THE MEASUREMENT OF SILT-LADEN STREAMS.

By Raymond C. Pierce.

GENERAL CONDITIONS.

Hydraulic engineers who may have occasion to measure streams carrying heavy loads of silt will doubtless be interested in the following account of the special difficulties encountered and the results obtained in measuring the flow of San Juan River.

The San Juan rises in southwestern Colorado, flows southward, and then takes a general westerly course across northwestern New Mexico and the extreme southwestern corner of Colorado into Utah, where it joins Colorado River a short distance north of the Utah-Arizona line. Its headwaters and those of its principal northern tributaries lie in the high mountains of southwestern Colorado and resemble those of other streams that rise in high, mountainous country. The heaviest run-off comes late in the spring and is caused by melting snow. These higher streams carry little silt. The lower tributaries of the San Juan, including those from southeastern Utah and northeastern Arizona, drain a rather barren mesa that is being eroded rapidly, are torrential, and at times of flood bring down great quantities of silt and sand.

For the greater part of its course through northwestern New Mexico and the first 20 or 30 miles of its course in southeastern Utah the San Juan occupies a broad, winding, sandy channel in an arid valley. Through the last 100 miles of its course it runs through rocky canyons.

A little less than 100 miles above the mouth of the river and about 10 miles below the site of a dam proposed by the United States Reclamation Service, a gaging station was established in October, 1914, by L. W. Jordan, junior engineer, United States Geological Survey. The drainage area tributary to the river above the gaging station is approximately 24,000 square miles. The station is about 20 miles downstream from Bluff, Utah, the nearest settlement.

The conditions at the station are peculiar. About 200 feet above the gage the river enters the small end of a funnel-shaped gorge, its channel narrowing abruptly from about 150 to 75 feet. There is sufficient fall at this point to produce a sharp riffle at low water, and the rapids are turbulent and the velocity is great at high water. As the stream gradually widens the current is diffused, so that at the cable, 500 feet below the upper end of the gorge, the velocities are very uniform for the greater part of the width of about 200 feet.

Neither the nature nor the position of the control is known with certainty. When the station was established it was thought that the control was of rock and that it was near—probably just below—the cable section; but as lower stages give no indication of this supposed rock control it is now thought that the control may be a wide bar thrown across the stream by deposition of débris carried through the rapids above, and that the diffusing action of the funnel-shaped gorge tends to maintain uniform conditions on this bar. At the lower end of the bar, at the cable, the bottom is a very loose sand underlain with loose gravel. An attempt at low water to measure the flow by wading at this section showed that the bed is so unstable as to make wading dangerous. The disturbance of the bed in walking over it caused large holes to wash out, so that anyone who wades the stream will have much difficulty in getting back to shore.

The section above the gorge, owing to the unequal deposition of débris and the consequent shifting of the current from side to side, did not afford permanent conditions.

The station is equipped with a cable and car, a stay line, and a chain gage. Because of the high velocities it was found necessary to use a 60-pound torpedo weight, which was handled easily and effectively by means of a windlass fitted into one end of the car. The gage was read daily by an Indian trader living about half a mile from the gage.

SILT IN THE SAN JUAN.

The spring flood from the part of the drainage basin in the mountains of Colorado usually comes in June. Through the upper course of the river this flood is like the spring floods of other streams that flow from high mountainous regions, but on reaching the broad sandy stretch of river channel the flood from the upper part of the stream picks up a load of the sand and silt deposited by the smaller torrential floods of streams flowing from the lower parts of the basin. Hence the spring flood from the high mountains carries through the lower course of the river and into Colorado River considerable silt and sand picked up in transit. Observations made by the Reclamation Service 20 miles above the gaging station show an average content of silt, by weight, of 0.37 per cent for the period from May 16 to June 30, 1915, and for the period October 18, 1914, to August 2, 1915, 0.44 per cent.

The heaviest loads of silt are carried during the torrential floods of summer and fall. A sample taken by the writer just after the peak of a sudden heavy flood that occurred in the afternoon of August 26, 1915, and examined after settling for 24 hours, showed that 75 per cent of the original volume of sample was silt and red sand, chiefly the latter. The discharge at the time was approximately 13,000 second-feet, all of which except about 1,000 second-feet was coming into the river from Chinle Creek, 10 miles above the gaging station. The flood lasted only a few hours. A sample, consisting of silt and very fine sand, taken two hours after the first one, at a discharge of about 5,000 second-feet, showed a silt load of 45 per cent. At the peak of the flood and for almost an hour afterward the river ran with a smooth, oily movement and presented the peculiar appearance of a stream of molten red metal instead of its usual rough, choppy surface. A sample collected at the height of the July flood, which lasted several days and reached a maximum discharge of about 30,000 second-feet, showed 12 per cent of silt by volume and 9 per cent by weight.

The silt records obtained by the United States Reclamation Service show a maximum silt content of only 1.67 per cent, by weight. These samples, however, were taken 20 miles upstream, where the river is fairly wide, and from a point close to the shore, where velocities are low. Furthermore, it is probable that samples were not obtained at times of maximum silt load, as only 62 samples were taken in 289 days.

It should be borne in mind, however, that though very heavy loads of silt are occasionally carried by the San Juan, yet for the spring period, in which the greater part of the yearly run-off occurs, the loads of silt are considerably lighter.

MOVEMENT OF DÉBRIS.

In addition to the silt and débris carried in suspension by a stream, a large amount of heavier material is carried on or near the bottom. This method of transportation of débris is especially well illustrated by the San Juan.

Gilbert [1] describes very concisely the modes of transportation, classified as to movements of particles, as follows:

> Some particles of the bed load slide, many roll, the multitude make short skips or leaps, the process being called saltation. Saltation grades into suspension.

The modes of transportation, classified as to the method of collective movement, he describes as follows:

> When the conditions are such that the bed load is small, the bed is molded into hills, called dunes, which travel downstream. Their mode of advance is like that of eolian dunes, the current eroding their upstream faces and depositing the eroded material on the downstream faces. With any progressive change of conditions tending to increase the load, the dunes eventually disappear and the débris surface be-

[1] Gilbert, G. K., The transportation of débris by running water: U. S. Geol. Survey Prof. Paper 86, p. 11, 1914.

comes smooth. The smooth phase is in turn succeeded by a second rhythmic phase, in which a system of hills travel upstream. These are called antidunes, and their movement is accomplished by erosion on the downstream face and deposition on the upstream face. Both rhythms of débris movement are initiated by rhythms of water movement.

The dune movement is seen more often than the antidune movement. A low-water stage on a clear, sandy stream will usually show the dune movement going on in the bed of the stream. The exposed beds of silt-bearing or sand-bearing streams nearly always show the imbricated pattern associated with this movement. The second or smooth movement is merely transitional, provided the silt load is increasing. Only on heavily loaded silt streams is the third or antidune movement seen at its best. The visible surface effect of this collective movement is commonly known as the "sand wave." In appearance the sand waves much resemble the waves thrown up by a stern-wheel river steamboat.

On the wide, shallow sections of San Juan River sand waves may usually be seen below the riffles at medium stages. In the deeper sections they appear at their best development on rapidly rising stages. In the immediate vicinity of the gaging station, so far as observed, the sand waves appear on rapidly rising stages between gage heights of approximately 4 and 7 feet. With the rise of stage beyond this range the movement is drowned out. Three miles above the gaging station, where the river is wider, sand waves usually may be seen at any stage from about 4 to 10 feet. That section of the river was not visited at stages higher than 10 feet, and it is not known whether the sand waves continue or are drowned out, as in the vicinity of the station.

The usual length of the sand waves, crest to crest, on the deeper sections of the river is 15 to 20 feet, and the height, trough to crest, is about 3 feet. However, waves of a height of at least 6 feet were observed. The sand waves are not continuous, but follow a rhythmic movement. Their appearance, as seen on the lower San Juan, is as follows: At one moment the stream is running smoothly for a distance of perhaps several hundred yards. Then suddenly a number of waves, usually from 6 to 10, appear. They reach their full size in a few seconds, flow for perhaps two or three minutes, then suddenly disappear. Often, for perhaps half a minute before disappearing, the crests of the waves go through a combing movement, accompanied by a roaring sound. On first appearance it seems that the wave forms occupy fixed positions, but by watching them closely it is seen that they move slowly upstream. In the narrow parts of the stream the waves may reach nearly the width of the river, but in the wider parts they occupy smaller proportional widths. Usually they are at right angles to the axis of the stream, but at some places, particularly in the wider parts of the river, they may suddenly assume a diagonal position, moving rather rapidly across the stream in the direction toward which the upstream side of the wave has turned.

In the experiments made by Gilbert at Berkeley he found that the water surface closely paralleled the surface of the antidunes. In natural streams this is not always the case. The writer was informed by Prof. H. E. Gregory, of Yale University, that in swimming down through a short section of the San Juan he found that in going over the crest of the antidunes he could touch bottom with his feet and at the same time keep his head above water, but that in the trough of a wave he had to go down more than arm's length below the surface to touch bottom. From this it would seem that where the antidune movement is well developed and where there is a considerable depth of water the undulations of the sand surface are not closely followed by the water surface, but that the effect is partly smoothed out in being transmitted to the top. It might be proper to infer from this that at high stages the antidune movement may still go on, although no indication of it reaches the surface. This inference must be qualified by the fact that at high stages more of the bed load is picked up and carried in suspension, thus necessitating a lowering of the bed and the movement of new débris.

DIFFICULTIES ENCOUNTERED IN MAKING DISCHARGE MEASUREMENTS.

High velocities.—One of the difficulties connected with the work at the station on the San Juan and one that is probably common on streams bearing heavy loads of silt was found to be due to high velocities. The trouble was accentuated by the fact that at the only available site for the cable the vertical rock walls on each side made it necessary to put the cable nearly 50 feet above the bed of the stream. A car was built having in one end of it a windlass with a drum 5 feet in in circumference. Radial handles, of a length to make a 2 to 1 ratio with the radius of the drum, made the handling of the 60-pound torpedo weight fairly easy. The wire meter cable passed from the drum through a pulley swung in one end of the car, thus causing the cable to wind straight on the drum even when the meter happened to be swinging downstream.

A very simple and effective system was devised for measuring the depths and for placing the meter correctly. At each two-tenths of a foot around the drum slats were nailed parallel with the axis. The footmarks were indicated by paint marks on the drum but were not numbered. On the inside of the car, adjacent to the face of the drum, 10 quarter-inch holes were drilled one-tenth of a foot apart. The procedure in making a sounding was as follows: The weight was lowered to the bottom and the cable tightened; a marking peg was then placed in the hole opposite the footmark on the drum which happened to stand in front of the foot scale; the weight was drawn up to the water surface, the footmarks passing the peg being counted and the number of tenths between the last footmark and the peg added. In measuring down from the surface the direction of reading was reversed.

In conjunction with a stay line, the use of the heavy weight and windlass made it easy to measure velocities of nearly 17 feet a second. At these high velocities the weight and meter remained steady. It is believed that much higher velocities could have been measured if drift and trash carried beneath the surface had not interfered. The writer is of opinion that this method may be used with excellent results in making high-water measurements on streams where it has heretofore been possible to measure only surface velocities. Care must be used if drift is running, as the weight can not be lifted quite so rapidly as a small weight can be lifted by hand. A small ax should be kept close at hand, so that the meter cable can be cut if absolutely necessary.

Trash and drift.—Measurements at the San Juan station were made very difficult by the large amount of trash carried in suspension in the water and the driftwood carried on the surface. The trash carried in suspension consists of weeds, water-soaked sticks and roots, and fine fibrous roots. On rising stages the amount of this trash is generally so great that current-meter measurements are out of the question. This is particularly true of the torrential floods of summer and fall. The amount of driftwood carried by the stream at the higher stages makes the taking of discharge measurements other than by the subsurface or drift-velocity methods almost impossible.

Shifting channel.—Soundings covering a considerable range of stage show, at different points across the width of the stream, a shift of bed ranging from 1½ to 3 feet. These shifts so nearly counterbalance each other that the cross-sectional areas of the different measurements, plotted against their respective gage heights, show a maximum average shift of only 0.8 foot.

Soundings were not made for any stage above 9 feet because of trash and drift and of the inability of the engineer to tell when the weight touched bottom. Above the crucial stage of about 10 feet it may be that the sand of the river bottom is in such a state of agitation that there is no sharply marked surface that can be called the stream bed. Gilbert,[1] in discussing his Berkeley experiments, says:

> It appears equally difficult to give definition to the bed as a datum from which to measure upward, and to select and define a locus for bed velocity. There is reason

[1] Gilbert, G. K., op. cit., p. 156.

to suspect also that the problem as thus stated is unduly simplified by the assumption that the bed is a stable entity, clearly separate from the zone of saltation above. It did indeed so appear when the process of saltation was studied through the glass wall of the observation trough, but what was witnessed was the phase of the process at the edge of the channel bed, where the current was retarded by the resistance of the channel wall. At a distance from that wall, in the region where the cloud of saltatory particles effectually precludes visual observation, the passage from stability to mobility may be less definite. I am led to this suggestion by the observations, quoted by McMath, of a civil engineer who descended in a diving bell to the bottom of the Mississippi at a point where the depth was 65 feet and the bottom of sand. Stepping to the bed, he sank into it about 3 feet, and then, thrusting his arm into the yielding mass, could feel its flowing motion to a depth of 2 feet, the velocity diminished downward. In interpreting these phenomena, allowance must be made for the fact that the presence of the diving bell created an abnormal condition and if it rested on the bed put a stop to saltation. The flow of the sand is then to be ascribed to the difference in water pressure on the two sides of the bell. But the fact of the flow seems to indicate an antecedent state of mobility, a layer of the bed being supersaturated so as to have the properties of quicksand. If such a layer exists, then the transition from the bed to the saltation zone is not abrupt but gradual.

The probability that under certain conditions the bed of the stream is in a state so mobile that soundings can not be made is suggested by the following incident: On a rapidly rising stage of 5 to 7 feet, when the sand waves were running and when the suspended trash carried in the body of the stream made measurements of velocity with a meter impossible, soundings with the 60-pound weight alone were attempted. At the time the fact that it was not possible to determine when the weight touched bottom was ascribed to the large amount of débris lodged on the meter wire, but it is now thought that the failure may have been due largely to the agitation of the sand in the stream bed, in the lower stratum of the zone of saltation.

This difficulty in making high-water soundings is unfortunate, for it is certain that the measuring section is enlarged at high stages. At a low stage a reconnaissance of part of the stream bed under the cable was made by wading. A layer of quicksand 2 or 3 feet deep was found overlying a bed of very loose gravel, into which a pointed stick could be shoved a foot or so. It would seem that at the high velocities of the higher stages a large part of this loose bed of sand and gravel would be picked up and carried partly in suspension and partly by traction, thus giving considerably greater areas. This supposition is borne out by the fact that two surface measurements made on a rising stage and one on the peak of the flood, computed from soundings made after the flood on a lower and falling stage, show velocities considerably in excess of those indicated by the general trend of the velocity curve. On the other hand, two surface measurements made on the falling stage of the same flood, computed from the same soundings, show velocities consistent with the curve. For the above measurements corrections for changing slope due to changing stage have been figured and have been found to be negligible. More weight is given to the supposition that the channel scours out on high rising stages and fills in on lowering stages by the fact that the first two sets of soundings made on the falling stage of the above-mentioned flood show that the bed was filling in at the rate of 4 inches in four hours.

The two difficulties due to shifting bottom, then, have been found to be, first, the inability of the engineer to determine when the weight touches the bottom, when otherwise soundings might be possible, and, second, the uncertainty as to the depth to which the stream bed scours during the higher flood stages.

Rapid variations in stage.—Difficulties due to the rapid fluctuations in stage were handled as follows: Each half hour during the course of a measurement a series of 10 consecutive gage readings was made. The means of several series made consecutively showed that there was liability of an error of only one or two hundredths by this method, though maximum variations of three or four tenths of a foot often appeared in one series of readings made at flood stage.

Although daily fluctuations are large, preliminary computations for the period from March 16 to July 24, 1915, based both on readings made daily and three times a week show a difference of only about 1 per cent.

VERTICAL VELOCITY CURVES.

The importance of obtaining vertical velocity curves on the San Juan was not realized by the writer until the last part of the summer. Late in July a flood of more than double the discharge of the spring flood made necessary the use of subsurface and float measurements. Four vertical velocity curves were then taken during the falling stage, and these, in connection with the results obtained by comparing the top with the mean velocities of the highest measurements made by the two-point method, were used to determine the proper surface-velocity coefficient.

The depths at the points where the vertical velocity curves were taken ranged from 3.6 to 4.3 feet. The amount of silt carried in the water at the time was rather low. The percentage by volume (sample partly dried) was about 2, and by weight (sample completely dried) about $1\frac{1}{2}$. A sample taken at the peak of the July flood showed a percentage, by volume (sample partly dried), of about 12, and by weight (sample completely dried), 9. In getting the percentages by weight the ratio used was that of the dried sample to weight of original volume of clear water. The amount of silt carried at the time the vertical velocity curves were made was much less than the amount necessary to produce sand waves at the cable. The gage height was about 4.3 feet.

The four curves are shown by the accompanying diagram (fig. 5). It will be noticed that for the upper two-thirds of their length they have the shape that is characteristic of deep, smooth-flowing streams. The lower parts of the curves show a tendency to break sharply toward the point of zero velocity. Because of the liability of injury to the meter in putting it below the 60-pound weight, it was only possible to get velocities within 0.55 foot of the bottom; hence the lower parts of the curves are not so well defined as desirable. But, with the points obtained, it does not seem possible to break the curves much less sharply. The natural tendency is in the other direction, and increases the discrepancy found between the velocities measured by the 0.2 and 0.8 method and the vertical velocity curve method.

The measurements were made carefully, the meter being held in position by means of a stay line. In this connection it will be well to state that the use of the meter in the middle meter-bar hole, with the 60-pound weight suspended from the lower hole, does not seem to affect the determination of velocities. A series of 18 careful readings made with the meter in the top hole, then in the middle hole, and finally in the top hole again, showed an average difference of less than one-tenth of 1 per cent. The weight was of excellent design.

The mean velocities obtained by taking the average of the 0.2 and 0.8 depth velocities were 2.0, 2.5, 3.0, and 3.7 per cent higher than those obtained by using the entire curves.

As the number of curves is so few, and as the content of silt was not large, these results may be taken only as showing a tendency. The need for further study is obvious.

RESULTS.

The results of discharge measurements made at the San Juan gaging station, together with a diagram (fig. 6) showing the rating curve, area curve, and velocity curve, are presented herewith, as well as estimates for the four months (May to August, 1915) that the writer was engaged on the work.

Except for a period of about 24 hours on July 27 and 28, the stage of the stream during the year 1915 did not go above 10 feet. In the July flood the stream reached a stage of 15 feet. The flow during the short time that the stage stood above 10 feet is subject to considerable uncertainty, and the discharge for the periods when sand waves were running below the gage is also uncertain, but these periods of uncertainty are very short compared with the total period.

For normal conditions below the 10-foot stage a good rating curve has been developed. With 22 measurements well distributed over this range the maximum variation of any measurement from the curve is less than 8 per cent. If the first three measurements, which were

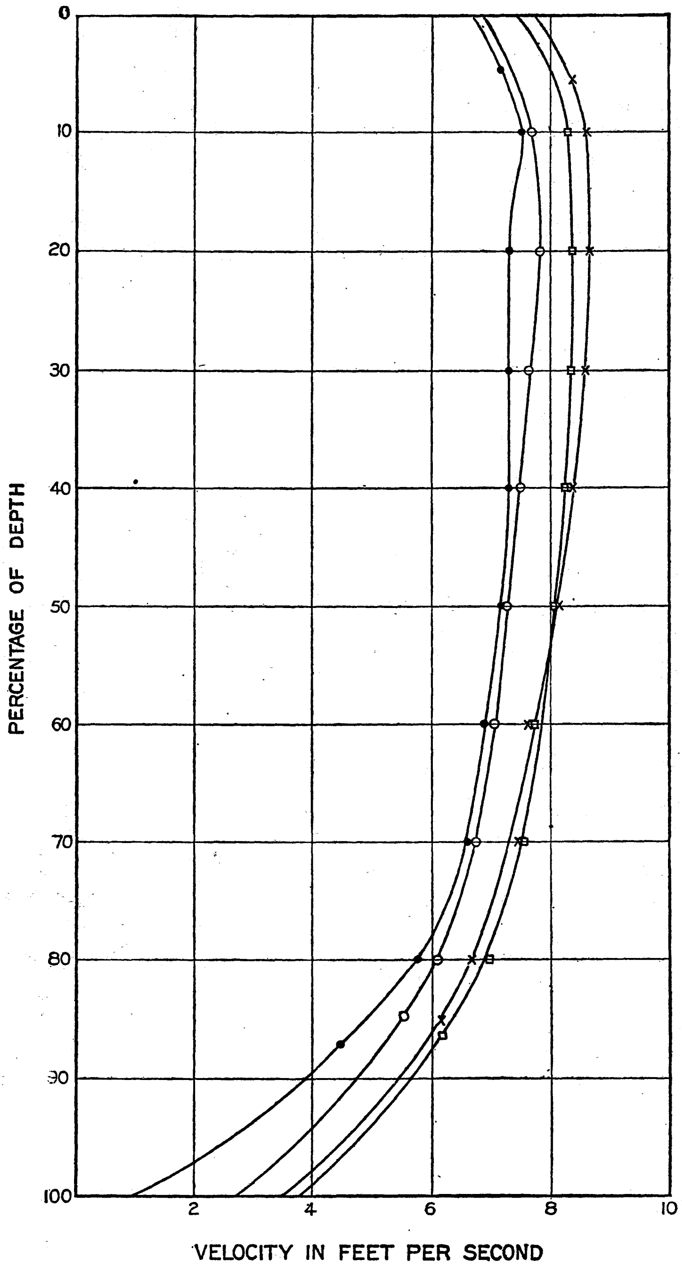

FIGURE 5.—Vertical velocity curves, San Juan River near Bluff, Utah.

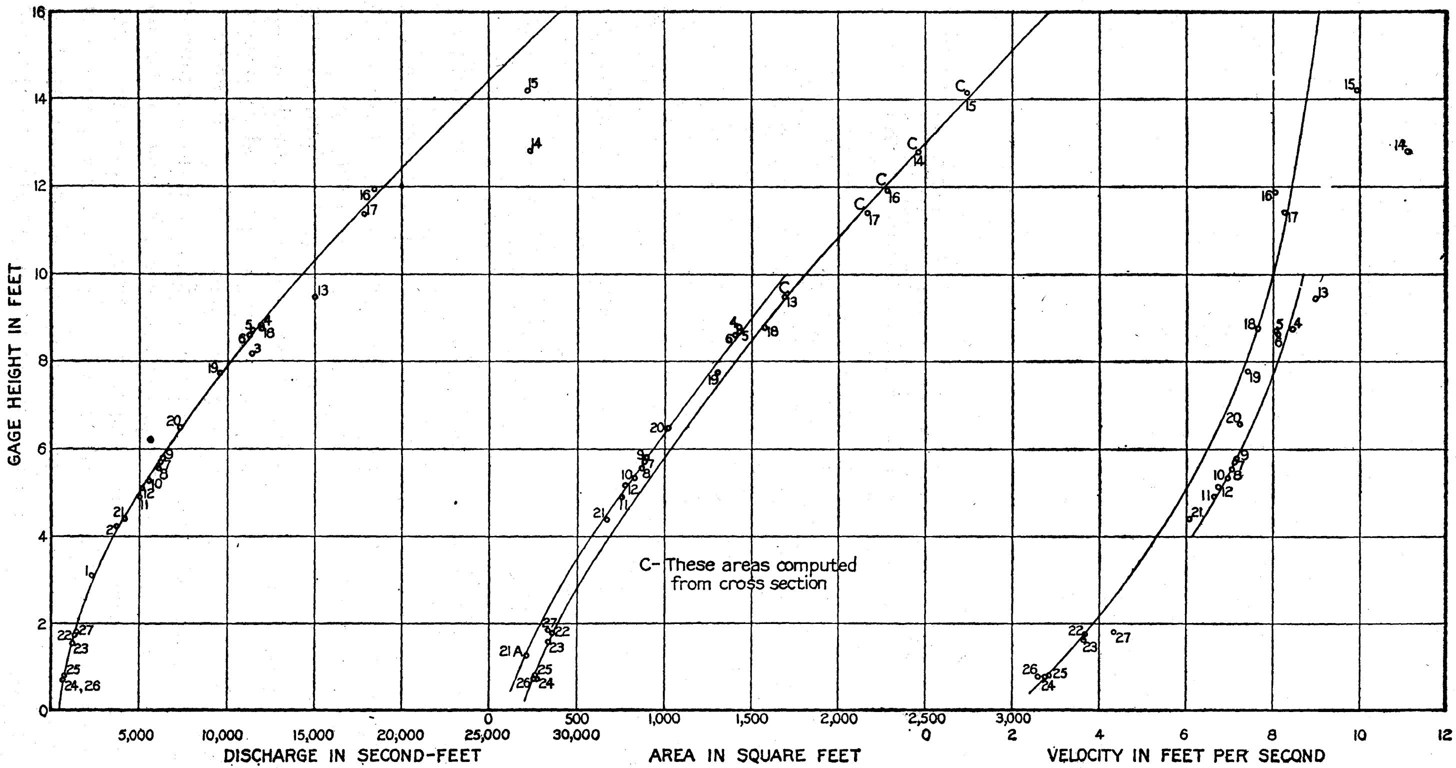

Figure 6.—Rating, area, and velocity curves, San Juan River near Bluff, Utah. Measurements 3 to 24 inclusive made during period May 21 to August 28, 1915. Measurements 13 and 14 made by timing driftwood past a measured range. Measurements 3, 15, 16, and 17 made with current meter held 1 foot below surface. (Coefficient applied.)

made from a bridge and under difficult conditions due to high velocities, are not considered, the maximum variation from the curve is less than 4 per cent. It is thought that more measurements at the lower stages may show larger percentages of variation from the rating curve, but because of the small discharge at these stages the variations should not produce large errors in the determination of total run-off.

It seems probable that the error in the monthly run-off will not exceed 10 per cent and that any error due to the possible failure of the two-point method of measurement to give correct results will not figure largely in the year's results.

It is of course fortunate, in view of the shifting character of the stream, that the relation of stage to discharge at the site selected for the station should be so stable.

Discharge measurements of San Juan River near Bluff, Utah, during the years 1914–1916.

Date.	Made by—	Gage height.	Discharge.	Date.	Made by—	Gage height.	Discharge.
1914.		*Feet.*	*Sec.-ft.*	1915.		*Feet.*	*Sec.-ft.*
Oct. 30[a]	L. W. Jordan	3.10	2,310	July 28	R. C. Pierce	14.18	[d] 27,200
				28	.....do	11.92	[d] 18,400
1915.				28	.....do	11.39	[d] 17,900
Apr. 3[a]	.....do	4.26	3,680	29	.....do	8.77	12,000
May 21[a]	R. C. Pierce	8.19	[b] 11,500	29	.....do	7.75	9,620
June 18	.....do	8.79	12,000	30	.....do	6.52	7,380
19	.....do	8.69	11,500	Aug. 1	.....do	4.38	4,120
20	.....do	8.63	11,400	27	.....do	1.74	1,330
July 7	.....do	5.70	6,260	27	.....do	1.58	1,240
7	.....do	5.56	6,130	28	.....do	.73	700
8	.....do	5.76	6,300	Oct. 24	L. W. Jordan	.79	723
9	.....do	5.30	5,710	24	.....do	.74	716
9	.....do	4.89	4,980				
10	.....do	5.18	5,200	1916.			
27	.....do	9.47	[c] 15,000	Mar. 4	A. B. Purton	1.82	1,490
27	.....do	12.80	[c] 27,300				

[a] Made from bridge; all other measurements made from cable.
[b] Surface velocity observed; coefficient of 0.85 used to reduce to mean velocity.
[c] Surface velocity by floats; coefficient of 0.9 used to reduce to mean velocity.
[d] Surface velocity observed; coefficient of 0.9 used to reduce to mean velocity.

Gage height, in feet, and discharge, in second-feet, of San Juan River at Bluff, Utah, May 1 to Aug. 31, 1915.

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	9.4	13,100	7.2	8,830	7.3	9,020	4.3	3,880
2	9.4	13,100	7.3	9,020	7.1	8,640	3.9	3,320
3	8.3	10,900	....	10,300	7.0	8,450	3.4	2,720
4	7.3	9,020	8.7	11,700	5.8	6,340	3.2	2,510
5	6.4	7,360	8.5	11,300	5.8	6,340	2.9	2,240
6	6.5	7,540	6.7	7,900	5.3	5,490	2.6	1,970
7	6.4	7,360	6.3	7,190	6.1	6,850	2.5	1,880
8	5.9	6,510	5.8	6,340	5.7	6,170	2.4	1,800
9	5.5	5,830	4.9	4,820	5.2	5,320	3.0	2,330
10	5.4	5,660	5.3	5,490	5.2	5,320	3.0	2,330
11	5.2	5,320	6.1	6,850	4.8	4,660	2.7	2,060
12	5.0	4,980	7.4	9,210	4.7	4,500	2.5	1,880
13	5.5	5,830	8.8	11,900	4.8	4,660	2.3	1,720
14	7.5	9,400	9.0	12,200	4.9	4,820	2.0	1,490
15	9.3	12,900	8.2	10,700	4.2	3,740	2.3	1,720
16	9.4	13,100	7.7	9,780	4.1	3,600	1.9	1,420
17	9.1	12,400	7.8	9,970	4.2	3,740	1.7	1,280
18	8.9	12,100	8.3	10,900	3.9	3,320	1.7	1,280
19	9.3	12,900	8.8	11,900	3.5	2,840	1.6	1,210
20	9.4	13,100	8.9	12,100	3.3	2,610	1.6	1,210
21	8.2	10,700	9.3	12,900	3.7	3,080	1.7	1,280
22	8.0	10,400	9.1	12,400	3.6	2,960	1.5	1,140
23	7.5	9,400	8.9	12,100	4.7	4,500	1.2	960
24	6.8	8,080	9.0	12,200	4.7	4,500	1.3	1,020
25	6.7	7,900	9.0	12,200	5.7	6,170	1.3	1,020
26	7.3	9,020	8.9	12,100	7.1	8,640	1.6	1,210
27	7.6	9,590	8.5	11,300	12.0	19,000	2.5	1,880
28	7.1	8,640	8.0	10,400	13.2	21,900	.75	705
29	6.6	7,720	7.6	9,590	8.6	11,500	.80	730
30	7.1	8,640	7.4	9,210	6.5	7,540	.95	810
31	7.2	8,830	....	....	4.9	4,820	.45	555

	May.	June.	July.	August.
Mean discharge....second-feet..	9,270	10,100	6,490	1,660
Maximum discharge....do....	13,100	12,900	21,900	3,880
Minimum discharge....do....	4,980	4,820	2,610	705
Run-off....acre-feet..	570,000	601,000	399,000	102,000