Response to reviewer #1

We sincerely thank the reviewer for their constructive assessment of our work. While we are glad that the general value of the study is appreciated, we are just as happy to revise our manuscript according to the comments made and believe that this will further strengthen its quality.

In particular, we will make sure to more sharply articulate the conceptual novelty of our study in the introduction and discussion during revision by highlighting (i) the consistent breakpoint across solutes, (ii) the groundwater depth as an indicator for the transition of the hydrological catchment state, and (iii) the additional insights gained by high-frequency and multi-solute data, compared to low-frequency and single-solute data.

Finally, we will streamline the discussion to (i) highlight novelties (as described above), (ii) add literature (especially the references provided by the reviewer) on already established processes, iii) reduce redundancies, and iv) make sure that we clearly distinguish between quantitative results and qualitative interpretations. We agree that, especially by removing redundancies and focusing more on the novelties, the discussion can very likely be shortened without losing depth and critical information.

Our answer to the specific comments:

Line 38ff: nice review of water chemistry under droughts literature

Thank you!

Line 43: "can alter …" can you state how can they alter, like what was detailed for the Mosley 2015 paper. it would be more informative this way.

→ Sure. We will add: *In a survey of 182 catchments in Germany, Saavedra et al. (2024) reported seasonal differences in the way droughts can alter stream water nitrate concentrations during or after a drought event. Across all seasons, a large share of catchments showed lower nitrate concentrations during or after droughts, compared to normal conditions. However, winter drought and post-drought periods caused higher-than-normal concentrations in a considerable share of catchments (25% and 19%, respectively), especially in wetter catchments with high nitrogen surplus or low nitrogen retention.*

Suggest changing "biochemical" to "biogeochemical" throughout the manuscript. They mean very different things

We will change our wording from biochemical to biogeochemical throughout the manuscript.

Line 83, before this paragraph, I expect a knowledge gap about water chemistry during drought, in addition to the data limitations, as one major goal of introduction is to introduce knowledge gap. What is the current status of our understanding about water quality during drought?

→ This is a good point. In line with our analysis and results, we will add:

Most studies that analyzed drought impacts on water quality relied on single (Winter et al., 2023, Saavedra et al., 2024) or very few (Dupas et al., 2025) solutes or on results from low-

frequency data (Mosley 2015, Saavedra et al., 2024, Dupas et al., 2025). Therefore, generalizable information across solutes that differ in their sources and their susceptibility to biogeochemical processes is still missing. Moreover, drought studies relying on low-frequency data may have overlooked critical catchment-transition points occurring on short time scales that can only be revealed by high-frequency data.

Line 85; Hypothesis, can you also state why that is the case in the hypothesis?

→ Instead of explaining the hypothesis in more detail in line 85, we prefer to explain the results from Dupas et al. (2025) in more detail in the introduction (around line 43), so that the hypothesis in line 85 should be self-explanatory. We will add: *More recently, Dupas et al. (2025) showed that the effects of drought on nitrate, dissolved organic carbon, and soluble reactive phosphorus concentrations can be predicted from the overall concentration-discharge (C-Q) relationship of a catchment. Higher concentrations in source areas that remain hydrologically connected during low flow, such as deeper groundwater, increase in their relative importance during dry conditions, causing a negative C-Q relationship. Conversely, a higher source strength of solutes in areas that are mainly connected during wet conditions or that mainly stem from point sources, cause a positive relationship. This general relationship does not fundamentally change between normal (e.g. seasonal) hydro-meteorological variations and drought conditions, implying that the general direction of the drought response does not fundamentally diverge from the general C-Q behavior. Nevertheless, additional processes, like a disruption of the hydrological connectivity or near-stream biogeochemical processes, might additionally influence the magnitude of the C-Q relationship under anomalously dry conditions.*

Section 4.1. Much of the hydrology and biogeochemistry literature has talked about the fact that during dry conditions, most stream water comes from groundwater (e.g., Carroll et al., 2018, 2019). For example, Stewart et al. (2024) and Kerins et al. (2024) quantified the flow fractions of stream water from surface, shallow, and deep waters using streamflow and chemistry data, and they found flow fraction of groundwater is essentially 100%.

Thank you for this helpful and detailed information. We will incorporate it in section 4.1

Section 4.3. Explanation of the CQ patterns. Alternative mechanisms. In addition to the possible reactions and processes mention, Could they reflect the depth distribution of solutes in groundwater. As groundwater table become lower and lower during droughts, groundwater from different depths contribute to stream water, such that they reflect gw chemistry at different depths.

→ We will more explicitly discuss the potential impact of a vertical distribution of solute concentrations in the groundwater, as, for example, also mentioned in Knapp et al. (2022) and Seibert et al. (2009). However, in the Erlenbach catchment, the increasingly chemostatic response of solutes during drought does not imply substantial changes in the source strength of these solutes in deeper groundwater layers. Sulfate is the only exception, in which concentrations continue to increase with decreasing catchment wetness. This might be explained by higher concentrations in deeper groundwater. However, as explained in line 335-336, this alone would not explain why the recovery of sulfate concentrations took longer than the hydrological recovery and the recovery of any of the other solutes observed. Hence, we argue that additional biogeochemical processes (due to a change in redox conditions) have taken place that have altered the availability of sulfate (see 336 – 340). We will add and expand this information in section 4.3.

Section 4.6 on transferability. This is good discussion. But I found myself longing for some broader discussion echoing the review on water chemistry under droughts in Introduction. Are the findings here similar to or different from what was reported in literature? How do they resemble or differ?

→ We will add: *Our findings from the Erlenbach catchment align well with results from the literature. They confirm the significant impact of drought on water quality (e.g., Mosley 2015, Winter et al., 2023, Saavedra et al., 2024) and show that the general direction if the C-Q relationship did not change (Dupas et al., 2025). However, the unique dataset of multi-solute high-frequency data also allowed for additional insights into the underlying mechanisms. In particular, the consistent breakpoint towards more chemostatic patterns across solutes shows that the water quality response to drought can be explained by a generalizable hydrological transition of the catchment. Especially the groundwater table head proved to be a good indicator for the continuous dry-down of the catchment. In addition, solute-specific differences point to additional biogeochemical processes that vary among solutes, depending, e.g., on their redox sensitivity or roles as nutrients.*