Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2018-242-AC2, 2018

Hydrology and Earth System Sciences Discussions
Open Access

HESSD

Interactive comment

Interactive comment on "Conservative finite-volume forms of the Saint-Venant equations for hydrology and urban drainage" *by* Ben R. Hodges

Hodges

hodges@mail.utexas.edu

Received and published: 18 December 2018

xcolor

From the author: My thanks to Reviewer 2 for the constructive comments. I believe that responding to these comments has significantly improved the paper.

I have added a supplemental file that is a markup using a blue font for all the major changes.

REVIEWER: Comment 1: -p.8, eq. 17: I have some doubts on this equation. For what I understand, the LHS term of Eq. 17, in which appears the vector u_i, is in vector form. The RHS terms seem to be scalars (i.e., projections). Unfortunately, the vector $\hat{i}$ is allowed to change between the upstream and downstream sections of the finite volume (only his slope is allowed to change, of course, as his horizontal direction is assumed constant here). In the RHS, the first term is projected along $\hat{i}_u$, the second term is projected along $\hat{i}_d$, the third term I do not know. Please clarify.

Response: This is now eq. 19. You've pointed out an area of the paper that really wasn't very clear. The advective terms are not the prime focus of the paper, so I wasn't quite as detailed as I should have been. I have revised the discussion substantially and added Appendix A to clarify the details. The complexity arises because of the subtle distinctions between the streamwise velocity ($u_{\hat{i}}$) that is at an angle to the control volume face and the normal velocity $u_k n_k$ that the provides the flux Q. The key point is that for a simple straight segment with a linear free surface, the control volume formulation integrates to exactly eq. 19, and for a curving system and/or non-linear free surface the equation is approximate, but exact as $L \rightarrow 0$. The discussion has been substantially revised and the definition of M_e, the source/sink terms, moved from above the equation to below the equation, which makes it easier to find.

REVIEWER: Comment 2: p 9, l.21-ff: This reasoning seems to be tailored for rectangular cross-sections with the breadth B=constant. It is not so intuitive (to me) to extend it to cross-sections of general shape. If the breadth changes along the control volume, the side pressure has a component along the channel axis too. How it this considered? At p.11, l.1 I see "bottom pressure term", but the wet boundary of the channel is not only its bottom.

Response: I did not intend "channel bottom" to apply only to prismatic shapes where the flat bottom is distinct from sides. I find that conceptual models requiring a separation of sides and bottom to be troubling as the transitions in a natural channel seem to be arbitrary. The intent (although I clearly missed the mark in the explanation) is to treat general bottom topography with some local surface normal $\hat{n}$, from which only the components in the streamwise direction can have impact on the flow. This applies even when the bottom is a side. In effect, when the channel side changes from uniform to increasing breadth the surface normal changes from pointing across the channel to pointing slightly downstream. This is translated into a stair-step area that provides a pressure contribution in the streamwise direction. I have substantially revised the discussion under the section **Pressure on bottom** – including renaming the section **Pressure on bottom topography** to emphasize the point. I think the addition of Fig. 4 and the revised discussion helps illustrate how widening of the channel is represented as part of the 3D stairstep structure. I have introduced a further way of envisioning the bathymetry as rectilinear bricks that may help seeing how the concept extends in 3D.

REVIEWER: Comment 3: p.12, l.10-ff: This reasoning should apply also to the cross-sectional area, not only to the bottom elevation (if the cross section is not prismatic, see the comment above).

Response: This discussion, starting before Eq. 28 has been completely rewritten to be clear that it applies to general topography and not simply to prismatic sections.

REVIEWER: Comment 4: p13, l. 4: the implications of the second approximation deserve some additional comments. Does this approximation mean that the derived equations are only suitable for (smooth) subcritical flows? The power of FV scheme is the ability to handle rapidly varying flows, discontinuities and shock waves.

Response: The second approximation you're referring to is that "effects of momentum redirection around bends are handled in friction and non-hydrostatic pressure terms". As a direct answer to your question: this approximation (although poorly described) does not have any effect on whether the derived equations can be used for only smooth subcritical flows – the question of suitability for transcritical flows depends on the discretization of the scheme rather than the governing equations. The point I was trying to make (albeit badly,) is that this is a fundamental approximation in all Saint-Venant solutions of real river channels that have curvature – but is ignored in almost all the literature. Momentum in the x direction doesn't just become momentum in the y direction around a bend without the intervention of a pressure gradient. And yet, when we solve equations that "unwrap" the river with a streamwise coordinate system, we are assuming that that pressure-induced redirection is immaculate and without loss of momentum.

To try to clarify, the statement in question has been re-written as "the effects of momentum redirection around bends is either negligible or is handled in friction terms" so as to avoid prolonged discussion of the role of cross-channel gradients of hydrostatic pressure and non-hydrostatic pressure in momentum re-direction. In the section on the advection terms (where the approximation is originally introduced), the following is the revised discussion: "the use of a gradually-varying streamwise $\hat{i}$ direction implies that pressure is perfectly redirecting momentum through bends and aligning the momentum with the free surface. These are (generally) unstated approximations used in common 1D SVE formulations. However, it should be noted that this perfect momentum redirection is not precisely correct; e.g., secondary circulation in bends affects bed shear, velocity distribution, and frictional losses (Blanckaert and Graf, 2004)."

REVIEWER: Comment 5: -p.19, l.28: When the cross-sections are broadly spaced... This is not a trivial issue. In fact, in hydrology and urban drainage applications is generally difficult to include a great number of (close to each other) cross sections. However, the use of broadly spaced cross sections conflicts with the 2nd geometric restriction (bottom elevation varying monotonically within the control volume). Moreover, how to find a tradeoff between broadly spaced cross-sections and an effective representation of convective accelerations? (this last point is maybe less important when considering smooth flows).

Response: I entirely agree. Broadly-spaced cross-sections are not a trivial issue and there are many trade-offs to be considered. However, to delve into this issue in the Discussion section of the paper would probably be too speculative given that what is practical depends quite strongly on the discretization of the model rather than specifically the governing equations - with the proviso that S_0 is a major issue of the governing equations. From my perspective, if a modeler has the cross sections that shows the river is non-monotonic then those cross sections should be used in the model to avoid non-monotonic finite volumes. My personal opinion is that the difficulty in including a large number of cross sections in hydrological and urban drainage models is due to (1) poor model construction that makes inefficient use of parallel computing power, and (2) the introduction of non-smooth S_0 that makes it difficult to converge a solution where cross sections are close together. There are certainly some data problems associated with getting enough cross sections, but I've seen too many instances of cross sections that are close together being thrown out simply because the model couldn't converge. The idea that we throw out good data because it doesn't work in our models is really quite troubling. I've added some further discussion on the use of S_0 and why we shouldn't use it – I hope you find this useful.

REVIEWER: Minor comments (not repeated here)

Response; All the minor comments have been fixed, with the exception of the comment about repetition of the approximations to the full equation in the discussion section. I agree that the Discussion section contains a lot of summary, so I have renamed this Summary and Discussion. I believe the approximations associated with the governing equations are important and deserve to be restated in a prominent place.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-242/hess-2018-242-AC2-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-242, 2018.