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Interactive comment on "Rapid and objective characterization of channel morphology in a small, forested stream" *by* Carina Helm et al.

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Dear Associate Editor, and Reviewer 2:

Authors have responded to all comments below in full, with Reviewer 2 comments shown in bold, and responses as regular text. Notable new additions to the paper include implementing a consistent terminology for the morphological units the manuscript describes mapping. Please see below for detailed replies to all queries from Reviewer 2.

REVIEWER 2 COMMENTS

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Discussion paper

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General comments
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The paper presents a novel and useful methodology for mapping channel morphology that is well within the scope of ESurf. The methods were sound, logical and well presented. The introduction and discussion for the paper could use some adjustments, in particular clarification of the use of terminology such as channel morphology, morphological units, channel units, channel type, and morphology type. It was difficult to follow what was meant by each of these terms and if they were being used interchangeably or not. From the introduction I was expecting more of a reach scale channel type classification scheme, but I would argue that what this paper does would be better described as mapping or classification of morphological units (also called geomorphic units, channel units, habitat units, etc).

The authors are grateful for the constructive comments from Reviewer 2. In particular, the comment on using a consistent channel morphology terminology is an important one. The authors have updated the manuscript such that we are consistent with referring to the scheme classifying “morphological units” or “channel units”. Please see below for detailed responses to further queries.

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Specific comments
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Title: I recommend the title including that the method uses a RPA or remote sensing.

The comment has been accepted. At the suggestions of Reviewer 1, Reviewer 2 and Reviewer 3, the title has been changed to “Characterization of morphological units in a small, forested stream using close range RPA imagery”.

Abstract: Line 6 states "This paper seeks to demonstrate an objective method for characterizing channel attributes over large areas, using easily extractable data from RPA imagery collected under the forest canopy in a small stream, and to provide information on the spatial scale necessary to cacpture the dominant spatial morphological variability of these channels." - Rather than saying "characterizing channel attributes" it would be more precise for the author to say they are classifying or mapping channel morphological units. - provide clarification to what constitutes "large areas" - in "provide information on the spatial scale" does spatial scale mean longitudinal spatial extent?

This comment has been accepted. At the suggestion of Reviewer 2, we have replaced “characterizing channel attributes” with “classifying channel morphological units”. Furthermore, at the suggestions of Reviewers 1 and 2, we have clarified the spatial scales under investigation with the text below:

“This paper seeks to demonstrate an objective method for classifying channel morphological units in small, forested streams and to provide information on the spatial scale necessary to capture the dominant spatial morphological variability of these channels. This objective was achieved using easily extractable data from close-range RPA imagery collected under the forest canopy (flying height = 5 – 15 m above

ground level) in a small (width = 10 – 15 m) stream along its 3 km of anadromous salmon-bearing channel."

Abstract: Line 14 "for characterizing these systems" it also would be better here to be more precise about mapping or classifying morphological units.

This comment has been accepted. At the suggestion of Reviewer 2, we have replaced "for characterizing these systems" with "mapping morphological units".

Introduction: paragraphs 1 and 2 were confusing and misleading to me and could use clarification between reach scale stream classification and smaller, geomorphic/morphological/channel unit scale.

This comment has been accepted. At the suggestion of Reviewer 1 and Reviewer 2, the first two paragraphs of the introduction have been reworded for clarity and to describe that the analysis is aimed at classifying morphological units:

"Channel morphological units such as pools and riffles constitute the building blocks for reach scale channel morphologies (Buffington and Montgomery, 2013a). Variability in these units within a channel reach can provide critical habitat diversity. As a result, characterization of morphological units is the goal of many habitat-based classification schemes (e.g. Hawkins et al., 1993). Their classification may be particularly important in forested, gravel bed streams, where episodic and transient geomorphological processes (Pryor et al., 2011; Wohl and Brian, 2015; Hassan et al., 2019), can lead to a high degree of channel complexity even within a relatively homogeneous channel type (Madej, 1999; Nelson et al., 2010; Gartner et al., 2015). For these streams, classification schemes can serve an important role in facilitating

discussions on stream management among disciplines (Buffington and Montgomery, 2013b). This is evident in the array of classification schemes proposed to characterize channel types and morphological units for both geomorphologists and ecologists alike (e.g. Hawkins et al., 1993; Rosgen, 1994; Montgomery and Buffington, 1997; Brierly and Fryirs, 2005). A common challenge of these classification approaches, however, is their descriptive nature (Buffington and Montgomery, 2013b; Hassan et al., 2017) and that their implementation can be subjective, differing between classifiers.

Challenges in objectively classifying morphological units are further compounded by difficulties in determining the appropriate spatial extent for capturing the primary structural variability that influences geomorphological and ecological processes at the reach or basin scale. While approaches are often taken to select 'representative sites' when the characterisation of channel variables is necessary (Harrelson et al., 1994; Bisson et al., 2006), site selection is often based on a narrow subset of metrics (e.g. gradient, see Montgomery and Buffington, 1998) and 'rules of thumb' are frequently used to define the spatial extent of the surveyed area (Bisson et al., 2006). Furthermore, traditional survey techniques often limit classification to short, accessible channel areas due to time and cost constraints, and these limitations may bias our understanding of the larger river network as a result of missing important channel areas and processes (Fausch et al., 2002; Hugue et al., 2016). Given the logistical difficulty and cost of undertaking field surveys in small, forested gravel-bed streams, a more precise approach for site selection and objective technique for classifying morphological units is warranted."

Methods: Line 146 says that in-stream wood was digitized, but I did not see this used or relevant later in the paper

The authors accept this comment. Channel wood was digitized as part of the initial

inventory of channel variables but was not used in the analysis. The line has been removed from the revised manuscript.

Section 3.3: The author states that the 5 variables were chosen in part "because they reflect larger basin scale variables relevant to channel form, such as geology, climate and land use." A citation and/or examples here seem necessary

The authors have cited Buffington and Woodsmith, 2003 here. Specifically Figure 1 of their paper shows how the channel characteristics we included give rise to channel types, and are the manifestation of certain process drivers and watershed conditions. In addition, at the suggestion of Reviewer 1, we have added the following text explaining why those variables were selected:

"Channel slope is a key variable to consider, as it has been shown that there is a general progression of channel morphologies from pool-riffle, plane-bed, and step-pool to cascade morphologies with increasing slope (Montgomery and Buffington, 1997). Water depth metrics are important for discriminating between pool environments and other shallow water environments. Finally, grain size is a key variable, as there tends to be a coarsening in bed material from glides and pools to riffles and runs (Garcia et al., 2012)."

Analysis: Section 3.4: line 178 describes how a morphology type is attributed to each cluster. It would be helpful to lay out prior to this what the morphology types being used are, and the criteria used for them. The author does cite 3 papers for the criteria, but it isn't clear what specific criteria from those papers were used. Also, within this paragraph it isn't clear if morphology type is synonymous with channel type or not.

The authors accept this comment. The morphological units being classified have now been introduced prior to introducing the criteria. A table (now Table 1) has also been added summarizing the criteria extracted from these papers. The terminology has also been changed to morphological unit to ensure consistency through the manuscript:

"Following clustering of the cross-sectional variables, the mean values of each channel variable for each cluster were examined and one of the following morphological units attributed to each cluster: pool, riffle, coarse riffle (riffleC), glide, run or plane-bed. The units were assigned to clusters based on obvious features (e.g. shallow water slopes and greater depth for pools, negative pool exit slopes for glides, and steeper pool entry slopes for runs) and criteria presented in Church (1992), Anonymous (1996), and Buffington and Woodsmith (2003). These criteria are described in Table 1. The resulting assignment of morphologies to clusters leads to a continuous classification of morphological units found along the study reach at 1 m intervals, and provides insight into the survey extents necessary to adequately capture the heterogeneity of the system."

Figure 6: needs a scale bar

This authors accept this comment. A scale bar has been added to Figure 6.

Conclusion: The conclusion would be easier to follow if it were organized in the same order as the rest of the paper.

The authors accept this comment. We have rearranged the paragraph so that the ac-

quisition of RPA derived rasters and ensuing PCA comes first, followed by the sentence on the exploration of the necessary spatial extent to capture the channels variability. This now follows the order of the methods.

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