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Interactive comment on "The influence of a vegetated bar on channel-bend flow dynamics" *by* Sharon Bywater-Reyes et al.

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Interactive comment on "The influence of a vegetated bar on channel-bend flow dynamics" by Sharon Bywater-Reyes et al.

AC: We thank the reviewers for their insightful comments, to which we have responded in detail below. Major revisions to the paper include A) reframing the introduction and motivation of the research by synthesizing what we know about vegetation and channel bends from the literature; B) clarifying details concerning methodology by adding this information to the main text or referring to the Supplement, where much of the details were already housed; C) more explicitly stating assumptions of modeling approach; and D) revising the discussion by deleting portions that bordered speculative

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(fine-sediment deposition and channel geometry in vegetated channels) and adding in additional insights related to ecogeomorphic feedbacks and chute channels on vegetated point bars. We believe the manuscript is clearer and more focused. Thanks for your consideration.

Anonymous Referee #2

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R2C1: This is an interesting study, which examines the impact of different vegetation types and densities on flow through a channel with a vegetated bar. The topic is relevant and the work builds on a significant literature in this area. While the work seems rigorous and of good quality, there are some details of the methodology that would benefit from clarification. Furthermore, the data could be better presented to improve clarity.

AC1: We have clarified methodology questions and will improve figures, in response to specific reviewer suggestions, before final resubmission.

R2C2: Major Comments: Representation of vegetation: The authors raise the issues regarding the use of roughness coefficients for representing vegetation. Accordingly, they adopt a much more suitable drag-based approach. However, there are still potential limitations with this approach. In particular: the parameterisation of drag coefficient, the distribution of drag elements in space and the assumption of a logarithmic profile may represent significant limitations of the study and could receive more attention in the text (see specific comments below)

AC2: We recognize that our modeling does not fully represent the complexities of field-based vegetation and flow conditions; we have added or revised text in several locations to highlight our assumptions and/or limitations, including a paragraph in the Discussion (end of 4.1) explicitly discussing these issues.

R2C3: Methods: There are a number of details regarding the numerical methodology which are currently not presented, but which may have a significant impact on the results (e.g. average drag force equation, grid size & type, relative errors, approximate depths, delineation of bar).

AC3: Both reviewers requested clarifications on modeling details. We have added text to address these details in both the main text and the Supplement (in some cases, the information requested by reviewers was in the Supplement in the original version). We have added a sentence pointing readers to the Supplement early in Methods. In some cases, we have moved details that were previously in the Supplement to the main text, in response to review comments, but some details we consider more suitable for the Supplement.

R2C4: Figures & Data: Figure 2b could be presented more clearly. Figures 5-7 could be made clearer, but also some data is referred to which is not present in these figures (higher Q values for XS1 &3).

AC4: The revised manuscript will include revisions to increase the clarity of several figures. Specifically, we will add the average curve for each seedling size to Figure 2. For Figures 5-7 we will add colors and include all figure combinations; important examples will be in the main text and additional combinations, of which there are many, will be presented in the Supplement.

R2C5: Specific comments: Pg 5 Ln 5: Is A_S defined? Appears in supplementary data, but I'm not sure it is defined in the main text?

AC5: Changed to Ac to reduce confusion/simplify

R2C6: Pg 6 Ln 12: What was the grid size used in the simulation? Was it constant for the whole domain? Was bank (wall) shear stress included too? (i.e. cells with wall boundaries too).

AC6: We have added details on grid resolution to the main text (2.5 x 2.5 m cells for calibration runs, 5 x 5 m cells for remaining runs); they are also in the Supplement.

The grid size was constant for the whole domain (although as noted, differed between calibration and other runs). We added a reminder in the main text to point readers to the Supplement. Wall stresses were not calculated. These should be negligible in the channel modeled here, where width » depth.

R2C7: Pg 6 Ln 20: In Table 1 it would be helpful see the relative magnitude of errors. Errors of 0.18m in WSE and 0.36m/s in velocity seem large, but may not be relative to the mean values? Table 1 does also not provide a comprehensive overview of the calibration. E.g. which different values were used for C_d? What was the sensitivity to this value? The two LEV values are an order of magnitude apart, were any other values in between tested? What was the rationale for picking these values? Also, the table seems to suggest that a model without any vegetation performed better than the model with vegetation?

AC7: We added more detail to Table 1 and the Supplement concerning WSE and Åł calibration. We added details to the text concerning the range of LEV and Cd values tested. The model with vegetation for Q2 (453 m3/s) did perform slightly better in terms of WSE, but by a minimal amount. We do not have Åł measurements for this flow.

R2C8: Pg 7 Ln 11: These relaxation figures mean very little out of context. Please provide brief explanation of which variables they correspond to.

AC8: Added clarifying text ("FaSTMECH uses relaxation coefficients to control changes in a parameter between iterations (Nelson, 2013). Relaxation coefficients were set to 0.5, 0.3, and 0.1 for ERelax, URelax, and ARelax, respectively, through trial and error.")

R2C9: Pg 7 Ln 15: Why were you unable to maintain a curvilinear grid? This is unclear. Which nodes overlapped and why? Was the model run in Cartesian grid? Section 2.2 seems to suggest it was curvilinear (Pg 6, Ln 5). If values were converted between grids, how was this done, i.e. interpolation methods, grid sizes etc.

AC9: We added the text "We were unable to maintain a curvilinear, channel-fitted grid

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(nodes overlapped) so we projected our Cartesian coordinate flow solution output to the nearest grid cell of a curvilinear grid (2 by 2 average grid resolution) covering the main channel, and converted the associated output to streamwise and stream-normal values with a rotation matrix. A piecewise Cubic Hermite Interpolating Polynomial algorithm was applied to reduce artifacts from the transformation" to the Supplement.

R2C10: Pg 8 Ln 7: Presumably the model uses an equation in terms of drag force per unit volume? It would be useful to include the exact form here.

AC10: Added detail that drag is averaged over vegetation polygons. Because the model is 2D, drag force is per bed area, not volume.

R2C11: Pg 8 Ln 10: I agree with the authors that C_D=1 is a common first-order approximation, and probably does an ok job for the lower section of the plants where objects are likely to be cylindrical. However, for trees, with complex foliage I would expect this assumption to be less accurate. Therefore, it might be worth reflecting on the accuracy of the model at different discharges

AC11: We added a paragraph in the Discussion (end of 4.1) discussing these issues.

R2C12: Figure 3: How was the vegetated bar delineated? Current vegetated extent?

AC12: Vegetated bar was delineated based on current mapped vegetation extent (Fig. 1), as indicated in the main text and the Supplement. (one of our responses to Referee 1 also addresses delineation of the vegetated bar)

R2C13: Pg 8 Ln 13: If I am correct, a height-dependent value of A is used (from Figure 2). However, regardless of depth, the near-bed vegetation geometry will not change. Therefore, in terms of defining near-bed processes linked to sediment transport, I wonder what the impact is of changing A_c as depth increases, given that this impact may only be significant towards the top of the flow? Above a certain height, does the effect of area on bed-processes diminish?

AC13: This is correct, a height-dependent value of frontal area is used, from Fig. 2

(which we will revise for clarity; we have also made minor revisions to the caption for clarity). As shown in Fig. 2, the height dependence of Ac is most important for depths between ~0.2 and 1 m, with variations among growth stages, and diminishing effects at greater heights (Fig. 2). We agree that near-bed processes most linked to sediment transport are not fully captured by this approach. Given our focus on hydraulics, rather than near-bed sediment transport processes, we consider our approach to be adequate. Indeed, we consider using field measurements of vegetation structure with ground-based LiDAR to determine frontal area and variations with height, for different growth stages, and incorporation of height / depth-dependence of frontal area into modeling, to be an advance over standard modeling practices and a strength of our study.

R2C14: Pg 8 Ln 12: How does the grid resolution compare with the stem density? Are the effects of a single stem artificially 'smeared' over many stems? If so, particularly for low vegetation densities, the flow patterns may not correspond well with single, isolated large area blockages, which will have a very different impact to wide-spread small blockages.

AC14: We have added details on grid resolution to the main text; they are also in the Supplement. Stem density is used to calculate projected vertical frontal area of vegetation and vegetation form drag (eq. 1). Our intent here is not to represent the effects of vegetation at all scales, but rather to assess two end-member density and vegetation drag scenarios. We recognize the complexity of vegetation affecting hydraulics at multiple scales as a function of patch configuration. We have treated these topics in other papers (see response to comment below). We reference Vargas-Luna et al. (2015a) in that representing vegetation as cylinders averaged over an area works best for dense vegetation.

R2C15: Pg 8 Ln 13-14: The flow will typically not be logarithmic where there is vegetation present. Therefore, what errors does this assumption introduce? Are the results valid?

AC15: We recognize that vegetation will disrupt logarithmic velocity profiles, and we agree that a complete representation of vegetation effects on the velocity profile is a worthy goal, albeit one that we consider beyond our scope. We added text more explicitly recognizing the limitation of assuming a log velocity profile ("The model assumes a logarithmic velocity profile, although we recognize this is an over-simplification of how factors such as vegetation submergence alter velocity profiles (e.g., Manners et al., 2015)." In general (including via revisions in response to comments here) we have sought to be transparent about the limitations of our modeling approach, and to emphasize results and insights that we consider valid even in light of those limitations.

R2C16: Pg 9 Ln 5: 20 stems per square metre seems very dense for saplings and trees? Also, for such densities, is it still valid not to consider the mass blockage effect of the vegetation?

AC16: Densities of 20 stems / m2 are indeed dense, but are consistent with literature values; we have added references. Furthermore, our objective is to investigate end-member cases. With respect to the second part of the comment, regarding mass blockage effect, we agree that this could be an important effect for larger-diameter plants. For the size (diameter) of plants in our field site, even at the high densities considered here, we do not expect plants to act as collective bodies with mass blockage effects. We have thought extensively about the relationship between vegetation morphology and organization on hydraulics. In Bywater-Reyes et al. (2017, JGR-ES), we use terrestrial laser scans of woody seedlings to measure roughness density, blockage effects, and implications for hydraulic structures. In Manners et al. (2015, JGR-ES) and Diehl et al. (2017, ESPL), we measure (in a flume) how woody seedlings differentially affect hydraulics and topography depending on whether they are organized individually or in patches.

R2C17: Pg 9 Ln 32: Decreasing velocities in the thalweg is surprising –but seems to correspond to additional flow along a separate channel to the right of the vegetated bar? It seems this is quite an important aspect which affects other results too (e.g.

flow deflection into this channel for certain vegetation conditions). This could be made clearer within the discussion which frames the problem as a simple channel bend with vegetated bar.

AC17: We have added text to the Discussion (section 4.2) about the low-elevation area on the inside of the bar, which resembles a chute channel, and identifies this as a common feature along vegetated point bars.

R2C18: Pg 9 Ln 32: Are the observed decreases/increases in velocity significant with respect to uncertainty/error?

AC18: We have added more detail to methods addressing uncertainty in velocities.

R2C19: Figures 5-7: These graphs are not easy to read. I wonder if colour could be used in addition to line style, or results separated for density & type? Furthermore, it is unclear why lateral velocities are not reported for XS2?

AC19: The revised final manuscript will include revisions to increase the clarity of these figures, including use of color. We will also add new plot for additional scenarios (e.g., lateral velocities for XS2), some of which will be in the Supplement.

R2C20: Pg 14 Ln 9: Would be helpful to show the data for each XS for Q>10, not just XS2.

AC20: We will add figures showing results for additional scenarios (but with some in Supplement)

R2C21: Pg 14 Ln 16-17: As mentioned above, it seems the side channel to the right of the patch plays an important role in conveying discharge, particularly for higher Q values. Is this process more important than channel bend processes?

AC21: As noted above, we have added text to Discussion regarding the low-elevation / chute channel on the inside of the bend, and linking to field studies on interactions among chutes, vegetation, and morphodynamics in meandering channels.

R2C22: Pg 15 Ln 8-10: I agree that results show that the impact of vegetation increases with Q, but I do not think results show that the vegetation begins to impact on channel-bend hydraulics for Q>Q2. It seems to me that even at Q=Q2 there are significant differences in velocity distributions that may, over a long period cause significantly different channel morphology?

AC22: We have revised the text here in an effort to clarify the discharge dependence of vegetation effects on hydraulics, and to emphasize that the effects are most clear from Q2 to Q10. Below Q2, inundation of vegetation is insufficient for it to have a substantial effect. We added information on what effect is detectible given our calibration of velocity.

R2C23: Pg 15 Ln 16: I do not think the results show any evidence of 'linear' trends?

AC23: Reworded

R2C24: Pg 16 Section 4.2: It would be good to quantify the correlation between sediment and vegetation, beyond the visual observation in Figure 8. Also, these patterns demonstrate the limitation of assuming constant vegetation density across the bar as mentioned earlier.

AC24: We deleted Fig. 8; our intention in including it was to show general relationships between vegetation and sediment patches, rather than to go further in quantifying correlations. We have added additional text to the Discussion (4.2) about vegetation and sedimentation on bars, drawing from literature.

R2C25: Pg 18 Ln 21: The authors mention the presence of bars with vegetation/no vegetation. This study investigates the difference of plant type (age) but this in itself is related to channel morphology (e.g. plant succession over time) and flood discharges (e.g. destroying plants or creating new bars). It would be interesting to think about how the model could be developed to introduce different vegetation types, depending upon bar age, etc.

AC25: Future versions of the model will likely have more flexibility in terms of the vegetation characteristics that can be included. However, since the model is 2D and typically calibrated to specific conditions, it would be difficult to do all that here. We believe the Kleinhans group has been working on something similar to what you are proposing, and we have added citations to the text to better represent their work, as well as explicitly identifying directions for future modeling (end of 4.1).

Please also note the supplement to this comment:
https://www.earth-surf-dynam-discuss.net/esurf-2017-56/esurf-2017-56-AC2-supplement.zip

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