MODELLING OF SEDIMENT TRANSPORT: LINK IN A CHAIN

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1. INTRODUCTION

Rather than reporting on a specific topic of current research in the broad field of sediment transport and river morphology, the writer will give a general contemplation on the state of the art. This will not be a review in the usual sense. The allotted space would then be filled easily with references. References will only be made here if it cannot be avoided. Moreover only sediment transport due to currents will be treated.

To avoid confusion it is necessary to indicate that modelling of sediment transport is used at present (1977) in at least three meanings (it is only necessary to look at the titles of the papers grouped under this heading at the Baden-Baden Congress):

(i) A theoretical framework for sediment transport proper. This mainly implies a relation between hydraulic parameters and the amount of sediment transport. This framework will have to be supplemented with experimental data before a useful transport predictor is attained.

(ii) A mathematical framework for morphological processes in rivers, used to forecast morphological changes in rivers e.g. due to human interference (morphological computations).

(iii) A scale model with mobile bed of a river in order to carry out similar predictions as under (ii) (mobile-bed scale models).

In which follows the vague term "modelling of sediment transport" will be avoided if confusion may be introduced.

The leading thought in this contribution will be that we can only improve efficiently our knowledge on the various topics in sediment transport and river morphology if we use application as a guide. It should not be overlooked that modelling in sediment transport is only a link in a chain.
2. APPLICATION AS A GUIDE

2.1. Transport predictors

Many transport predictors are known (as will become clear the word "transport formulae" will be avoided here). This implies already that "the best transport predictor" does not exist. It is remarkable that handbooks on sediment transport - the writer rates Graf (1971) and Raudkivi (1967) as the best - do hardly pay attention to the use of transport predictors.

In many cases attention is paid to the comparison of measured and calculated transport. Much is written on the accuracy available in this respect; very little on the accuracy required. A few remarks have to be made here.

A good way to judge the available accuracy between measured transport \( S_m \) and calculated transport \( S_c \) is to plot these quantities versus each other. The deviation from the line of perfect agreement can then be seen clearly. If sufficient data are available then the probability distribution of \( S_m / S_c \) or a similar procedure used by White and Ackers (1973) can be used.

Figure 1 shows a \( S_m vs. S_c \) for data of the Magdalena River in Columbia as quoted from Jansen (1978). It regards here values of \( S_c \) determined by the transport predictor of Engelund and Hansen (1967); this one appeared to give the best results. However, is the available accuracy sufficient? This question is important because if the answer is negative then further (expensive) research may be necessary along a number of lines:

- improvement of transport predictors
- improvement of measuring techniques, including instrumentation.
Fig. 1 Comparison measured and calculated transport (Magdalena River, Colombia)
It is the writer's feeling that too little attention is paid to the aspect of required accuracy. Is this due to the fact that this problem is so complicated?

2.2. A hypothetical test case

Suppose a reservoir has to be built in a river (e.g. for water power, irrigation etc.). The sedimentation of this reservoir has then to be forecasted. The (probability distribution of the) economic life time has to be estimated. The accuracy of the answer depends on the accuracy of methods and data used for the prediction. In principle the sedimentation can be simulated mathematically. This simulation process in fact is a chain in which three main links are:

(i) The prediction of the discharge (rainfall runoff)
(ii) The prediction of the sediment transport due to the discharges (transport predictor)
(iii) The prediction of the sedimentation (morphological computation).

It is not easy to guess which main link is the weakest. In other words, can improvement of the final answer (economical life time) be obtained, if necessary, in the field of hydrology, sedimentology or morphology?

In fact, this hypothetical test case results in a plea for integrated approach of research to find the weak link(s). Only in that case research can be efficient and not turn out to be riding a hobby horse.
2.3. Roughness predictors

It has to be said here that Figure 1 is misleading. The Engelund-Hansen predictor used to determine $S_c$ was based on the measured alluvial roughness (e.g. expressed in the Darcy-Weisbach friction factor $f$). This, however, is not allowed if the transport predictor is used to forecast sedimentation of reservoirs. For those cases not only the discharge but also the roughness should be predicted and from these two values the prediction of $S_c$ should be made.

For the Magdalena River case the plot $S_m$ vs. $S_c$ disimproved substantially if the roughness data were predicted! Qualitatively this would indicate that improvement of the available roughness predictors will improve the accuracy of the predictions of the sedimentation of the hypothetical reservoir of section 2.2. However, improving of rainfall-runoff models still could be strengthening a weaker link.

In spite of this remark some considerations have to be given on roughness predictors and transport predictors. Why has the wording transport formula been avoided here? There is a simple answer to this question. When Einstein (1950) presented his method to determine $S_c$ from the hydraulic data it had two main characteristics:

(i) This predictor was not just a formula, but a procedure which in that pre-computer time was time consuming.

(ii) It was questionable, considering the scatter in the observations ($S_m$) whether such a complicated predictor was necessary or whether a much simpler formula would not do as well.

The situation has changed during the last decades. With the help of our modern slave - the computer - there is no longer a need to select a simple formula on the basis of time consumption. More complicated transport predictors are now acceptable. However, this
is only justified when it is necessary. Nevertheless an important constraint is taken away.

A similar situation is present for roughness predictors. The writer has the feeling that the - in general - bad results obtained with presently available roughness predictors can easily be explained... not easily taken away! Steady uniform flow, both for water and sediment, can be obtained easily for laboratory conditions. For natural rivers steady uniform flow does hardly exist. It is a great challenge to include time-effects in roughness predictors!

3. TRANSPORT PREDICTORS AND MEASURING PROCEDURES

The writer only rather recently has given his views on the use of scale models and morphological computations in a general sense (de Vries and van der Zwaard, 1975). Therefore this aspect will not be discussed here. Attention will be given to the fact that research on morphological computations can be fruitful to research on transport predictors.

For rivers with bed-load transport mainly, morphological computations can be based on the assumption that the local transport is related to local hydraulic conditions. It has been shown by Kerssens (1974) that for suspended load a different approach may be necessary (see also Kerssens et al. 1977). Whether or not this is possible depends on the scale of the problem. The available models for bed load can be used for suspended load also if the river reach under consideration is long compared to the adaptation length, i.e. the distance over which the vertical distribution of the concentration is adjusted to the local hydraulic conditions.
This has a remarkable consequence, because it means that suspended load is more difficult to measure than bed load. This requires an explanation. Why is sediment transport measured? In the writer's opinion very rarely, because it is just nice to know how much sediment passes a given station of a river. In the majority of the cases sediment transport is measured to be compared with a transport predictor. The best transport predictor is then used to forecast morphological changes.

But this implies that as long as transport predictors assume steady uniform flow for water and sediment, this kind of flow should also be present during the measurements. In rivers steady uniform flow is an exception. Hence the hydraulic parameters of a cross-section may not be determining for the suspended load through this cross-section! But this can mean that the present procedure: measuring suspended load in a cross-section has to be reconsidered.

It is an example of the logical fact that insight in the physical phenomenon has to be used to adjust measuring procedures. It has to be recalled that earlier it was already stated that for certain situations bed load should not be measured in a cross-section (de Vries, 1973). For bed load this is due to unsteadiness of the transport in detail (via the bed form). For suspended load it deals with the overall unsteady character of the transport.

These remarks can perhaps contribute to a way out from the present deadlock: There is hardly a need to improve the simple transport predictors as long as the measurements show so much scatter, but there is also hardly a need to improve instrumentation and measuring procedures as long as our theoretical frame work (transport predictor) is so weak. The search for the required accuracy can be a guide.
Symbols

\( S_c \)  \text{calculated transport (bulk volume)} [L^3 T^{-1}]

\( S_m \)  \text{measured transport (bulk volume)} [L^3 T^{-1}]

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