58 percent of those computed by the "temporal-concentration-graph" method when only 1 year of record was used, but were within 12 to 21 percent when 2 to 4 years of record were averaged.

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