Evaluating sediment yield estimations from large-scale hydrologic systems using the rating curve concept

DEMETRIS ZARRIS, DEMETRIS KOUTSOYIANNIS

Department of Water Resources, National Technical University of Athens, 5, Heroon Polutechneiou St., Athens, 15780, Greece; zarris@itia.ntua.gr

Abstract: A new approach in studying sediment yield from large hydrologic systems is presented that utilizes sediment rating curves in conjunction with reservoir sediment deposits downstream of the measurement site. It is shown that the rating curves, even with inadequate measurements, can provide a good basis for the computation of sediment yield.

Key words: sediment yield, rating curves, Acheloos river

INTRODUCTION

There are two widespread techniques for the estimating sediment yield of hydrologic basins, namely sediment rating curves and measurement of reservoir deposits. The former is preferred when sediment yield estimates in comprehensive time steps are required, provided that a quite frequent sampling program was established and a substantial number of measurements in high discharges taken. The latter delivers a more accurate long-term quantitative estimate of the total sediment load, provided that the retention efficiency of the reservoir is unified and the density of the deposits are well measured.

Rating curves are drawing serious criticism from various researchers. For instance, FERGUSON (1986) argues that when the rating parameters result from a log-log regression between suspended sediment and river discharges, an underestimation of sediment yield is resulted. Another cause of the inaccuracies associated with the use of rating relationships is the fact that a large proportion of the total suspended sediment load is transported by a few major flood events, which represent only a very small proportion of the total time. In most cases, particularly in Mediterranean type catchments, most of the annual sediment load is transported over a few days around peak flow conditions. These observations indicate two important implications for the likely accuracy of rating curve estimates of suspended sediment load. Firstly it means that a regular sampling programme is unlikely to provide samples representative of those periods when the majority of the load is transported. Secondly it means that because the rating plot is fitted by least squares to the whole range of discharge and sediment discharge of the available data, its trend may be largely determined by the main mass of samples representative of low discharges and sediment discharges, and may therefore be unrepresentative of the conditions during which the majority of the

Short scientific paper

load is transported (e.g. WALLING, 1977; ASSELMAN, 2000; SYVITSKI ET AL., 2000).

This paper's aim is to show that with an appropriate translation of sediment discharge measurements, even with inadequate data, rating curves seem to be a satisfactory tool for estimating sediment yield, at least for engineering design.

STUDY AREA AND RESEARCH METHODOLOGY

The Acheloos River is located in Western Greece and is the most important river in terms of discharge. The upper Acheloos River is discharges into Kremasta reservoir, which is the largest reservoir in the country. River flows are continuously measured at Aulaki gauging station, located some kilometers upstream from the reservoir, whereas 30 sediment discharge measurements at the same station were taken during the years 1966 to 1971. The catchment area at the Aulaki gauging station is equal to 1358 km^2 and at the reservoir's delta is 1760 km^2. Kremasta reservoir first operated in 1966 and the mass of deposited sediments were measured during the year 1998. It was found that the mean annual sediment discharge and yield are equal to 66.6 kg/s and 1185 t/km^2 respectively (ZARRIS ET AL., 2002). Mean daily discharges at the Aulaki gauging station were made available from the Public Power Corporation (PPC) for the hydrologic years 1985-86 to 1994-95. The well known distributed hydrological model MIKE-SHE (BATHURST AND O'CONNELL, 1992) was used in order to calibrate the hydrologic response of the catchment on a daily basis and to simulate the mean daily discharges for the whole period of the reservoir's operation.

RESULTS AND DISCUSSION

Two different rating curves can be deduced using sediment discharge measurements (Figure 1). The first one with only a unique power relationship valid for all discharges and the second one with different power relationships at different discharge classes (see also JANSSON, 1996). For the first curve, should be noted that a cluster of points at high river discharges are located away from the curve towards higher sediment discharges. This means that the error terms are

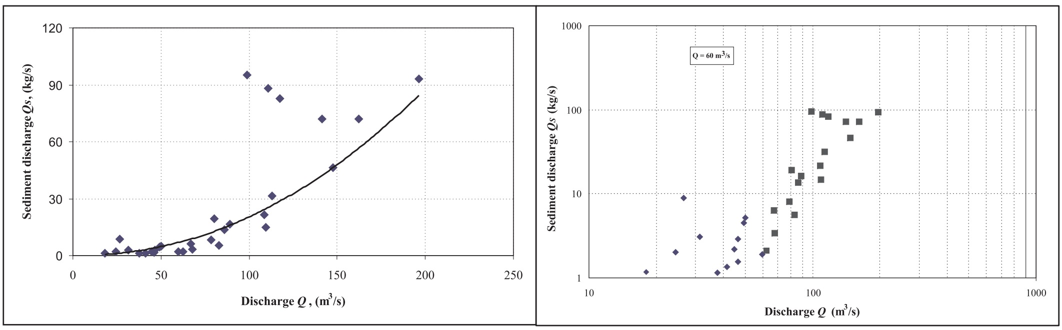

Figure 1. A rating curve for all discharges (left) and a broken-line curve for two discharge classes in log-log plot (right).

serially correlated and the rating curve obviously underestimates sediment discharges at high river flows. This underestimation could be dramatic in very rare and intense floods. The second curve is constructed with the application of broken-line smoothing methodology (Koutsoyiannis, 2000), separating the flow discharges into two classes, one below and one over a threshold of 60 m^3/s. It should be noted that the rating relationship above this threshold has a much higher slope, which could be the result of new sediment source areas available for erosion.

The application of the whole set of mean daily discharges to either the rating curves reveal very interesting preliminary results. The mean annual sediment discharge with the unique power law regression and the broken-line smoothing is equal to 13.5 kg/s and 75 kg/s respectively. The difference in the results is prominent and is explained from the influence of flood events, which are transformed into sediment discharge with a curve of a much higher slope for the latter case. It also shows that the application of the rating curve for two discharge classes results in a mean annual value of sediment discharge very close to the respective value that was computed from the hydrographic survey of the reservoir and the measurement of the deposited sediments' mass, which can be treated as the correct value.

Conclusions

This research paper shows that the rating curve concept, even with infrequent and inappropriate sampling, could give satisfactory results, provided that a proper physical explanation and an accurate mathematical representation of the data were made. It also shows that, in terms of physical processes, it is unrealistic to consider that sediment discharge exhibits the same characteristics for all the regimes of the hydrologic response of the catchment under consideration.

References

Asselman, N.E.M. (2000): Fitting and interpretation of sediment rating curves. *Journal of Hydrology* 234, 228-248.

Bathurst, J.C, O'Connell, P.E. (1992): Future of distributed modeling: the Systeme Hydrologique Europeen. *Hydrological Processes* 6, 265–277.

Ferguson, R.I. (1986): River loads underestimated by rating curves. *Water Resources Research* 22 (1), 74-76.

Jansson, M.B. (1996): Estimating a sediment rating curve of the Reventazon river at Palomo using logged mean loads within discharge classes. *Journal of Hydrology* 183, 227-241.

Koutsoyiannis, D. (2000): Broken line smoothing: a simple method for interpolating and smoothing data series*, Environmental Modeling & Software* 15, 139-149.

Syvitski, J.P., Morehead, M.D., Bahr, D.B., Mulder, T. (2000): Estimating fluvial sediment transport: The rating parameters, *Water Resources Research* 36 (9), 2474-2760.

Walling, D.E. (1977): Assessing the accuracy of suspended sediment rating curves for a small basin, *Water Resources Research* 13 (3), 531-538, 1977.

Zarris, D., Lykoudi, E., Koutsoyiannis, D. (2002): *Sediment yield estimation from a hydrographic survey: A case study for the Kremasta reservoir basin, Greece*, Proceedings of the 5th International Conference "Water Resources Management in the Era of Transition", Athens, 4-8 September: 338-345 p.