Interactive comment on "Morphological dynamics of an englacial channel" *by* G. Vatne and T. D. L. Irvine-Fynn

P. Carling (Referee)

p.a.carling@soton.ac.uk

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REVIEWER: PAUL CARLING

"general comments"

I found this manuscript to be a potential useful contribution to the understanding of the evolution and function of englacial streams. The authors should be congratulated for obtaining survey data over many years in a demanding environment. The introduction and theoretical context are thorough and it is especially useful to draw analogy with the development of channels in homogeneous bedrock. However, the degree of detail provided in some sections reduces to vague speculation and the manuscript would make a better and more impactful paper if some of this additional information was excised. I provide examples below.

Response

We thank the Reviewer for complementing this work as an academic contribution to stream morphology. Specifically, we are pleased to see the Reviewer finds our introductory material linking englacial channels to form and process found in terrestrial river systems useful. We thank the Reviewer for highlighting areas by which our manuscript may be tightened in terms of the additional detail that would help eliminate any residual uncertainties. However, we also note that the Reviewer finds some degree of lacking focus particularly in the latter portion of the manuscript. Here, we concede that, particularly with a similar view shared by the other Reviewers 2 & 3, our discussion is rather heavily weighted to the "conceptual model" we developed in terms of the englacial channel development over the course of our observation period. To address this issue, given we feel that presenting the conceptual model still holds value, as emphasized by Reviewer 3's comments, we would careful revise the discussion section to focus more clearly and direct on the specifics retrieved from the results aligned with our core questions: (i) do englacial conduits exhibit time-invariant morphological characteristics? and (ii) which factors control knickpoint face gradient and upstream recession rate? To reduce any suggestion of unsubstantiated speculation, we would edit material presenting our conceptual model by introducing a new, short section with the subtitle "Conceptual model of channel development". This subsection would appear as a revised component within the discussion text. We note that Reviewer 3 indicated that our discussion advances our understanding of these englacial systems with "sound qualitative explanations" for the found morphological evolution, and so we see no need to substantially change our inferences or interpretation. However, as Reviewer 3 also noted, areas within the text could be presented more succinctly and so we assume that the proposed reorganisation and shortening of the entire discussion section would meet these concerns, presenting our ideas in a more logical order and with a heightened degree of brevity. We note our responses to more specific details and concerns over material that may be considered "supplementary" as the Reviewer highlighted are addressed in the text that follows, below.

"specific comments"

It was not clear to me why this example of a englacial stream should be of the cut- and-close kind, rather than an engacial conduit developed along fissures. Detail of the channel morphology is diffuse within the manuscript. It is not clear if at times the con- duit is surcharged (cf phreatic) or always 'vadose'. Thus it is not clear what portion of the conduit is actually part of the wetted channel. For example at line 14 Page 7628 the depth of the conduit is c. 10m giving areas of 5m2 but how much of this actually conveys water? A better introduction to channel morphology could be included early in the manuscript that includes mention of meandering and cave development. Then the issues of meandering and cave development could be dropped from the later discussion tightening the work considerably. The issue of groove development is interesting but without better characterization and referencing this detail adds little. You need to improve the detail of grooving or just give it a mention in the description of the channel morphology and then leave it at that. Without a strong relation to discharge or slope the grooving is a distraction to the main thrust of the manuscript.

Response

We had endeavored to keep the manuscript as focused as possible in the submitted form. Specifically, we had felt that a lengthened "field site" section would substantially lengthen the introductory text prior to the presentation of our actual results, and thereby delay readers in reaching the quantitative data that forms the basis of this research paper. However, here, there is ample information on the nature of

the channel (e.g. Vatne 2001) and evidence of the flow regime that typified the summer melt season (e.g. Stuart et al., 2003). We will revise our site description (section 3.1) to include, briefly, additional material on the channel itself, and to clarify the evidence for its cut-and-closure form. We agree that by doing this, the "conceptual model" of the channel's development can be considerably shortened and thereby reducing the material the Reviewer felt remains somewhat speculative. We have considerable experience in terms of investigating this channel, and similar channels elsewhere in Svalbard, and perhaps there is an element of our expecting readers to hold some of the basic glacier hydrology knowledge - an assumption which needs to be revisited and can be readily met with minor additions to the main text where we introduce the study site.

At line 14 page 7622 (and elsewhere) the useful comment is made that little has been said about different step morphologies and the authors split the morphologies into channel-supported and ballistic nappe flow. The reviewer made prior comment on this classification in: Carling, P.A., Tych, W. and Richardson, K. 2005. The hydraulic scaling of step-pool systems. pp 55-63 in G. Parker and M.H. Garcia (eds) River, Coastal and Estuarine Morphodynamics. Vol 1.Balkema, Taylor and Francis, NY, ISBN: 0 415 39375 2. which the authors might find useful in their revision. This paper deals with bedrock channels in homogeneous media and includes breaching of steps by low-flow channels which is a subject mentioned elsewhere in the current submission. Note that you refer to breaching by low flows at line 6 Page 7639.

Response

We thank the Reviewer for this suggestion in terms of additional citation. We have been able to access and read the suggested paper and found it very useful. In light of the information contained there, we feel it is appropriate to be included as a reference, and so we will cite the paper and elaborate on breaching of steps in their evolution, particularly in our overview of terrestrial stream channels and the discussion of incision at low discharges.

At line 9 Page 7624 it is implied that there is a clear transition from meandering channel habit to a step-pool habit. However, as noted elsewhere in the submission the two channel forms are not exclusive - as you note at line 27 Page 7628. In passing I found the reference to certain aspects of meandering of the channels and the development of caves to be distracting. I say this because often the authors do not have detailed data to support statements which end up being vague and speculative. I provide examples below. To my mind the detail actually distracts from the main thrust of the argument of the manuscript and a better paper would result if speculation was excised.

Response

We acknowledge the Reviewer's point of view here. We had sought to provide information to clarify our thinking and logic in terms of explaining the evolution of the conduit, and the processes we imply to result in the changes in form we measured. However, in view of the previous points, we concede that a clearer explanation of the processes of channel formation as discussed elsewhere (e.g. Vatne 2001; Vatne & Refsnes 2003; Gulley et al., 2009) at an earlier stage of the manuscript here would help reduce an apparent absence of clarity on this topic. Again, we reiterate, it is through our experience of these cut-and-closure channels, through direct and indirect explorations of high-arctic glacier hydrology that we make a number of conceptual suggestions regarding the evolution of these channels. The Reviewer is correct to alert us to recognising the readership of HESS may not be as acquainted with 'glacier hydrology' as anticipated.

At line 1 Page 7628 it is not evident why the submerged portion of the step height is inversely related to the step height. You need to explain this reasoning and possibly provide a diagram to support the argument.

Response

This is a typographical error in the original document. The pools are directly related to step height. The word “inversely” is deleted.

Detail of grooves and their physical relation to steps and step walls I found confusing. In places the grooves are referred to as ’cuspate’. Some information is provided on Page 7628 in Section 3 and the subject is returned to on Page 7630. From Fig 5 the grooves look very much like chute furrows described and illustrated by Richardson, K. and Carling, P.A. (2005) A typology of sculpted forms in open bedrock channels. Geological Society of America Special Paper 392, 108pp. See R& C Figs 53 & 54 & 56. Several authors commenting on bedrock channels have noted such grooving develops just above steps (probably due to the well-known draw-down of the water surface above falls) and R&C supply references on their page 40. Note that Ikeda (1978) cited in R&C relates the spacing of grooves to formative discharge. You try to suggest a

relationship between grooves and a dominant discharge at line 6 Page 7636 but do not supply any justification and on Page 7638 you imply a relationship between grooves and slope (once again speculative). To illustrate these grooves a summary cartoon might be more useful to visualize them than the single Fig. 5 which does not seem to reflect the descriptions in the text.

Response
With reference to points raised by the other Reviewers, we are inclined to remove much of the material on groove formation. Here, we are aware that we looked to explain and evidence the incision process for the stream channel from a rather singular set of observations of cuspate groove forms on the channel wall. We remain of the opinion these groove forms hold potential to provide quantitative details to explain or elucidate rates of change in the channel's evolution. Consequently, we suggest we revise the manuscript to highlight these as observations, but to reduce the reliance on them in terms of a quantitative assessment of channel change. We agree that without additional data sets from groove-sets in other locations along the channel reach, and in differing years of observation, our suggestions become more subjective and speculative. We will edit our text to reduce the inferences we draw from this in the results and discussion, but allude to the potential use of such forms in quantifying channel change. We thank the Reviewer for providing another source that would seem to lend itself to supporting this argument. We appreciate such constructive input on our manuscript.
We will look to revise Fig 5 to present a parallel figure pair - using the image to provide a real view of a cartoon which better explains the features observed and inferences we feel can be drawn from these feature

I found that lines 13 Page 7635 to line 26 Page 7636 became vague and often included unsupported speculation. Lines 8 to 17 Page 7639 also are vague. It is not clear at all what the relationship of caves to step-pools and meandering might be from the information you have and I would not engage in such speculation until you have better morphological data. Much of this vague text could be excised and a stronger paper would result.

Response

As we have described above, we feel that a revision of the discussion section of the manuscript would address the concerns voiced by the Reviewer, which are reiterated by comments made by the other Reviewers 2 and 3. We are disappointed that our efforts to explain the evolution of the mapped englacial channel was viewed to be speculative, but we are able to address this without substantial change to the scientific content by downplaying inferences we make. We note Reviewer 3 was of the opinion our scientific thesis here was essentially sound.

"technical corrections"

Response

We thank the Reviewer for a thorough review of typographical, terminological and technical uncertainties, and we agree that all these do require editing and we will correct all items suggested and listed by the Reviewer as below.

At line 6 page 7618 and at many other places in the manuscript the authors start a sentence with 'This' but do not include a subject word. Consequently a phrase and not a sentence is produced. In this case I suggest inserting the word 'observation' after 'This. ditto: line 11 page 7618 line 3 page 7628 line 23 Page 7629 line 17 Page 7633
line 25 Page 7634 line 24 Page 7636 line 8 Page 7640 line 6 Page 7641 line 2 Page 7642

At line 6 page 7620 and at line 2 page 7636 and at line 27 Page 7642 replace 'comparable to' with 'comparable with' It is 'compare with' or contrast to' not a mix

At line 24 page 7624 delete "at depth'

At line 26 Page 7628 delete 'is' and insert 'are'

At line 7 Page 7630 delete 'groves' and insert 'grooves'

At line 9 Page 7632 parentheses around Baynes needs correcting

At line 20 Page 7634 delete 'evidenced' and insert 'demonstrated'. There is no English word 'evidenced'

At line 6 Page 7635 delete the extra 'that'

At line 5 Page 7639 delete 'less' and insert 'lesser

At line 8 Page 7640 delete 'being' and insert 'is

At line 11 Page 7640 delete the extra 'erosion' and 'surface'

At line 16 Page 7641 delete the reference to unpublished data. Unpublished data effectively do not exist and the inclusion is not helpful to the reader.

Flow directions are required in Figs. 4, 5, 7 and 8.