Reply to Comments by Referee #2:

Dear Referee,

Thank you for giving us the opportunity to revise our manuscript. We appreciate the careful review and the comments and suggestions provided. We believe these comments will help to strengthen the focus of this paper and improve the message and key points we are trying to convey. Below, we address the specific comments as they were made, point by point and provide clarifications where necessary. We are confident that through this process we can improve the structure and effectiveness of the paper and communicate the results more clearly.

Sincerely,

Dr. Maria Magdalena Warter (on behalf of all co-authors)

Reply to General Comment:

The authors of this manuscript carried out an inter-comparison study of two anthropogenically impacted catchments (rural vs. urban land use), by integrating a hydro-meteorological and an isotopic-based monitoring. Data used for the analysis cover about five hydrological years, and such high-resolution isotopic datasets are particularly rare, especially for urban catchments. These datasets were used to investigate how drought periods affect the hydrological functioning of the two catchments and to characterize runoff persistence and resilience during droughts and in response to storm events.

The topic of the manuscript falls within the scope of the journal, and this study could represent a valuable contribution. Overall, the paper is well structured and written, but I have some major concerns that should be addressed in the revision. First of all, based on the discussion, it seems that most of the differences in the hydrological functioning of the two catchments is related to the very different land use; however, the inter-comparison was not conducted on two catchments with just a different land use, because they also differ in area, geology and annual rainfall. Secondly, based on Figure 1, it looks like that the density of weather stations is very low considering the size of the two catchments, and therefore, I am wondering whether rainfall measurements (especially during storm events) are representative of the entire catchments. Finally, I think that at the beginning of the results there should be a section focusing only on the seasonal distribution of the rainfall, the characterization of the drought periods as well as on the storm events (something described later in Section 4.4).

** First, we would like to thank Referee 2 for their overall positive evaluation and also their critical feedback.

We noticed that we weren't clear in our original manuscript re that both catchments are tributaries of the river Spree, a major river for the water supply of the City of Berlin. Thus, they are located in the same regional climate zone though do show different local climates.

The two presented catchments are quite different in their land use, size, and geology. However, as also mentioned in reply to Referee 1, there are similar studies that conducted such inter-comparisons on hydrological responses of catchments that differ in size, underlying geology and hydroclimate properties (i.e. Tetzlaff et al., 2009a, b; von Freyberg et al. 2018). Our goal was to do something similar by using these admittedly contrasting catchments to understand how two key endmembers (urban vs agricultural) of anthropogenically impacted catchments, which are climatically impacted in Berlin/Brandenburg region, which was the focus of the special issue that this manuscript was submitted to.

However, we would also like to note that while current land use in both catchments may be different now, the urban catchment had a similarly agriculturally dominated land use prior to the rapid expansion of urban areas. Therefore, we believe that comparing these two specific catchments allows us to also evaluate in a way the effects of urbanization and streamflow management on streamflow generation in times of drought and extreme events, compared to rural less managed streams.

Secondly, regarding weather stations, we primarily used open source long-term data, and their number is limited. The station in Berlin Buch (open data by the German Weather Service) has been used in previous studies by the group of the Panke catchment (see Marx et al., 2021, 2023) and is representative for the catchment. The distance between weather station and catchment outlet is <15km. Similarly, the weather station in Hasenfelde (Brandenburg) has been used in previous studies of the Demnitzer Millcreek catchment (see e.g. Kleine et al., 2020, 2021) and is considered to be representative of rainfall dynamics (distance < 10km) in the area. As the focus of the study is not detailed storm event analysis we would argue that the use of these stations for the scope of our study is acceptable.
Finally, we agree that the results section will benefit from editing and appreciate the suggestion to restructure it. In line with similar suggestions from Referee 1, we will start with a presentation of the seasonal distribution of rainfall and rainfall events and also highlight more the dry periods in between. We will do this by merging text from sections 4.1 and 4.3 into a more condensed form to reduce wordiness and repetition.
This will be followed by a description of the streamflow patterns (Section 4.2) and isotope dynamics (Section 4.3) and finally the description of young water fractions and transit times (Section 4.4).

Specific comments:
Section 2: These two catchments have more differences than similarities, so I am not sure that many findings can be related mostly to the land use. Maybe the focus of the manuscript should be more on the analysis of inter-annual variability (and on droughts) than on the catchment inter-comparison.
** We were not clear enough in our original submission that both catchments are actually located in close proximity (ca. 100 km) and both tributaries of one major river system (the Spree). We appreciate the suggestion to focus more on a comparative analysis of inter-annual variability of streamflow generation and the expression of drought. We will give the drought more emphasis in the revision to fit also with the topic of the SI (drought risks in Berlin/Brandenburg region).

Figure 1: There are very few weather stations in the two study areas; are the rainfall measurements representative of the real spatio-temporal variability of rainfall over the entire catchments? Did the authors check the measurements during storm events and compare them to weather radar data?
**Yes, as mentioned above the two weather stations can be considered representative of the two catchments and have been regularly used in previous studies in the same catchments (see Marx et al., 2021, 2022, Kleine et al., 2021, 2020). We are therefore confident that using the two weather stations sufficiently captures the spatio-temporal variability of rainfall over each respective catchment. We point out that we are not modeling at sub-daily time steps, where convectional differences would be more important and require a higher resolution of weather data.

Figure 4a: Despite the different land use, area and geologies, for WY2019 I was expecting to see the lowest discharges in both catchments (compared to the following years). Based on the flow duration curves, it is clear that the different climatic conditions in the two catchments may have led to a different runoff response.
**Rather than only different climatic conditions, this is also a result of increased contributions of effluent into the urban catchment during the drought, that causes the increased discharge in the urban stream. Furthermore, in the urban area of Berlin during WY 2018/19 there were still several large summer convective events (up to ~50mm) while in the rural area, no rainfall was

recorded for several weeks between March – May and only limited rainfall in summer, resulting in a much more severe decrease in streamflow.
The effects of the drought only became fully visible in WY 2019/20 in the urban area – as seen by the lowest discharges in that year (compared to following years).
When plotting the double mass curves (see below) per WY, the differences in cumulative amounts become even clearer between WY2019 and the following WY2020 (see below), with the effects of drought being visible in WY 2020.

Section 4.3: Besides flow duration curves, I recommend adding double-mass curves (cumulative precipitation vs. cumulative specific discharge) for comparing the hydrological response of the two catchments during different years and at the seasonal scale (the focus could be on drought periods as well as on very wet months).
**We appreciate the suggestion to add double-mass curves for comparing the hydrological responses and will do so during the review. We will add them to Figure 4 to complement the flow duration curves.

Section 4.4: The characterization of the rainfall events should be anticipated in the results and merged to the first section of the results, in order to help understand the hydrographs and the flow duration curves.
**We agree with this suggestion and will restructure the section to present the seasonal distribution as well as characterization of rainfall events at the beginning of the result section, followed then by the results of streamflow patterns and flow duration.

Section 4.5: What is the sensitivity of young water fraction estimates on the sampling design for both rainfall (how many collectors were used?) and stream water? I wonder whether capturing the isotopic variability during flashy events in the urban catchment would have determined a different estimation. Furthermore, in this case, results on young water fractions and MTT may be due to a combination of factors, such as catchment area, geology and land use.
**For the collection of rainfall isotopes, generally only 1 collector is used. We did use two separate datasets of precipitation isotopes from Berlin Steglitz (for the urban catchment) and from the AWS in Hasenfelde (for the rural catchment).
Regarding sampling of stream water isotopes, we collected daily samples to insure continuity. This is a high resolution for stable isotopes in particular as sampled of longer periods (inter-annually). However, it is likely that sampling over the course of a rain event could give different estimates of young water contributions, which may be more damped when sampling just on daily basis, especially in the urban catchment where runoff responses can be relatively quick. From previous sampling, we know that there is minimal effect on young water estimates during flow peaks.
We agree, that estimates of young water fractions and MTT are likely due to a combination of factors related to land use and catchment area, and in the case of the urban catchment – the overwhelming influence of wastewater, which complicates the estimation of MTTs.

Table 2: Adjusted R2 are very low and RSE are very high for the urban catchment. Perhaps, these values should be considered carefully during the interpretation of the results.
**Yes, we agree these values need to be considered with care. They highlight the difficulties of these methods to estimate young water fractions in urban catchments with a strong influence of wastewater, as the isotopic variability is much more damped than in the rural stream, resulting in higher RSE and lower R2. We will make sure to critically discuss this in the discussion section.

Section 5.3 should be revised (please see the comment about the inter-comparison); based on this text and Figure 7, it seems that land use represents the main factor determining the different hydrological functioning of the two catchments during drought and wet periods.
**We agree that the discussion about the wider implications will benefit from revision and more specific arguments. As mentioned also to Referee 1, we will amend the schematic graphic in such a way that there is less focus on land use effects but on the aspects of different streamflow patterns under drought/wet periods in different anthropogenic environments. We will add amounts of young water estimates (in months) and flux amounts (in mm) to give a specific link to the results.

Figure S2: In late April of WY2020, there should be a rainfall event triggering the flash and marked discharge increase; however, there is only a rainfall pulse with a very low magnitude. Is this correct? Discharge in WY2020 seems to have a very different behaviour compared to the following years; is there a specific explanation?
**These distinct flashes in the urban streamflow regime are not necessarily associated with rainfall pulses but rather with streamflow management and opening of a weir upstream. This generally triggers such a marked streamflow response downstream, as is visible between late April and May 2020. This is usually done during drier periods – as was the case during the spring of 2020, to increase the flowrate and avoid the stream drying out. In this particular case the increased flow lasted for about 2,5 weeks before being reduced again (weir closed). We will make clear in the revised manuscript that this context is understood.

Technical corrections
Line 84: ‘as part of’ can be deleted.
**Agreed. Will be corrected.

Line 96: ‘selected’ instead of ‘select’.
**Agreed. Will be corrected.

Line 100: ‘in an integrated way’ can be deleted.
**Agreed. Will be corrected.

Line 216: ‘MTT’ instead of ‘MMT’.
**Will be changed.

Figure 2: For baseflow I see pink or purple lines, not red lines. Furthermore, I do not see the winter and summer events highlighted in red and green, respectively.
**We will change the color scheme to be more visible and easier to distinguish.

Line 398: If the correlation is negative, r should be -0.49.
**Yes, will be changed.

Line 434: ‘2018-19’ instead of ‘208-19’.
**Will be changed.

Line 499: ‘due to’ repeated twice.
**Will be deleted.

Line 500: Unclear ‘lack of recharge. Hydromorphic conditions…’.
**The sentence will be clarified – a connecting phrase was missing.

Additional References:

Bonneau, Jeremie, et al. "The impact of urbanization on subsurface flow paths–A paired-catchment isotopic study." *Journal of Hydrology* 561 (2018): 413-426.

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Marx, C., Tetzlaff, D., Hinkelmann, R., & Soulsby, C. (2023). Effects of 66 years of water management and hydroclimatic change on the urban hydrology and water quality of the Panke catchment, Berlin, Germany. *Science of the Total Environment*, *900*, 165764.

Tetzlaff D, Seibert J, Soulsby C. (2009) Inter-catchment comparison to assess the influence of topography and soils on catchment transit times in a geomorphic province; the Cairngorm Mountains, Scotland. *Hydrological Processes*, 23, 1874–1886.

Tetzlaff D, Seibert J, McGuire KJ, Laudon H, Burns DA, Dunn SM, Soulsby C. (2009) How does landscape structure influence catchment transit times across different geomorphic provinces? *Hydrological Processes* 23, 945–953