We appreciate Referee #1's thorough review and insightful suggestions. We truly believe that the changes suggested by Referee #1 will enhance the quality of the manuscript. Below are detailed replies addressing each specific comment:

Comments to the Author:

The manuscript authored by Liu et al. addresses a relevant scientific topic in the framework of natural hazards, such as the hydrological response of burned watersheds under present and future climatic conditions. The analyzed case study is in the USA, where several research teams are working on the same hazard due to relevant impacts associated to post-fire floods and debris flows occurring every year. The work is well presented and described, and it could be helpful to a broad community focusing on fire-related hazards and effects of climate change.

R: We appreciate the reviewer's insightful comments.

After a careful revision, I have identified a series of points that the Authors should address before considering the manuscript ready for publication. As general remarks, the Authors should clarify that they worked on a large watershed not prone to quick flooding response like those affected by post-fire flash floods that, however, respond to sub-hourly rainfall. In addition, I did not find field measurements performed in the three years following the wildfire to validate outputs of the used Kineros 2 model, in terms of soil saturated hydraulic conductivity, net capillary drive, and hydraulic roughness. Some of the model outputs support the Authors in the definition of the window of disturbance associated to the analyzed site, that I suggest to stress together with the distinction between rainfall-runoff events strictly related to the wildfire and those that can be considered as ordinary river floods (i.e., not fire-related). The simulated increasing of the peak discharges should be also discussed in terms of liner or non-linear relationships with rainfall intensification.

R: Here the comments include three questions. The first question is about the type of floods. We appreciate this insightful suggestion and agree that it warrants clarification. We revised the manuscript to highlight that our study watershed (49.4 km^2) is relatively large, typically experiencing river floods driven by prolonged rainfall (hours to days), unlike smaller, flash-flood-prone catchments (<10 km^2). But flash floods do occur in larger watersheds (> 200km^2) in AZ due to convective systems associated with the North American Monsoon (Yang, et al., 2017; https://journals.ametsoc.org/view/journals/hydr/18/12/jhm-d-17-0089_1.xml). Here, in this study, wildfires significantly alter soil hydrological properties (e.g., hydrophobicity, reduced infiltration), resulting in unexpectedly rapid runoff responses similar to flash flood dynamics. Specifically, time-to-peak flows were less than one hour for eight out of ten post-fire events and approximately 2–3 hours for the remaining two events, consistent with observations from comparable-sized watersheds (Liu et al., 2022). This unexpected rapid response highlights the importance of this study that wildfire effects can shift the response toward flash flood-like behavior, even in a larger watershed. We added the following clarification in the introduction:

> "While this watershed is larger than those typically associated with flash floods (e.g., <10 km^2), post-fire alterations to soil hydrologic properties, such as reduced infiltration capacity, can enhance runoff generation, leading to rapid streamflow responses to sub-hourly rainfall events, similar to flash flood dynamics observed in smaller watersheds."

The second question is about the field validation measurements.

We did not make any field measurements as part of this study, but estimates of soil hydraulic properties following the fire have recently been published by Barra et al. (2025). They estimated soil hydraulic properties at many sites following the Bighorn Fire using tension infiltrometers. We will incorporate their findings into the discussion section and provide some more specifics in our response to comments below.

> Barra, C., Fule, M., Beers, R. et al., 2025. Soil biogeochemical and hydraulic property response to wildfire across forested ecosystems of the Santa Catalina Mountains, Arizona, USA. CATENA, 250, https://doi.org/10.1016/j.catena.2025.108802

The third question is about the distinction between fire-related and not fire-related events (ordinary river floods). See reply to Line 395.

Specific Comments:

Line 34: I suggest to spend some words about the role played by burn severity

R: Burn severity significantly influences post-fire hydrological responses. We clarify and emphasize this point by adding the following description in the paragraph:

> "Soil burn severity significantly affects hydrologic response by altering key soil properties, with higher severities leading to reduced infiltration and increased runoff, particularly in the initial post-fire events (Moody et al., 2016)."

> Moody, J. A., Ebel, B. A., Nyman, P., Martin, D. A., Stoof, C., & McKinley, R. (2016). Relations between soil hydraulic properties and burn severity. International Journal of Wildland Fire, 25(3), 279–293. http://doi.org/10.1071/wf14062.

Line 51-52: This has been already stated before. Please, remove.

R: Good suggestion. Removed.

Line 72: Authors should remark that a watershed so large is not prone to flash floods but to classic river floods requiring hourly rainfall and not sub-hourly rain bursts cited before in the Introduction section. In terms of hazard assessment, there is a significant difference between post-fire floods and flash floods that the Authors should clarify.

R: We have clarified the flood type as suggested. Please refer to our detailed reply in the general comments above.

Line 109: As suggested before, the applied dNBR thresholds should be mentioned here.

R: We added the SBS thresholds as follows:

> "The BARC dNBR thresholds for soil burn severity are 84, 142, and 202."

Line 120-121: Is this gauge the one called MFLD in Figure 1? Please clarify

R: Yes. We revised the text as follows:

> "We further installed one tipping bucket rain gauge (Onset HOBO RG3-M), which we refer to as the Loma Linda gauge (LD, Fig 1), near the headwaters of the CDO in July 2020"

Line 251-252: Events 1-5?

R: No. Events 1-4, pre-4, and pre-10 commenced with relatively dry soil conditions. Event 5 had higher initial soil moisture but a short duration.

Line 256-258: Besides data collected with hydrologic monitoring, field observations would have been useful to distinguish runoff responses related or not to the fire event. It is not clear if all of the 12 events are connected to the fire according to a cascading mechanism or not. In fact, in some cases, post-fire hydrologic responses occur up to one year since the fire. The following ones can be not more fire-related. Do you have field evidences to make this kind of assessment?

R: Good observation. We used all 12 post-fire events in this study, excluding five (events 6-10) whose runoff mechanisms were not adequately captured by KINEROS2. We assume that any systematic changes that we observe in model parameters are driven by the fire and subsequent recovery. This assumption is supported by records of rainfall and runoff in the watershed in the years prior to the fire that indicate no or minimal runoff in response to typical monsoon rainstorms. This shift in watershed response from prefire to postfire leads us to interpret the inferred postfire changes in model parameters to fire effects and their subsequent decay as a function of time since fire.

Field observations indicated that vegetation type and density in areas burned at moderate to high severity were substantially different from prefire conditions throughout the study period from 2020-2022. In addition, field measurements from Barra et al. (2025) indicate an increase in the geometric mean of the field saturated hydraulic conductivity in areas burned at moderate to high severity between 2021 to 2023. In 2021, the geometric mean of field-saturated hydraulic conductivity in areas burned at moderate to high severity is approximately 20 mm/h while it is 28 mm/h in 2023.

Line 282-283: This is strange since the fire has a strong capacity to modify roughness on hillslopes, and thus the runoff response.

R: We agree the fire's significant impact on roughness on hillslopes. This study, however, focuses on roughness in the channels. Because the time runoff at the watershed outlet is affected mainly by roughness in the channel. We recognize this apparent anomaly and discussed it in the manuscript (Discussion section, lines 432-440), explaining the relatively constant roughness as potentially due to the recent history of fire in this watershed and absence of post-fire dry ravel observed at our site.

> "In contrast to several past studies in the southwest US, which have generally found that hydraulic roughness is lowest immediately following fire and then increases with time (Canfield et al., 2005; Liu et al., 2021), we found that hydraulic roughness was relatively constant with time since fire. Liu et al. (2021) inferred an increase in nc from roughly 0.09 to 0.3 over a time period of roughly two years after a fire in the San Gabriel Mountains, CA. Postfire dry ravel is common in the San Gabriel Mountains and can load channels with substantial amounts of relatively fine hillslope sediment, decreasing grain roughness in channels immediately after fire. We did not observe any evidence of widespread dry ravel in the CDO following the Bighorn Fire, which could account for the more muted change in nc as a function of time since fire compared to that found by Liu et al. (2021). Increases in hydraulic roughness as a function of time since fire could also result more generally from preferential transport of fine sediment and the exposure of cobbles and boulders (Rengers et al., 2016), regardless of whether postfire dry ravel is an active process. We hypothesize that such a trend may also have been less pronounced at our site due preferential transport of fines following the fire in 2003."

Line 311: Are you considering the hydraulic response of the watershed as linear or non-linear? This theoretical finding should be contextualized to the analyzed watershed.

R: It is apparent that the watershed response to rainfall intensification is non-linear. Intensified rainfall produces more overland flow in shorter timeframes, especially through preferential flow paths. The burned watersheds amplify these non-linear responses due to significantly reduced infiltration capacities. We added the following text in the Discussion section:

> "The watershed response to rainfall intensification is non-linear, particularly in burned areas where infiltration capacities are reduced. Intensified rainfall generates

rapid runoff responses and more pronounced peak discharges, further enhanced by concentrated flow along preferential pathways created or accentuated by fire effects."

Line 338: As remarked before, I believe that the analyzed watershed is not prone to flash floods but to river floods, due to its dimension.

R: Addressed in general comments and introduction (see above).

Line 389: You can stress the concept of "window of disturbance", since you have a proper dataset and outcomes to define it in your case study (i.e., about 2 years).

R: Good suggestion. We added the following sentences in this paragraph:

"This implies wildfire impacts persist for a limited period, defining a 'window of disturbance' during which altered soil hydraulic properties significantly influence watershed runoff responses."

Line 394: Before in the text you speak about saturation-excess and not a mixture. Please be consistent throughout the manuscript.

R: All the 12 events can be grouped into two categories. One is primarily infiltration-excess the other is either saturation-excess or a mixture of two. The relevant description in line 383-390:

"Among the 12 simulated events in this study, five (events 6-10) exhibit initial soil saturation (SAT, defined as soil moisture divided by porosity) equal to or greater than 0.55, or rainfall durations exceeding 7.6 hours. Under these conditions, infiltration-excess overland flow is less likely to be the dominant runoff-generated mechanism. The model performance of these events is, as expected, relatively poor compared with other events (Figure 4). We therefore excluded events 6-10 from our efforts to use K2 to quantify changes in soil hydrologic and hydraulic roughness parameters as a function of time since fire. The apparent shift from flood generation due primarily to infiltration-excess to saturation-excess overland flow, or a mix of the two mechanisms, in less than two years following fire is consistent with the relatively rapid increase in soil infiltration capacity inferred from model calibration of events 1-5 (Figure 4; Table 3)."

Line 395: In my opinion, and in accordance with your statements, infiltration-excess is the most common mechanism related to the effects of wildfires that control the post-fire runoff generation. When this mechanism change into saturation-excess, this may indicate the end of the fire effects on the soil hydraulic properties, and so the limit of the window of disturbance. The saturation-excess overland flow generation could be typical of runoff not associated to fire effects. In the light of this, you may add something about the role played by SWR that, however, you did not assess in the CDO case study.

R: We think the assertion that linking the shift in runoff generation mechanisms to the end of the disturbance window needs a more cautious examination. In this study, the events 1-5 were classified as infiltration-excess dominated based on two observations: 1) initial soil moisture is low combined with a short-duration rainstorm, and 2) the rainfall intensity exceeding soil infiltration capacity in postfire condition. However, the events with saturation-excess dominated or mixture flows are mainly because of the antecedent conditions plus the prolonged duration of rainstorm, rather than merely the soil properties.

To determine the window of disturbance, we recommend further investigation that includes: 1) field measurements, such as the reviewers' suggestion of SWR assessments, soil hydraulic properties, and soil physical properties (e.g., bulk density, organic matter) 2) modeling additional rainfall-runoff events, particularly those in prefire conditions or several years after fire.

Line 418-421: The lack of Ks field measurements to validate the model outputs can be a criticism of this study. However, the cited measurements are useful to support your findings, since most of them were collected by the same authors of the current work and in the same part of the USA.

R: We agree that comparing field measurements of related soil hydraulic parameters is helpful and will add some relevant text to the discussion section. To summarize, the data from Barra et al. (2025) provide information about changes in soil hydraulic properties, including field-saturated hydraulic conductivity. There are challenges associated with estimating watershed-scale effective values of soil hydrologic parameters, such as Ks, based on point-scale measurements of related soil hydraulic properties (e.g., Liu et al., 2023). The data from Barra et al. (2025), for example, indicate a more modest change in field-saturated hydraulic conductivity over time relative to what we infer from watershed-scale modeling. In areas burned at moderate to high severity, their data indicate an increase in the geometric mean of field-saturated hydraulic conductivity from roughly 20 mm/h in summer 2021 to 28 mm/h in summer 2023. They did not make measurements in 2020, the first summer after the fire. We estimate increases in saturated hydraulic conductivity from 11 mm/h in 2020 to 29 mm/h in 2021 and 60+ mm/h in 2022. The apparent differences in estimates for saturated hydraulic conductivity are likely to due several factors. First, spatial variability in soil hydraulic properties can make it challenging to translate between point-scale data and watershed-scale, effective parameters (Liu et al., 2023). Second, data from tension infiltrometers best captures flow through the soil matrix whereas estimates of soil hydraulic properties inferred from model calibration would also represent infiltration through macropores. In cases where macropore flow is of greater relative importance, we could expect estimates of saturated hydraulic conductivity derived from a watershed-scale model calibration to be greater than those estimated from tension infiltrometer measurements. Availability of macropores could be low initially following fire and increase over time (Nyman et al., 2014).

Liu, T., McGuire, L.A., Youberg, A.M., Gorr, A.N. and Rengers, F.K., 2023. Guidance for parameterizing post-fire hydrologic models with in situ infiltration measurements. Earth Surface Processes and Landforms, 48(12), pp.2368-2386.

Nyman, P., Sheridan, G.J., Smith, H.G. & Lane, P.N. (2014) Modeling the effects of surface storage, macropore flow and water repellency on infiltration after wildfire. Journal of Hydrology, 513, 301–313. https://doi.org/10.1016/j.jhydrol.2014.02.044

Line 437: Please, indicate in the methodology section if you performed field surveys or used remote sensing after the wildfire, as well as SWR or other tests to get field measurements aimed at validating or interpreting the model outcomes.

R: We did not make any field measurements as part of this study but data from the recently published paper by Barra et al. (2025) are relevant. See replied to above comments.

Line 450-452: You may add some references to studies documenting similar outcomes in Europe, Australia, Canada or China.

R: Good suggestion. We added the following references from Europe, Australia, and China to provide broader international context:

Vieira, D.C.S., Basso, M., Nunes, J.P., Keizer, J.J., Baartman, J.E.M., 2022. Event-based quickflow simulation with OpenLISEM in a burned Mediterranean forest catchment. Int. J. Wildland Fire 31, 670–683.

Nyman, P., Sheridan, G. J., Smith, H. G. & Lane, P. N. J. Modeling the effects of surface storage, macropore flow and water repellency on infiltration after wildfire. J. Hydrol. 513, 301–313 (2014).

Cai, L., Wang, M., 2025. Simulating watershed hydrological response following a wildfire in southeast China with consideration of land cover changes. Catena 250, 108755, https://doi.org/10.1016/j.catena.2025.108755

Line 454: inferred by model

R: Yes. Revised as follows:

"In this study, the lowest levels of infiltration capacity immediately after the fire, inferred by the model, suggests..."

Line 474: This is true for large watersheds only (e.g., CDO). Please, clarify and spend some text about small-scale watersheds with area below 1 square kilometer.

R: We added the following sentences in the paragraph:

"The effect of the spatial variation and rainfall coverage on runoff does not apply to smaller, high-order small watershed (less than 1 km^2)."

Line 484: Staley. Please, correct.

R: Thanks for pointing out that. Corrected to “Staley”.

Figure 1: The black triangle in the panel b should be highlighted with a different color and enlarged. More information about the soil burn severity classification should be provided (e.g., dnbr thresholds)

R: We revised Figure 1(b) to enlarge and highlight the gauge (triangle) and included explicit dNBR threshold details, enhancing visual clarity.