Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2020-44-RC3, 2020

Earth Surface Dynamics Discussions

Interactive comment on "Controls on the hydraulic geometry of alluvial channels: bank stability to gravitational failure, the critical-flow hypothesis, and conservation of mass and energy" *by* Jon D. Pelletier

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Received and published: 24 August 2020

In this manuscript the author sets out to demonstrate that bankfull heights of river banks, and thus the well established hydraulic geometry equations, can be defined by cohesion modulated geotechnical stability. The author tests their hypothesis for a large (387) database of river banks in the Mississippi River Basin (MRB). The author uses large scale soil databases to derive geotechnical properties of the river banks, a welcome approach to address data paucity. The results show that river bank height does indeed appear to be controlled by clay content and the ensuant bank cohesion

defining geotechnical stability. This manuscript comprises a large dataset and the author has done a thorough job of compiling and testing the data, and associated errors implicit in the soil survey data used. I think that the application of such a diverse dataset to this problem warrants publication, but I have a few comments and queries regarding some of the assumptions and discussions made in the paper, detailed below, which I hope the author finds useful.

The proposition of the manuscript (ln 9) is that bankfull depth is predominately defined by the maximum geotechnical stable height of the banks for a given cohesion. Once the critical bank height is exceeded, failure will occur resulting in a self-limiting mechanism on bankfull depth. By definition, if a bank exceeds its stable height for a period of time, it will fail back to a stable height. In the strictest sense, this proposition is not new or previously unexplored. Indeed, as stated by the author in line 34 "This paper demonstrates that bankfull depths predicted by a bank-stability model correlate with observed bankfull depths estimated. . ..in the Mississippi River Basin". The bank-stability model used is that of Chen et al (1971) and the ASCE (1999) – lines 61 – 75 and Eq's 2 -4. Thus, the model in itself is not new, so in effect what this paper is doing is applying a well-established model of critical bank height to a large set of observed data to demonstrate that the model matches observed bank heights. Is this, therefore, a novel premise if the model is known to represent the physical well and has been widely applied? By definition, a channel can not be deeper than the distance between the maximum stable bank height and the deepest part of the channel (for a persistent period for time), therefore it is likely that global (or large) datasets will average out at this maximum stable height as a statistical average.

I find the section between lines 30 and 34 quite confusing. The author states that channel incision or floodplain deposition may increase bank height (OK so far). This causes banks to collapse once a critical bank height is reached. The subsequent failure results in channel widening which tends to increase water depths back towards the stable bank height. It is this last bit that I find counter to the previous few lines. I follow the argument that a wider channel results in slower flows, but the reduction in flows is a result of the increased channel capacity due to increasing width, and so there is no need for the channel to continue to incise of raise water depths to hold the same volume of water, as the increased width accounts for this. Furthermore, it has been shown recently that over long time frames, channels tend to maintain an equilibrium width (and thus presumably bank height; see Mason and Mohrig, 2019) and that the channel adjustment due to bank collapse also often sees increased deposition on the inner bank (see van de Lageweg et al. 2014). A clearer explaination of how bank failures can result in increased water depths would be welcome.

The author also notes a few potential limitations to the data exploration in the discussion, but does so briefly and in passing. I would like to see a more developed discussion around the role of vegetation induced cohesion, and also the role of failed material (particularly in clay rich soils which are more likely to fail and persist in blocks at the base of the river bank), as these are likely to be key local controls on any variation in the relationships the author has presented. Another potential source of variaiton that isn't raised but may also be important is the role of floodplain topography in defining bankful depths and bank heights. If a bank is eroding through a scroll-bar then it is likely that following a failure the local bank height may decrease as a result of variable local topography (i.e. on a floodplain where elevation is sloping away from the bank). Following the model presented here, will that new bank remain stable until its critical height either is reached through channel incision or build up from floodplain deposition?

Following on from this, on Ln 272 the author states that an increase in bank height caused by floodplain deposition may trigger bank failure. Presumably, to deposit material on the bank the flow needs to be over-bank. Therefore, is it the deposition of the material on the bank during these flows, for the increased water velocity and bank shear stresses that will induce this erosion?

Overall, I think a lot of the issues raised above come down to the temporal scale being examoined here and there is a need for some discussion the manuscript around the

time-scales over which these processes may become the dominant factor and how time-averaging of the other processes involved in river bank erosion occurs. Could the author examine any historical rates of bank erosion for sites analyses in the manuscript to see whether the theoretical model holds for different time periods?

A small point on the colouring of figure 1: To my eyes the background panel surround the basin appears the same as the 30% clay content colour and is very confusing. Could this be changed to avoid confusion.

Refs not included in original manuscript: Mason, J. and Mohrig, D. Differential bank migration and the maintenance of channel width in meandering river bends, Geology (2019) 47 (12): 1136–1140.

van de Lageweg, W.I. and van Dijk, W.M. and Baar, A.W. and Rutten, J. and Kleinhans, M.G. (2014) 'Bank pull or bar push : what drives scroll-bar formation in meandering river?', Geology., 42 (4). pp. 319-322.

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