A Summary of Revisions and Responses to the "Identification of watershed priority management areas based on landscape positions" (Ref: HYDROL44601)

With regards to comments from the Editor:

"two referees have provided feedback on your manuscript. Both reviewers agree that this topic is interesting and a good fit for the journal. However, both have suggested major revisions before this manuscript can be accepted for publication. One of the major concerns of both reviewers was the fact that this new approach was only reviewed for one watershed with results that may or may not represent a significant improvement; therefore, this weakness should be addressed should you choose to revise and resubmit."

Thank you for your comments. In the Zhongtianshe case study of the original manuscript, it was found that the proposed method improved the effectiveness of PMA identification compared to commonly used subbasin units from the perspectives of spatial distribution and cumulative load contribution. In the current submission, we have also added a new study area (the Willow River Watershed), which could help demonstrate the applicability of the proposed method more sufficiently. The Willow River Watershed (212 km^2), located in western Wisconsin, USA, has different geographic characteristics from the former watershed, such as relatively low precipitation, high evapotranspiration, wetlands scattered across the entire watershed, and grassland as the dominant land use type. These characteristics lead to differences in the pollutant release, transportation, and transformation processes of the two watersheds. More details can be found in the third paragraph of Section 3.1. The experimental results show that detailed spatial units support more accurate identification of PMAs and benefit the decision-making of watershed management practices in both case studies. We believe that the two cases in the revised manuscript can sufficiently verify the proposed method.

With regards to comments from Reviewer #1:

1. "The first controversial point of this study is how the promotion of the introduction of SWAT+ model for PMAs identification. It is undeniable that a more detailed characterization of watershed processes would improve the reliability of identification rather than traditional SWAT model. Modifying Markov chain based on mechanistic model was the idea of many researchers five years ago. However, the researchers found that relying solely on water quality indicators to quantify PMAs resulted in a lack of reliability in actual watershed management. More studies at present focus on the comprehensive assessment PMAs between different indicators, such as pollutant load, intensity, cost, ecology, etc. Therefore, I think there is a limitation of research dimension in this study."

Thank you for your comment. The main contribution of this study is the use of landscape position units within subbasins to identify PMAs to balance the general applicability to diverse geographic environments and the representation degree of spatial heterogeneity. The proposition is based on three principles for determining proper units, as summarized in the literature review: 1) to be broadly available and not limited to a specific geographic environment; 2) be capable of representing the spatial heterogeneity of underlying surface characteristics, physical geographic processes, and/or anthropogenic activities inside the study area by a small number of units; and 3) have hydrologic connections among each other. The proposed identification method was inspired by a Markov chain-based surrogate model for pollutant source appointment (Grimvall and Stålnacke, 1996). However, since the Markov chain-based method was proposed, the existing follow-up studies have continued to consider the subbasin unit as the lump unit for pollutant release and retention processes. This means that the original method cannot consider the degree of representation of the spatial heterogeneity within the subbasin. In this study, we separate the pollutant release and retention processes on landscape position units and channel units, respectively, to make the Markov chain-based method support PMA identification at finer levels.

As an implementation of the proposed method for identifying PMAs on landscape position units, the restructured version of the SWAT model, $SWAT^+$, was selected because of its new design of the spatial delineation scheme (i.e., HRU→LSU→subbasin). The new scheme provides a more realistic representation of watershed processes than traditional SWAT (please refer to the 2nd paragraph of Section 2.1). Therefore, the introduction of $SWAT^+$ helped verify the proposed PMA identification method based on landscape positions.

In existing studies, PMAs are defined by the distribution of pollutant load amount, intensity, or contribution. In this study, we adopted the pollutant load contribution that considers both pollutant production and transportation processes. Therefore, PMAs are the result of analyzing the current situation of watershed pollution, which are ideal spatial locations to be prioritized for watershed management. Identification of PMAs can be regarded as the first step in watershed management. These factors further affect actual watershed management decisions (such as investment, stakeholders' willingness, environmental goals, and cost-effectiveness of various BMPs) and could be considered in the spatial configuration of BMPs to derive practical management plans. We have emphasized this point in the first paragraph of the Introduction.

2. "The second controversial point is the allocation from upland to floodplain and channel. I would like to see more distribution based on different hydrological condition or physical mechanism rather than area ratio (Line 141)."

Thank you for your suggestion, which has encouraged us to consider this study more broadly. The SWAT$^+$ model uses a constant flow distribution ratio to represent the hydrological connectivity of each upland to its floodplain and channel. SWAT$^+$ provides two ways to determine this ratio: the user-specified global value for all upland units in the watershed and the area ratio of each upland to its floodplain. The area ratio method has been proven to be more realistic in representing connectivity than the fixed ratio for the entire watershed (Bieger et al., 2019). Therefore, we adopted the area ratio method in this study. Accordingly, we have rewritten the introduction of the flow distribution strategy from the 2nd to the last sentence in the 2nd paragraph of Section 2.1.

In addition, we recognized that many factors such as topography, land cover, and rainfall intensity affect the hydrological connectivity of uplands to floodplains and channels. Although there is an improvement in the spatial representation in SWAT$^+$, the lack of an inner physical mechanism representing hydrological connectivity still exists, and model development in this aspect is accordingly limited. Therefore, it is worth studying how to better quantify the hydrological connectivity of uplands to floodplains and channels, and its effects on PMA identification. We added this point as the 2nd future research direction in the 2nd paragraph of the Conclusion.

3. "In addition, this research is more suitable as a case study, so it is suggested to modify the title appropriately."

The main contribution of this manuscript is the use of landscape position units within subbasins to identify PMAs to balance the general applicability to diverse geographic environments and the representation degree of spatial heterogeneity (please see the first paragraph of the response to the first comment). The proposed method is exemplified by an improved Markov chain-based surrogate model and SWAT$^+$. We believe that the proposed method and the implementation example in this study provide the basis for future exploration of more possible types of spatial units with explicit upstream-downstream relationships for identifying PMAs under the support of proper watershed models.

Considering that the method design and implementation based on SWAT$^+$ are both introduced in the "Method design" section, we adopted this suggestion and modified the title to "Identification of watershed priority management areas based on landscape positions: an implementation using SWAT^{+}" in current submission. We have revised the manuscript accordingly to address this point.

With regards to comments from Reviewer #2:

1. "To test the model's effectiveness, many catchments that represent varied landscapes (slope profiles and positions in the landscape) need to be assessed and compared. The use of a single catchment shows the model may have improved, but it doesn't tell us if this is universal or specific to a certain type of landscape, i.e., the one tested (and among many other catchment characteristics intertwined in the real process, and the SWAT modelling)."

The main contribution of this manuscript is the design and implementation of a method using landscape position units within subbasins to identify PMAs. In the implemented method, $SWAT^+$ was selected as the proper watershed model because its ability of representing landscape position units (LSUs). The previous experiment was conducted in a typical hilly area using the same watershed model (i.e., $SWAT^+$) to compare the effectiveness of the proposed LSUs and the widely used subbasin units.

We agree that a case study with different geographic characteristics can further verify the applicability of the proposed method. Thus, we have added a new case study of the Willow River Watershed, western Wisconsin, USA, in the revised manuscript. Compared with the Zhongtianshe Watershed in China, the Willow River watershed has a relatively flat topography, low precipitation, scattered wetlands, and different dominant land use types (i.e., grassland). More details about the watershed can be found in the third paragraph of Section 3.1. The results further demonstrate the effectiveness of the proposed PMA identification method based on landscape positions.

2. "The language (English) will need some investment of time and effort. The sentence and paragraph structure require improvement. Some words are used incorrectly. (But an excellent effort from authors who are clearly far advanced in their non-native language skills.)"

Thank you for your comment. We have chosen the language Editing services provided by Elsevier to edit the revised manuscript before resubmitting it to the Journal of Hydrology. The certificate serial number is LE-248134-E43A1A4E9930. We hope that the language of the current manuscript is of a higher standard and acceptable to the journal.

3. "The structure of the manuscript doesn't meet the standards expected, e.g., an introduction with clear goals and objectives, methods, results, discussion."

In general, we followed the IMRaD structure, that is, the introduction, methods, results, and discussion. This study mainly focuses on designing a new PMA identification method based on landscape units and exemplifies the implementation using $SWAT^+$. The proposed method and the implemented tool can be applied to different study areas.

Therefore, we divided the “Methods” section into the “Method design” and “Experimental design” sections to highlight the general design of the proposed method. We introduce an exemplified implementation within the method design to clearly express the basic idea of the proposed method. We hope that this structure is acceptable and helpful for readers.

To clarify the research goals and objectives, we have added a sentence at the beginning of the last paragraph of the Introduction in the revised manuscript, i.e., “This study proposes a PMA identification method based on landscape position units exemplified by $SWAT^+$ (i.e., the restructured and enhanced version of the Soil and Water Assessment Tool) and evaluates the effectiveness of the proposed method by comparing it to widely used subbasin units. ”

4. “The referencing is disjoint. In some cases, the statements of the authors and the provided citations don't agree. I found myself reading the citation papers and then citation papers therein in an attempt to understand what the authors were trying to connect. As an example, 'priority management area' (PMA) introduced in the first sentence is given two references and neither speak to PMAs. I searched these references and then the references therein and the definition of a PMA was not there (it is circularly cited among the manuscript authors). A PMA is intuitive and sometimes called a critical management unit or area. It is acceptable to introduce it and speak to others using the term, but it isn't widely accepted at this time and the language of the text should reflect the reality. A better approach would be to build on the idea that refining the spatial delineation of areas and degree of pollution (from coarse to finer scales) is the more effective approach for managers because it allows them to prioritize management actions, e.g., best management practices.”

Thank you for your suggestion. The terms critical source area (CSA), priority management area (PMA), and others (such as high-risk areas and hot spots) are often adopted with similar meanings in existing research. This study adopted the term PMA because it emphasizes the units’ propagation effects from upstream to downstream, which is essential in watershed management decision-making. In the original manuscript, we cited some representative references that met the definition of PMA, although some may have used other terms such as CSA (Pionke et al., 2000). We agree with the reviewer that the term PMA has not been clearly defined and is not currently widely used. Therefore, we have revised the statement of the term in the first two sentences of the Introduction to provide a clear definition, that is, “the priority management area (PMA) is a prioritizing area for management in the watershed, which has a high pollutant production, and more importantly, a high contribution to the pollutant load of its direct or indirect downstream water bodies (Chen et al., 2014). This concept is similar to the critical source area (CSA), which is more commonly used to identify highly polluted areas (Pionke et al., 2000; White et al., 2009) but usually does not emphasize propagation effects from upstream to downstream in the watershed, which is essential in the decision-making of comprehensive watershed management”.

We then demonstrate the significance of PMA in the decision-making of comprehensive watershed management and provide a literature review of the current identification methods for PMAs from the perspective of identification units. We have also carefully checked the main text to ensure that the references were correctly cited.

5. "As a modeler I understand the excitement of seeing an improvement in a model's predictions. However, the modelling output change to 68.34% from 56.17% and from 31.76% to 39.66% is undoubtedly not statistically significant which can only be tested by using many catchments as stated previously. Also, the reporting of 2-significant digits doesn't reflect the reality of the model outputs which are rampant with uncertainty. I point this out because modelers often get lost in the trivia of the mathematics and forget that the real value of their work is the effectiveness and acceptance of their hypotheses (the model)."

We strongly agree with your comment that modelers should focus on verifying the proposed method or their hypotheses instead of getting lost in the mathematics trivia. In this study, we believe that detailed spatial units with geographic meanings representing spatial heterogeneity within subbasins could improve the effectiveness of PMA identification. Then, we propose to adopt landscape position units as identification units because they have hydrologic connections across the hillslope and can construct a hierarchy of routing networks with channel units. Landscape position units can be applied to most geographic environments. We have clarified the inherent characteristics of landscape positions to provide the rationality of the geographical process of the proposed method in the second-to-last paragraph of the Introduction.

The statistics in the results proved the effectiveness of the proposed method by showing the relationships between the cumulative areas of spatial units and the corresponding load contributions (Figs. 8 and 9 in the revised manuscript). That is, the LSU-based PMAs always contribute more pollution than the subbasin-based PMAs under the same cumulative area (see the last sentence in the 2^{nd} paragraph in Section 4.2). For example, LSU-based PMAs of the Zhongtianshe Watershed contributed 48.6% of the total nitrogen in 23.3% of the area, whereas subbasin-based PMAs contributed less (only 44.7%) in a larger (30.1%) area. We also verified the proposed method in another study area to support its applicability. We have revised the first paragraph of the "Experimental design" section to clarify the above-mentioned points. In addition, the statistics have been corrected to one decimal place in the revised manuscript instead of two significant digits.