Sympathetic changes in river regime

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The Author has provided an interesting analysis of the data of Schumm^{1,6} relating to rivers which have experienced changes in hydrological conditions and appear subsequently to have attained stability. He proposes to apply the relationships so derived to rivers subjected to constraints by training and other engineering works.

39. The equations derived correlate the channel dimensions of width, depth and slope with discharge and bed material size, similar in form and parameters to the Lacey equations for steady regime flow channels in alluvium.^{4,8} The Lacey equations do not allow for variation in sediment load and are not generally applicable where this differs appreciably from the rather low concentration found in irrigation canals. These equations can be used in certain cases of constraint, for example to indicate depth where a channel is constricted in width, using an equation relating depth to discharge per unit width, provided the sediment concentration is low. However, in rivers the relationships are more complex because of the wide variation in discharge and sediment load and the diversity of conditions leading to energy loss by factors other than bed forms. The variation in discharge might be allowed for by the dominant discharge concept of Inglis,⁹ but it has not yet been shown whether this would be the same in respect of width, depth and slope and whether it is approximated by, say, the bankful discharge irrespective of the pattern of flood flows. With regard to sediment load it is known that this has a marked effect on width, depth and slope; Schumm,^{1,6} using the same data as used by the Author, showed that the proportion of silt and clay in the bank material influences or is related to the channel shape. As these factors were not included in the parameters it is not surprising that the Author found such large variation and scatter in his results.

40. The data used in derivation of the equations in the Paper, are only 38 in number and come from only two geographical regions. Moreover, the particular constraints to which the rivers concerned have been subjected are not stated, the characteristics of these rivers are not compared with data of corresponding rivers which have attained a stable regime without constraint, and the equations put forward have not been tested against data of actual cases outside the data used in their derivation. Is it assumed that the equations must apply to any case of constraint, regardless of the type of constraint implicit in the data? If so, this calls for explanation. It appears from Schumm's papers^{1,6} that the catchment of the Murrumbidgee river had undergone a climatic change leading to a reduction of width, discharge and sediment load, whereas in the cases of the American rivers the changes were due to the construction of dams and diversion works upstream. In the case of storage reservoirs the effect would be through a changed pattern of flood flows and trapping of sediment over a long period, whereas in the case of diversion dams without much storage the effect would be on sediment load for a shorter period. In all these cases the downstream river would adjust to the new

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conditions by changes in width, depth and slope but, although width and depth might adjust over a period of years or decades, modification of slope involving building or cutting of a flood plain might occupy a much longer period. In the meantime width and depth might reach a temporary or primary stability consistent with the contemporary slope.

41. A presumption in the Paper is that the channels were stable. They may have been sufficiently stable for Schumm's purposes but some may still have been at the stage only of primary stability. It also appears that the constraint in all the cases was in the slope and that where final stability had been reached the constraint would have disappeared and the river would be free to adopt a stable regime in the normal context of varying discharge and load.

42. Examination of Schumm's papers shows that the discharge given in Table 5 of the Paper was the bankful discharge calculated by the use of Manning's formula, therefore requiring assumptions of the value of Manning's n . The depth was the maximum depth, not the average depth as stated. I was puzzled by differences between data of some of the rivers, apparently at the same sites, quoted in two of Schumm's papers^{9,10} but I understand that the differences were due to the results of surveys made at different locations at different times. Some of the differences were considerable and show the wide variation which can be found in the same river at nearby sites. In reference 6 sediment samples were taken at a depth of 4 inches and were considered to be more reliable than those taken in reference 10.

43. For a further appraisal of the data I calculated Manning's n and mean shear stress and compared the bankful channel dimensions with those calculated by the Lacey regime equations, which broadly indicate stable dimensions of straight channels in alluvium with steady flow and small but significant sediment load. It was not expected that the rivers would be identical, because they have a varying flow and load and their sinuosity and bank roughness results in steeper energy gradients, but the Lacey channels provide a useful basis of reference. In nearly half the cases Manning's n had been chosen between 0.02 and 0.04, but in ten cases it lay between 0.04 and 0.05, and in ten it exceeded 0.05. There was thus a great range and more than half the rivers were given very high values which put them in a separate category. If these values are correct they indicate the need for another parameter in the slope equation to represent rugosity or sinuosity. How did the Author assess n ? 24% of the river channels had widths less than the Lacey widths for the same discharge and bed material size; the remainder ranged to twice the Lacey width. A trend of falling river/Lacey width ratios with *increasing percentage of silt and clay in the samples confirmed Schumm's observation*. More than half the rivers had depths greater than the Lacey depths; some were more than twice as deep. The Murrumbidgee river generally had slopes less than the Lacey regime slope, associated with greater depths, but the American rivers had slopes 1–14 times the Lacey slopes—a very wide range. Comparison with Shields'¹¹ criterion for threshold bed movement showed that in all 38 cases mean shear stress exceeded 10 times Shields' values, in 28 cases it exceeded 20 times and in 8 cases 50 times. This diversity generally reflected the variation in slope, but must also have been associated with variation in sediment load. No data of sediment load were available and this may have been a major cause of scatter in the Author's correlations as he was unable to include this parameter.

44. I therefore think that the data presented cannot be considered to be adequate in number or spread for the derivation of general equations. In the absence of data on sediment load, which are difficult to obtain, the Author might consider the use of another parameter related to it, such as the ratio of mean shear stress to Shields' value for threshold movement.

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Mr Thomas has highlighted several shortcomings of the data. In rivers the conditions are indeed different from those in alluvial canals and several factors come into play

which are not included in the parametric correlations evolved in the Paper; this has resulted in a large scatter in results.

46. I also agree that insufficient data are presented for the equations to be considered valid in general application. However, it was beyond the resources available to me to obtain more data and it was considered that at least a start could be made on the analysis of river data for derivation of parametric interrelationships which could be progressively improved on when more comprehensive data become available.

47. It is true that there is an implied presumption in the Paper that the channels were stable. This presumption could be challenged as no river could be said to be in perfect stable regime. There are seasonal as well as long-term changes in all rivers; some are due to natural causes and others to man-made interference. The only precaution that could be exercised under such conditions is that rivers which are grossly in unstable regime could be omitted from consideration.

48. Mr Thomas states that the equations have not been tested against data of actual cases outside the data used in their derivation. In fact, the statistical correlations were derived on the basis of 36 observations in reference 5 and their applicability was tested subsequently using data from 38 observations on rivers in the USA and Australia given in Table 5.

49. Mr Thomas has questioned whether the equations are considered to apply to any case of constraint regardless of the type of constraint implicit in the data. The data used in derivation of the correlations pertained to rivers with different constraints and so the equations in Table 3 based on pooled data are considered applicable to all rivers regardless of the type of constraint. When specific constraints are imposed, these equations reduce to the form derived in §§ 16-29.

References

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