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Interactive comment on "Declining suspended sediment in United States rivers and streams: Linking sediment trends to changes in land use/cover, hydrology and climate" *by* Jennifer C. Murphy

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Response to Referee #2

RC: This manuscript presents an extensive data set of suspended sediment and TSS trends at 137 stream sites across the contiguous US and explores potential drivers of these changes. Overall, I think the manuscript is well written and will become a worthwhile contribution to the hydrological community. The proposed method also has the potential of being applied elsewhere. I do have some comments for the author,

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which I hope can help improve the manuscript.

AR: Thank you for the supportive and constructive comments on my manuscript. I've provided author respondes (AR) to the referee comments (RC) below.

RC1. On the flow-normalization trend method: It would be helpful to provide an example to guide the readers through the calculations of MTC and QTC and how the two approaches differ from each other. This essential information could be shown as Figure 1.

AR1: Referee 1 also requested additional information and explanation of the MTC and QTC methodology and suggested adding this information to the Supporting Information. Showing how the methods are applied at a specific site is another interesting suggestion. I will spend some time thinking about the best way to incorporate additional, clarifying information about the methods – either in the Supporting Information or in the manuscript with a figure.

RC2. On the use of sediment concentration: Why is not sediment flux used instead? Given that both concentration and flux are assessed in the flow-normalization, why did the author choose to focus on concentration in this work?

AR2: I went back and forth about this choice prior to beginning the analysis. Ultimately, I decided to go with sediment concentration because my primary goal of this analysis was to explore potential drivers of change. Since sediment loads are very closely related to streamflow, I thought I would be better able to identify the influence of other changes, such as land use and climate, if I used concentration (better able to get the "signal" out of the "noise" using concentration as opposed to load). I decided to only go with concentration, as opposed to concentration and loads, to keep the manuscript digestible. I suspect many of the conclusions will be similar between concentration and load because streamflow is typically positively related to both concentration and load (so increases in Q are likely to lead to increases in concentrations and loads).

RC3. Abstract: Suggest adding an opening sentence to place the work into a broader context. Also, suggesting adding 1-2 sentences to highlight the implications and relevance of the major findings.

AR3: Ok will do.

RC4. P2L22: List some examples under the category deterministic approaches and empirical approaches.

AR4: Good point, I will update.

RC5. P3L1: Be more specific on “the latter two contributions” and support this argument with literature.

AR5: I will enhance this paragraph to better support these ideas.

RC6. P3L4-L23: I appreciate these thoughtful statements on the relative effects of streamflow and landscape management. However, how about efforts/practices that might affect both the streamflow regimes and landscape functioning?

AR6: I agree that there are plenty of efforts/practices that affect both streamflow regimes and landscape functioning. I plan to dig into that more throughout the entire manuscript but will add some discussion on that here in the introduction as well.

RC7. P3L25: “suspended sediment and total suspended solid”

AR7: Will add.

RC8. P6L8: What is the window for loess smoothing?

AR8: Loess smoothing was applied in R using the loess() function with the span argument set to 0.75. Meaning 75% of the points are used in each window and these points have tricubic weight. Will update text to clarify.

RC9. P8L30: Could you support this last sentence by showing the distribution of trends among different regions for just the undeveloped sites?

AR9. Referee 1 also noted this sentence as being vague. I plan to drop this sentence ("Thus, the stark difference between the largely downward SSC. . ..”). Most of the undeveloped sites are in the Western US. Site counts for the other geographic regions are too small to gain much insight. For SSC sites, there are 12, 1, and 2 sites in the Western, Central, and US regions. For TSS sites, there are 18, 5, and 6 sites, respectively.

RC10. P10L3-L16: I appreciate these discussions by the author. However, this is not well supported by the scientific literature. Could you provide some relevant references?

AR10: I respectfully disagree. It is well supported that TSS determinations are more uncertain that SSC determinations, and typically biased low. TSS determinations tend to result in a "sediment deficient" subsample based on the techniques used to retrieve a subsample from the original sample for analysis. These issues become more severe with increases in the proportion of sand-sized sediment in a sample. See method comparison by Gray et al (2000). While I discuss Gray et al (2000) in other places in the manuscript, I see that I did not include it in this section. I will rectify that issue.

Additionally, many studies have shown the preferential settling of coarser material as streamflow slows. With respect to conservation practices, White et al. (2007) showed that forested filter strips are efficient at removing coarse-textured sediment (> 20 um in diameter) but that small particles (<2 um, generally clay and smaller) are not affected. Lee et al. (2000) found that trapping efficiencies varied depending on the vegetation type used in vegetative buffers but were highest for coarse sediment. Meyer et al (1995) found that grass hedges trapped nearly all sand-sized sediment but allowed silt and clay-sized sediment through. Bimbino et al. (2008) found decreases in sediment size over a reach that had 3 check dams. I do agree this section of the manuscript lacks supporting references, so thank you for that comment. I will update the manuscript with appropriate references, such as the ones described above.

Gray, J.R., Glysson, G.D., Turcios, L.M., and Schwarz, G.E.: Comparability of

Suspended-Sediment Concentration and Total Suspended Solids Data. U.S. Geological Survey Water-Resources Investigations Report 00-4191, 2000.

White et al., 2007, Sediment retention by forested filter strips in the Piedmont of Georgia. Journal of Soil and Water Conservation 62, no. 6., 453-463.

Lee et al., 2000, Multispecies Riparian Buffers Trap Sediment and Nutrients during Rainfall Simulations. Journal of Environmental Quality 29, n. 4., 1200-1205.

Meyer et al., 1995, Sediment-trapping effectiveness of stiff-grass hedges. Transactions of the American Society of Agricultural and Biological Engineers 38(3): 809-815.

Bombino et al., 2008, Sediment size variation in torrents with check dams: Effects on riparian vegetation. Ecological Engineering 32, 166-177.

RC11. P11L14: Any reference on these stated effects of CRP?

AR11: Often process-based watershed models (such as SWAT) are used to assess the effectiveness of conservation practices on water quality, for example see the US Department of Agriculture's Conservation Effects Assessment Project (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd889806.pdf). However, identifying these effects empirically has proven challenging. To my knowledge, no one has assessed the influence of CRP on sediment transport nationally (some studies have been done for nutrients, see Sprague and Gronberg (2012)). Studies completed at individual basins give a mixed story. Davie and Lant (1994) found CRP enrollment influenced sediment erosion rates but not sediment loads downstream. They also suggest that the location of CRP near the stream might be important for effecting downstream sediment load. Support for this idea is shown in figure 6b. Lizotte et al. (2012) found decreases in sediment in an oxbow lake related to the implementation of best management practices and CRP enrollment in the surrounding drainages. Cullum et al. (2010) found the conversion of cropped land into forested CRP land in the drainage surrounding an oxbow lake reduced the sediment load entering the lake by an order

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of magnitude. I will enhance this section of the report by elaborating on the documented effects of CRP in individual watersheds and discuss the difficulty of gauging these effects on a national scale.

Davie, D.K., and Lant, C.L., 1994, The effect of CRP enrollment on sediment loads in two southern Illinois streams. Journal of Soil and Water Conservation 49(4), 407-412.

Lizotte, et al., 2012, Water quality monitoring of an agricultural watershed lake: the effectiveness of agricultural best management practices. Transactions on Ecology and the Environment 160, doi:10.2495/DN120251.

Cullum, et al., 2010, Effects of Conservation Reserve Program on Runoff and Lake Water Quality in an Oxbow Lake Watershed. Journal of International Environmental Application and Science 5, (3): 318-328.

RC12. P13L14: One very relevant example on the effects of dams on sediment trend is the Conowingo Dam on Susquehanna River. There are also documented effects of many small mill dams in the mid-Atlantic region.

AR12: Agreed. It was surprising the effects of dams were not more pronounced in this study. The manuscript provides several reasons why this may be the case.

RC13. Figure 1: I don't think this figure is necessary. You may move it to SM.

AR13: Agreed. I will be moving the analysis pertaining to the riparian land-use change to the Supporting Information.

RC14. Table 3: I found the table with such lengthy descriptions difficult to follow. Could you convert it to a figure or shorten the descriptions?

AR14: I respectfully decline this suggestion. I am unsure how this table could be converted to a figure and the descriptions are about as concise as I can make them. The bolded portion of the table provide the information in a succinct format; the descriptions are provided so that a reader can gain a better understanding of how to interpret the magnitude and direction of MTC and QTC estimates.

RC15. Figure 2: Consider using smaller symbol to make the Eastern stations more distinct. I appreciate that the author is using the font size to represent different magnitudes, but that might be less important. Alternatively, and perhaps more conveniently, enlarge the size of the figure to be full-page so the stations can be more distinguishable.

AR15: Referee 1 also had issue with Figure 2 and the clustering of sites. I will rectify this issue by adding transparency to the symbols, eliminating the different symbol sizes, or enlarging all or a portion of the maps.

RC16. Figure 3: There are outliers for many of the boxplots. What are those stations and why they have such large trends? This deserves attention from the readers and more discussion by the author.

AR16: My goal for this paper is to present a national perspective on changes in sediment concentration since 1992 across the US. Thus, I chose not to explore and elaborate on these sites with outlier changes in sediment since these likely present unique situations.

RC17. Figure 5: I think this is such an important figure in the manuscript and it deserves to be made larger (say full-page) to be clearer. How about transposing this figure?

AR17: My plan is to move the riparian land-use change analysis and results to the Supporting Information. Doing this will remove the riparian land-use change correlations from Fig 5 and will allow more space for what remains. I will also explore transposing the figure.

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