Review response to 13-Jan-2026 (RC3)

Reviewer Comments

Black – reviewer; Blue – response

Overall, the manuscript is well written and easy to comprehend.

The authors apply a hydrologic model to calculate discharge and then convert it into a dimensionless unit discharge. The dimensionless discharge is then compared to a 15-min dimensionless-discharge rainfall ID threshold. Input parameters used in the hydrologic model included the use of mini disk infiltrometer data to estimate hydraulic properties of soil, remote-sensed metrics such as NDVI and dNDVI to estimate changes in vegetative cover, and sediment grain size to estimate roughness and control critical Shields number/shear stress used in developing model-derived ID thresholds. Two main findings reported by the authors include 1) unsaturated hydraulic conductivity increased by an order of magnitude between the wet and dry season four years post fire, suggesting unsaturated hydraulic conductivity is a significant factor in post fire debris flow (PFDF) occurrence, and 2) vegetative cover and grain size provided less influence compared to hydraulic conductivity in controlling PFDF occurrence.

Although the results of this study do show some similarities with other studies, the methods applied lack scientific rigor with the use of only a few data collected in the field to fully test influences of hydraulic conductivity and changes in vegetative cover. For example, the finding that seasonal variability in unsaturated hydraulic conductivity is a significant factor appears to be based on mini disk infiltrometer measurements taken at the outlet of four basins, with three of the four basins showing an increase in hydraulic conductivity from the wet to dry period. Mini disk infiltrometer measurements are known to exhibit large variability between measurements at the same location and typically vary spatially across the landscape. Therefore, relying on just a few values of hydraulic conductivity measured at the outlet of basins is not advised and additional data would be required.

Moreover, the authors rely on dNDVI to approximate changes in vegetative cover. NDVI is known to be sensitive to seasonal variations in vegetative cover, largely as a function of vegetive health and the natural cycle of plant growth. For example, plants actively growing in the spring will have NDVI values approaching 1 compared to the same plants that go dormant and dry out during the late summer. Thus, NDVI as a sole predictor of vegetative cover is not recommended. Instead, use of a combination of indices including NDVI, LAI, and vegetative water content has been demonstrated to provide better predictors of vegetative cover, particularly when used to inform hydrologic models (Lahmer et al, 2025; Thomas et al, 2021; Nourani et al., 2017).

Regardless of the remote-sense metrics used, it is important to validate measured values against in-field observations, including vegetative type, density, height, and ground cover.

Based on the limitations and findings contained within this study, it is difficult to except it for publication unless substantially changed.

Please see comments below for additional context

Lines 90-102: The authors describe making field measurements at the outlet of five basins that include taking samples for grain size analyses and performing mini disk infiltrometer measurements. In reading the text, it appears the sediment samples were taken from the channel and represent sediment that was transported from source areas above. It also appears the mini disk measurements were performed in the channel adjacent to where the soil samples were collected. If this is the case, then the mini disk measurements were made on deposits of transported material (e.g. alluvium/colluvium within the channel) and may not be representative of in-situ soils across the basin that would control infiltration and runoff. A more acceptable approach would have been to conduct far more and spatially dispersed measurements across the basin.

Thank you for the comment. We responded to a similar comment from Reviewer #1.

We acknowledge these issues and agree that the lack of debris flows may result in less mixing, especially at the basin outlets and that collecting upslope measurements would be the best representation of the basin and debris flow source. However, given the difficulty accessing upslope, we believe this method could provide a better representative of the basins. We will include this in the discussion.

Additional information on the method applied to perform the grain-size analyses is needed. For example, were the samples run in the lab using an established method such as ASTM D422? If so, please state the standard method that was applied. The grain size listed in Table 2 and Figures 3 and 4, suggest grain size with a D50 as low as 0.08mm. It implies that hydrometer tests were performed to quantify the grain size distribution. Grain sizes equivalent to silt and clay are not frequently encountered in channels where fluvial process occur. Such fine grains would dramatically influence the dimensionless discharge and the critical dimensionless discharge used to set the ID rainfall threshold. Please elaborate.

We used ASTM E11 test sieves with mesh size 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm. Sieves were stacked and shaken on a RO-TAP sieve shaker. This information will be added to the revised manuscript.

Please state or reference the standards that were applied in performing the mini disk infiltrometer tests. If you followed the manufacturer's standards, please state so and include a reference.

Also, please state the suction head applied and if you used a thin layer of silica bedding sand to ensure good contact with the mini disk.

We performed with a suction head of 1 cm without silica bedding. We added the tension infiltrometer reference and the METER's User Manual. This information will be added to the revised manuscript and a reference for the METER's User Manual as noted below.

Watson, K. W. and Luxmoore, R. J.: Estimating macroporosity in a forest watershed by use of a tension infiltrometer, Soil Sci. Soc. Am. J., 50, 578–582, https://doi.org/10.2136/sssaj1986.03615995005000030007x, 1986

METER Group, Inc. USA. (2021). Mini Disk Infiltrometer Operator's Manual

As discussed, it does not appear more than one measurement was performed at each of the basin outlets for each sampling period. If this is incorrect, please indicate the number of tests performed and show the results of each test in the supplement.

This is correct. We have responded to a similar comment above.

Year 0 mini disk measurements were not conducted. Instead, Year 0 results were assumed by extrapolating results obtained on the Fish Fire. Additional information justifying the use of values obtained on the Fish Fire should be done. For example, bedrock type, soil type, slope aspect, slope gradient, pre-fire vegetation, and post-fire soil burn severity should all be shone to be relatively similar to apply the Fish Fire results to the Lake Fire study area.

We will add the following text and references to the manuscript:

We assumed the similarity with Fish Fire due to the similarity in granitic bedrock, average slope for all basins are 30 degrees with all aspect NW facing Lake Fire (Fish Fire has slope ranging between 46 to 51 degrees).

Using National Land Cover Dataset, both fires have similar categories of Shrubs/Scrub. The entire Fish Fire is dominated by California mesic and dry-mesic chaparral, mixed evergreen woodland and mixed conifer and woodland, and montane grasslands (Staley et al., 2018). This is similar to the Lake Fire sites within the Los Angeles National Forest area where Chaparral also dominates (Payson et al., 1980).

Staley, D. M., Tillery, A. C., Kean, J. W., McGuire, L. A., Pauling, H. E., Rengers, F. K., & Smith, J. B. (2018). Estimating post-fire debris-flow hazards prior to wildfire using a statistical analysis of historical distributions of fire severity from remote sensing data. International Journal of Wildland Fire, 27(9), 595–608. https://doi.org/10.1071/WF17122

Paysen, T. E., Derby, J. A., Black, H., Jr., Bleich, V. C., & Mincks, J. W. (1980). A vegetation classification system applied to southern California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-45. Berkeley, CA, USA. 39 pp. https://www.fs.usda.gov/psw/publications/documents/psw_gtr045/psw_gtr045.pdf

Lines 110-113: It is unclear what "15-minute duration threshold" is being referred to here. Is it the fire-wide USGS I15 threshold of 24mm/hr used to estimate debris flow likelihood? Or is it basin specific thresholds derived by the USGS assuming a probability of occurrence of 50%. Or is it basin specific derived using the critical dimensionless discharge model? If the "threshold" being referred to is associated with the USGS model, then it would only apply for years 0-1, since the USGS model does not predict thresholds after year 1. Also, Table S7 and Figure S2 don't refer to "thresholds" in the sense of triggering thresholds. Table S7 simply shows the dates that rainfall exceeded 15mm/hr in 15 minutes and Figure S2 shows peak I15 rainfall events that exceed 20mm/hr.

The 15-minute duration threshold corresponds to the USGS I15 threshold used to estimate the debris flow likelihood. In our study, we vary the rainfall intensity (i.e. 15, 20, 25 mm/hr) to evaluate whether debris flow can be triggered. Therefore, the thresholds in Table S7 and Figure S2 represent the minimum rainfall conditions needed to trigger debris flows.

Section 3.4, starting on Line 158: Additional information is needed to explain the hydrologic model used. It is understood that the authors applied the Green-Ampt formula for infiltration and Kinematic Wave formula for routing using the program KWAVE (Renger et al., 2016), yet there is a lack of detail on how the models were parameterized. For example, additional information is needed to explain how saturated hydraulic conductivity, sorptivity, soil porosity, initial soil moisture, infiltration depth, and Mannings # were obtained and used in the hydrologic model. The list of parameters summarized in Table 2 is insufficient, and the broad generalization of assumed values applied and discussed on lines 190-192 are poorly justified. See methods section in Tang et al., 2019, and McGurie and Youberg, 2020, for examples how to explain the model and parameterize it.

We understand that the studies noted performed a series of calibration and measurements for their hydrologic model. However, in our study, the focus of the study was to understand how different parameters guided by samples & measurements that we obtained would change debris flow likelihood. Regardless, we will include a detailed description of the model such as the equations used and clarify the variables that we have set as constant or varied.

Lines 190-192: The authors suggest the use of dNDVI to assess vegetative cover and post-storm response, including sediment transport and deposition associated with debris flows. It is understood that dNDVI can show the location of vegetative-free areas, but to infer flow response, such as flood flow or debris flow, in areas using dNDVI would require field verification.

We could not match the correct lines. However, we agree with the reviewer.

Results 4.0, starting on Line 194: It is difficult to understand why the modeled dimensionless discharge have bell-shaped curves with peak discharge occurring at slope angels of about 35 degrees. Typical plots of dimensionless discharge start low at high slope angles and increase at lower slope angles. These results are suspect and difficult to rationalize. Further explanation is needed.

One of the possibilities could be due to soil exceeding the angle of repose where steep slopes do not have much loose sediments given that they would have been mostly eroded prior to any high intensity rainfall. Secondly, the lack of slope (data) to could potentially create a robust discharge for the steeper slopes – as seen with the high variability of dimensionless discharge values at the tail end of the slopes (x-axis).

We will add more explanation about this point to the discussion section.

Figure 2: The riparian zone shown in the Dec 2020 photos following fire suggest low burn severity due the lack of consumption and observed intact organic mat on the ground surface in padel (a). The coarse resolution of the BARC map used by the BAER team likely didn't capture the low burn severity in the mainstem channel and within the lower elevations of the basins. Because field observations and data were collected only at the basin outlets, near their intersection with the main channel, it is possible the data is biased towards areas of low fire severity and not indicative of conditions located upslope within the basins.

We understand the comment and agree with the potential of high-resolution corroborating field observations. Our field collection is not shown here but is focused upslope. We will mention in the captions that the arrows do not indicate location of sample and add more field photos with their location more clearly mapped.

Figure 3: In looking at the shades of blue and red in areas outside the burn scar, it appears that seasonal changes in vegetative cover may not have been accounted for and may mislead the interpretation of vegetative recover inside the burn scar using dNDVI.   For example, areas outside the burn perimeter in panel a show no change with the color being light grey to white. This is expected. However, panels b, c, d, and e all show some level of change occurring within the unburned areas due to seasonal variations that are likely due to soil/vegetation moisture content or vegetation health. To correct this, the average observed dNDVI values in unburned areas should be subtracted from the values inside the burned areas.

Thank you for the comment and suggestion for using the unburned area to normalize the burned areas. The dNDVI's shown here are the raw values from the bands and we used this to show the difference between burned and unburned areas which is large in the image.

We agree that normalizing to values outside the burn scar is ideal. However, we were unsuccessful in applying this correction likely due to several factors that might influence the normalized dNDVI. Specifically, 1) shadow effects are stronger in higher resolution imagery, we can see ridges with different aspects with different dNDVI values and using unburned dNDVI values could affect the normalization. 2) If we were to use all the unburned areas within the satellite imagery, the inconsistent timing of the images and, sun direction due to seasonality would need to be considered. This is a process that requires more technical studies and approach to correct for, which is outside the scope of this study. Thus, we only use and mention values within the basins only.

Panel d appears to be missing the inset indicating the dates of images used in the differencing analysis.

Please provide units for the D50 grain size.

Thank you for pointing this out. This will be corrected in the revised manuscript.

Figure 4: It is relatively apparent that the dNDVI method is a good metric of evaluating vegetative health, but it may not be a good metric to indicate the overall vegetative density and cover present within the basins. Additional field methods evaluating type and density of vegetative cover present on the hillslopes would be needed to better interpret the dNDVI data.

We agree. Please see our response to a similar comment by Reviewer #1

Please provide units for the D50 grain size.

Please refer to Table 2, rather than Table 3, for median grain size.

Thank you for pointing this out. Corrected.

Figure 5: Again, the bell-shaped curves depicted in the dimensionless discharge plots against slope are odd and difficult to interpret. Please provide additional discussion explaining the reason for the shape.

We address the comment above.

The red line that represents the modeled critical dimensionless discharge separating flood flow from debris flow does not appear to differ between basins and as recovery occurs. Is this the case, and if so, can it be explained? It is expected the critical dimensionless discharge used to set the ID threshold would vary between basins and increase as recovery occurs.

We understand this comment and agree that variation does exist in real systems (Hoch et al., 2021). The threshold (red line) represents the number of pixels in a given basin exceeded a given threshold at a specific rainfall intensity. The threshold (red line) is selected if more than 50% of the dimensionless discharge within the basin at the specific rain intensity is exceeded. Given our sites require significant rainfall intensity (>30 mm/hr of I15) and the fact that we did not observe rainfall of this intensity, we utilized a generalized threshold from the Fish Fire that Tang et al. (2019) has observed. We will include this explanation in the main text.

Table 2: It is difficult to understand why the vegetation cover fraction drops significantly from the wet to dry season. I suspect this is due to change in soil/vegetation moisture content, suggesting a near complete reduction in vegetative cover between April and September 2024. This appears unrealistic. There is likely similar vegetative cover between these reported periods, but the vegetation has gone dormant and dried out in September compared to the earlier April

period. Again, additional field data would be necessary to identify the type and density of vegetative cover in the basins and help interpret the remote-sensed NDVI products.

We understand the reviewer's comment and we responded to a similar question to Reviewer #1. We will include more field photos in the supplement.

We performed a validation using the 20 meter point-intercept survey at along the riverbanks that is accessible outside the burn scar and found an ~81% vegetation cover. The mean NDVI along the same transect on the same day is 0.5191 (max NDVI within image is 0.74). The dNDVI from between the field measurement and 7 months before (Sept 2023) has a mean of 0.034 (indicating not many changes).

We note that the point-intercept transect method is not necessarily a direct comparison to the pixels of satellite imagery. Thus, we used the percentage of vegetation and non-vegetation for comparison to derive vegetation cover of an area from each method. We will address this point in additions to the main text and supplement.

To assess the reliability of the satellite-derived measurements, we also utilized ground surveys within a 3 × 3 m field plot for validation. However, we agree that a more detailed approach is needed in the future to better characterize the box plot method for vegetation cover as satellite imagery captures the canopy cover better than the understory vegetation.

References Cited not already included in manuscript

Lahmers, T. M., Kumar, S. V., Ahmad, S.K., Holmes, T., Getirana, A., Orland, E.,et al. (2025). An observation-driven framework for modeling post-fire hydrologic response: Evaluation for two central California case studies. Water Resources Research, 61, e2023WR036582. https://doi.org/10.1029/2023WR036582

Nourani, V; Fard, AF; Gupta, HV; Goodrich, DC; Niazi, F (2017). Hydrological model parameterization using NDVI values to account for the effects of land cover change on the rainfall-runoff response. HYDROLOGY RESEARCH, 48(6), 1455-1473.