Response to Review 1 (I. Fuller)

Response to general comments:

We welcome the comments of Professor Fuller and his wider discussion of the applicability of interventionist approaches for enhancing river function viewed against the backdrop of a growing appreciation of the need to make room for rivers and the concept of erodible river corridors. In the specific case of Glaisdale Beck, a large landslide actively coupled to the upland stream channel prompted the trial of a novel channel diversion and subsequent hard-engineering approaches to help address the perceived impact of excessive fine sediment load on the stream system. We do not advocate such approaches as standard practice for the management of upland rivers (P1199 L9), and recommend more holistic approaches for the enhancement of aquatic habitats within these systems.

As Professor Fuller rightly highlights, despite the diversion demonstrably abating the flux of material from the progressive landslide complex, in the wider context of ensuring habitat conditions suitable for the endemic species, there is still considerable room for further improvement. This can only be achieved through an integrated, catchment based approach. In recent years, the wider application of this concept in the UK has highlighted the need to think at the large-scale, including the examination of distributed processes operating over a range of temporal scales (e.g. sediment source/pathway variability). In the case of Glaisdale Beck, addressing the issue of wider degradation is continuing, facilitated by the Environment Agency and other public partners (e.g. BIFFA, National Postcode Lottery) funded under the auspices of the Glaisdale Beck Restoration Project. This project will enable significant improvements across the wider catchment including over 2 km of fencing adjacent to the stream channel, tree planting, installation of livestock drinking bays, cattle pumps and crossing points to reduce agricultural impacts (NYMNPA, 2015). Additionally, in the headwaters over 300 ha of moorland have been surveyed with over 18km of grips and gullies being blocked to enhance stability and reduce sediment supply from the wider catchment (YPP, 2011).

Response to specific comments:

Comment 1. *I did wonder whether there may have been any change in flood regime during the monitoring period, since larger floods have the potential to destabilise upland channels as we well know (e.g. Warburton et al., 2002; Milan 2012). […] Some comment on flood regime during the monitoring period could be worthwhile, tabulating or graphing flood events over the period. From that, could you then comment on whether the adjusted managed diversion is in good shape to respond robustly to projected increased flood frequency and magnitude?*

Reply 1. Despite our geomorphological surveys continuing between 2007 and 2014, hydrometric monitoring of the catchment only occurred from 2007 - 09, limiting our ability to place the hydrology of the monitoring period within the wider context of the long-term hydrological regime. However we acknowledge that this information would be beneficial to assess whether the diversion had been exposed to significant geomorphological forcing. We will therefore assess the recent flow series from the nearest gauging site to determine whether there is evidence of recent trends and to place the observed events within the wider context.

Comment 2. *The role of lateral erosion in channel development in the British uplands has also been demonstrated in the River Coquet, where extremely high rates of change were measured by Fuller et al. (2003) in response to bend cutoff (p1181, L14).*

Reply 2. We intend to incorporate the lateral retreat rates presented by Fuller et al. (2003) within the introduction section to provide additional information about the role of lateral inputs within upland systems. However, Glaisdale Beck differs from the River Coquet as it is much more confined hence the coupling of hillslope failure complexes direct to the channel.

Comment 3. *The location of the landslide complex contributing sediment to the pre-diverted channel could usefully be added to Figure 1.*

Reply 3. Due to the scale of the catchment map presented in Figure 1 we are only able to visibly present the location of the modified reach with additional labelling of the landslide complex being unclear in the Figure's current form. However, we will produce an inset diagram showing the location of the river channel and extent of the landslide. We will also modify Figure 3 to explicitly label the reach impacted by the landslide.

Comment 4. *I wondered whether the geomorphic changes identified in Figure 8 and discussed on p1193 had been mapped? If so, such a map would provide a useful addition to the paper.*

Reply 4. Unfortunately we did not conduct geomorphic mapping of the bank collapses presented in Figure 8. We relied on the collection of photographic evidence to document the change between visits to the site. The general sites of actively failing banks can be marked on the base map (Figure 3).

Comment 5. *I must confess to finding it hard to discern evidence for knickpoint migration from Figure 10. Perhaps a trend line is needed to highlight this? Also, is the over-deepening evident downstream of the lower drop structure (A) genuine degradation, or a return to the pre-engineered channel bed following flushing of sediment accumulated in the channel immediately following re-alignment? The 2009 survey is two years after the 2007 engineering, so it is quite possible that the elevated bed level here reflects an initial infilling response from sediment eroded from the bed upstream. It might be helpful to identify which part of the long profile relates to the realigned channel.*

Reply 5. In response to the diversion a distinct knick-point step in the long profile whose morphology varied depending on the local substrate as shown in Figure 9. We intend to plot an asymptotic fit to this figure which will display the rate of knick-point migration over time. We agree that this will further highlight the nature of the system response. Downstream of structure (A) in Figure 10 we do indeed observe a degree of erosion between the 2009 and 2014 surveys. This is most likely to be a result of the initial response (captured in the 2009 survey) resulting in downstream aggradation within pools and low-energy zones, with progressive events acting to winnow this material over time, re-exposing the pre-diversion surface (captured in the 2014 survey). For ease of interpretation we will modify Figure 10 to display the area within the plot which represents the realigned area of the channel.

Comment 6. *You comment on the arrest of the landslide within the old abandoned channel (p1196, L19) – is there any evidence / data on activity of this landslide you can refer to here? Is there the potential for landslide movement to resume, or even reach the new channel?*

Reply 6. The landslide itself was not subject to direct monitoring. However the activity of the mass-movement was informally evaluated as a result of routine site visits. Evidence of the relative stability is shown through repeat photographs of the area. Images collected in 2014 (Figure R1) clearly demonstrate several key features including: i) revegetation of the erosional surface; and ii) progressive reduction in bank angle due to the lack of fluvial activity at the landslide toe and storage of hillslope material in the former channel. The storage of this material at the base of the slope is buttressing the landslide and arresting further progression. Based on observations during the active monitoring period, it is unlikely the landslide will re-activate given current site conditions.

Figure R1. Images of the landslide 07/04/2014 looking (a) NE towards the slip-face and (b) upstream in a SE direction.

References

North York Moors National Park Authority (NYMNPA) Catchment Trilogy – Part 1 https://northyorkmoorsnationalpark.wordpress.com/2015/12/07/a-catchment-trilogy-part-1/ Accessed 14 April 2016).

Yorkshire Peat Partnership (YPP) Yorkshire Peat Partnership, Research and Monitoring, Feb 2011 http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/Yorkshire%20Peat%20Partnership,%20Research%20and%20Monitoring,%20Feb%202011.pdf Accessed 14 April 2016.