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TN 310 DISCUSSION

Simulation of surges after removal of a separating barrier between shallower and deeper bodies of water

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The problem of inception and propagation of a shock in open channel flow, taking friction into account, has been dealt with by a number of investigators.[8–12] There are two approaches to solving this problem: the method of isolating the shock and the method of continuous calculation. In the first method the shock is isolated, the jump conditions are applied at it and the St Venant equations used on either side of it. Use of the characteristic grid makes it possible to isolate a shock. However, programming with this method can be complicated. Vasiliev[10] used this approach in conjunction with a movable grid. To overcome difficulties resulting from the non-prismatic character of natural channels, he used a difference scheme of the predictor–corrector type, as had previously been used in gas dynamics by Alaliken *et al.*[13] The calculations were done in two stages. In the first, the unknowns were calculated on an intermediate time level using a non-divergent scheme. In the second stage, the unknowns were computed using an explicit divergent scheme. The Authors have followed Vasiliev, but used only the first stage of his difference scheme. In practical cases of flows in which a number of surges might form and interact, the method of isolating the shock would present almost insurmountable difficulties in programming.

16. The method of continuous calculation is quite suitable in the latter cases and has been dealt with by Terzidis and Strelkoff,[9] Vasiliev *et al.*[8] and Sivaloganathan.[12] They use a divergent form of the St Venant equations, which are solved throughout using diffusing scheme,[9,12] the Lax–Wendroff scheme[12] or an implicit scheme.[14]

17. The Authors have used the Colebrook-White formula in the evaluation of the friction slope term of the St Venant equations apparently because of its merits as applied to steady flow computations.[1,15,16] However, they have expressed the view that in the numerical simulation of laboratory-scale channel flows, the use of the uniform channel flow formulae for the evaluation of the friction slope term is unsatisfactory. They do not substantiate this opinion. The adequacy or otherwise of any formula for the evaluation of the friction slope term should be judged by its performance in the unsteady channel flow equations and not from steady flow

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considerations. The Authors have assessed the performance of the Colebrook–White formula for the said purpose, but do not appear to have used the Manning (or Chezy) formula for the same purpose before making their judgement on the adequacy of the latter for the purpose.

18. The Manning formula has been used successfully for the evaluation of the friction slope term, in the numerical simulation of unsteady laboratory-scale channel flows, by a number of investigators.[8,9,12] Favre's experiment[11] 7 series 111(7), the results of which were used by Terzidis and Strelkoff,[9] Vasiliev *et al.*[8] and Sivaloganathan,[12] is of particular interest. In this experiment, water was initially at rest at a uniform depth of 0·205 m in a horizontal channel of rectangular section 0·42 m wide and 75 m long with Manning's constant 0·01. Then, at the upstream boundary, a discharge of 0·028 m^3/s was introduced in 0·2 seconds. Vasiliev *et al.*,[8] Terzidis and Strelkoff[9] and Sivaloganathan[12] performed computations for the resulting flow (and surge movement), each using different finite difference schemes and a Manning's constant of 0·01, and found satisfactory agreement with observed results. The percentage differences in depths that result for this case, if the Colebrook–White formula is used in the evaluation of the friction slope term, are given in Table 1. The differences are so small that they cannot be visibly indicated on figures to the scales used in the Paper. Table 2 gives percentage differences that result if friction is ignored. It is clear that the effect of the friction term on the solution of the St Venant equations is relatively small in cases where shocks are involved.

19. The scales of Figs 3–6 are such that the magnitude of the differences between observed and computed depths are not readily apparent. In Figs 3 and 4 a number of the observed depths appear to exceed the computed depths by 8–14%. In Fig. 6 differences of 12–18% are apparent. In the face of differences of such magnitude between observed and computed results, I do not understand the relevance of the much smaller differences that result from the use of one or the other of the formulae in the evaluation of the friction slope term.

20. In some experiments by the Authors, roughness sizes of 0·127 ft have been used. What were the depths involved in these experiments? If they were of the

Table 1. Percentage difference between depths using Manning's formula and Colebrook–White formula in friction slope evaluation; Favre's experiment 7 series 111 (7)

Time, s	Distance, m					
	0	20	31·5	43·5	55·5	75
10	0·122	0·000	0·000	0·000	0·000	0·000
20	0·239	−0·043	−0·345	0·000	0·000	0·000
30	0·347	0·073	−0·085	−0·245	0·000	0·000
40	0·454	0·180	0·030	−0·127	−0·280	0·000
50	0·549	0·284	0·130	−0·023	−0·175	−0·768
60	0·646	0·380	0·240	0·084	−0·670	−0·577
70	0·730	0·475	0·324	−0·447	−0·413	−0·409
80	0·820	0·560	−0·237	−0·232	−0·228	−0·409
90	0·895	−0·081	−0·080	−0·075	−0·070	−0·066
100	3·336	0·080	0·088	0·094	0·098	0·102

Table 2. Percentage differemce between depths with Manning's $N = 0{\cdot}01$ and with friction ignored for Favre's experimental series 111(7)

Time, s	Distance, m					
	0	20	31·5	43·5	55·5	75
10	−0·387	0·000	0·000	0·000	0·000	0·000
20	−0·774	0·139	1·042	0·000	0·000	0·000
30	−1·140	−0·246	0·273	0·807	0·000	0·000
40	−1·504	−0·615	−0·110	0·419	0·944	0·000
50	−1·850	−0·976	−0·473	0·049	0·569	2·627
60	−2·190	−1·325	−0·829	−0·313	3·856	2·724
70	−2·518	−1·664	−1·173	1·433	1·400	1·392
80	−2·837	−1·992	0·826	0·810	0·799	0·791
90	−3·146	0·256	0·240	0·224	0·213	0·205
100	1·194	−0·321	−0·334	−0·350	−0·361	−0·368

order of 0·25 ft or 0·5 ft, a roughness height of 0·127 ft would represent 50·8% or 25·4% of the depths respectively. In this event, what portion of the water section area is occupied by these projections? Was this taken into account in the evaluation of the section properties such as the area of section, hydraulic mean depth and hydraulic depth?

Professor Barr and Dr Das

Many papers have been published on the numerical methods of solution of the St Venant equations in different physical situations, e.g. flood routeing, the dam-break problem and tidal flows. Price[17] compared the four basic numerical methods and concluded that they are of similar accuracy, although they vary in efficiency according to the nature of the problem considered and the permitted error in calculation. Wylie[18] concluded, after solving an example by means of the implicit method, that although this method provides stable results, it is liable to produce incorrect results if the reach length and the corresponding time increment are increased to extreme values. Successful application of the explicit method of solution has been shown by Orlob,[19] Shubanski and Sheffey,[20] and Balloffet[21] in estuary flow problems, and by Balloffet *et al.*,[22] Chen and Armbruster,[23] Muskatirovic[24] and Marvaud[25] in the dam-break problem. Thus many investigators have found methods and special details that best suit their needs, and have achieved results which are satisfactory for their particular problems and range of variables. We initially started[6] with Vasiliov's oblique grid but eventually developed it into an explicit scheme of computation. Details have been given[7] of computations, first in mobile grid points with subsequent evaluation in the original grids by interpolation by this explicit method, and with the determination of the front by the method used by Sakkas and Strelkoff[26] based on Whitham's[27] approximation at the tip region.

22. The advantages of using the Colebrook–White function have been explained.[2,3,6] The Manning n or Chezy C is not intended to be used to assess the resistance once the flow conditions enter the transition turbulent zone. The successful application of Manning's n[8,9,12] as cited by Dr Sivaloganathan may

result from the unsteady flows used always being in the rough turbulent zone. The small percentage difference in depths resulting from use of the Colebrook–White function as given in Table 1 may be due to the same conditions of rough turbulent state of flow. In this connection, Ragan[28,29] showed experimentally how Manning's *n* changes with depths. He concluded that numerical solution of St Venant equations is very sensitive to errors to roughness coefficient. Thus the use of a constant value of Manning's *n* seems unrealistic and the small percentage difference in Table 2 with constant Manning's $n = 0{\cdot}01$ and friction ignored seems at variance with the findings of Ragan.

23. Dr Sivaloganathan has pointed out that the difference between observed and computed depths in Figs 3 and 4 is 8–14% and, in Fig. 6, the differences of 12–18% are apparent. Differences of this order between observed and predicted points are not unusual in numerical solutions. In the dam-break model of Chen and Armbruster,[23] the differences in observed and computed peak discharges, travel time of leading fronts and stage hydrographs were of the order of 22%, 37% and 17% respectively. Considering the approximations, simplifications and assumptions involved in developing a numerical model, our overall discrepancies in observed and computed points seem to be acceptable from the viewpoint of engineering applications. Comparison was primarily between observed and predicted front positions, and some graphical error may be involved in respect of depths. The system was closed, and with the amount of fluid in the system actually invariant, such representation was not thought so critical as front position.

24. Although Dr Sivaloganathan and we have referred to the Colebrook–White function, it was not the basic function for the commercial roughness route which was used in the case of the roughened flumes. The pipe sizes of Nikuradse were originally assessed volumetrically, after the roughness was in place. So visualization if ever the equivalent of Nikuradse's sand grains has to take this into account. The ability to provide equivalent resistance by arrangements that are volumetrically of less effect than even the half sand grains which have to be visualized as the standard addition, has often been observed. Until comprehensive data are available, we believe that our calibration process was satisfactory, provided undue extrapolation outside the range of observation is not attempted.

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