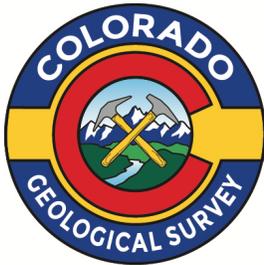

COLORADO GEOLOGICAL SURVEY

303.384.2640
kaberry@mines.edu

1801 Moly Road
Golden, CO 80401



July 27, 2021

Jim Raymond, MPA, CEM
State Recovery Officer
Colorado Office of Emergency Management DHSEM
9195 E Mineral Avenue, Suite 200,
Centennial, CO 80112

Dear Jim:

Re: Black Hollow Debris Flow Preliminary Report

Executive Summary

- The Black Hollow drainage and adjacent side slopes still contain a significant amount of sediment and boulders. It is a question of when not if additional debris flows or mud floods will occur. Even smaller mud floods pose safety risks to the remaining homes. In addition, the sediment currently in the Black Hollow drainage could also present a hazard to the homes immediately upstream of the alluvial fan, Highway 14, and homes and crossings downstream, should it enter into the Cache La Poudre River corridor.
 - It is not safe for remaining Black Hollow residents to stay in their homes, especially overnight.
 - CGS hazard maps (<https://cologeosurvey.maps.arcgis.com/apps/webappviewer/index.html?id=5fe3c49e98dc4713a4bf83f647047143>) show the location of existing alluvial fans where debris flows and mud floods have occurred in the past and are likely to happen in the future. Many of the channels tributary to these fans are full of sediment and rock, and steep side slopes are undergoing erosion. Homes located on or near these fans are at risk for events similar to Black Hollow Road.
 - To the extent possible, from late spring to early fall, residents should not occupy homes, especially overnight, with debris flow risks. To do so, even for a short time, is dangerous. If this isn't possible, the county may wish to evaluate early warning systems for areas with the most significant risks.
 - Given the recent events, it would be prudent for the county to update or reevaluate its debris flow risk assessment. If requested, CGS could assist in these efforts. The upstream and downstream impacts of the additional sediment and
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debris loading (July 20, 2021, event) on flood risk are unknown. We recommend that the county contact the Colorado Water Conservation Board to assist in these efforts.

OBSERVATIONS AND RECOMMENDATIONS

At your request, the Colorado Geological Survey visited the site of the recent debris flow generally located at the intersection of Black Hollow Road and State Highway 14 in Larimer County. On Tuesday, July 20, 2021, approximately 1 inch of rain fell in 30 minutes (Paul Schlatter, NWS, news interview) over the Cameron Peak burn scar and the Black Hollow watershed resulting in a large debris flow that destroyed five homes and damaged three others. To date, the event killed three people, and one other is missing.

As you are aware, the watershed above Black Hollow Road is steep, with elevation ranging from approximately 10,500 to 7600 feet. The head of the watershed is located near the Browns Lake trailhead parking lot. Soil burn severity maps show the higher elevations and steep side slopes within the watershed are rated high to moderate. The lower section of the watershed is rated as low to very little/no soil burn.

Existing hazard maps (Colorado Geological Survey) show the homes destroyed or damaged by the Black Hollow debris flow and flooding located on or near an alluvial fan. Mapping also shows other fans in the area are subject to debris flows and mud floods. We don't know the frequency and magnitude (return interval) of debris flows and mud floods in the area and on each fan. In addition, maps show areas within the Black Hollow watershed that contain rockfall and other slope instability hazards. In short, the homes were located in an area with a prior history of debris flows and other hazards. The Cameron Peak Fire burn scar increases these risks.

We were able to walk sections of the Black Hollow debris flow and viewed photographs and videos taken by your staff and from USGS. Some of our initial observations are listed below:

- At the mouth of Black Hollow, we saw evidence of flooding and debris flow. The debris flow consisted of woody debris, fine-grained material, and cobbles to large boulders. Photos indicate that hillside erosion rather than a slope failure initiated the debris flow. The images show that the Black Hollow drainage and adjacent
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side slopes still contain a significant amount of sediment and boulders. It is a question of when not if additional debris flows or mud floods will occur. The size of the events will depend on several factors, including the amount of rainfall or snowmelt and the volume of available sediment and other debris. Even smaller mud floods pose safety risks to the remaining homes. In addition, the sediment currently in the Black Hollow drainage could also present a hazard to the homes immediately upstream of the alluvial fan, Highway 14, and homes and crossings downstream, should it enter into the Cache La Poudre River corridor.

- The Black Hollow stream formed a new active channel, but this channel is shallow and located in unconsolidated materials. A small boulder, tree limb, or erosion could easily result in the channel changing course. In short, the channel is volatile and can quickly and radically change direction. Any home or structure on or immediately adjacent to the debris fan is at risk, even homes that survived the initial debris flow.
- The rock and sediment deposited on the alluvial fan are generally stable in their current configuration. There will be some erosion of the surface and consolidation of the deposit, but there is little risk of a massive slope failure into the Cache La Poudre. However, any site grading should not undercut the toe of the alluvial fan or cause significant downcutting of the active channel. For example, lowering the elevation of the fan surface may trigger incision and erosion in the Black Hollow drainage and result in significant quantities of sediment entering the Black Hollow neighborhood, and the Cache La Poudre River. Outside of woody debris removal and recovery operations, other grading activities should be done very carefully and only after careful analysis of how it may impact the active channel and risks to structures. It is unnecessary to remove boulders on the debris fan or adjacent to the toe of the fan as part of exigency efforts.
- While the focus of the site visit and this memo is the Black Hollow drainage and debris flow, it is essential to note that there are similar conditions and hazards throughout the burn scar. The attached maps show the location of existing alluvial fans where debris flows and mud floods have occurred in the past or are likely to happen in the future. Our site visit and review of aerial photos revealed that many tributary channels to these fans are full of sediment, and rock and steep side slopes are undergoing erosion. Homes located on or near these fans are at risk for events similar to Black Hollow Road.

CGS offers the following recommendations for consideration:

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- It is not safe for remaining Black Hollow residents to stay in their homes, especially overnight.
 - Given the recent events, it may be prudent for the county to update or reevaluate its debris flow risk assessment. If requested, CGS could assist in these efforts. CGS recommends that the county use existing geology and geology hazard maps to help identify homes and other structures located on or near alluvial fans and areas with known rockfall hazards.
 - To the extent possible, residents should not occupy homes, especially overnight, with debris flow risks, from late spring to early fall. To do so, even for a short time, is dangerous. If this isn't possible, the county may wish to evaluate early warning systems for areas with the most significant risks.
 - The Black Hollow debris fan can store additional material from future debris flow and mud floods that may lessen impacts to the river. If homes, roads, and septic systems are rebuilt, the ability to attenuate additional events will be reduced. Because of this and safety risks to residents, if possible, the county should consider working with residents and families on potential buyouts and conversion of home lots to open space. CGS can assist in developing criteria for disaster risk reduction to support buyout efforts.
 - The upstream and downstream impacts of the additional sediment and debris loading (July 20, 2021, event) on flood risk are unknown. We recommend that the county contact the Colorado Water Conservation Board to discuss implementing Fluvial Hazard Zone mapping for the Cache La Poudre River and other significant tributaries in the burned area. CGS also recommends that the county consider integrating Fluvial Hazard Zone maps into the county's updated risk assessment.
 - A significant analysis will be required to determine the best location and design of the active channel and the configuration of the overall development. If homes are rebuilt, it must be done carefully and not on a lot-by-lot basis. Improper grading and design on one lot may increase risks to adjacent lots. Debris flow mitigation should be required, and again it cannot be done effectively on a lot-by-lot basis.
 - Excessive settlement can occur when builders place homes on alluvial and debris fans, especially in new deposits. Professionals with experience assessing and mitigating collapsible deposits should evaluate risks before builders design and construct foundations and septic systems.
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CGS based its recommendations upon the preliminary information we gathered, and others provided. As more information becomes available and, if requested, CGS can provide additional or revised observations and recommendations. Please let us know if you need further assistance.

Regards,

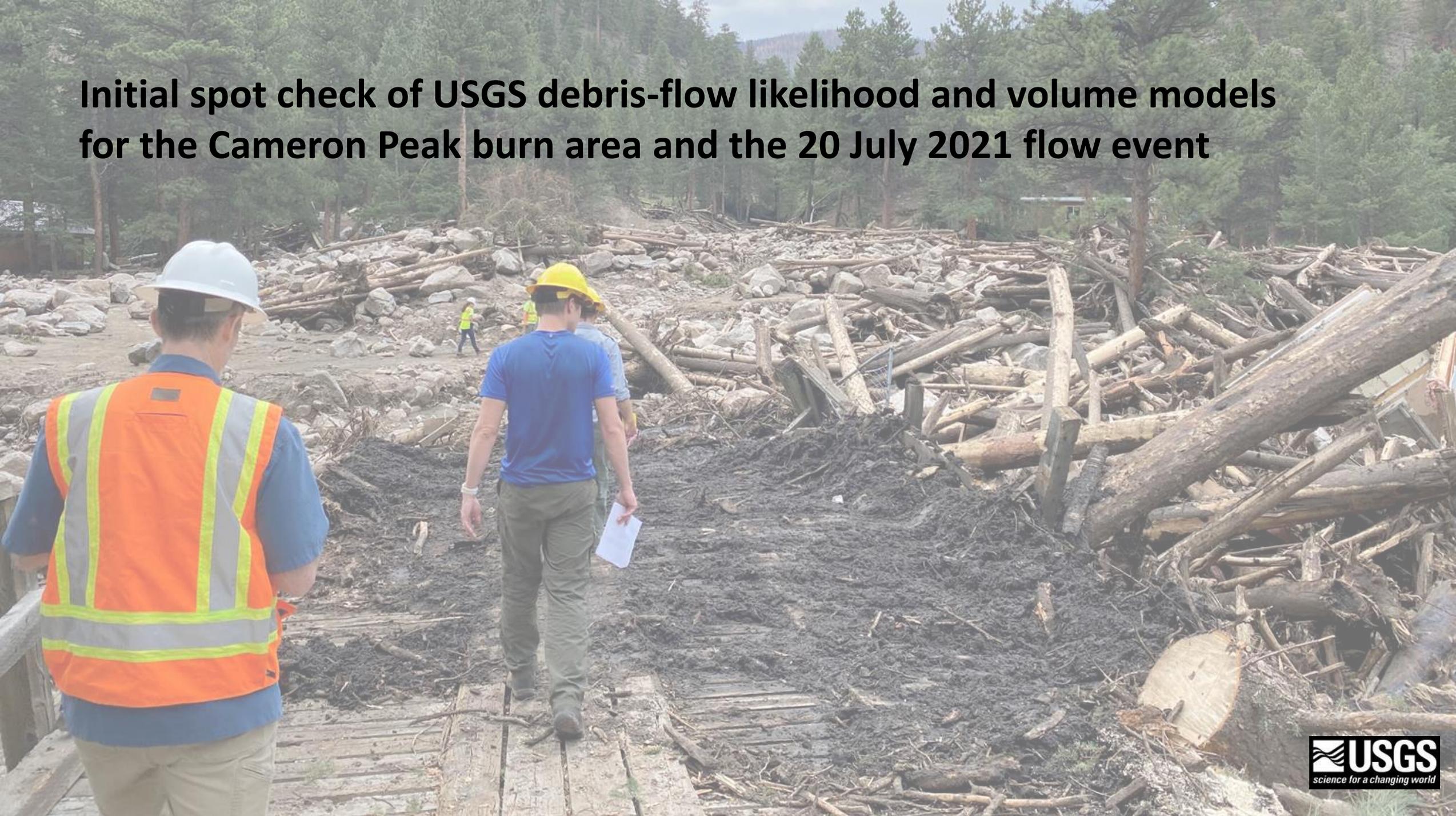
A handwritten signature in black ink that reads "Karen Berry". The signature is written in a cursive style with a large initial "K" and a prominent "B".

Karen Berry, AICP, PG

State Geologist and Director

Colorado Geological Survey

Initial spot check of USGS debris-flow likelihood and volume models for the Cameron Peak burn area and the 20 July 2021 flow event

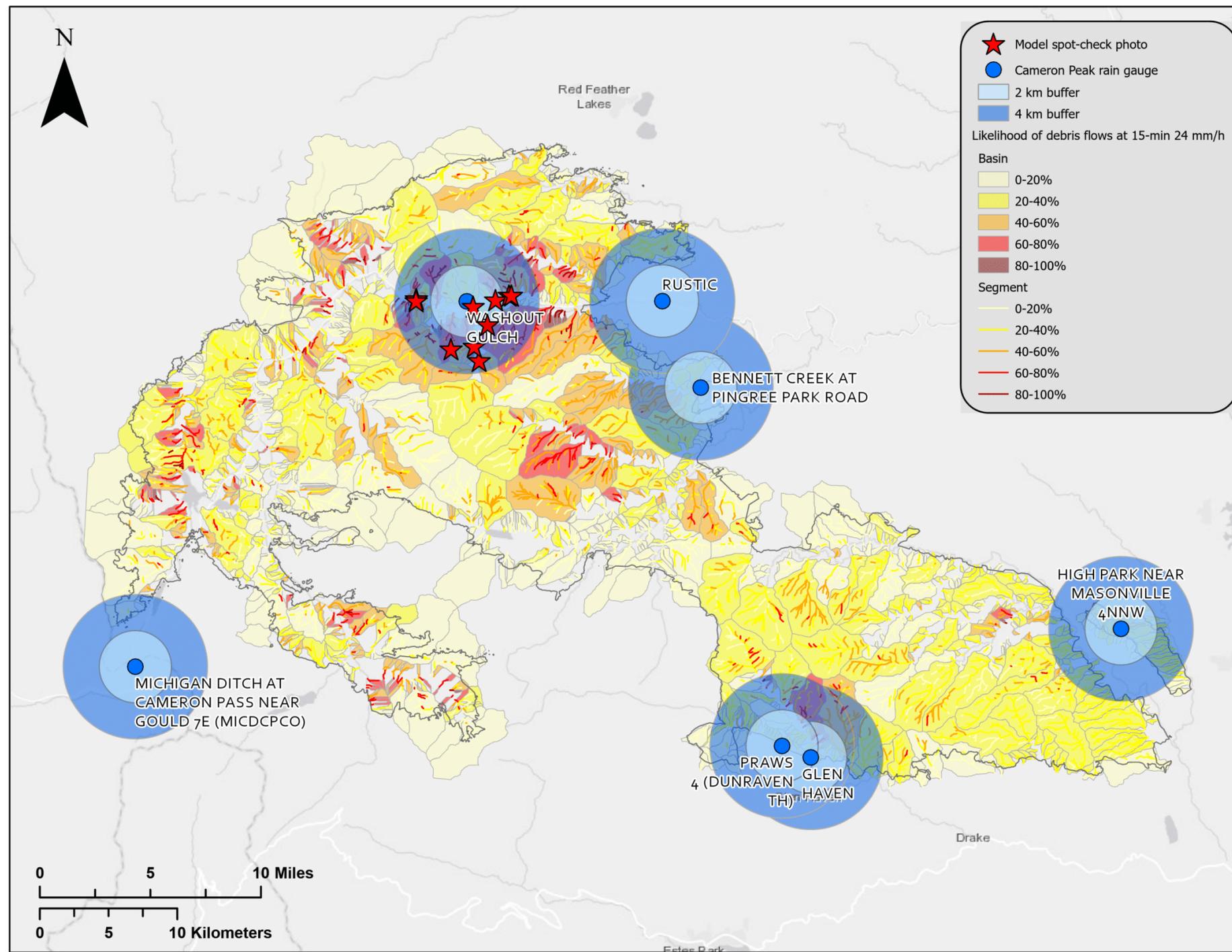


Where was rainfall recorded?

We limit our analysis to an area within **4 km** of measured rainfall to reduce uncertainty in rates due to spatial variability of rainfall.

Analysis will be updated as we obtain additional data from other rain gauges, reliable radar estimates of rainfall, and field observations.

The Washout Gulch rain gage is presently the only known gage near our observations of flow activity in the Cameron Peak burn area.



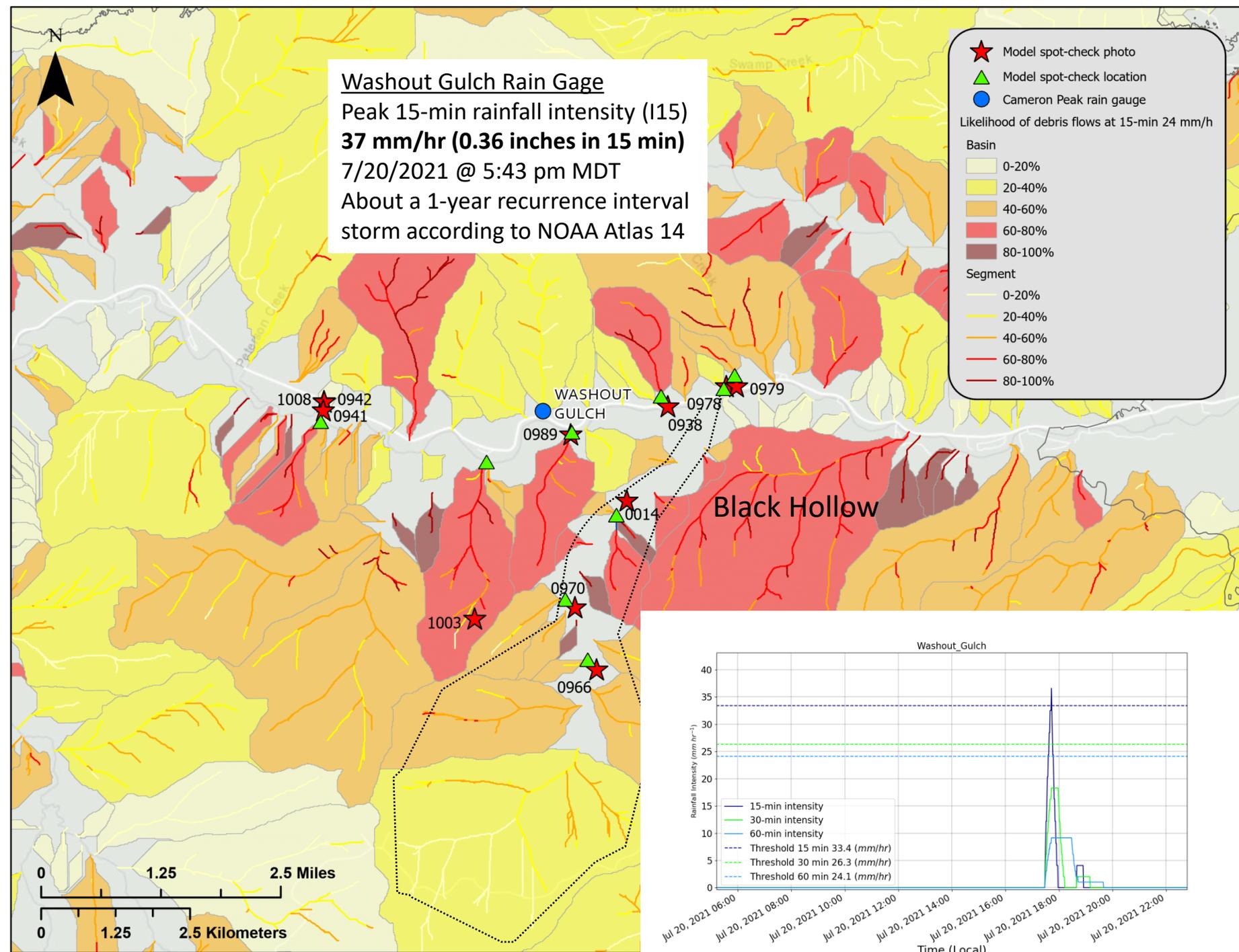
Where was flow observed?

Flow activity was observed on the ground 7/22 and by helicopter 7/24.

We paired observations of significant flow with model predictions of debris-flow likelihood and volume using observed I15 of 37 mm/hr.

Additional field work is needed to differentiate flood flow from debris flow.

The outlet of Black Hollow is beyond the 8 km² limit of debris-flow model predictions; however, contributing basins were modeled.



Observation 0966

Small side drainage in Black Hollow

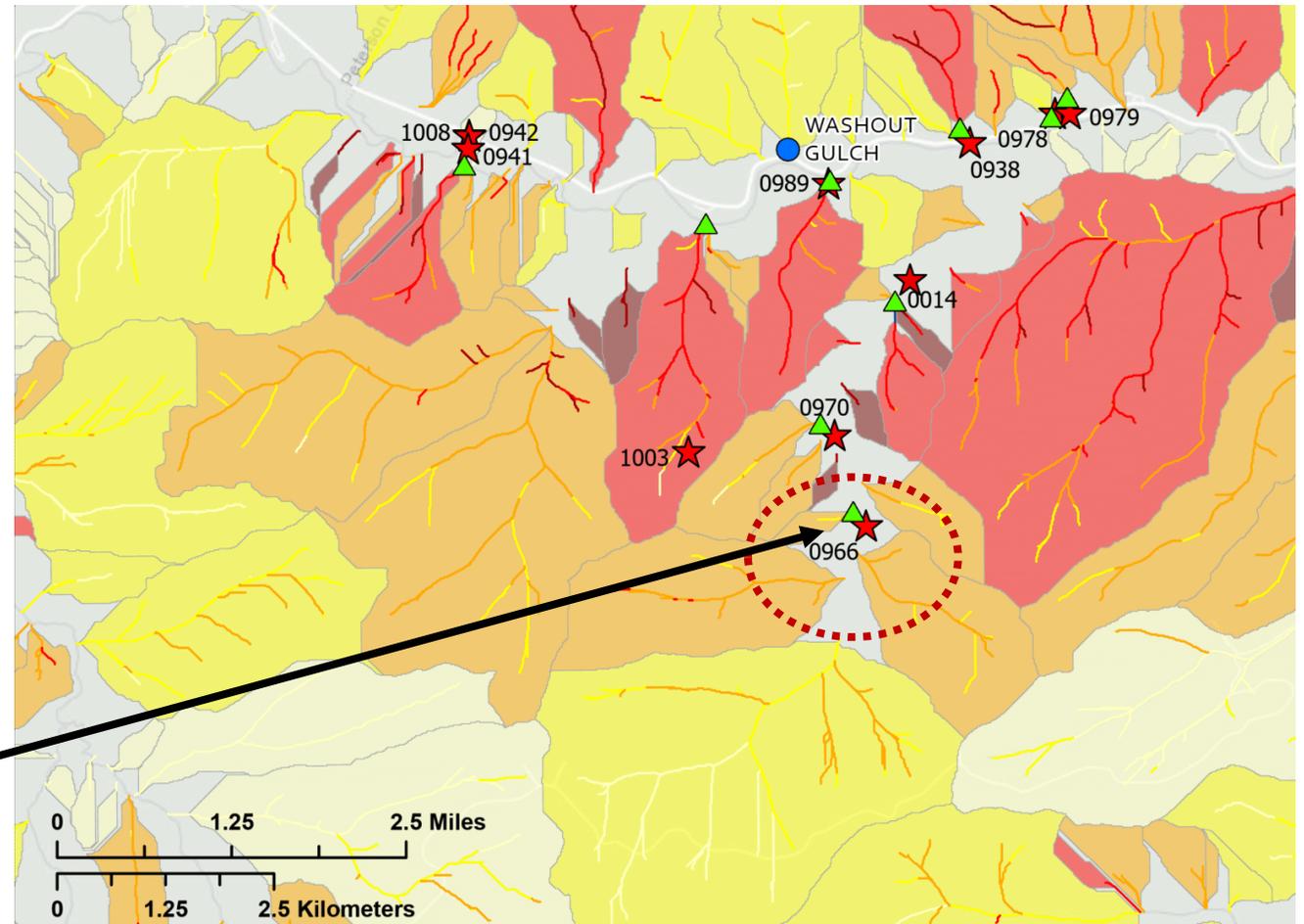


Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
7538	37	89	2,000



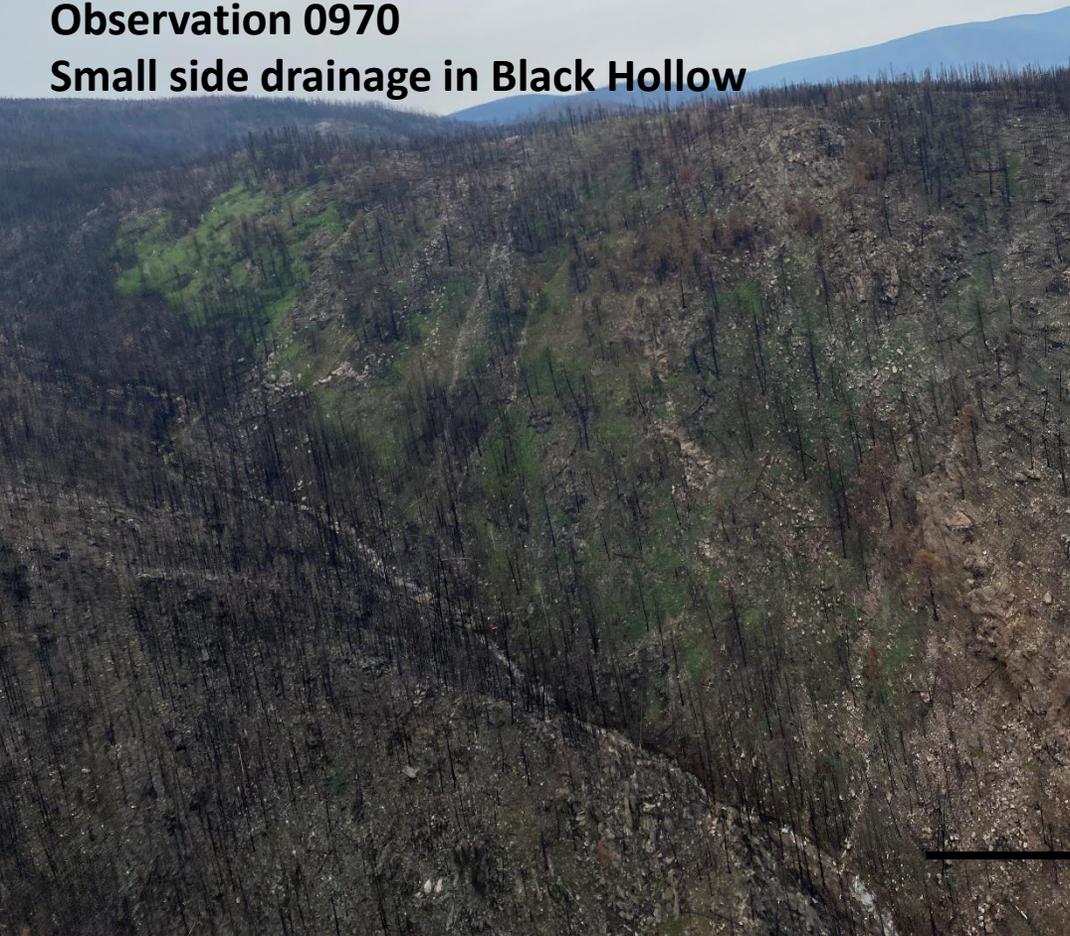
Stream segment id refers to geodatabase of model results:

https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=337

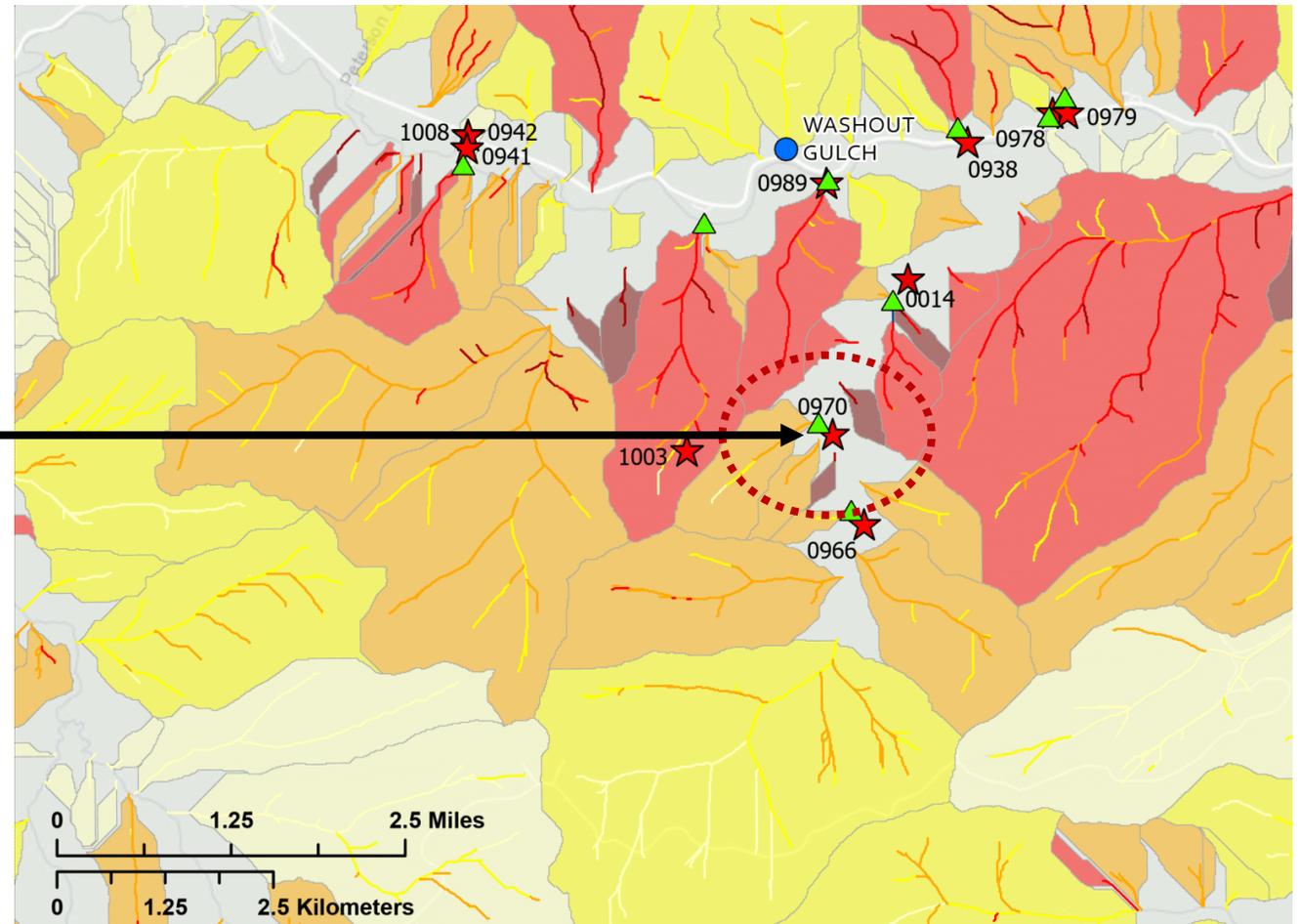


Observation 0970

Small side drainage in Black Hollow



Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
6603	37	90	9,000

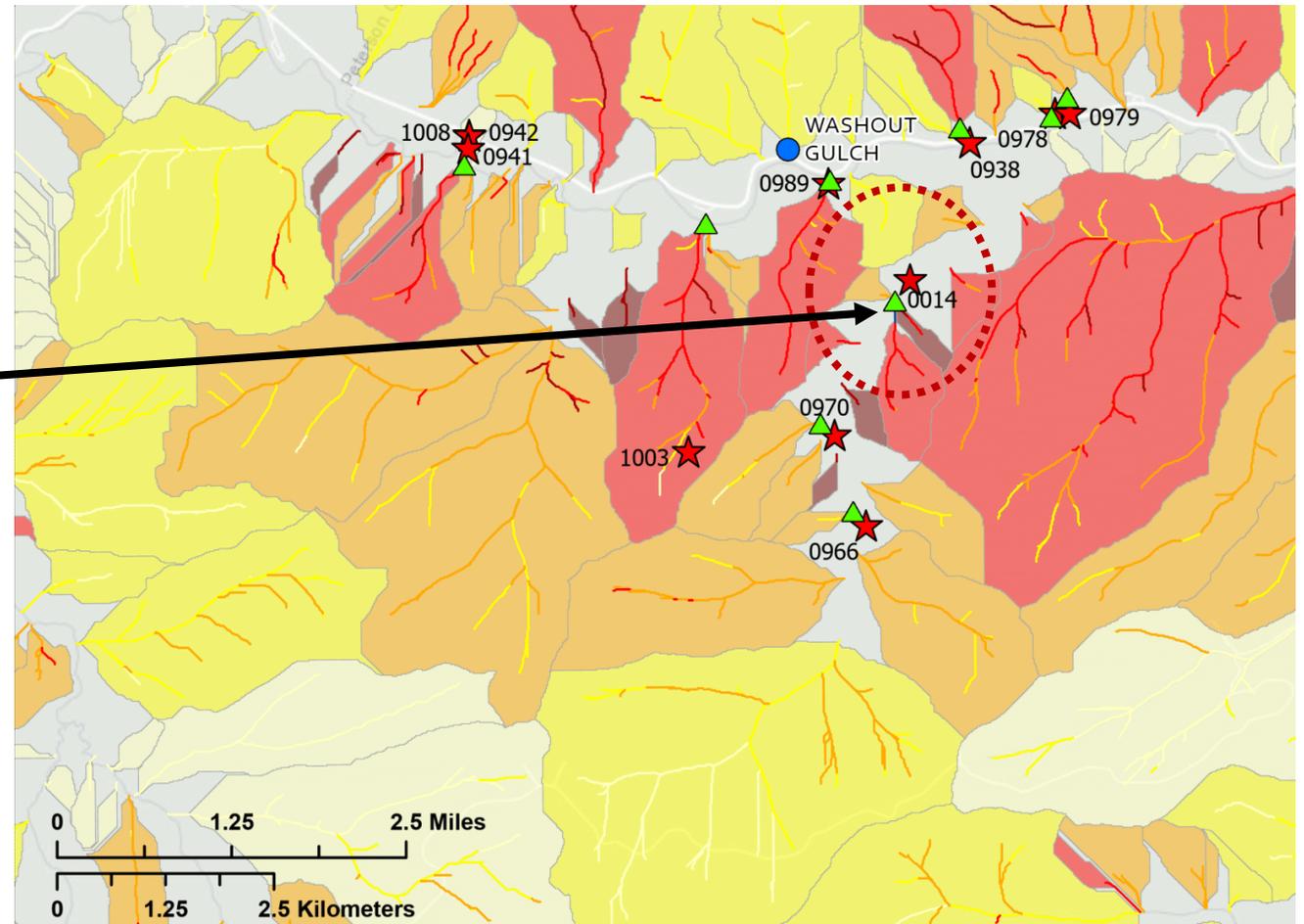


Observation 0014

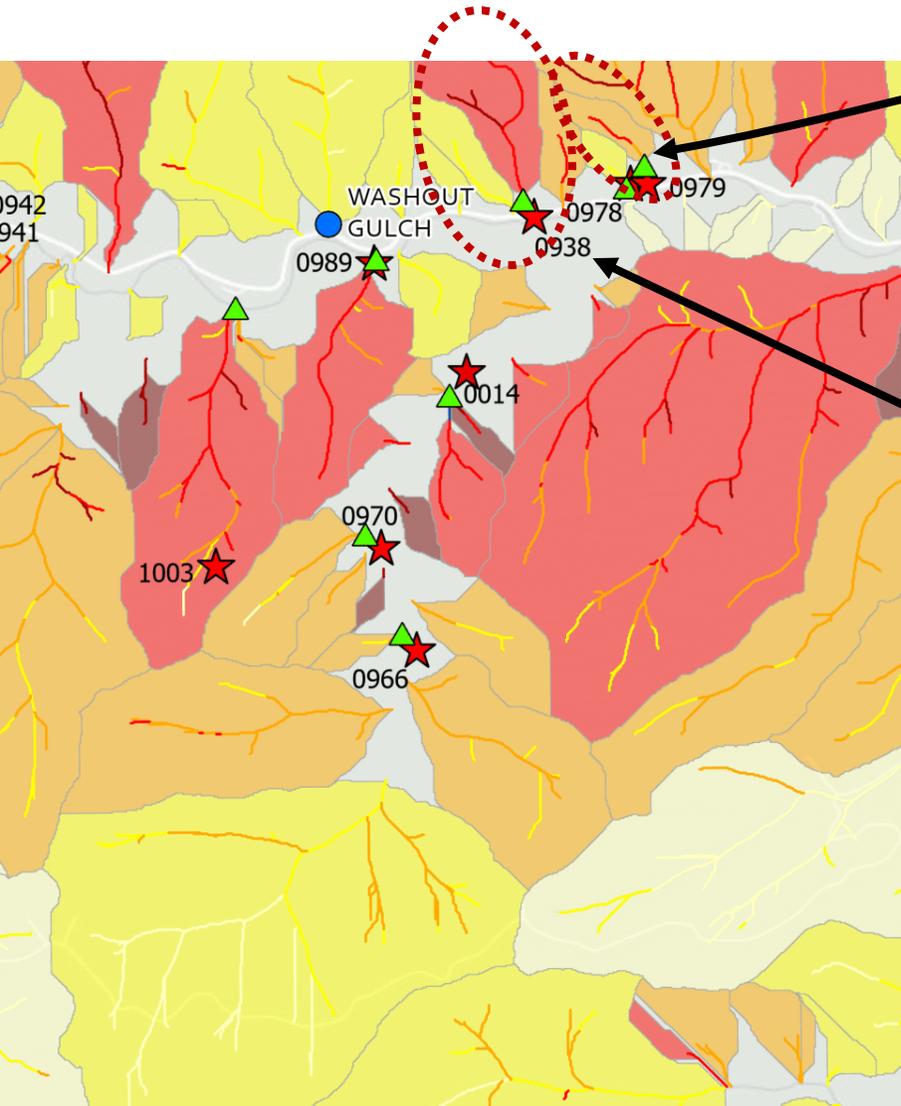
Small side drainage in Black Hollow



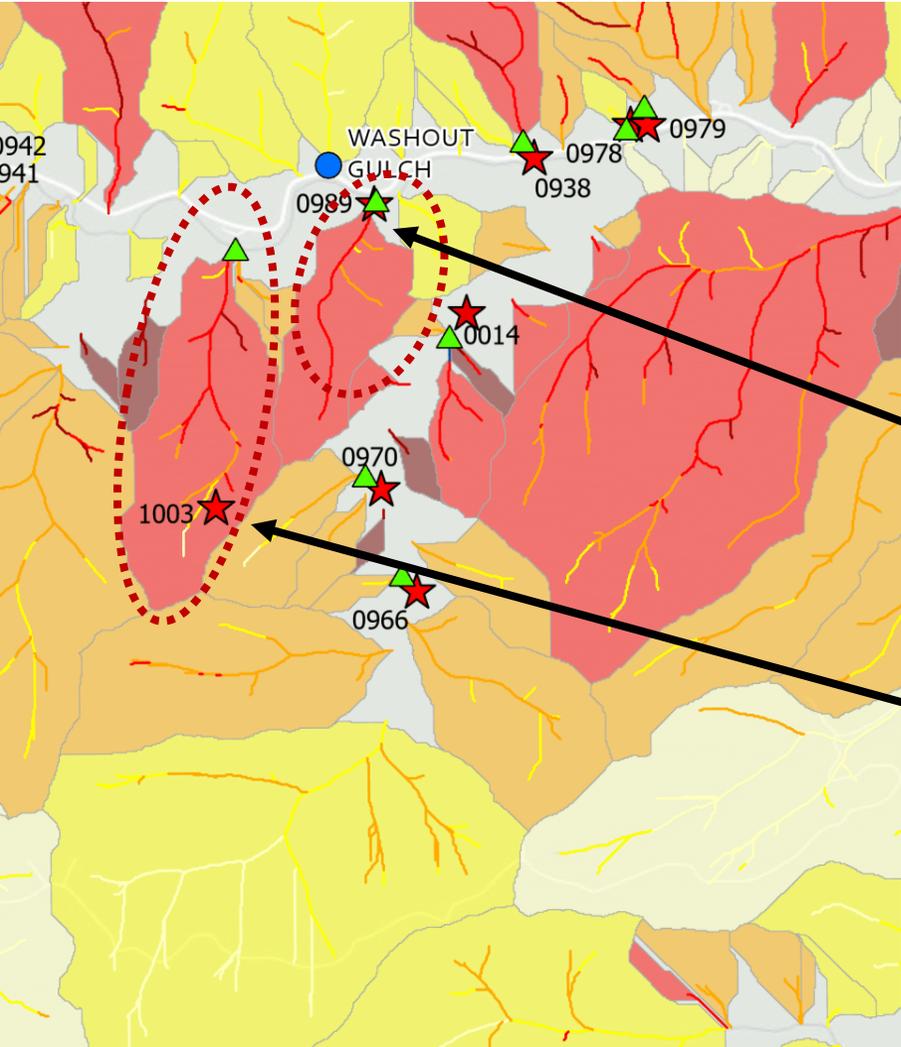
Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
5963	37	98	9000



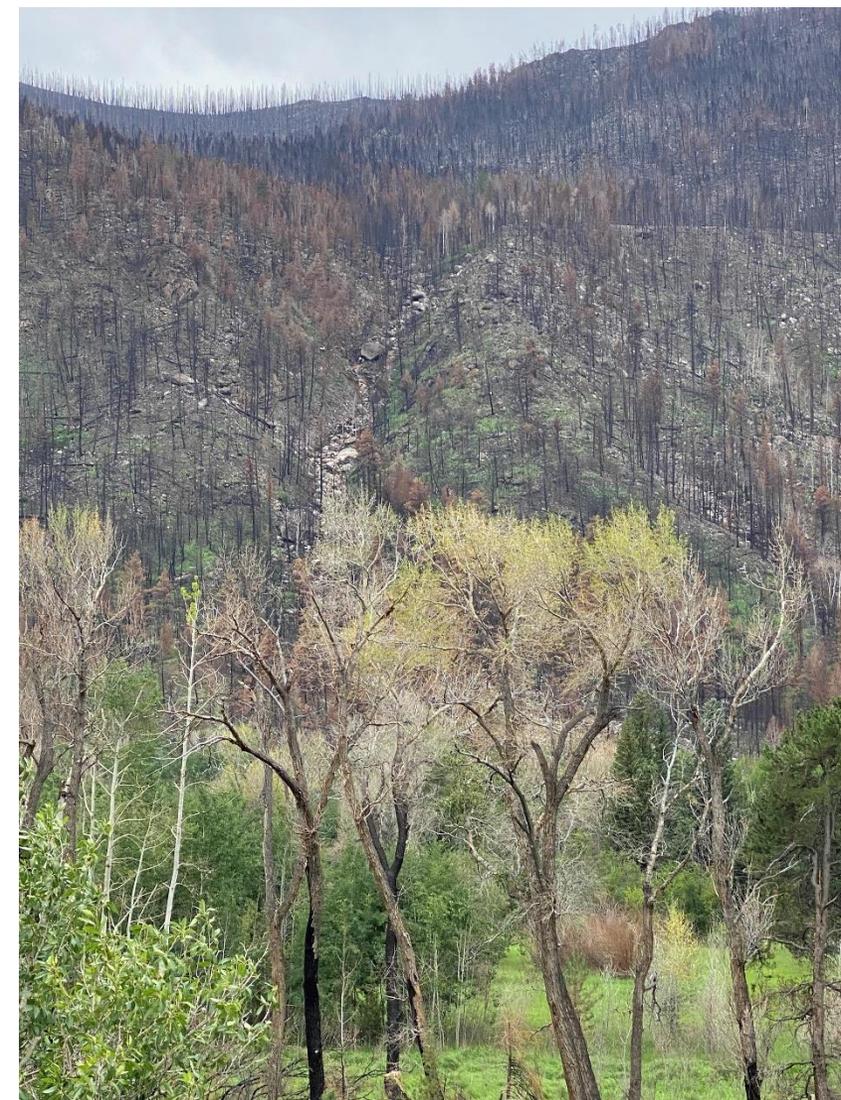
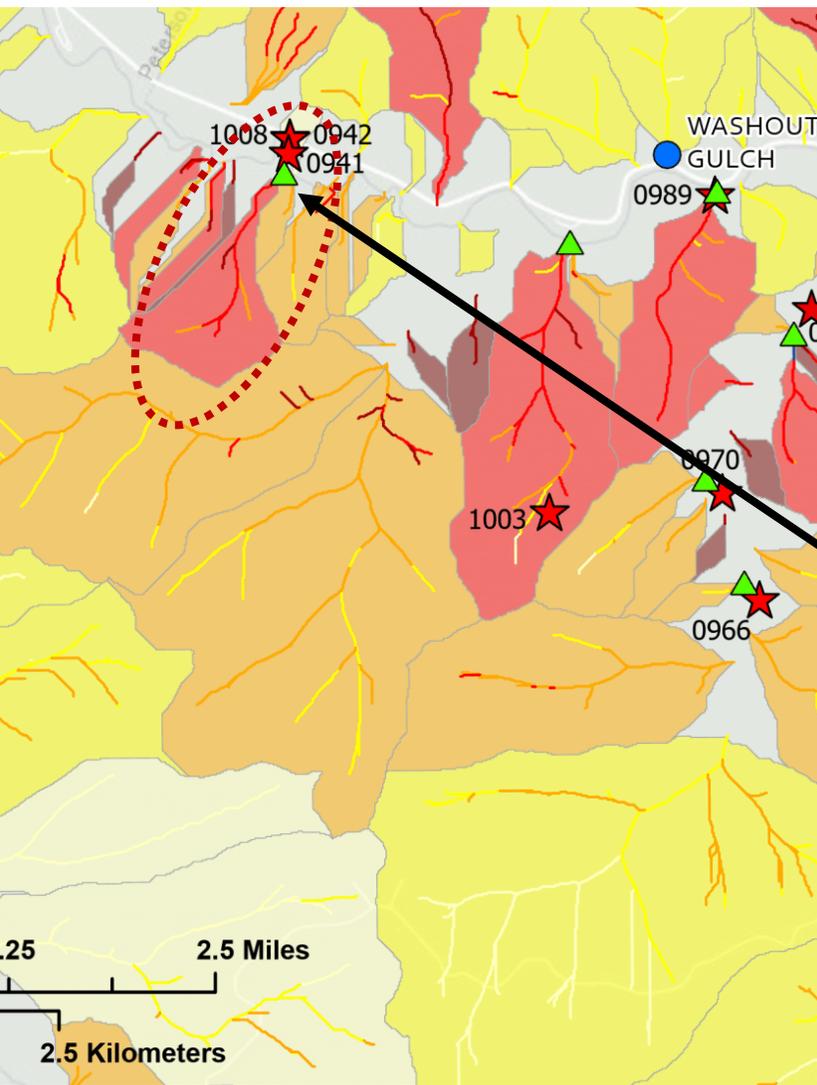
Obs. #	Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
0938	4363	37	97	10,000
0979	4174	37	89	2,000



Obs. #	Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
1003	4824	37	96	25,000
0989	4174	37	95	10000



Obs. #	Segment ID	Obs. I15 (mm/hr)	Likelihood (%)	Volume (m ³)
1008, 0941	4893	37	94	15,000



Takeaways / Questions

- Qualitatively, the debris flow likelihood and volume models are valuable for ranking basins in terms of susceptibility and potential magnitude. Models correctly identify locations with steep slopes burned at high and moderate burn severity and estimated volumes scale with drainage area.
- Initial spot check of likelihood model shows significant flow was observed in drainages with predicted high likelihoods (>89%) using observed rain rates.
- Volume estimates may be high, but more work is needed to assess the accuracy of the volume model.
- More observations will be added with planned field work coordinated through ARNF.
- Did it rain harder in Black Hollow than Washout Gulch? More rainfall data and/or reliable radar estimates could improve the analysis.
- Rainfall thresholds will likely increase by next summer due to vegetation and hydrologic recovery. The likelihood model provides initial guidance on year-2 thresholds, which can be evaluated by tracking storms / flow response next year.

Contact: Jason Kean (jwkean@usgs.gov)