Turbidimeter measurements in a tropical river, Costa Rica

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ABSTRACT Sediment transport in the Reventazón river in Costa Rica was estimated by using turbidity measurements. Two types of turbidimeter instruments were tested and advantages and disadvantages with the two turbidimeter instruments are described. Sediment concentration variations during day/night and during a long period of time are discussed. The article ends with a discussion of how to design a water sampling program for a reliable sediment rating curve in this tropical river. The time variation of the water discharges and sediment concentrations constitute the basis of a representative water sampling program.

INTRODUCTION

In order to get realistic values of suspended sediment load, turbidimeters were installed at the Palomo station of the Reventazon river in Costa Rica. A complete description of the sediment load investigations is found in Jansson (1992). The investigations were made in co-operation with the Costa Rican Institute of Electricity (ICE). The drainage area upstream of Palomo is located in humid tropical climate, subtropical in the upper parts because of the height above sea level. The mean annual precipitation is between 2 000 and 8 000 mm per year. The terrain is steep, for the most part steeper than 30° and is covered with rain forest except for the area closest to the measuring station where there are coffee plantations.

This article describes two types of turbidimeter instruments, installations of the equipment and calibration methods. Diagrams of turbidity recordings in the Reventazon river are shown and discussed with the object of making a reliable sediment rating curve. Finally, there is a discussion of a water sampling program for sediment rating curves.

INSTALLATIONS OF EQUIPMENT AND DESCRIPTION OF TURBIDIMETERS

Two types of turbidimeters were installed: Hach Surface Scatter 6 Turbidimeter, and Monitek Clam 52 LE. Water was pumped up to the measuring equipment with a Wacker ESS 750 submersible pump. A sketch of the installations is seen in Fig. 1. The submersible pump is installed in a metal well. The water is pumped to a hut located above flooding level. The water passes a trap for air bubbles and then passes the Monitek instrument that is positioned in the water tube and then to the intake of he Hach instrument. In the bubble trap, and after the passing of the bubble trap, there was often sedimentation. Therefore measures were taken to remove this silt from the sedimentation pit with a small jet of spill water.

The Hach turbidimeter measures the scattered light at a 90° angle, as is demonstrated in Fig. 2. A light beam is focused on the flat liquid surface at an acute angle. A photocell detects the light scattered at 90° from the beam, converting it to an electric signal. After conversion to a digital form, data are displayed on a control unit, and

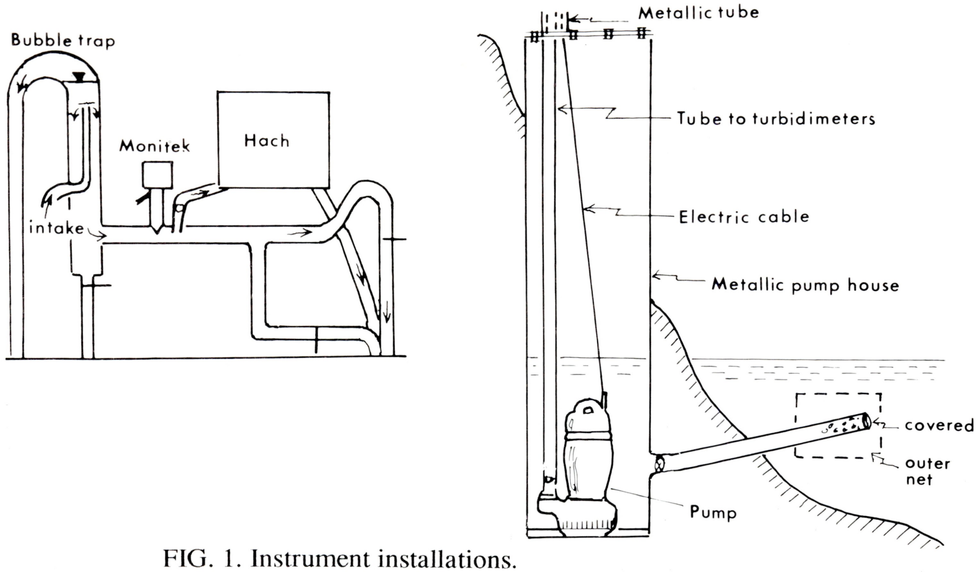

FIG. 1. Instrument installations.

talso stored in a data logger. The drawback with this instrument was found to be that the intake tube to the instrument is easily clogged with mud and organic material, especially shells from coffee beans. The intake flow should be 2 liters/minute. The obstruction of the intake tube mainly occurred at high water discharge when the water was highly

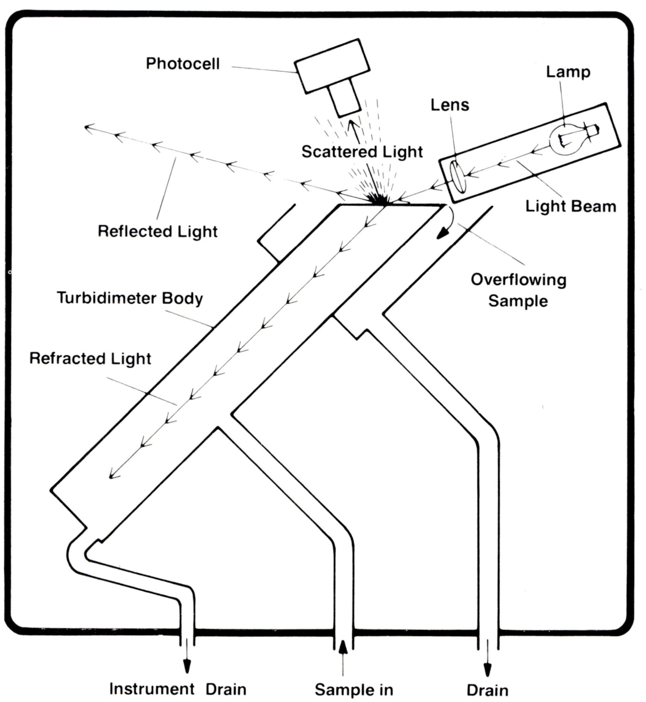

FIG. 2. Sketch of the Hach turbidimeter instrument.

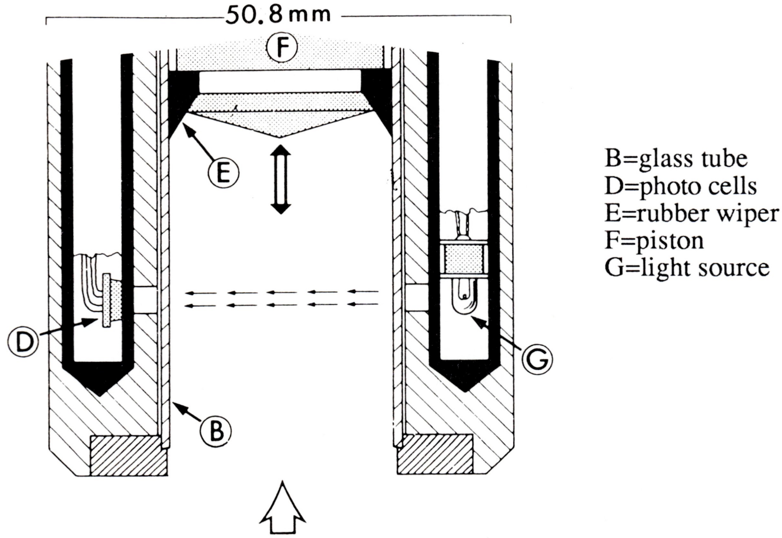

FIG. 3. The Monitek turbidimeter.

turbid, which was the most important time to get reliable data. Another consideration is that light scattering is very sensitive and needs a plane water surface. Therefore the rim has to be cleaned very often. The Hach turbidimeter needs great attention in order to function in this climatic environment.

Because of problems with clogging of the Hach instrument, a Monitek turbidimeter was installed at Palomo about two months before the end of the measurement period. The Monitec Clam 52 LE can be adapted to measure turbidity within the following ranges of concentration: 0-3 000 PPM, 0-10 000 PPM, and 0-30 000 PPM.

The Monitek Clam 52 LE instrument is based on a combination of 12° forward scattered light and transmitted light. The ratio between scattered light and transmitted light gives a linear function of turbidity without being influenced by the colour of the water. The Monitek Clam LE instrument has a short light path (Fig. 3). The sensitivity of transmitted light is due to the length of the light path through the water. However, the 12° forward scattered light needs a short light path. Low-angle forward scattered light has higher intensity relative to other angles of scattering and is more sensitive to the scattering from larger particles (cf. Gibbs 1974). The glass tube in front of the lamp and photocells is wiped automatically with a rubber scraper every 15 seconds during which new water is brought to the photocells (Fig. 3). The scraper cleans the glass of dirt and algae which can be a great problem in this climatic environment.

Data were stored in a logger at pre-determined time intervals. The time interval first chosen was three minutes, but was ultimately changed to five minutes. The data logger that was first bought together with the Monitek instrument had a very poor resolution and was changed to a new logger, Campbell CR10. The measurements were treated and logged in the following way with the Campbell CR10 data logger: Every five minutes 6 momentary measurements were made with 10 seconds interval. The average was calculated and stored in the logger. Between the water suctions every 15 seconds, sediment settles slowly and the concentration drops slightly. By averaging six values the great variations are evened out.

The same procedure of logger storing was used for the Hach measurements as was used for the Monitek measurements.

CALIBRATION

There are two aspects of calibration which need to be considered. First, calibration of the instrument for consistent reading. Second, calibration of instrument readings against suspended sediment concentration in the stream to make a calibration curve (Finlayson, 1985).

The Hach instrument is calibrated with formazin in the range of 0-9999 Nephelometric Turbidity Units (NTU). As is the case with sediment concentration, scattered light in formazin is small in the 90° direction. In formazin, scattered light is five times more intense in the 25° direction. The calibration is easily performed, and it is easy to check the calibration consistency now and then. The correlation of Hach recordings with river water concentration was not made satisfactorily during the investigation period. The peaks appeared in the evenings and nights and were difficult to predict. Therefore the calibration curve for high concentrations is not fully reliable and should be checked in the future.

The calibration of the Monitek turbidimeter was difficult as there was no calibration liquid. Perhaps formazin can be used in the future. A special calibration equipment was constructed. In a tube built as a circular flume, water with high sediment concentration is circulated and mixed with the help of a small motor. Suspended sediment from the river was used which would have been successful if it had been possible to make the mixture homogeneous in the flume. High concentration samples taken from the same mixture on one occasion varied considerably in values. The failure of efficient calibration of the Monitek instrument and the related checking of reading consistency are the main drawbacks at the moment with the Monitek instrument. However, there is no clogging of the instrument as with the Hach instrument.

A comparison between recordings from the Hach and Monitek turbidimeters is found in Fig 4. During some periods the nephelometric turbidity values (NTU) are constant but the Monitek values vary. The Hach turbidimeter seems to be choked on these occasions.

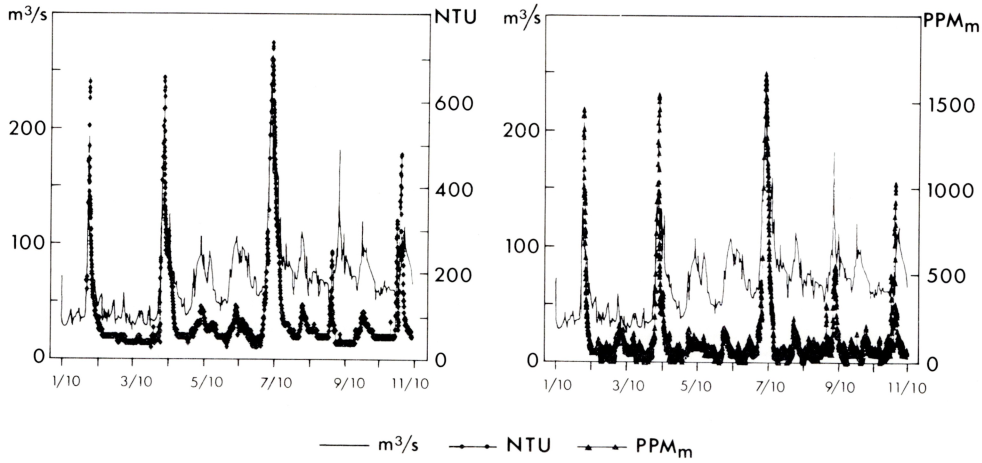

FIG. 4. Recordings from Hach (left diagram) and Monitek (right diagram) turbidimeters for the same period in October 1990. PPM_m means turbidity units from the Monitek instrument. The dates are indicated at 00.00 hrs.

SEDIMENT CONCENTRATION VARIATIONS

In order to construct suspended sediment rating curves it is essential to know water discharge and sediment concentration variations during day/night and variations during a long time period. A continuous record of concentration is then preferrable to discrete sampled concentrations. Looking at Fig. 4 it can be observed that at the Palomo station the water discharge and concentration peaks usually occur late in the afternoon or at night. It is necessary to have concentration data for evenings and nights in order to get a reliable rating curve here. With the use of turbidity recordings it has been possible to obtain sediment concentration variations for a long time for the Reventazon river at the

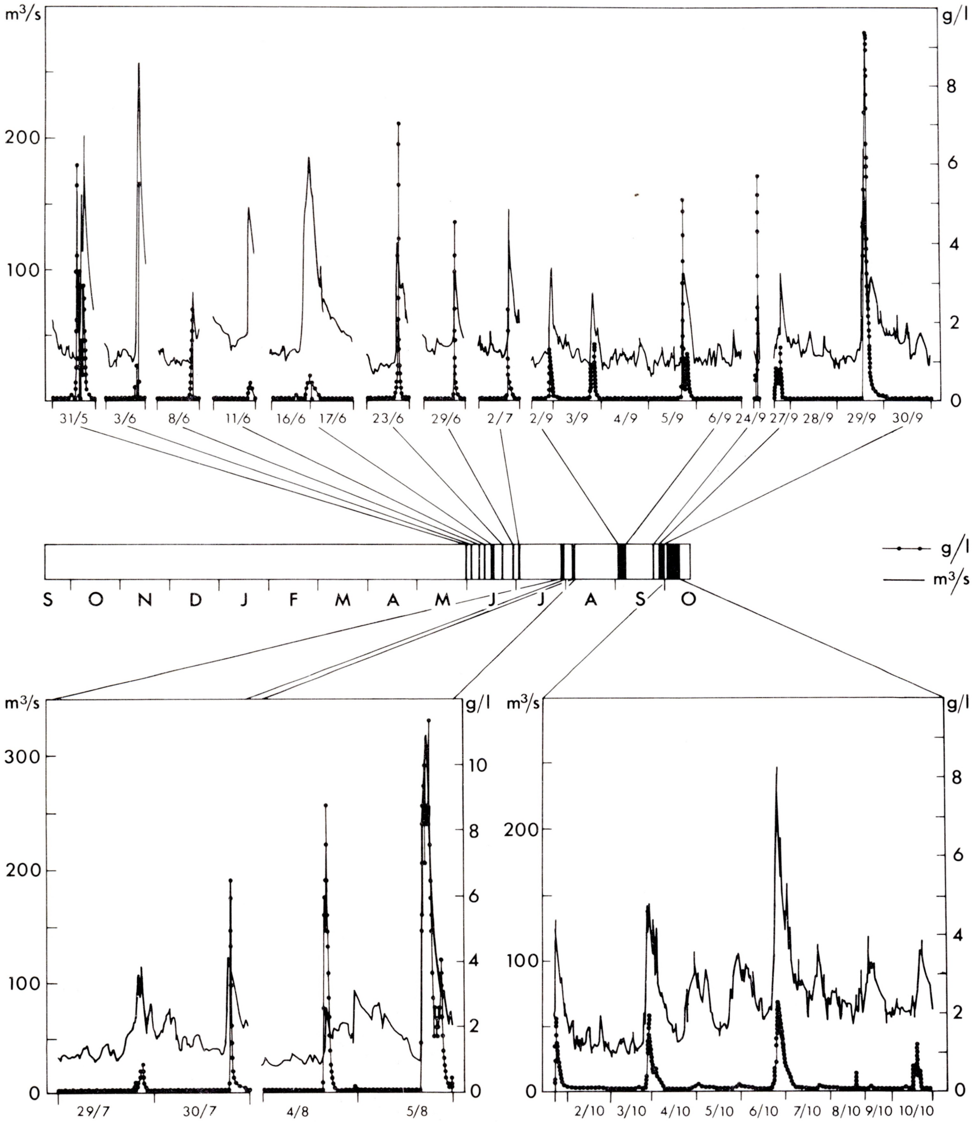

FIG. 5. Time distribution of the data base for sediment rating curves, Palomo.

Palomo station. These water discharge and sediment concentration variations are seen in Fig. 5. As can be observed, the sediment concentration varies widely between the different water peaks. Sometimes there might be slide material from river banks, road cuttings, coffee plantations or forested areas.

At the beginning of the rainier period of the year there is a tendency that the concentration peaks have a short duration (Fig. 6). Study of water-sediment loops offers a possibility to estimate from where the sediment comes. From Fig. 6 it can be concluded that the material comes from areas near the gauging station during the earlier period. Later on, the concentration peaks are broader and large amounts of material are also coming from the upstream part of the drainage area. However, the concentrations vary considerably from peak to peak. Therefore it is important to include data from as many water peaks as possible in the data base to get a reliable rating curve. It is desirable to base the curve on concentration values in each water discharge interval in relation to those of a long-term scattering in that interval.

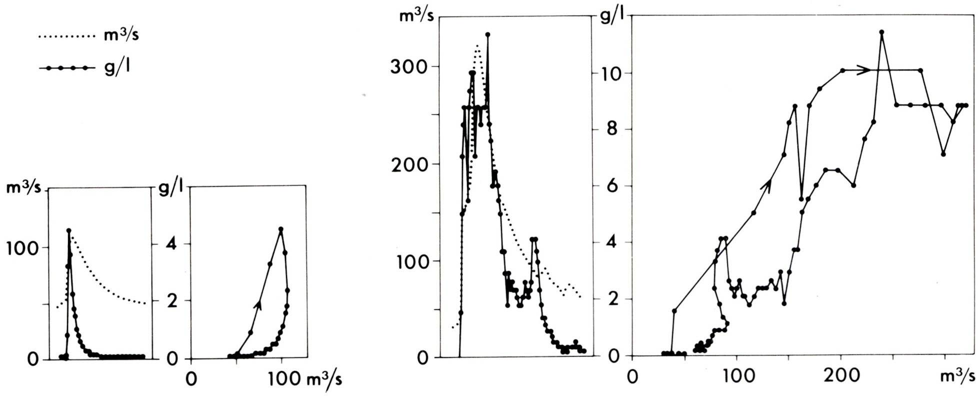

FIG. 6. Diagrams of water discharge and sediment concentrations at different high waters. The first occasion is June 29-30, 1990 and the second occasion is August 5, 1990. There are five or six minutes between recordings.

WATER SAMPLING PROGRAM FOR SUSPENDED SEDIMENT CURVES

A sediment rating curve was constructed for the Palomo station with the use of concentrations from turbidimeter measurements. The concentrations used for the rating curve are shown in Fig. 7. The data are the same as those presented in Fig. 5. The base flow is higher during some periods, thus affecting the correlation between water discharge and concentration. The scatter of Fig. 7 is very great. When we have such a scatter and want to make a sediment rating curve, it is necessary to calculate the mean concentration or load within water discharge classes. The means are easily applied in regression analysis and it is possible to see by eye if the regression curve is close to the means. A thorough analysis has shown that a log-log regression on means give good results as the bias is small (Jansson,1992).

The reliability of the sediment rating curve is of especially great significance in certain water discharge intervals in which most sediment is transported. Consequently, one should aim at fitting the curve as closely as possible to the data, especially in these discharge intervals. In order to know what water discharge intervals are crucial to cover

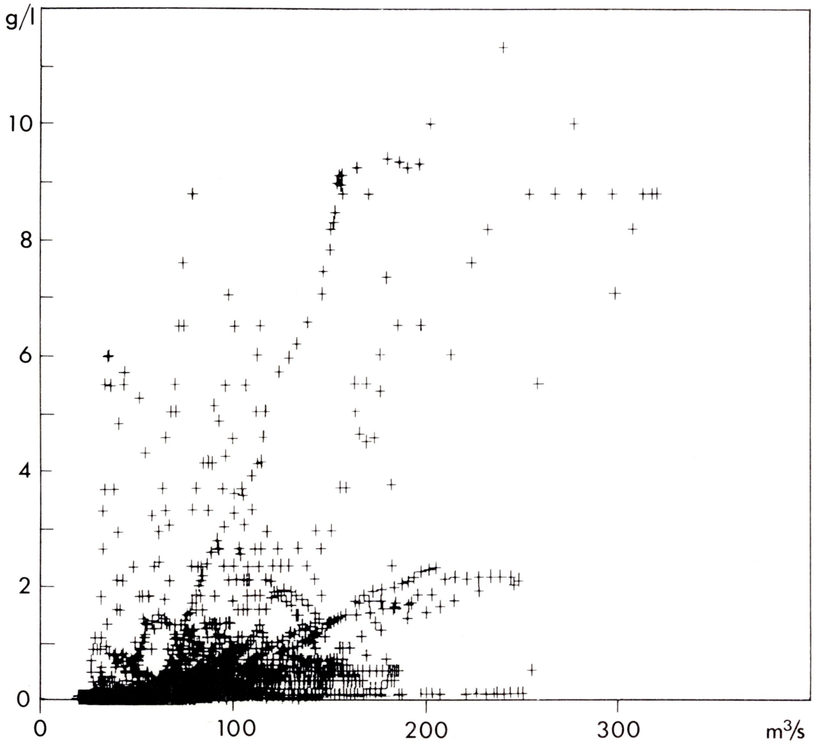

FIG. 7. Data on which the sediment rating curves are based.

in a sampling program, one can make a rough estimation of the load within water discharge classes. A water duration curve and a preliminary sediment rating curve is then used (Fig. 8). The water duration curve in Fig. 8 is based on hourly values. The duration of water discharge in class ranges of 10m^3/s is calculated.

Three sediment rating curves are compared in Fig. 8. The curve made by ICE is based on concentrations of water samples taken with conventional methods during many years. A second curve is a log-log regression on mean loads in water discharge classes calculated from turbidity data, and a third regression is a power regression on the same mean loads calculated from turbidity data.

The total loads in water discharge classes of diagram B are calculated by a combination of the water duration curve and the sediment rating curve of diagram A. For each water discharge class the total load is obtained by multiplication of the load value from the sediment rating curve equation at the mean water discharge of the class, and the duration of time within the water discharge class.

The load peaks are located far to the right of the water duration peak and also somewhat to the right of the greatest volume of water flow at 40-50 m^3/s (not shown in the Figure). Sediment loads are high in the range 30-200 m^3/s. At water discharges greater than 220 m^3/s the large difference between the sediment rating curves does not seem to affect the load to any great extent because of the low duration. Thus the critical range of the sediment rating curve, for a correct calculation of the load at Palomo, is between 30 and 200 m^3/s. Consequently, it is within this range that the resulting load is most sensitive to how correct the rating curve is and therefore one should be extra careful to adjust the rating curve as closely as possible to the data points (means) in this range. For a manual water sampling program it is essential to take many water samples

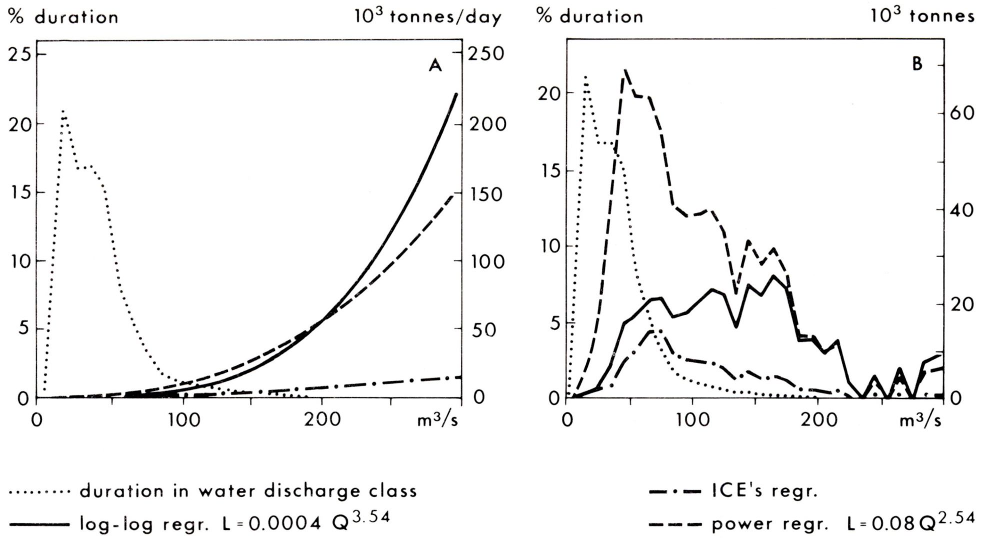

FIG. 8 A: Duration curve of water discharge for one year at Palomo based on 1-hour values calculated from digitized water stage curves. Three different sediment rating curves. B: Water duration curve and load within discharge classes calculated by means of the three regressions.

from different water conditions in this range to get representative data.

The turbidity measurements in the Reventazon river in Costa Rica have revealed that the following aspects should be considered in a manual water sampling program for sediment rating curves.

(a) Many water discharge peaks must be included because of the great concentration variations between different water discharge peaks.

(b) Water sampling must be undertaken during evenings and nights in order to include high concentrations of short duration.

(c) The crucial water discharge range to be sampled should be estimated by using water duration curves and a preliminary sediment rating curve.

ACKNOWLEDGEMENTS I wish to express my thanks to Doc. Thorsten Stenborg and Prof. Åke Sundborg for their constructive criticism of this paper. The research is funded by the Swedish Natural Science Research Council and the Agency for International Technical and Economic Co-operation.

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