CHAPTER 44

SEDIMENT TRANSPORT IN A TIDAL

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ABSTRACT

Tidal flow and suspended-sediment discharge were measured in or near the inlet to Bolinas Lagoon through seven ebbtides and six floodtides. The highest flows and suspended-sediment discharges occurred during the major daily ebbtide. Most transported sediment was sand and most sediment deposited in the lagoon was sand. Computations from a relation of suspended-sediment discharge and tidal range indicated that the annual suspended-sediment discharge of ebbtides exceeded that of floodtides by 9,000 tons. The highest concentration of suspended sediment occurred near the east shore of the inlet, which is at the end of a sand spit.

The measured volume of water moved by a tide ranged from 180 to 2,740 acre-feet and the maximum flow measured was 7,900 cubic feet per second. The highest average velocity for a measurement was 4.9 feet per second. The maximum average velocity in the inlet occurred within an hour after midtide during a floodtide and usually at about one-third tide during an ebbtide. The relation of average tidal velocity ($\bar{u}_t$) to tidal range (R), was $\bar{u}_t = 1.21R^{.508}$; the average flow for a tide can be estimated by multiplying this calculated average velocity by the average cross section of the inlet.

INTRODUCTION

Five series of measurements of the quantity of sediment being transported by tides into and out of Bolinas Lagoon, Calif., were made as part of a study to determine the rate of sediment deposition in the lagoon and to define the sources and movement of the sediment (Ritter, 1970). Three series of measurements were made at the inlet, and two series of measurements were made in two channels inside the lagoon not far from the inlet (fig. 1). In all, the suspended-sediment discharge for seven ebbtides and six floodtides was determined. The measurements were made during periods when inflow to the lagoon from upland sources was negligible; therefore, the values of sediment discharge represent those caused chiefly by tidal action.

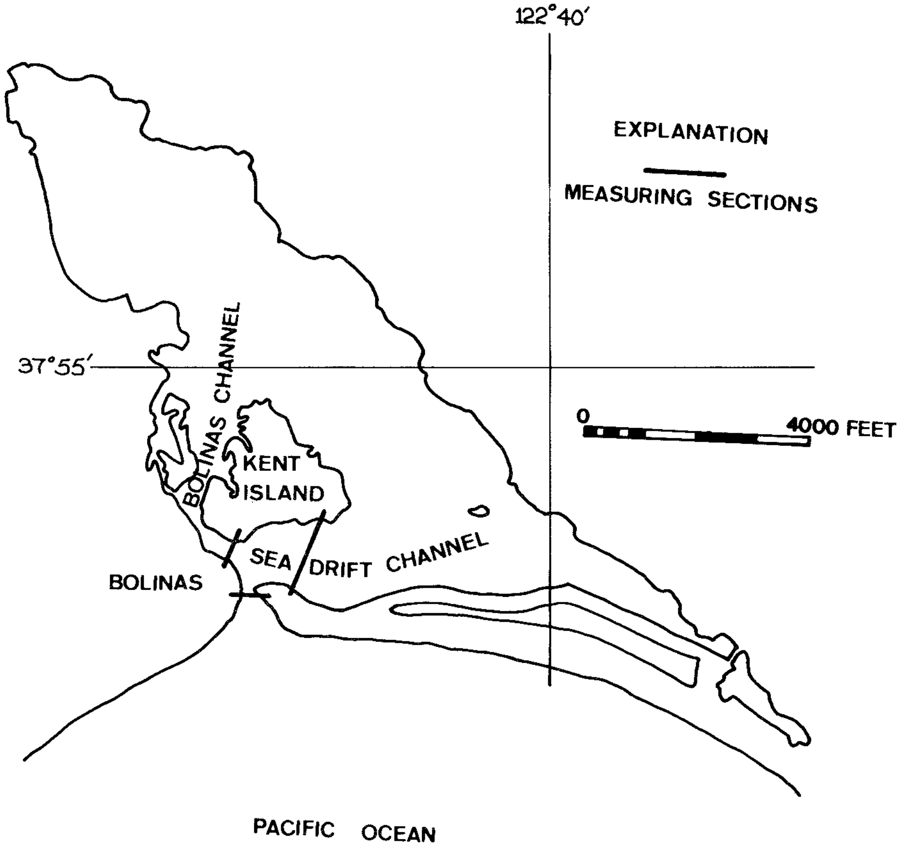

FIGURE 1.--Map of Bolinas Lagoon showing sections used to measure suspended-sediment discharge.

Bolinas Lagoon, the seaward end of a rift valley created by the San Andreas fault, is about 15 miles northwest of San Francisco. The lagoon has a triangular shape with maximum dimensions of 1 by 3 miles and an area of about 1,100 acres. Most of the lagoon is under water at high water, whereas over 50 percent of the lagoon is usually exposed at low water. The lagoon has been filling with sediment in historic time.

The mineral content of the bottom sediment in the lagoon, studies of the littoral drift, and observations of the littoral current, suggest that a major source of the bottom sediment is the cliff west of the inlet. This cliff is eroding at a rate of 2.5 feet per year (A. J. Galloway, oral commun., 1967).

The inlet to Bolinas Lagoon cuts between the end of a spit and the cliffs of a headland (fig. 2). The eastern or spit side of the inlet is composed of sand; the bottom of the middle of the inlet is bedrock or sediment larger than sand; the west side is bedrock but usually is covered by a narrow sandy beach abutting a high cliff. Tidal deltas have formed on both the lagoon and ocean sides of the inlet.

The inlet is 250 to 350 feet wide at mean sea level; the thalweg of the inlet is about 11 feet below mean sea level. The sides of the inlet have a slope as much as 16 percent. The thalweg remained about the same during the study; however, the width of the inlet changed greatly, especially between elevations of 2 and 8 feet above mean sea level (fig. 3).

During the first year of the study no large-scale changes in the width of the inlet were observed, but in the summer of 1968 the inlet was observed to widen considerably. Between August 1967 and December 1968, the inlet was eroded as much as 300 feet laterally and often more than 4 feet vertically. Most of the erosion occurred along the spit side of the inlet during the summer of 1968. By July 1969 deposition had replaced much of the sediment that had been removed by erosion, and the cross section of the inlet was becoming similar to that of August 1967 (fig. 3). Erosion of the end of the spit similar to that observed in 1968 probably recurs at intervals of several years but has not occurred recently (probably not within the last decade) judging from the quantity of vegetation on the dunes prior to erosion. The cause of the widening of the inlet in 1968 is not known; no correlation with wave conditions or littoral drift was observed.

Time-lapse photography by Beck (1971) from a cliff overlooking the inlet pictorially recorded changes in the configuration of the inlet during daylight hours for the period January 1968 to July 1969. That photography shows that erosion first began on the ocean side of the spit and that erosion moved progressively northward into the lagoon. Thus, forces responsible for the erosion must have originated in the ocean or from nearshore processes.

FIGURE 2.--Inlet to Bolinas Lagoon at low water. Pacific Ocean in background, Kent Island in right foreground, and spit midleft. Town of Bolinas at base of headland cliff and atop headland.

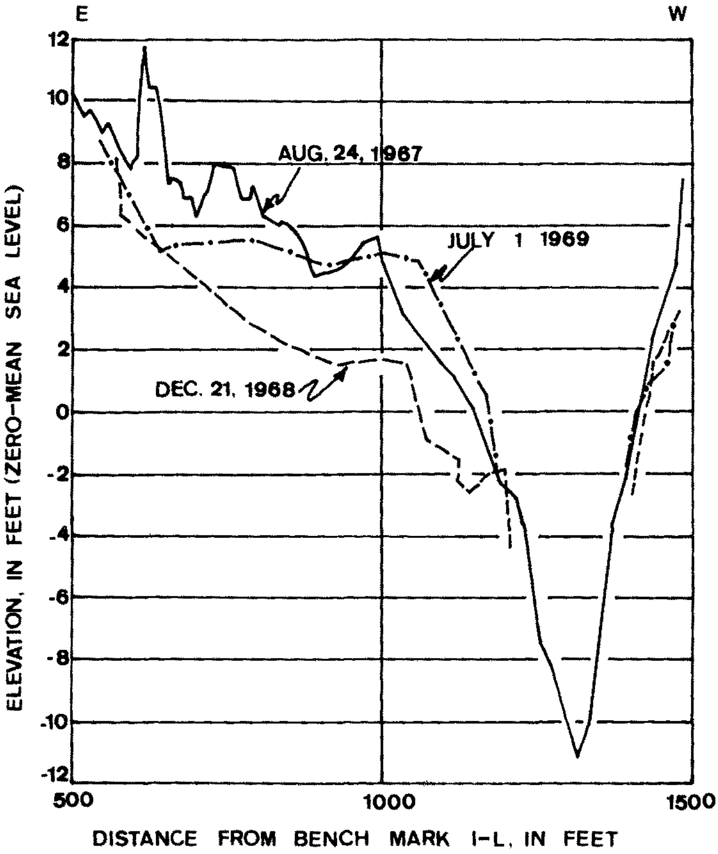

FIGURE 3.--Cross sections of the Bolinas Lagoon inlet, August 24, 1967, December 21, 1968, and July 1, 1969.

DESCRIPTION OF SEDIMENT-TRANSPORT MEASUREMENTS

Suspended-sediment transport in the inlet was measured on June 22, 1967, October 24-25, 1967, and May 16-17, 1968. Measurements spanning a 25-hour period were attempted during each series of measurements so that data for an entire tidal day would be obtained; however, only on October 24-25, 1967, was that successfully accomplished.

A moving-boat technique, in which the boat moved at a rate of about 10 fpm (feet per minute) along a cable stretched across the inlet, was used to measure the flow of water at the inlet. Two current meters, which were suspended from the boat and adjusted for changes in depth, measured the velocity of the current continuously at 0.2 and 0.8 of the depth. The direction of flow, sensed by a current-orienting compass, depth of water, station, meter revolutions, and time were continuously registered on a panel of counters aboard the boat. The panel was photographed about every 30 seconds by an automatically triggered 35-mm camera. The difference in the total count of meter revolutions per 30 seconds was used to determine the average velocity for the increment of width traversed. Then by multiplying the average depth of the increment by its width, the area of the increment was obtained. The area multiplied by the velocity corrected for the angle of the current to the measuring section was the flow for the increment. The total flow was the sum of the flows of the increments. The above calculations were made by computer from data tabulated from the film. Measurements of flow took from 9 to 25 minutes. The measured flow was assumed to equal the flow at the midpoint of the time interval of the measurement.

Suspended-sediment samples were collected from the same boat while flow was being measured. Depth-integrated samples were collected at five to seven stations during each measurement. On another boat, also in the inlet, point samples of suspended sediment were collected from various depths, and samples of sediment moving along the bottom of the inlet were collected with an Arnhem sampler so that bedload could be calculated.

An example of the temporal variations of tidal stage, average velocity, water flow, suspended-sediment discharge, and average concentration of suspended sediment for the three series of measurements is shown in figure 4. Tidal ranges during the three measuring periods varied from 0.2 to 5.7 feet (table 1); both extreme ranges were during ebbtides.

The maximum average velocity of a flow measurement, 4.9 fps (feet per second), occurred during the ebbtide having the maximum tidal range; the maximum instantaneous velocity at a vertical, 6.7 fps, also occurred then. The flow velocity in the inlet was consistently higher near the middle of the channel except sometimes when the tide was beginning to reverse. The inlet would be considered a neutral channel as there was no difference in the zones of maximum velocity for floodtide and ebbtide. Therefore, presence of flood and ebb channels could not be detected. The average velocity of the flow of each tide measured ranged from 0.4 to 2.8 fps (table 1).

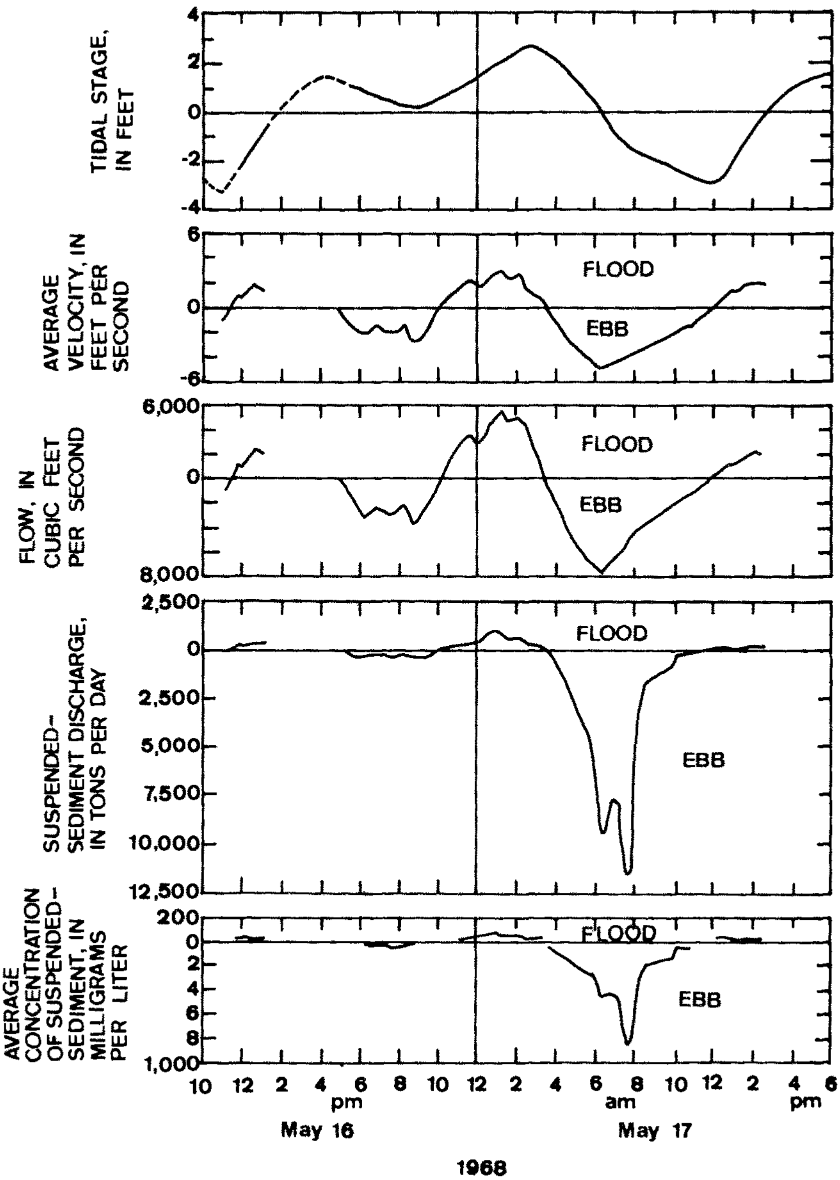
TIDAL STAGE, IN FEET
AVERAGE VELOCITY, IN FEET PER SECOND
FLOW, IN CUBIC FEET PER SECOND
SUSPENDED-SEDIMENT DISCHARGE, IN TONS PER DAY
AVERAGE CONCENTRATION OF SUSPENDED-SEDIMENT, IN MILLIGRAMS PER LITER
FLOOD
EBB
10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6
pm
am
pm
May 16
May 17
1968

FIGURE 4.

TABLE 1.--*Summary of tidal range, average velocity, volume of water moved, and suspended-sediment discharge for each tide measured in the inlet*

Date	Tide	Tidal range (ft)	Duration (hours)	Number of flow measurements	Average velocity (fps)	Volume of water (acre-feet)	Suspended-sediment discharge (tons)
June 22, 1967	Flood	[1]4.3	6	10	2.3	2,000	152
	Ebb	1.2	4	6	1.5	770	36
Oct. 24-25, 1967	Flood	1.3	6	11	1.6	1,340	85
	Ebb	4.5	9	17	2.8	2,330	495
Flood	Flood	3.2	7	13	1.8	1,330	85
	Ebb	.2	3	5	.4	180	3
May 16-17, 1968	Ebb	1.1	5	6	1.6	950	44
	Flood	2.4	5.5	9	1.8	1,410	96
	Ebb	5.7	8.5	14	2.8	2,740	1,150

[1]Elevation of lower low water was estimated.

The maximum flow measured during an ebbtide was 7,900 cfs; that during a floodtide was 5,810 cfs. Maximum flow usually coincided with the occurrence of maximum average velocity; however, maximum flow during the floodtide of June 22, 1967, followed the occurrence of maximum velocity when the increase in area of the channel offset the decrease in velocity. Conversely during some ebbtides maximum flow in an inlet may precede maximum velocity when the decrease in channel area offsets the increase in velocity. The total volume of water transported during an ebbtide ranged from 180 to 2,740 acre-feet during the measurement period (table 1). The volume of water for the measured floodtides ranged from 1,330 to 2,000 acre-feet.

Average concentration of suspended sediment for a flow measurement ranged from 5 to 862 mg/l (milligrams per liter). The lowest average concentration occurred during the ebbtide having the minimum tidal range (0.2 foot) and the minimum average velocity (0.4 fps) of the tides studied; the highest concentration occurred during the ebbtide having the maximum range (5.7 feet) and the maximum average tidal velocity (2.8 fps). Average concentrations during floodtides ranged from 9 to 125 mg/l. Thus, the maximum average concentration measured during an ebbtide was about 7 times greater than the maximum measured during a floodtide.

The highest concentrations of suspended sediment usually occurred near the end of the spit and probably were caused by the local erosion of sand from the spit. Concentrations also increased with depth. Most of the temporal, lateral, and depth fluctuations of suspended-sediment concentration were caused by changes in the concentration of suspended sand. The concentration of suspended sediment finer than sand remained relatively constant.

The measured instantaneous suspended-sediment discharge was as much as 11,600 tons per day, 98 percent of which was suspended sand. The total discharge of suspended sediment for the floodtides ranged from 85 to 152 tons, and the total discharge for ebbtides ranged from 3 to 1,150 tons (table 1).

Nineteen bedload measurements were made in the inlet during the series of suspended-sediment measurements. The maximum instantaneous bedload measured was 370 tons per day, but the high velocity in the inlet prevented sampling at the higher flows when probably much more bedload was transported. If the total load is assumed to be the sum of bedload and suspended-sediment discharge, then as much as 48 percent of the total load was bedload and the average was 16 percent. Most of the sediment transported as bedload moved along the bottom of the eastern or spit side of the inlet, the area of the highest suspended-sediment concentration. The size of the sediment moved as bedload generally increased from the end of the spit toward the center of the inlet, and the median size of the bedload material ranged from 0.2 to 8.9 mm. Dune movement of at least part of the bedload is suggested as dunes with amplitudes of as much as 2 feet were observed along the end of the spit at low water.

Between May 17 and November 14, 1968, the inlet to Bolinas Lagoon widened to such an extent that the wave action in the inlet precluded measuring sediment discharge in the inlet for the last two series of measurements. Instead, the measurements were made simultaneously at two cross sections inside the lagoon, one in Seadrift channel and the other in Bolinas channel (fig. 1). Discharges were measured only during one ebbtide and one floodtide each time.

The measurements of flow and suspended-sediment discharge in the Bolinas and Seadrift channels were made by a combination of wading measurements and boat measurements, using standard Geological Survey techniques (Buchanan and Somers, 1969). The tidal range during the measurements was as much as 4.7 feet and as small as 2.0 feet (table 2). Both extreme ranges occurred during ebbtides.

The maximum average velocities for flow measurements in Seadrift channel and in Bolinas channel (2.2 and 1.4 fps), were much lower than those measured in the inlet. The highest velocity for each flow measurement in Seadrift channel occurred in the south part of the channel during ebbtide and the north part of the channel during floodtide. Thus, ebb and flood channels seem to have developed with the main current of the ebbtide flowing close to the spit and that of the floodtide near Kent Island. No consistent difference in the zones of maximum velocity for ebbtide and floodtide were observed in the Bolinas channel, which seemed to be a neutral channel.

The instantaneous suspended-sediment discharge measured in Seadrift channel was as much as 1,830 tons per day for an ebbtide and as much as 1,080 tons per day for a floodtide; and in Bolinas channel it was as much as 78 tons per day for an ebbtide and as much as 57 tons per day for a floodtide. The total suspended-sediment discharge measured in Bolinas channel averaged about 5 percent of the total suspended sediment measured in both channels.

Bedload was measured intermittently in the Seadrift and Bolinas channels on November 14, 1968. Bedload was collected only in three of the seven attempts and the maximum bedload was only 10 tons per day which represents about 1 percent of the total load. In contrast, two bedload measurements, 136 and 28 tons per day were made at the inlet during the measurements of suspended-sediment discharge in the Seadrift and Bolinas channels in May 1969. These bedloads represent about 24 and 29 percent of the total load. These observations suggest that most of the bedload transported in the inlet probably moved only in the area in and near the inlet. It is interesting, however, that some fluorescent sand placed in the inlet on November 14, 1968, at slack tide was collected as bedload at the measuring cross section in Seadrift channel 2 hours later.

TABLE 2.--*Summary of tidal range, average velocity, volume of water moved and suspended-sediment discharge for each tide measured in Seadrift channel and Bolinas channel*

Date	Tide	Tidal range (ft)	Duration (hours)	Channel	Number of flow measurements	Average velocity (fps)	Volume of water (acre-ft)	Suspended-sediment load (tons)
Nov. 14, 1968	Ebb	2.0	6.5	Seadrift	7	0.8	1,490	68
				Bolinas	6	.5	150	11
						Total	1,640	79
	Flood	2.3	6.0	Seadrift	4	.9	1,680	137
				Bolinas	4	.6	200	8
						Total	1,880	145
May 20, 1968	Ebb	4.6	9.5	Seadrift	16	1.4	2,680	248
				Bolinas	10	.6	220	7
						Total	2,900	255
	Flood	3.4	6.5	Seadrift	14	.8	1,040	48
				Bolinas	4	.3	60	1
						Total	1,100	49

DISCUSSION

Although data collected through only seven ebbtides and six floodtides are hardly adequate for a thorough analysis of tidal parameters, certain trends are discernible by studying the interrelations between the various parameters and comparing the data with data and observations by others.

The figures given previously show that the maximum velocity, flow, suspended-sediment concentration, and suspended-sediment discharge of the measured tides all occurred during ebbtide. This was expected because, generally, lower low water follows higher high water, and the major daily ebbtide at Bolinas Lagoon occurs then; therefore, under normal conditions a larger volume of water and sediment would be moved during that ebbtide than during a floodtide. However, no measurements were made during a storm, which may cause floodtides to transport more sediment into the lagoon than they normally would.

Velocity of Flow

The equation that relates the average velocity of a tide to tidal range at Bolinas inlet is:

$$\bar{u}_t = 1.21R^{.508} \tag{1}$$

where $\bar{u}_t$ = the average tidal velocity and
R = the tidal range.

This indicates that average tidal velocity is approximately proportional to the square root of the range. The average difference between the nine measured velocities and velocities calculated from corresponding tidal ranges using equation 1 is about 12 percent; the maximum difference is 19 percent.

The equation for the curve of relation of the average velocity for each flow measurement made at the inlet to the maximum velocity observed during that measurement is:

$$u_{max} = 1.64\bar{u}^{.825} \tag{2}$$

where u_{max} = the maximum velocity and
$\bar{u}$ = the average velocity for a flow measurement.

It is interesting to note that, in the inlet, the maximum velocity measured in a vertical for each floodtide ranged only from 3.9 to 4.3 fps, but the tidal ranges for these floodtides ranged from 1.3 to 4.3 feet. In contrast, the maximum velocity in a vertical for each ebbtide that had similar tidal ranges (1.3 to 4.5 feet) ranged from 3.0 to 5.5 fps.

The two highest mean inlet velocities for a measurement were 4.90 and 4.71 fps. The Froude numbers for those two velocities were 0.31 and 0.33, about 50 percent greater than 0.2, which was given by Bruun (1967, p. 173) as the Froude number for tidal inlets at the maximum current velocity. However, Bruun (1966, 1967) also reported that the maximum mean velocity in tidal inlets should be about 1 meter per second (3.28 fps), a velocity well below the maximum mean instantaneous velocity observed in the Bolinas inlet. The Froude number computed for the Bolinas inlet for velocities nearest 3.28 fps for each of the three periods of measurement ranged from 0.19 to 0.24, which are comparable to the Froude number of 0.2 given by Bruun.

The maximum velocity of floodtide at the Bolinas inlet generally occurred within an hour after midtide, but the maximum velocity of three of the five ebbtides that were measured occurred near one-third tide and preceded half tide by as much as 90 minutes. The maximum velocity of the May 16 ebbtide (table 1) occurred at about three-quarters tide, but some erratic velocities measured during that tide probably were related to the tsunami that struck the coast that day. The maximum velocity of the ebbtide of October 25 (table 1), occurred about half tide, but the tidal range was only 0.2 foot and the flow was very small. Therefore, at Bolinas inlet the maximum velocity of floodtide probably occurs slightly after half tide and the maximum velocity of ebbtide probably occurs at about one-third tide.

Because the maximum velocity often is reached early in an ebbtide, the ebbtide velocity often increases more rapidly to its maximum than it decreases to its minimum as slack water approaches. In other words, a plot of velocity and time during an ebbtide is skewed toward the later part of the tide. The temporal relation for the floodtide velocity is more symmetrical with perhaps a slightly more rapid decrease than increase.

Flow

The average flow through the inlet for a tide can be estimated by multiplying the average velocity, as computed from equation 1, by the average area of the cross section for that tide as determined from a hydrographic survey. The average difference between the calculated flow and the measured flow was 13 percent, and the differences ranged from 0 to 50 percent (table 3).

The ebbtide flow in the inlet and in Seadrift and Bolinas channels generally increased more rapidly than it decreased. A combination of higher velocities and a larger channel cross section before the middle of ebbtide produced the more rapid increase. Conversely during floodtide, because the cross section increased throughout the tide and higher velocities occurred at or after half tide, maximum flow occurred after midtide and thus the rate of flow decreased more rapidly than it increased.

TABLE 3.—*A comparison of average tidal flow calculated from computations of average velocity and average channel area with average flow determined by tidal measurement*

Date	Tide	Tidal range (ft)	Average velocity[1] (fps)	Average channel area[2] (sq ft)	Average flow[3] (cfs)	Measured average flow (cfs)	Difference in flow (cfs)	Percent difference
June 22, 1967	Flood	4.3	2.5	1,440	3,600	4,000	-400	10
	Ebb	1.2	1.3	1,790	2,300	2,300	0	0
Oct. 24-25, 1967	Flood	1.3	1.4	1,840	2,600	2,700	100	4
	Ebb	4.5	2.6	1,460	3,800	3,100	+700	23
	Flood	3.2	2.2	1,250	2,800	2,300	+500	22
	Ebb	.2	.5	1,600	800	700	+100	14
May 16-17, 1968	Ebb	1.1	1.3	1,620	2,100	2,300	-200	9
	Flood	2.4	1.9	1,860	3,500	3,100	+400	13
	Ebb	5.7	2.9	1,500	4,400	3,900	+500	13
Nvo. 14, 1968	Ebb	2.0	1.7	1,680	2,900	3,100	-200	6
	Flood	2.3	1.8	1,740	3,100	3,800	-700	18
May 20, 1969	Ebb	4.7	2.6	1,520	4,000	3,700	+300	8
	Flood	3.5	2.3	1,300	3,000	2,000	+1,000	50

[1]Calculated from equation 1.
[2]Calculated from average channel area determined from survey of August 1967.
[3]Product of average velocity and average channel area.

The volume of water that flowed into and out of the lagoon by tides as determined from the tidal measurements was from 0.47 to 0.98 of the volume of water computed from the tidal prism of the lagoon. The average rate of change in tidal stage during an ebbtide or floodtide may be related to these ratios. If the stage for an entire tide rose or fell at an average rate of more than 0.3 foot per hour, the average ratio was about 0.65; if the average rate was less, the average ratio was about 0.95. These ratios were particularly consistent for the measurements made at the inlet. The measurements did not equal the volume of the prism because the water level in the lagoon is not horizontal. Tide records showed that the elevations of the tidal stage at various points in the lagoon differed as much as 2 feet at a given time.

Sediment Discharge

The maximum concentration of suspended sediment during a tide usually was observed within about a half hour of the time of the highest measured velocity for that tide. Postma (1967, p. 163), observed that usually there was a lag between the time of slack tide, when the average velocity is zero, and the time of the lowest concentration of suspended sediment. The lag was explained by the fact that, during a period of decreasing velocity, time is needed for sediment to settle and that during the succeeding period of increasing velocity, it takes time to reach a velocity that will resuspend sediment. At Bolinas Lagoon the concentration of suspended sediment sometimes decreased slightly during the first two measurements made after slack tide, an indication of the lag noted by Postma. The lowest overall concentrations for a tide occurred during an ebbtide with a tidal range of about 0.2 foot and a maximum average velocity of only about 1 fps. The ebbtide lasted only 3 hours, and the concentration of suspended sediment decreased progressively from 26 to 5 mg/l during that time.

Maximum average concentration of suspended sediment and tidal range for the five ebbtides measured at the inlet seemed to be directly correlated. No such correlation was perceived for the floodtides.

Suspended-sediment discharge is related to availability of erodible sediment, velocity, tidal range, and water flow. Colby (1964) showed that in sand-bed streams a relation existed between stream velocity and the discharge of sand. Data from measurements made at the inlet and at Seadrift and Bolinas channels were used to relate the discharge of suspended sediment in the inlet to average velocity (fig. 5). Discharge of suspended sand was similarly related and a comparison of the two curves is shown in figure 5. The sand discharge became almost the total suspended discharge when an average velocity of about 3 fps was reached.

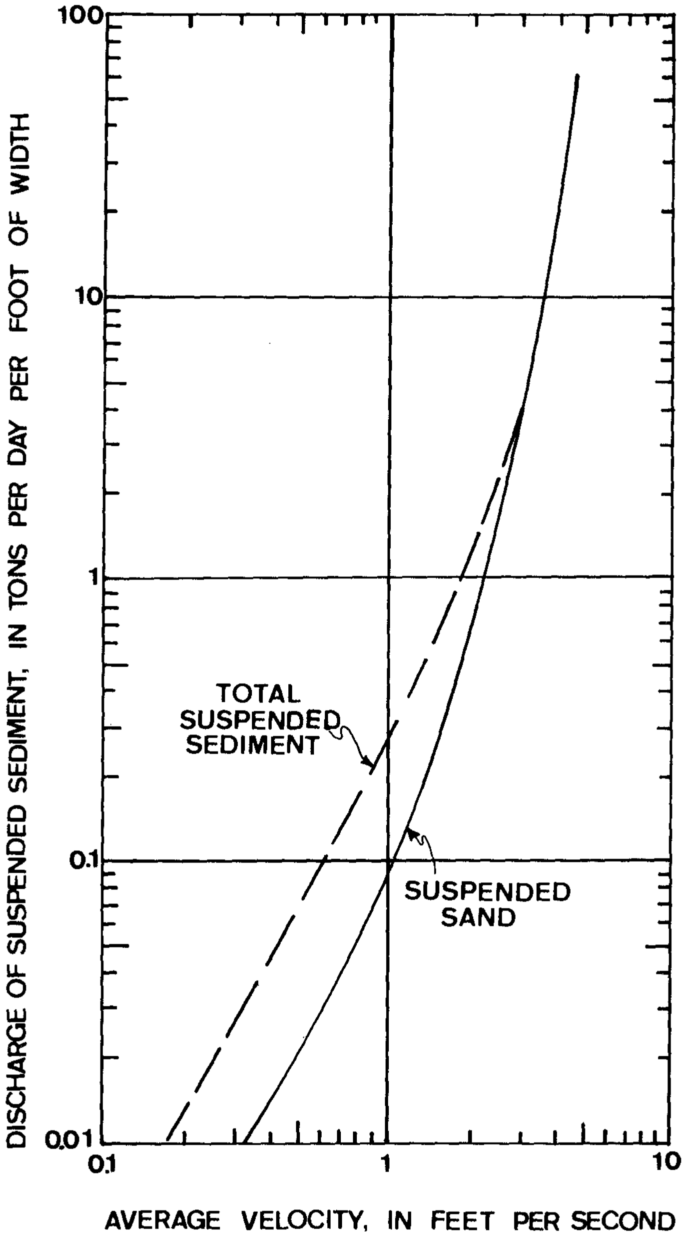

FIGURE 5.--Comparison of the relations of average velocity to the discharge of total suspended sediment and to the discharge of suspended sand per foot of width.

The relation of flow to suspended-sediment discharge for each of the periods of measurement was fairly consistent. This relation, however, changed during the tide. The suspended-sediment discharge for a given flow and the suspended-sediment concentration for a given velocity were larger in the later part of the ebbtide than they were in the earlier part. Except for the maximum flow, a given flow occurs twice during a tide; therefore, a plot of flow and suspended-sediment discharge and that for velocity and suspended-sediment concentration form loops which are counterclockwise with respect to time (fig. 6). The variation in suspended-sediment discharge at a given flow at the inlet was less than the variation at Seadrift channel. Part of the reason for this loop relation is the fact that an eroding velocity greater than a transporting velocity must be reached before sediment will move. In other words, once sediment is suspended by a moving current, less velocity is required to keep it moving.

The curve representing the floodtide relation of flow velocity to suspended-sediment discharge tends to loop in a clockwise direction (fig. 7). In this case, the rate of sediment transport was greater when a given flow first occurred than when it occurred again. The difference in the direction of the loop at floodtide and at ebbtide can be explained by differences in the relation of velocity and area of the channel during floodtide and ebbtide. The area of the channel is greater and the tidal velocity is less when the given flow first occurs than when it occurs later. During a floodtide, the process is reversed; the area increases and velocity decreases between the first and second time that a given flow occurs. Because suspended-sediment concentration is related to velocity, the concentration at a given flow is less early in an ebbtide than it is later in the ebbtide, and the concentration is higher early in a floodtide than it is later when the given flow again occurs.

Maximum suspended-sediment discharge and maximum flow seldom occurred at the same time. Usually maximum flow occurred before maximum suspended-sediment discharge although maximum flow occurred later during three of the tides measured.

Several methods of computing the suspended-sediment discharge were tried. The method that provided the best estimate was the simple relation of the suspended-sediment discharge per tide (Q_s) to the tidal range (R). The equation of the line of relation is:

$$Q_s = 31.3R^{1.433}. \tag{3}$$

However, the difference between the suspended-sediment discharge calculated from the above equation and that determined from tidal measurements was as much as 201 percent; and averaged 49 percent.

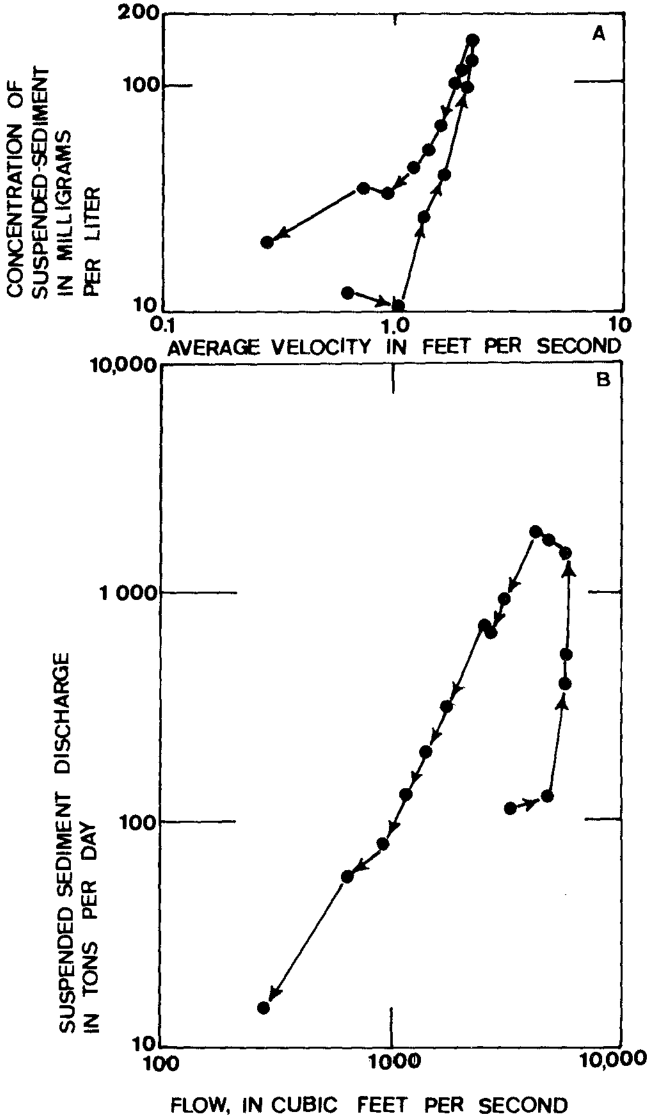

FIGURE 6.--Temporal variation during ebbtide of the relation of: A. average velocity to suspended-sediment concentration and B. flow to suspended-sediment discharge, Seadrift channel, May 20, 1969. Arrows indicate measurements.

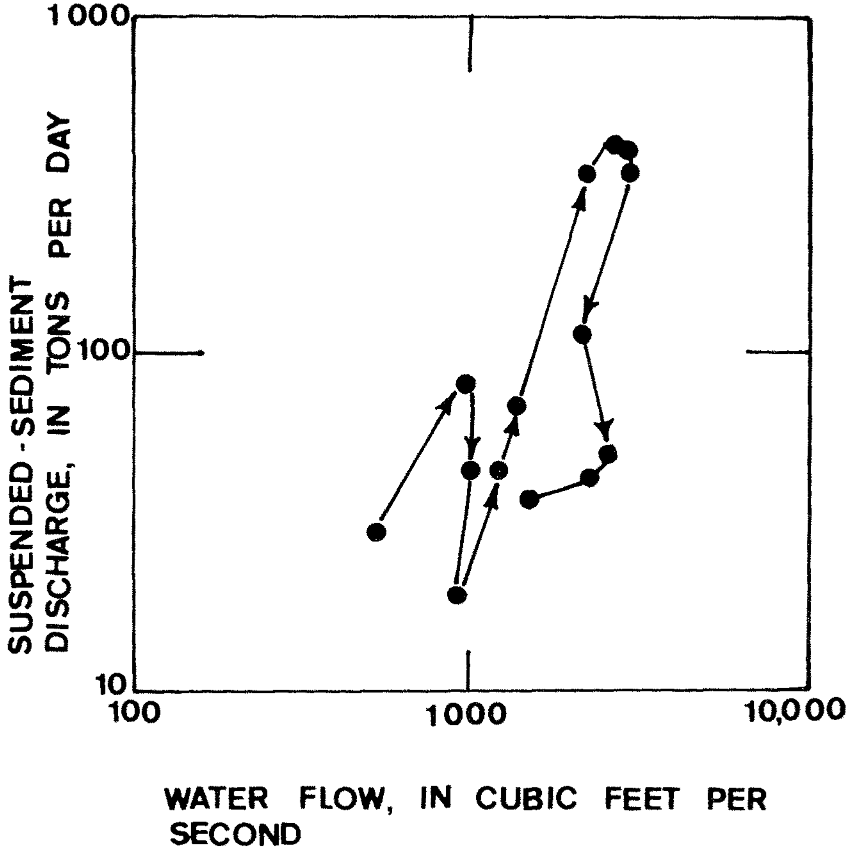

FIGURE 7.--Temporal variation during floodtide of the relation of flow to suspended-sediment discharge, Seadrift channel. Arrows indicate measurements.

Although the accuracy of suspended-sediment discharges calculated from equation 3 may seem questionable, annual suspended-sediment discharges for 2 years were computed using the equation. Floodtides carried an average of 115,000 tons per year of suspended sediment into the lagoon and ebbtides carried an average of 124,000 tons per year of material out of the lagoon. Thus, suspended sediment transported out of the lagoon exceeded that transported into the lagoon by about 9,000 tons per year. Bedload transported by ebbtides was 2,000 tons more than bedload transported by floodtides. Other calculations of sediment transport showed that about 46,000 tons per year were added to the lagoon by streams, wind, and bank erosion. The average net quantity of sediment added to the lagoon each year, therefore, is 35,000 tons. That weight of sediment, assuming 79 lbs/cu ft, represents a depositional rate of 21 acre-feet per year which is comparable to the rate of 16 acre-feet per year determined from surveys of the lagoon made in 1939 and 1968. Thus, calculations made from equation 3 seem to be adequate.

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