Estimation of annual average sediment loads in small and steep catchments

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INTRODUCTION

The revision of the Federal Act on the Protection of Waters and the water protections ordinance in Switzerland has the aim to decrease negative effects of water power use and revalue watercourses as an ecological living space. To achieve such a revaluation, measures to renovate the sediment balance which is often disturbed by existing constructions like water diversions, reservoirs and torrent control works, are applied. An existing enforcement aid for the assessment of the need for renovating the sediment balance was complemented with an additional practical guideline, which shows all necessary steps to calculate average annual bed load and was developed by private engineering offices by order of the Federal Office for the Environment FOEN (Hunziker et al, 2014).

The method encloses instructions to estimate average annual bed loads into receiving watercourses at a relative small expenditure. The level of detail is therefore smaller than the one of a detailed bed load budget study. Detailed analysis of dredging data of 75 sediment retention basins from the data base SOLID of the FOEN helped to develop the method.

METHOD

The first step of the procedure includes a selection of relevant catchments. Relevance is shown by traces of sediment transport found by aerial photo evaluation and field checks. Traces are i. g. delta in receiving water, fan apex going to the receiving water, obvious sediment transport in the channel.

The second step includes the bed load estimation for recurrence intervals of 2-, 10-, 30-, 100- and 300-years all the way downstream to the fan apex (Fig. 1). Fig. 1 shows on the right side the magnitude of sediment volume indicated by the arrow thickness. The estimation of bed load with recurrence intervals of 30-, 100- and 300-years is done after approved methods which were derived during the last years and also have been applied in the production of hazard maps (Gertsch et al., 2012). For bed load of higher frequency (recurrence interval of 2- and 10-years) new estimation methods have been developed. Data were derived from dredging in sediment retention basins and from hazard maps. Catchment dependent multiplication factors to assess the bed load volume of each recurrence interval could be introduced (high factor: important sediment sources, debris flows, steep channels; low factor: lack of sediment sources, accumulations).

The third step contains the evaluation of bed load loss between the fan apex and the receiving watercourse. The loss is mainly caused by so called sediment reducing elements (SRE) like sediment retention basins, overbank sedimentation, debris flow deposits, insufficient capacities of bridges and channels as well as by natural channels with small gradients. It is to check for each scenario, to what degree a SRE reduces the sediment volume. In Fig. 1, due to sediment loss by the SREs „natural overbank sedimentation“ and „insufficient capacity“ at a bridge, the sediment volume of a recurrence interval of 300 years will be reduced to the one of a recurrence interval of 30 years, indicated by decreasing arrow thickness of the recurrence scenarios 300y to 30y.

The calculation of average annual bed load (Gm) into the receiving water is the fourth step of procedure (Fig. 1). Every bed load scenario from the catchment area is reduced by the volume of the sediment loss between fan apex and receiving water. The calculation of the average annual bed load is done by using a fictive series:

Gm = ((1*300y)+(2*100y)+(7*30y)+(20*10y)+(120*2y))/300

300y is the bed load of a recurrence interval of 300-years.

CONCLUSION

Compared with methods to estimate bed load in terms of hazard mapping, the new method forms a methodical enlargement according to frequency and space: the evaluation in hazard maps only considers the 30-, 100-and 300-annual bed load up to the fan apex or to the entrance of the settlement area, while the method described here includes high frequency bed loads and the stream all the way down to the receiving water. As all sediment assessment methods, there are uncertainties to regard. There is not yet enough experience around to indicate the uncertainties, but a margin of error of 30 - 50% has to be accepted.
The method is also suited for other applications, e.g. flood control, hydraulic engineering or bed load deposit management, like:

– Selection of critical reaches along the stream, which will require a sediment budget study for more detailed information.
– Basis for the design of retention basins including their outlet structure.
– Evaluation of the periods of time to get sediment retention basins, reservoirs or other structures filled by deposits.

During the last two years the method was applied in Switzerland to evaluate structures in need of sanitation in parts of the cantons Valais, Schwyz and Obwalden.

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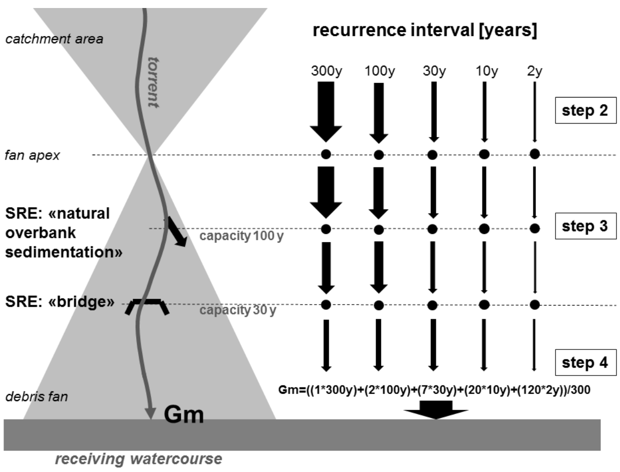

Figure 1. Assessment of annual bed load from an affluent (left side) in the receiving watercourse, considering different bed load recurrence intervals and loss on the fan because of SREs (right side). Magnitude of sediment volume is indicated by the arrow thickness.

KEYWORDS

Bed load; estimation; torrents; mean annual sediment; receiving water

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