Discussion of Post-fire runoff and Debris Flow Generation

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California Geological Survey

Focus of Talk

- ✓ Post-fire effects:
  - ➢ Hydrology and sediment bulking
  - ➢ Erosion-induced debris flows
- ✓ Current Research Project, 2018 Carr Fire
  - ➢ Overview
  - ➢ Preliminary Results
- ✓ Questions

Post-Fire Effects

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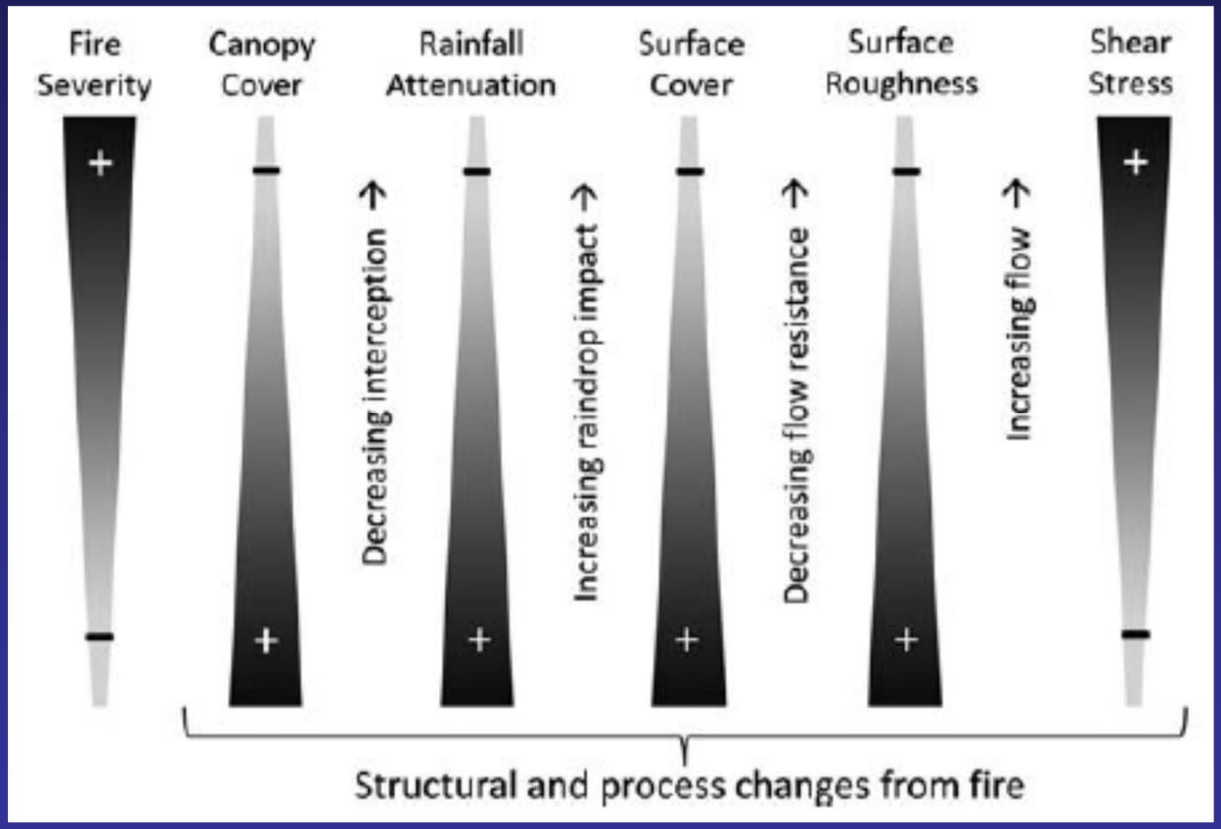
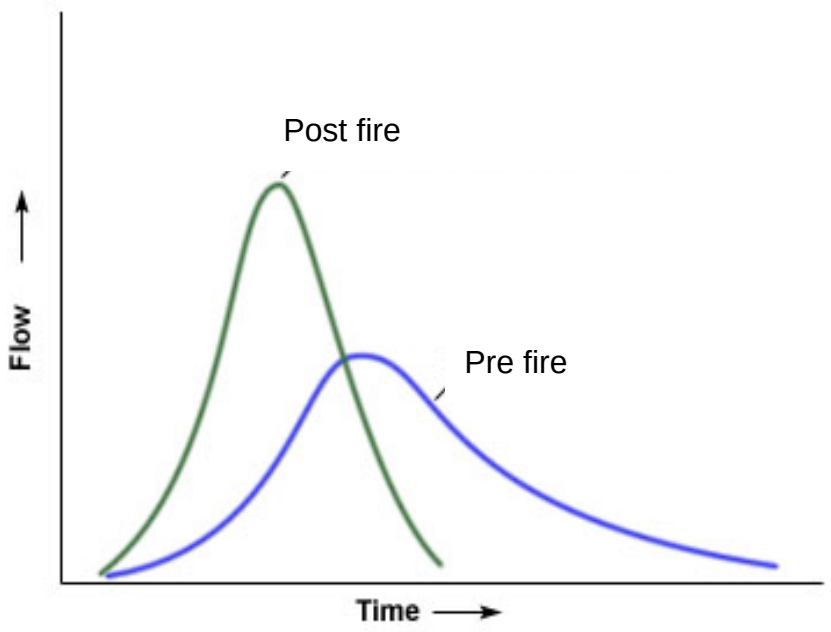
Post-Fire Effects

Adapted from Hyde et al., 2014



Runoff Hydrograph



CALIFORNIA GEOLOGICAL SURVEY

Increased flows and sediment bulking can be accounted for by:

- ✓ Increasing the runoff coefficient, C, and decreasing the time of concentration, Tc. (Rational method)
  - http://forest.moscowfsl.wsu.edu/BAERTOOLS/ROADTRT/Peakflow/

- ✓ Applying a bulking factor based on burn severity. Often ranges from 1.1 to 1.5, but could go higher depending site-specific geomorphologic and hydrologic conditions. FEMA reports a factor as high as 2.6.
  - http://www.asce-sbriv.org/sw_committee/documents/Bulking_Factor_Study%20_Final_Report_6_24_11.pdf

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2018 Carr Fire WERT report

Table 3. Estimated bulked post-fire flow multipliers for the eleven pour points shown in Figure 11. Post-fire multipliers should not be applied beyond the 10-year recurrence interval/return period.

Pour Point ID	Pour Point Number	Drainage Area (mi^2)	Low SBS (%)	Moderate SBS (%)	High SBS (%)	Bulked Post-Fire Multiplier
Clear Creek	1	70.9	45	18	4	1.5
East Fork Clear Creek	2	14.4	59	28	4	1.7
Clear Creek Tributary in French Gulch	3	9.1	47	47	2	2
Clear Creek in French Gulch	4	106	45	26	5	1.6
Clear Creek at Whiskeytown	5	118.6	45	29	4	1.7
Spring Creek Reservoir	6	15.7	38	35	2	1.7
Keswick Dam	7	39.3	24	16	1	N/A
Foothill Intake Upstream Drainage	8	16.7	41	52	1	N/A
Rock Creek at the Sacramento River	9	6	44	52	0	2
Middle Creek at the Sacramento River	10	4.3	34	63	2	2.3
Iron Mountain Mine intake	11	6.2	27	17	1	1.4

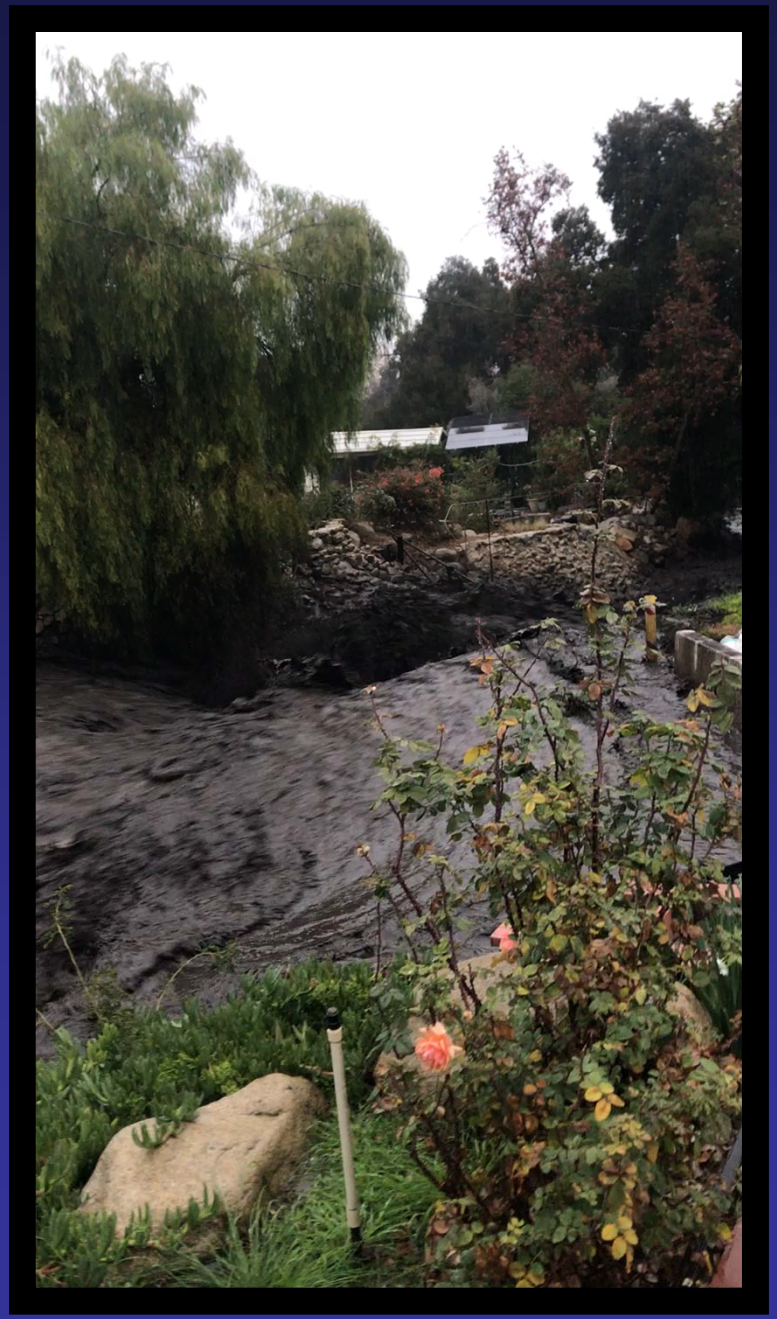
Ave. = 1.8

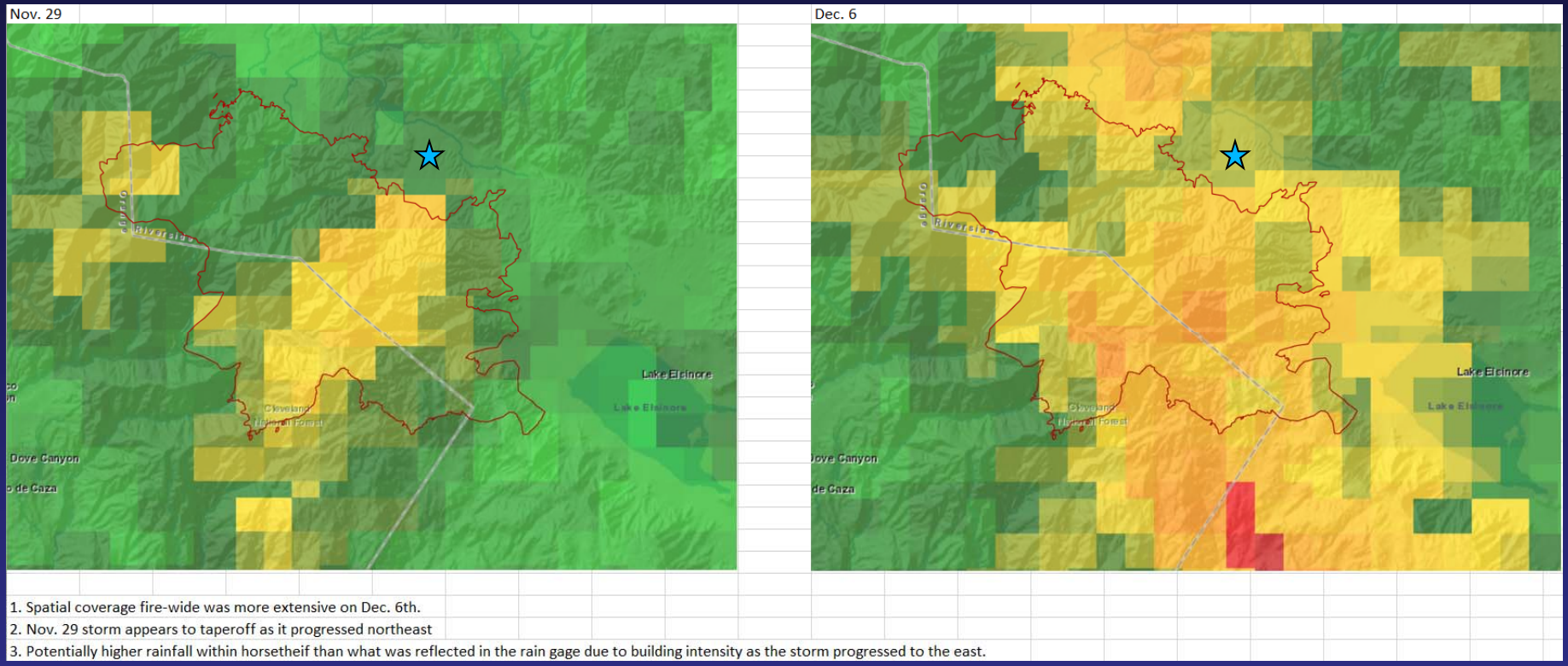
2018 Camp Fire WERT report

Pour Point ID	Pour Point Number	Drainage Area (mi^2)	Low SBS (%)	Moderate SBS (%)	High SBS (%)	Bulked Post-Fire Multiplier
Upstream of Little Chico Creek Diversion	1	25.4	18.8	3.1	0.0	1.1
Butte Creek Upstream of Little Butte Creek Confluence	2	117.4	5.5	0.6	0.0	1.0
Little Butte Creek Upstream of Butte Creek Confluence	3	30.2	39.9	9.8	0.2	1.2
Butte Creek at Covered Bridge	4	147.9	12.6	2.5	0.0	1.1
Butte Creek at Highway 99	5	157.9	14.8	2.6	0.0	1.1
Confluence of Dry and Clear Creek	6	49.3	35.5	5.8	0.0	1.2
West Branch Clear Creek at Steamboat Rd	7	3.6	58.8	5.2	0.0	1.2
Clear Creek near Clear Creek Cemetery Rd	8	5.9	76.0	12.4	0.0	1.4
Clear Creek at Durham Pentz Rd	9	11.7	60.1	7.8	0.0	1.2
Little Dry Creek on Book Family Farm Road	10	16.3	44.2	2.9	0.0	1.1
Hamlin Slough on Durham Dayton Road	11	23.3	37.4	4.9	0.0	1.2
Concow Reservoir	12	13.3	55.2	32.5	1.9	1.7
West Branch Feather River at Fire Perimeter	13	144.7	22.2	11.3	1.4	1.3
North Fork Feather River at Fire Perimeter	14	620.8	6.0	1.1	0.3	1.0

Ave. = 1.2

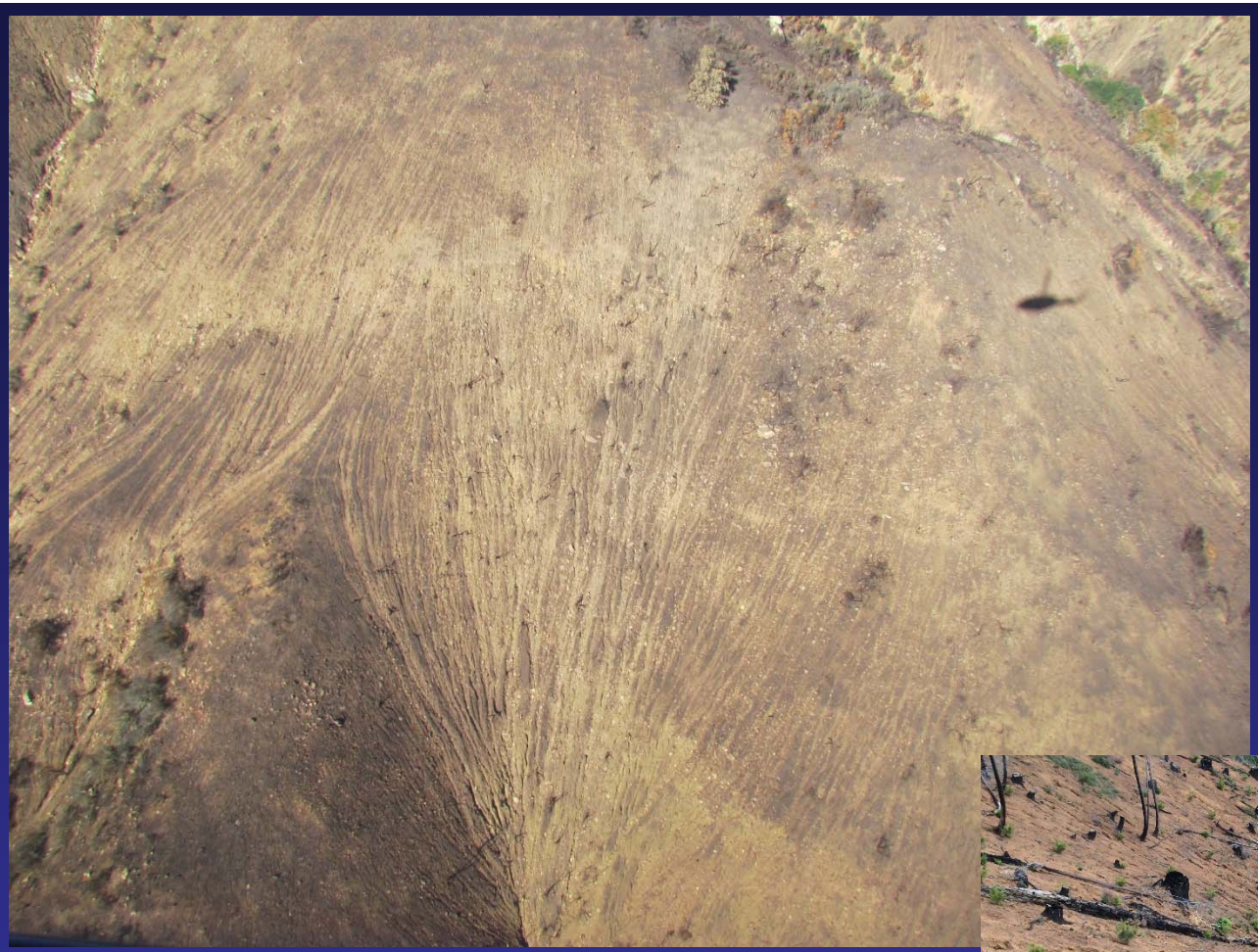
2018 Holy Fire





2018 Holy Fire

Storm Event	15 Min	RI	Discharge (CFS)	RI	Bulking Post-fire multiplier
Nov. 29	0.28	1.7 yr	1100	136 yr	15
Dec. 6	0.28	1.7 yr	2400	>500 yr	32



Erosion-induced Debris Flows

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CALIFORNIA GEOLOGICAL SURVEY

Montecito, CA
2017/2018 Thomas Fire

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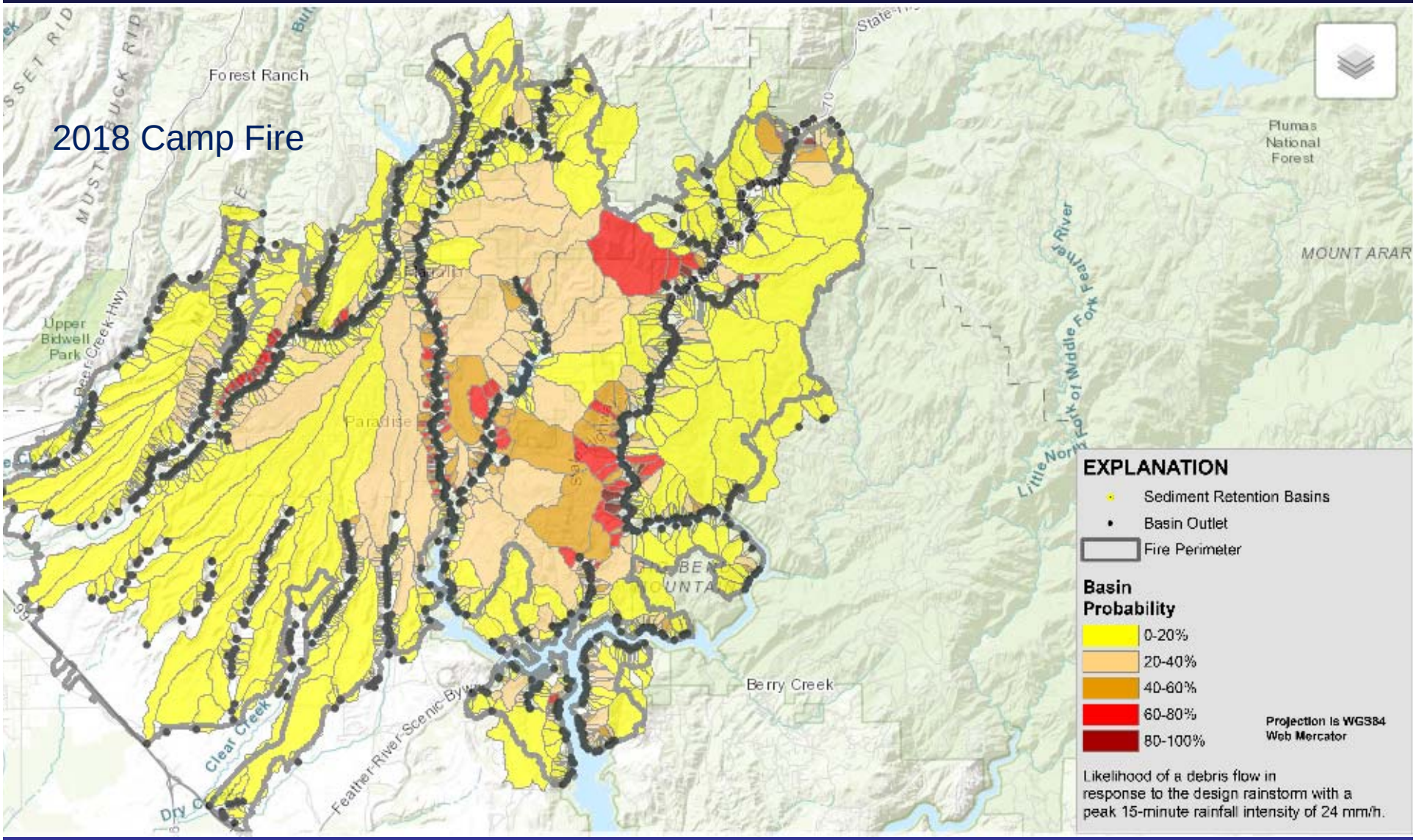


https://landslides.usgs.gov/hazards/postfire_debrisflow/

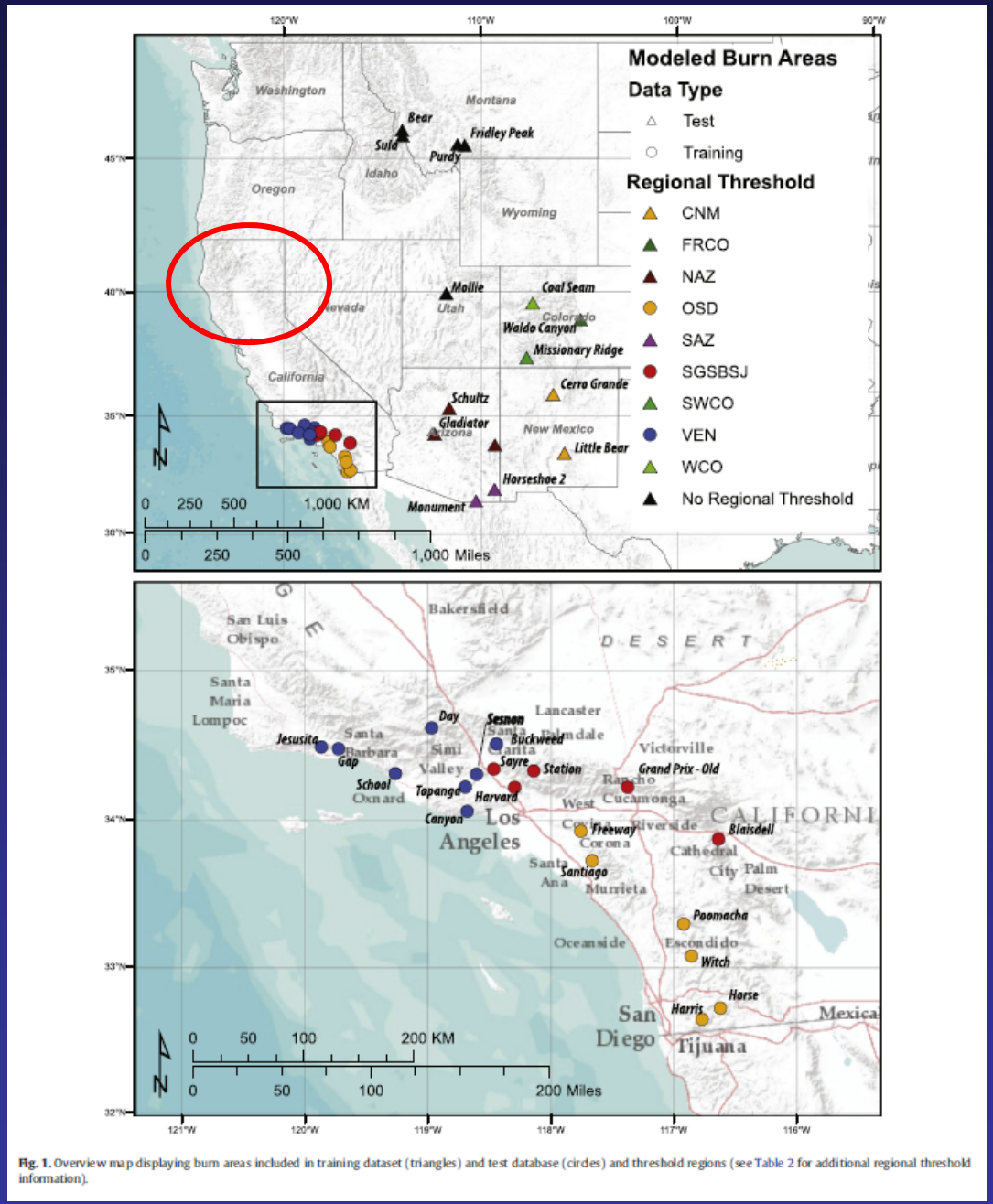


Fig. 1. Overview map displaying burn areas included in training dataset (triangles) and test database (circles) and threshold regions (see Table 2 for additional regional threshold information).

Staley et al., 2017

Carr Fire Research Project

SCIENTIFIC RESEARCH AND COLLECTING PERMIT

Grants permission in accordance with the attached general and special conditions

United States Department of the Interior
National Park Service
Whiskeytown

Study#: WHIS-00129
Permit#: WHIS-2018-SCI-0022
Start Date: Oct 01, 2018
Expiration Date: Oct 01, 2019
Coop Agreement#:
Optional Park Code:

Name of principal investigator:

Name: Dr Scott McCoy **Phone:**775-682-7205 **Email:**scottmccoy@unr.edu

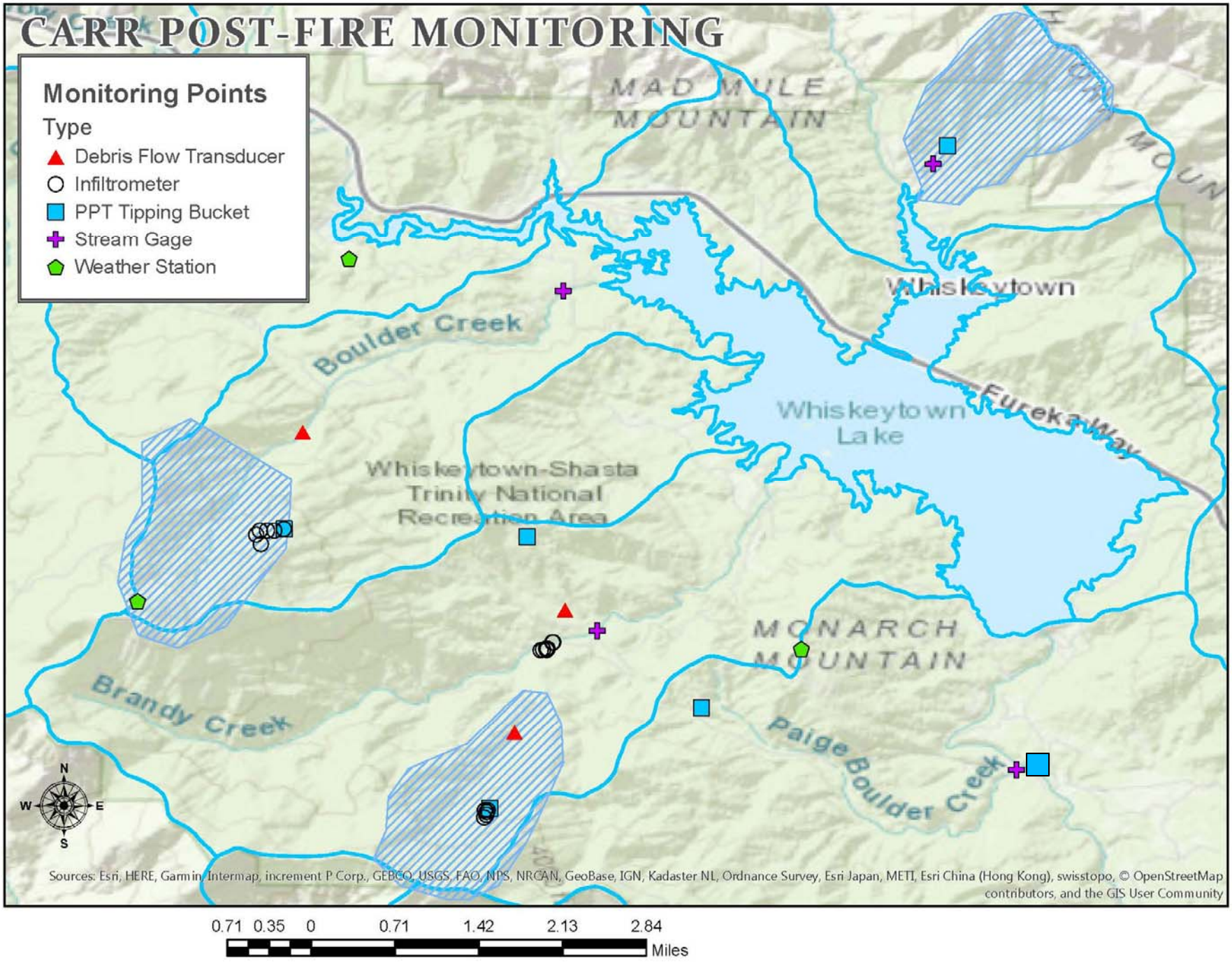
Name of institution represented:
University of Nevada - Reno

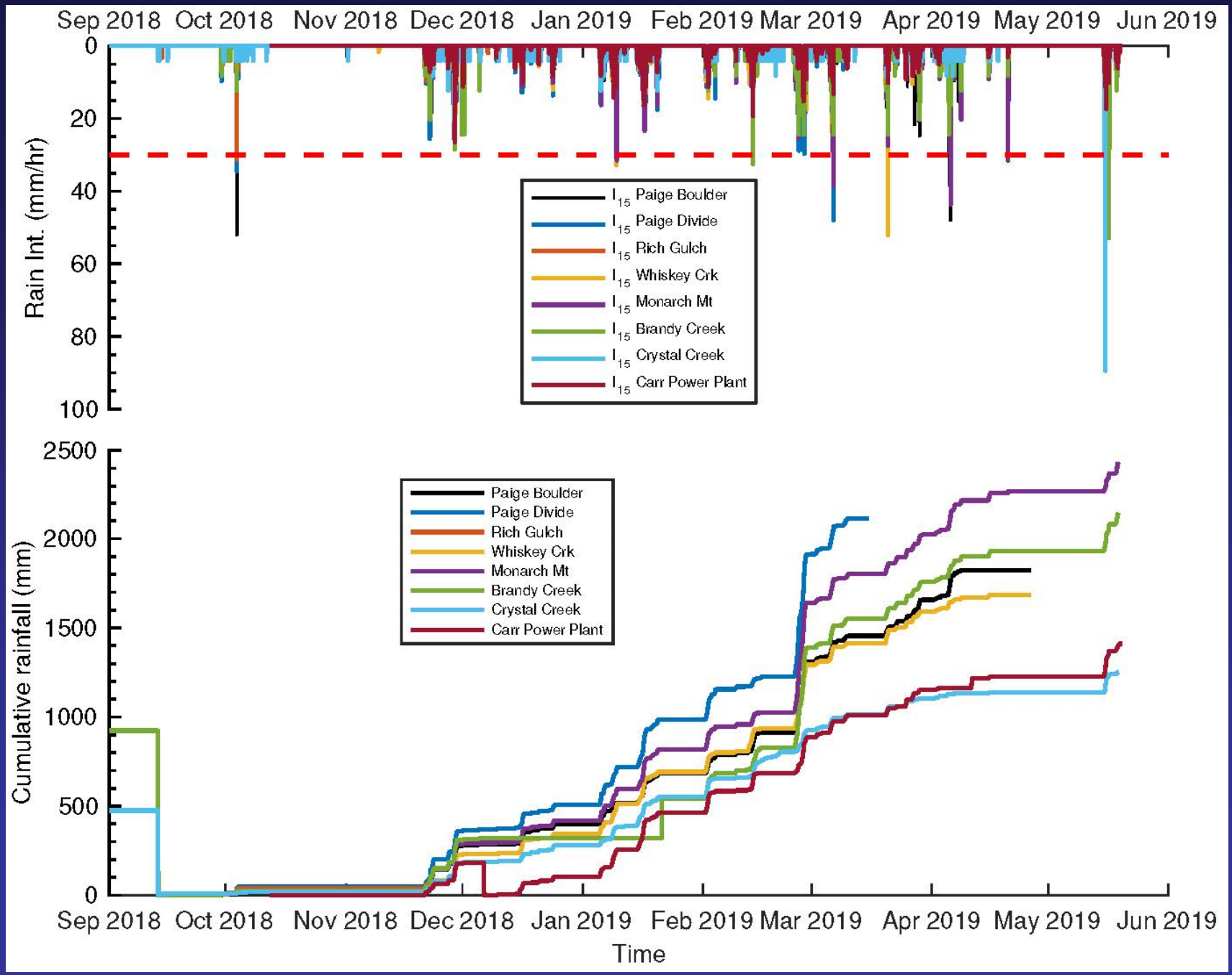
Additional investigators or key field assistants:

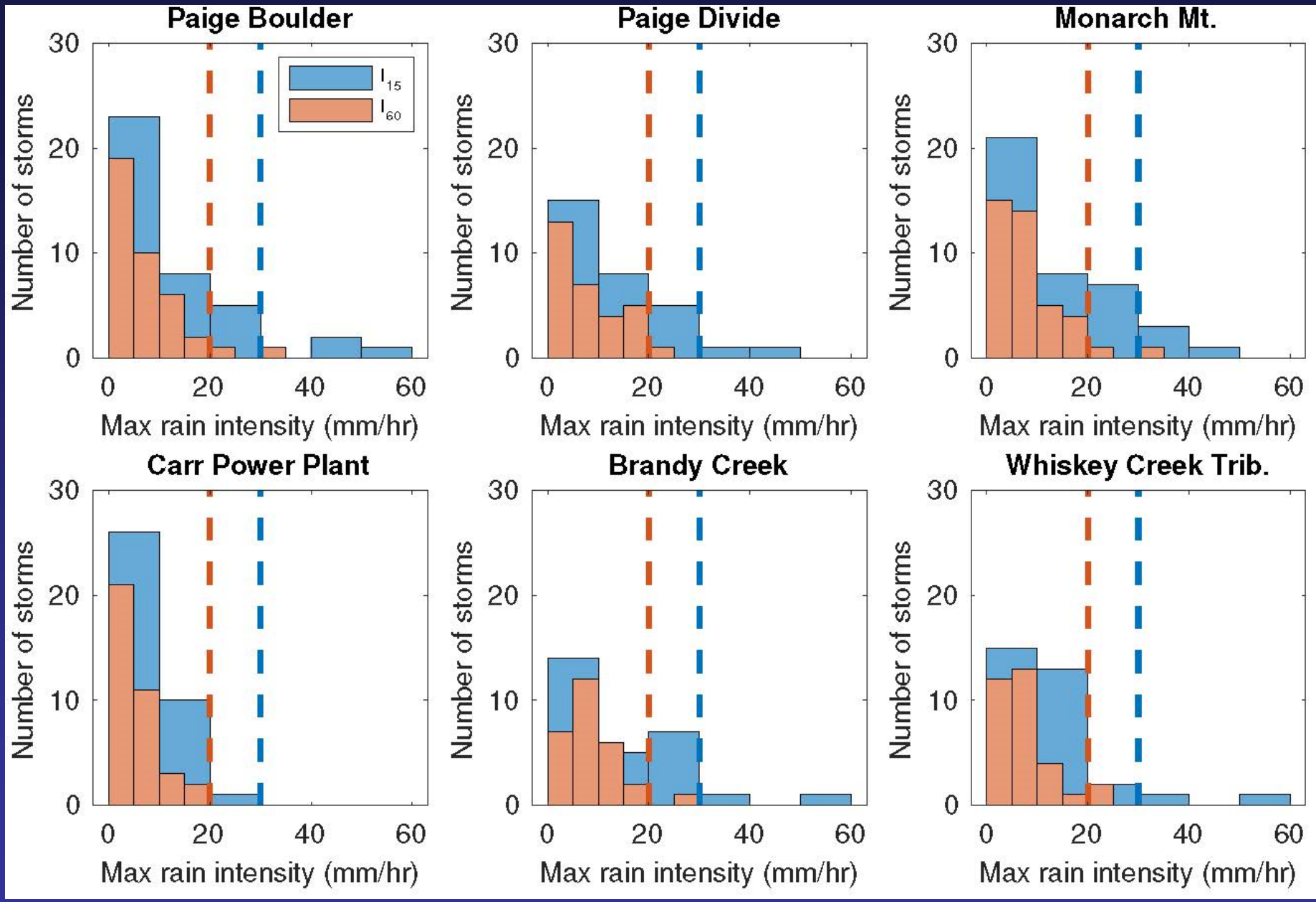
Name: Jason Kean **Phone:** 303-273-8608 **Email:** jwkean@usgs.gov

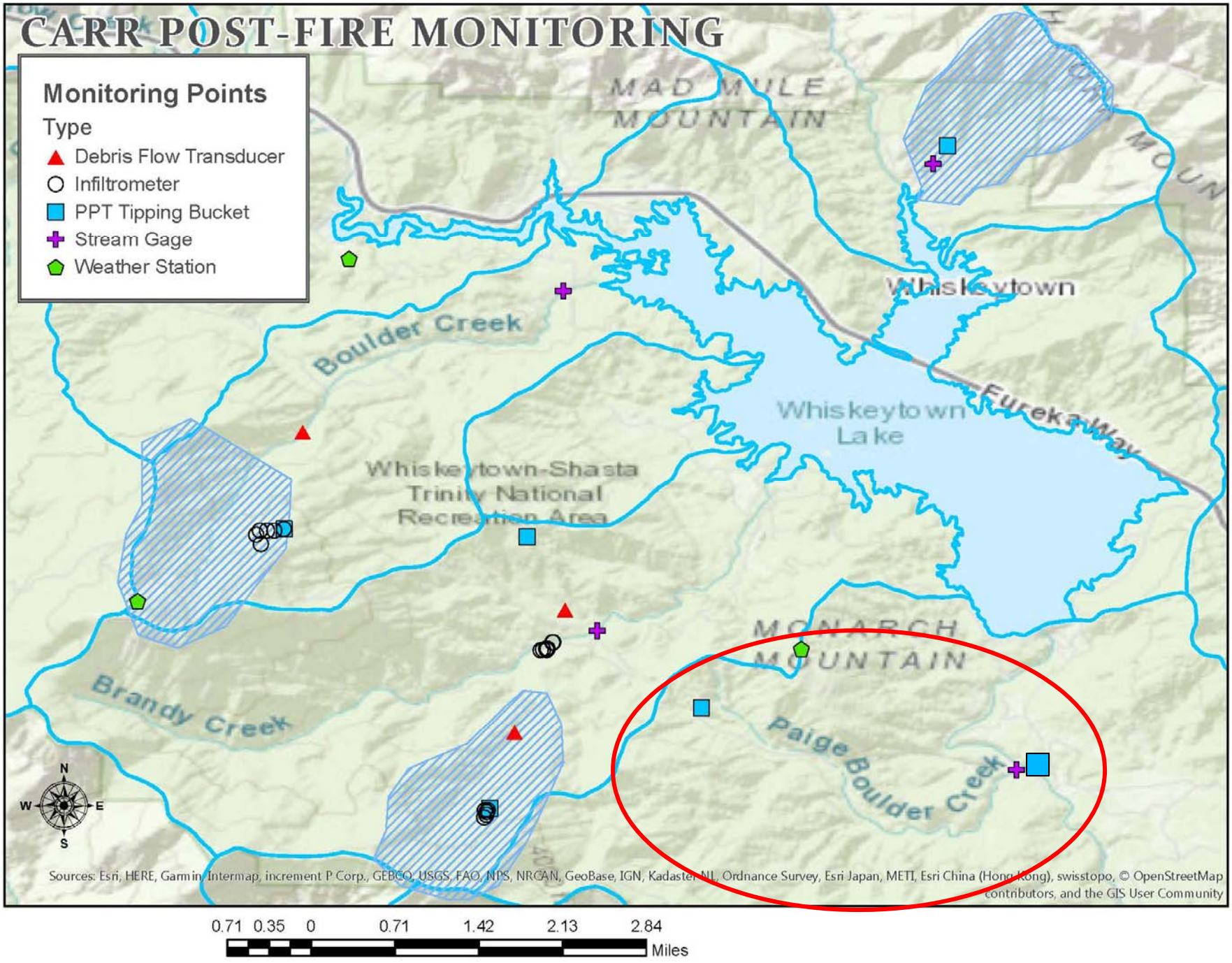
Name: Don Lindsay **Phone:** (530) 242-3457 **Email:** Don.Lindsay@conservation.ca.gov

Study Title:
Quantifying the Runoff, Debris Flow, and Landslide Response to 2018 Carr Fire

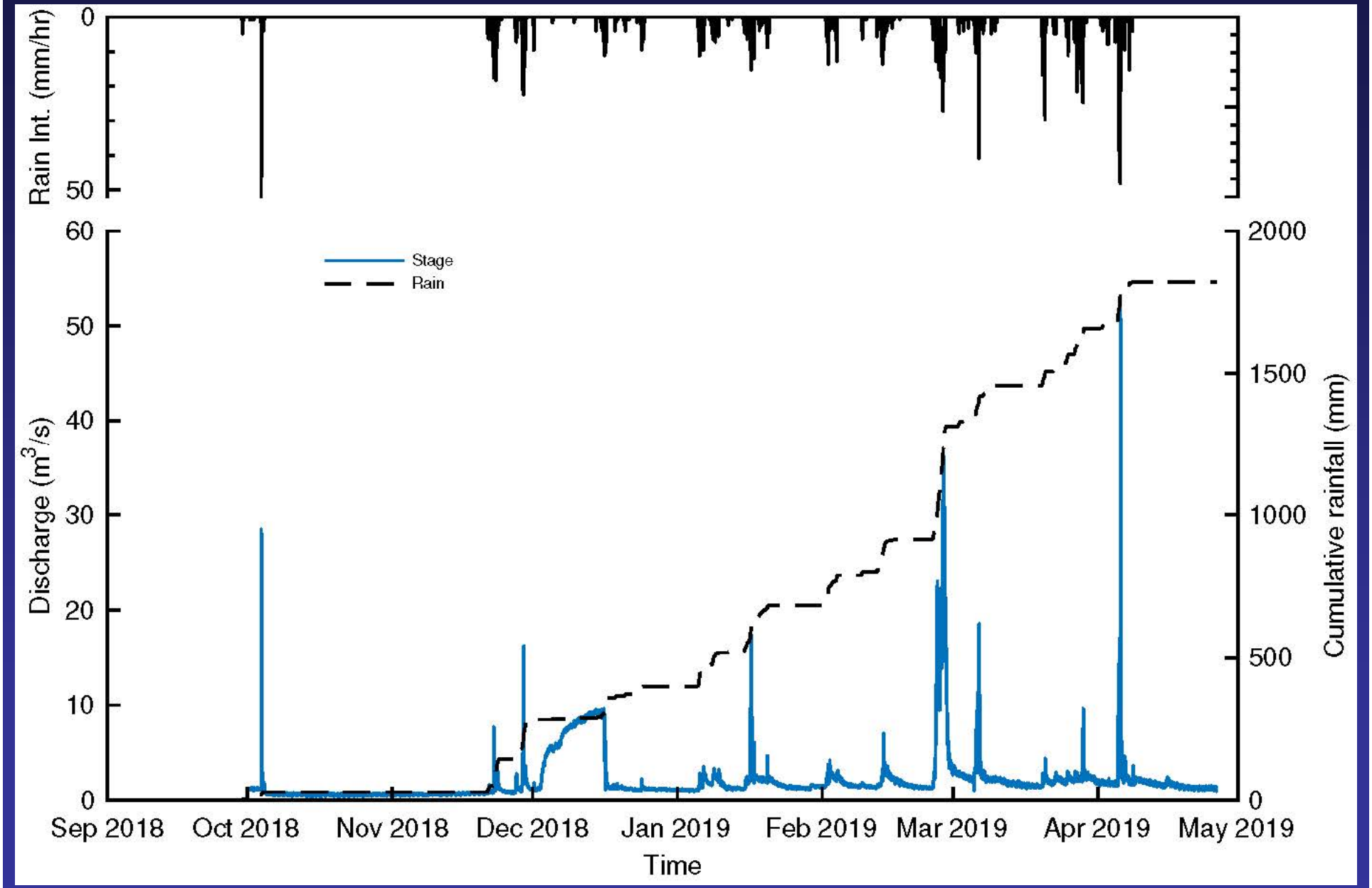

CARR POST-FIRE MONITORING
Monitoring Points
Type
Debris Flow Transducer
Infiltrometer
PPT Tipping Bucket
Stream Gage
Weather Station
MAD MULE MOUNTAIN
Whiskeytown
Boulder Creek
Whiskeytown Lake
Whiskeytown-Shasta Trinity National Recreation Area
MONARCH MOUNTAIN
Brandy Creek
Paige Boulder Creek
N
W
E
S
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
0.71 0.35 0 0.71 1.42 2.13 2.84
Miles

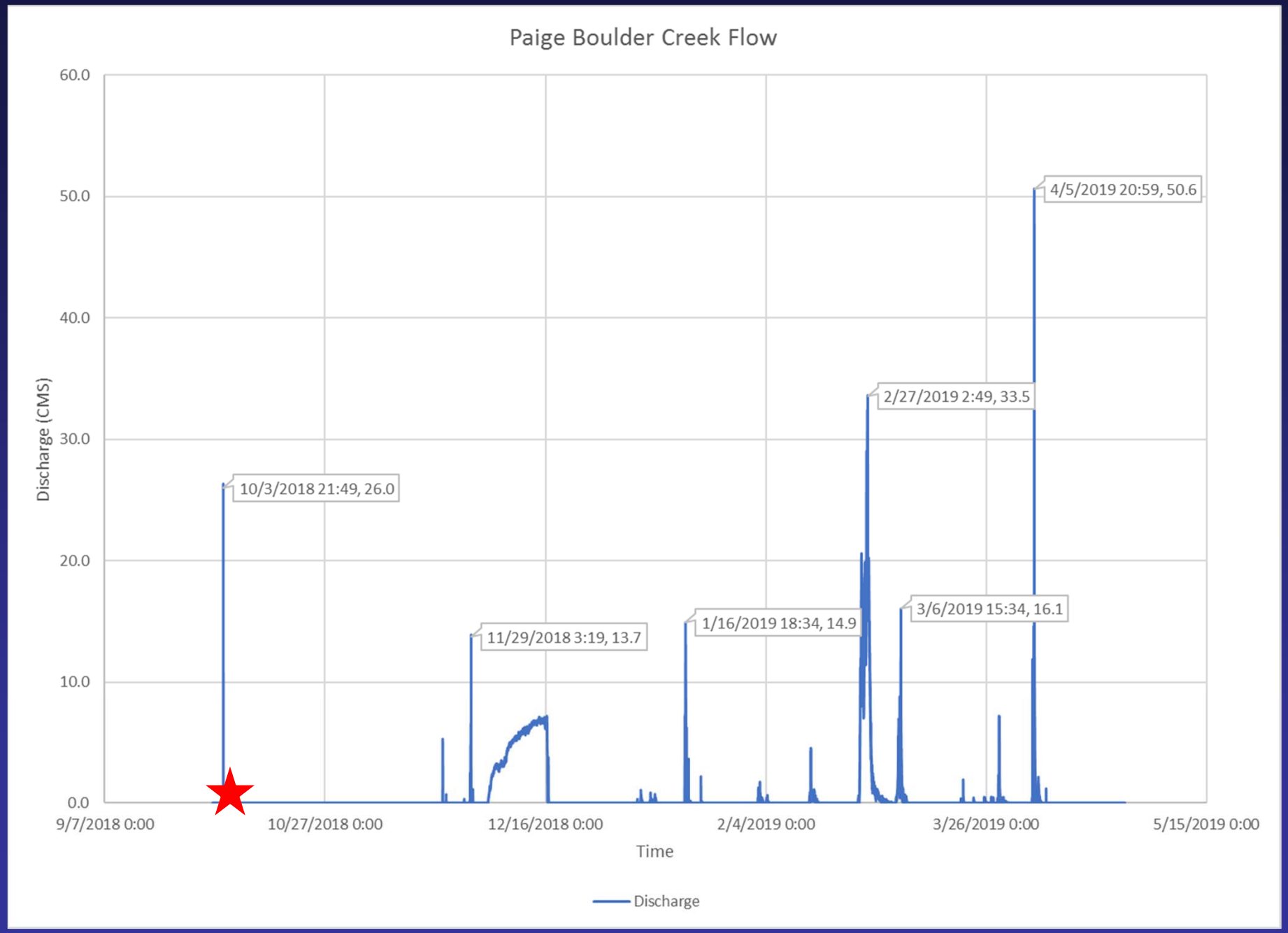

Sep 2018
Oct 2018
Nov 2018
Dec 2018
Jan 2019
Feb 2019
Mar 2019
Apr 2019
May 2019
Jun 2019
Rain Int. (mm/hr)
0
20
40
60
80
100
I15 Paige Boulder
I15 Paige Divide
I15 Rich Gulch
I15 Whiskey Crk
I15 Monarch Mt
I15 Brandy Creek
I15 Crystal Creek
I15 Carr Power Plant
Cumulative rainfall (mm)
2500
2000
1500
1000
500
0
Paige Boulder
Paige Divide
Rich Gulch
Whiskey Crk
Monarch Mt
Brandy Creek
Crystal Creek
Carr Power Plant
Time

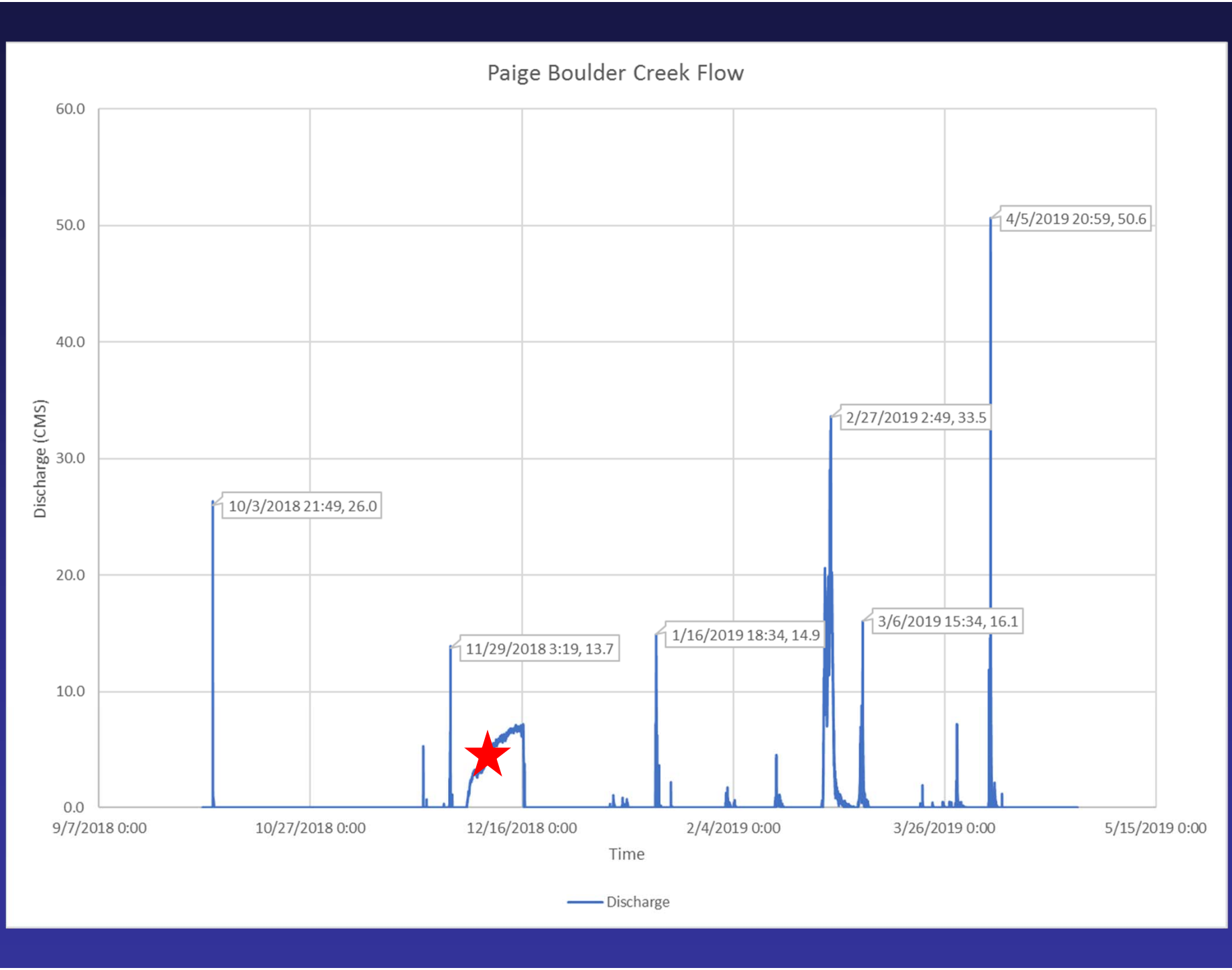

Paige Boulder
Paige Divide
Monarch Mt.
Carr Power Plant
Brandy Creek
Whiskey Creek Trib.
Number of storms
Max rain intensity (mm/hr)
I15
I60
0
10
20
30
0
20
40
60


CARR POST-FIRE MONITORING
Monitoring Points
Type
Debris Flow Transducer
Infiltrometer
PPT Tipping Bucket
Stream Gage
Weather Station
MAD MULE MOUNTAIN
Whiskeytown
Boulder Creek
Whiskeytown Lake
Whiskeytown-Shasta Trinity National Recreation Area
Brandy Creek
MONARCH MOUNTAIN
Paige Boulder Creek
N
W
E
S
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
0.71 0.35 0 0.71 1.42 2.13 2.84
Miles

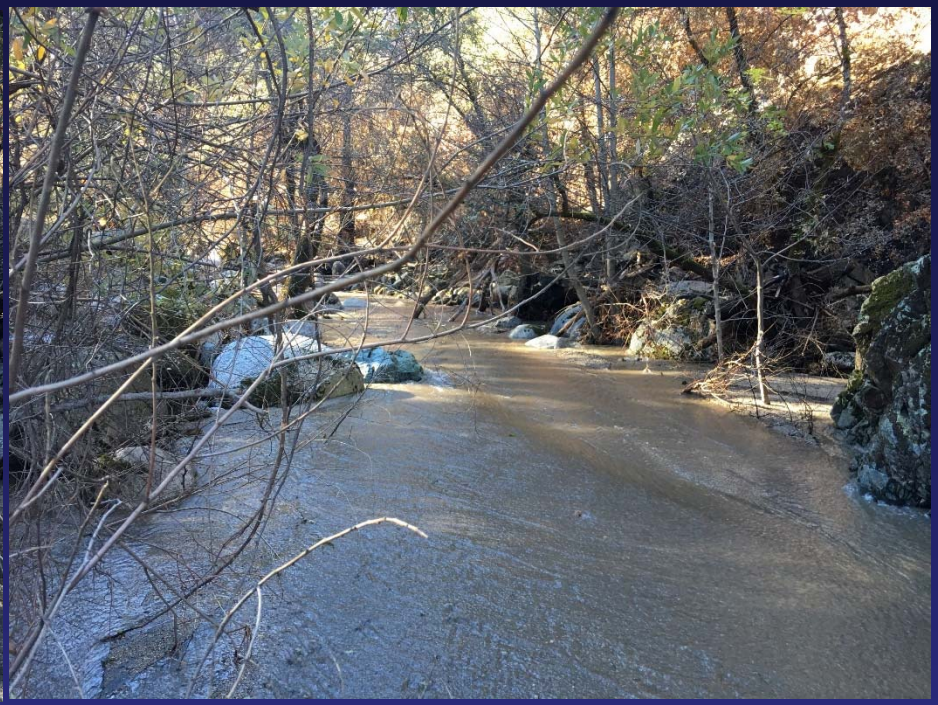
Paige Boulder Creek

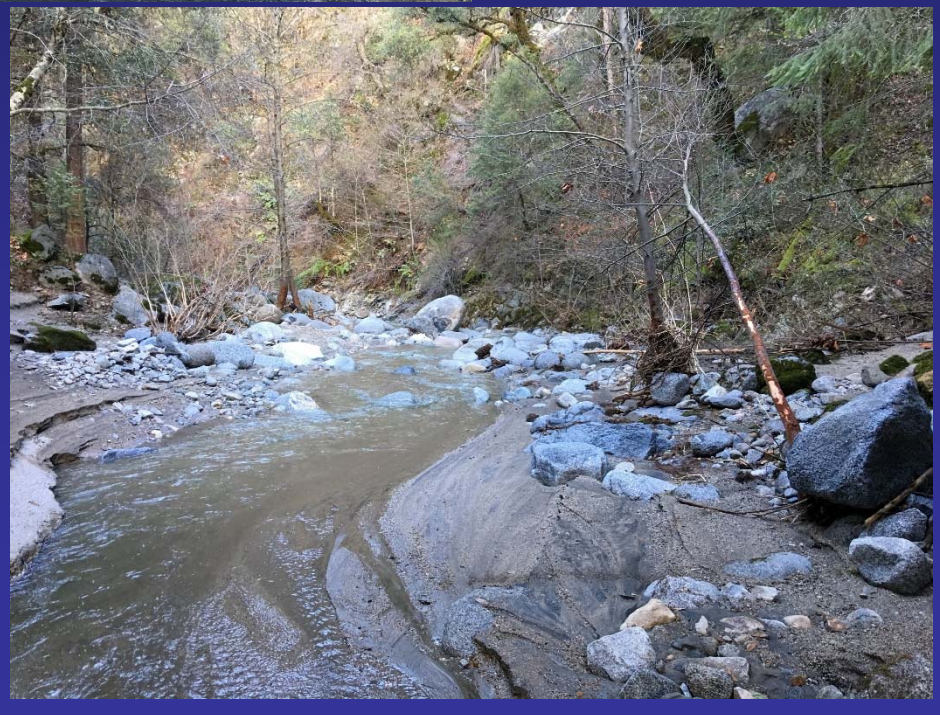



Paige Boulder Creek Flow
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Discharge (CMS)
10/3/2018 21:49, 26.0
11/29/2018 3:19, 13.7
1/16/2019 18:34, 14.9
2/27/2019 2:49, 33.5
3/6/2019 15:34, 16.1
4/5/2019 20:59, 50.6
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Time
Discharge

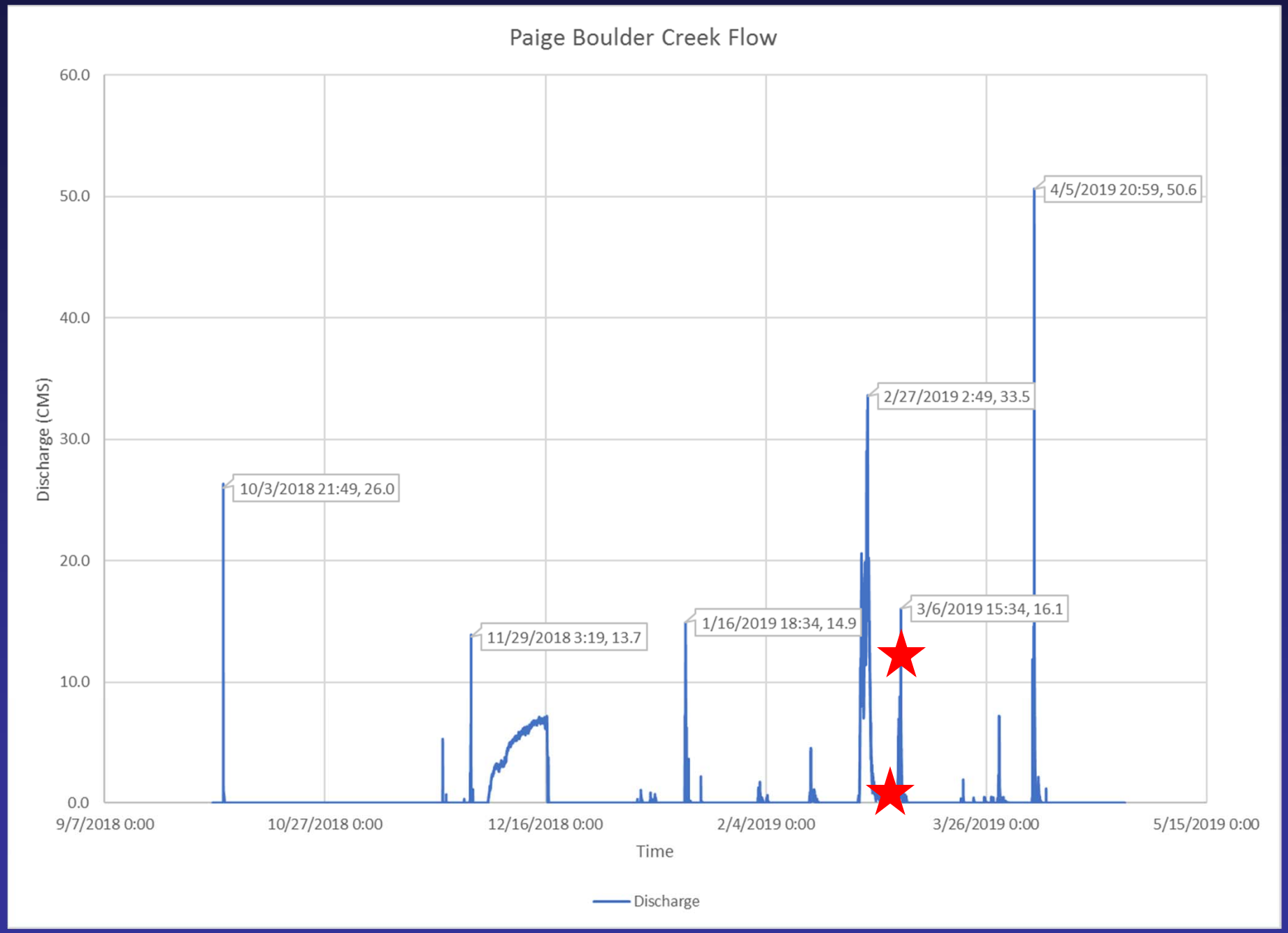

Paige Boulder Creek Flow
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Discharge (CMS)
10/3/2018 21:49, 26.0
11/29/2018 3:19, 13.7
1/16/2019 18:34, 14.9
2/27/2019 2:49, 33.5
3/6/2019 15:34, 16.1
4/5/2019 20:59, 50.6
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Time
Discharge

12-7-18

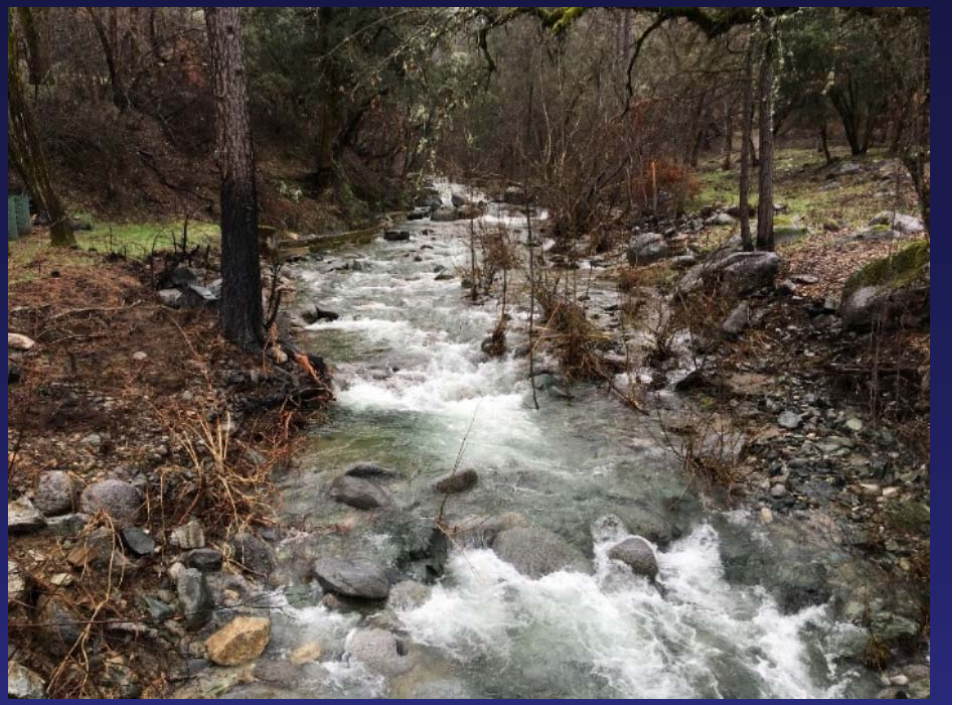


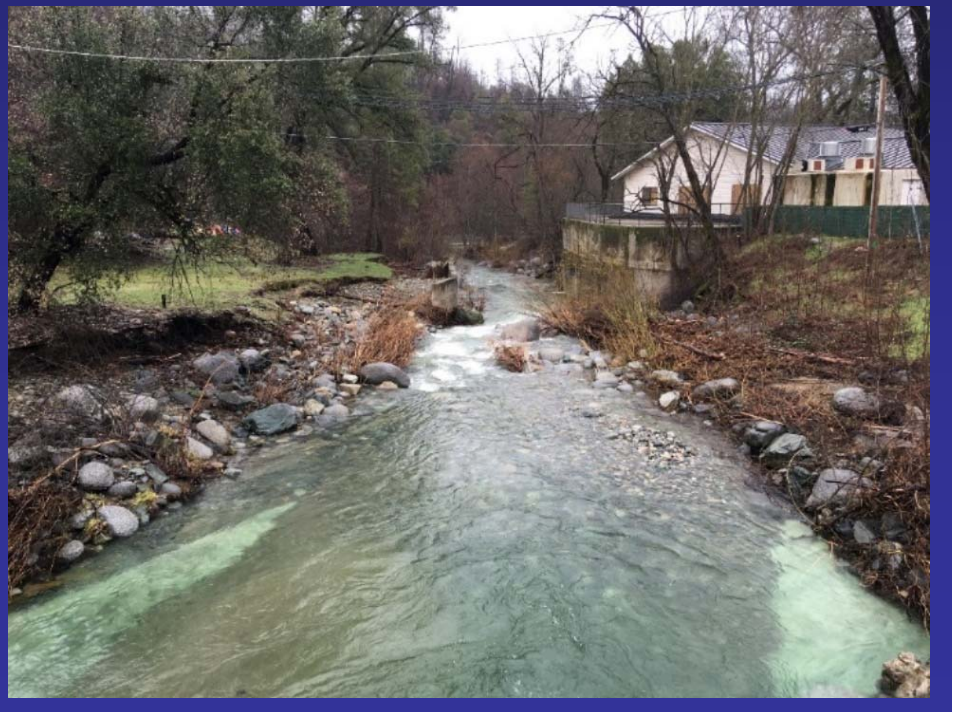


Boulder Creek
12-7-18

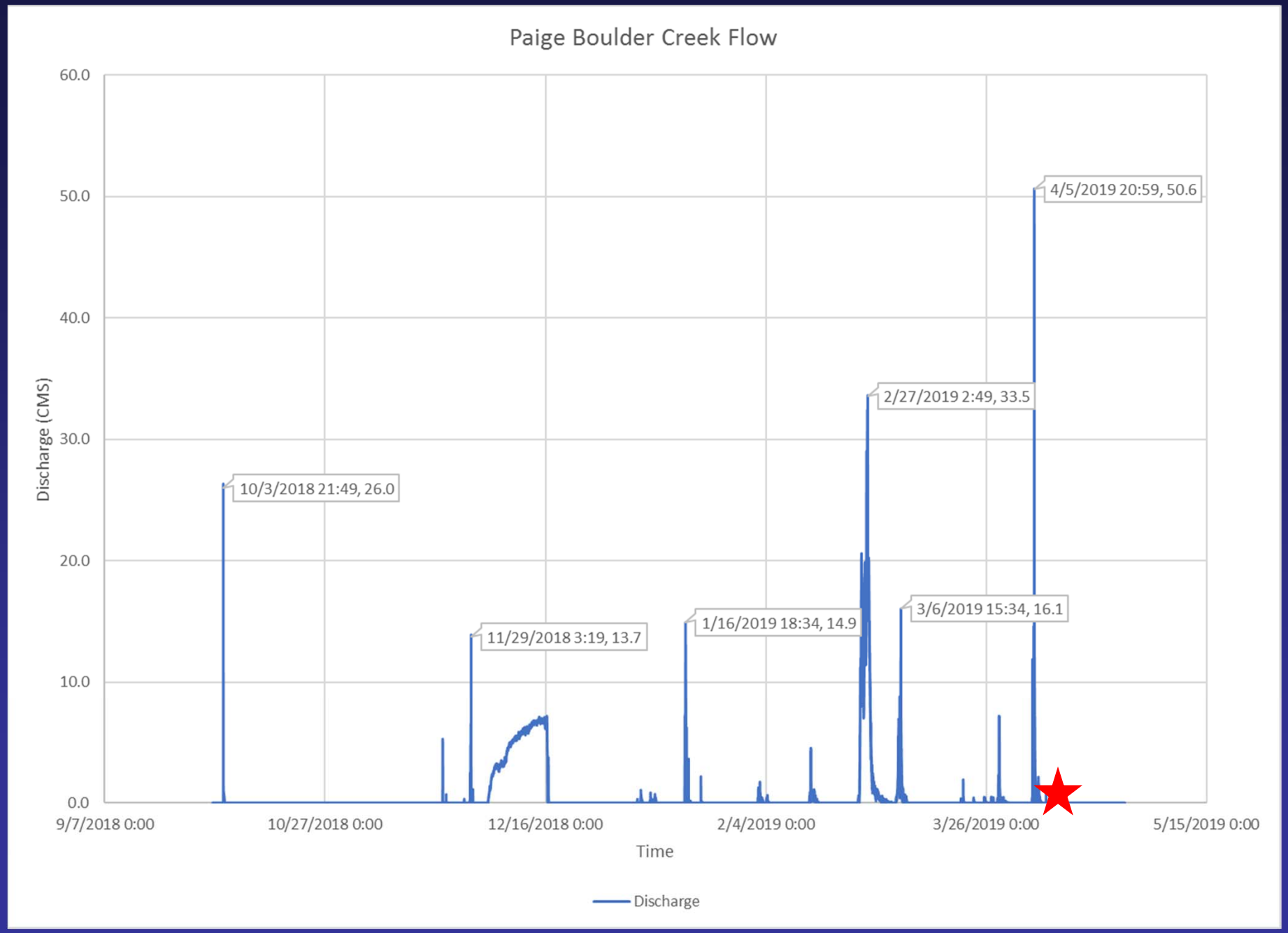

Paige Boulder Creek Flow
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Discharge (CMS)
10/3/2018 21:49, 26.0
11/29/2018 3:19, 13.7
1/16/2019 18:34, 14.9
2/27/2019 2:49, 33.5
3/6/2019 15:34, 16.1
4/5/2019 20:59, 50.6
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Time
Discharge

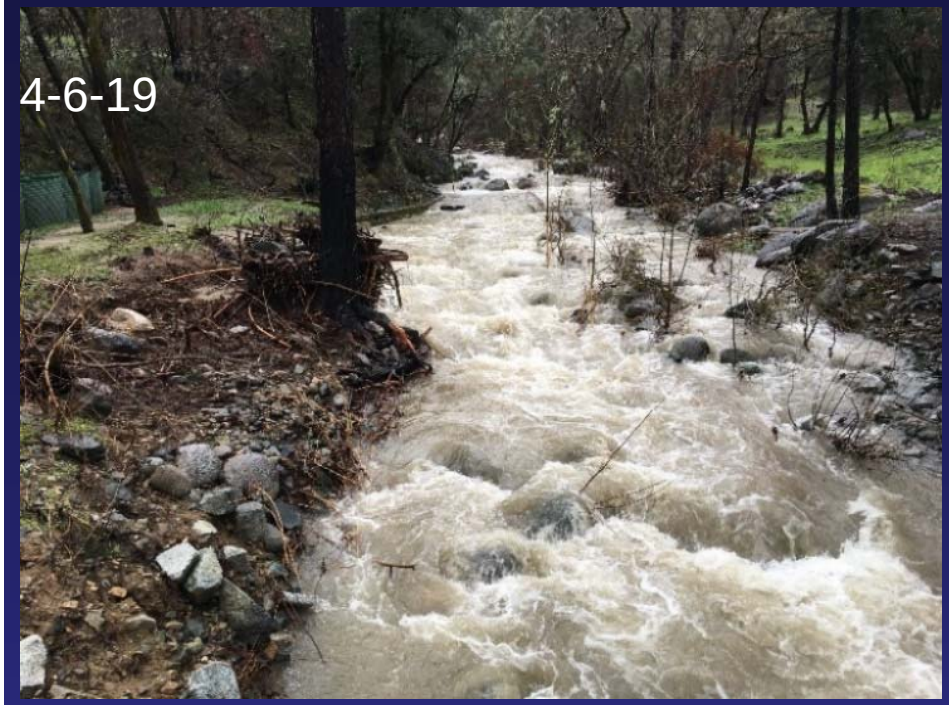
3-5-19



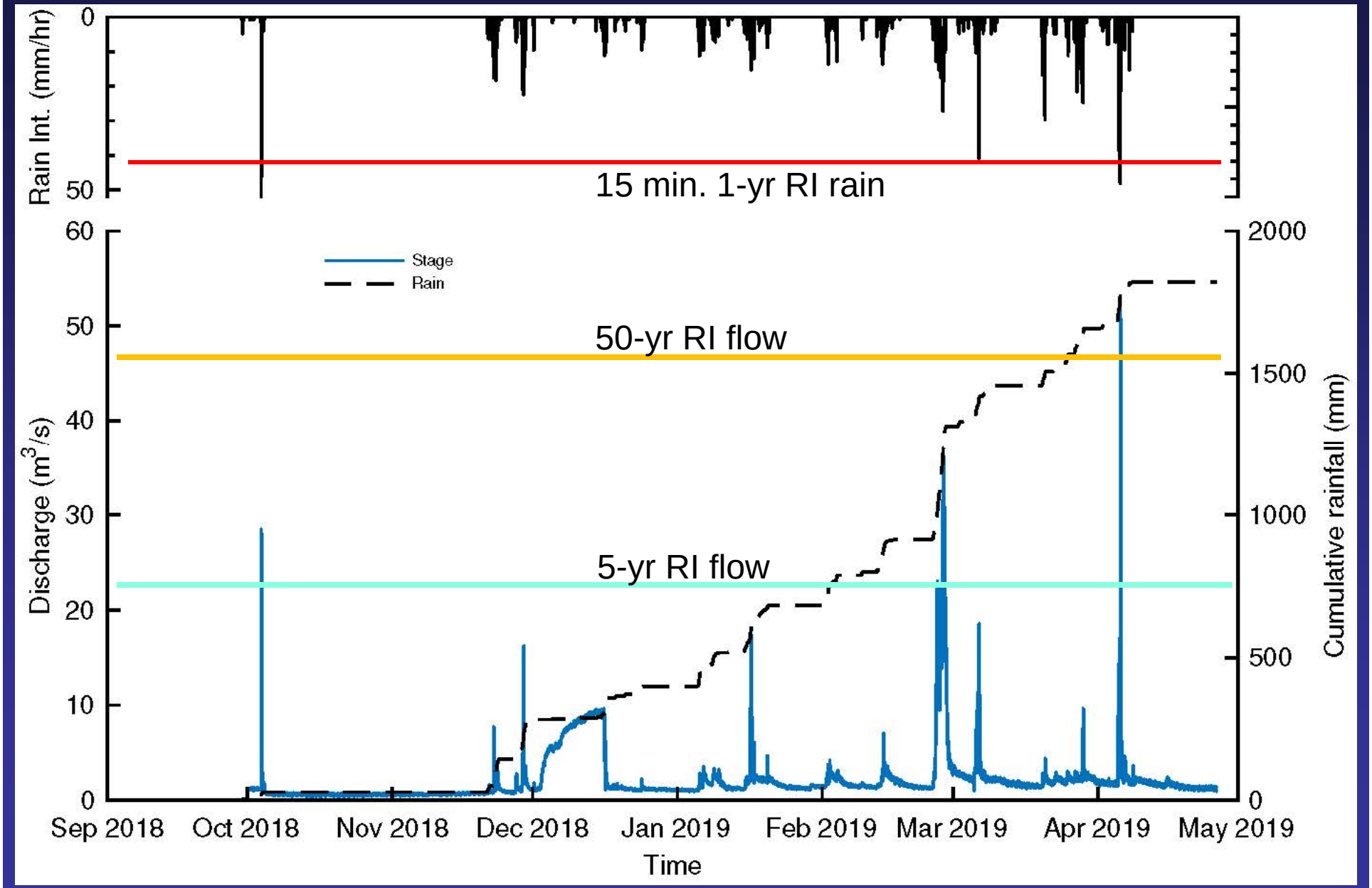


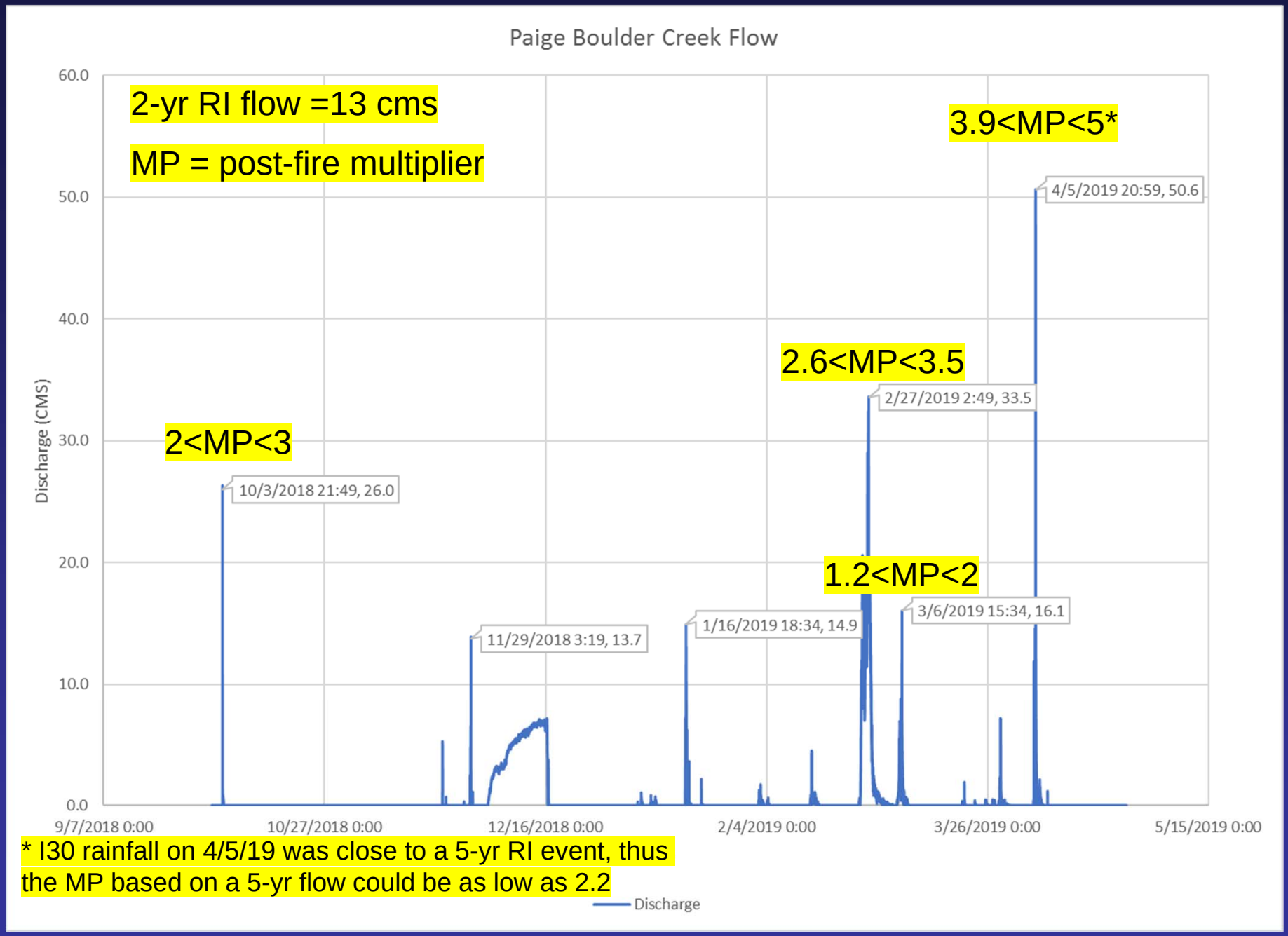
3-6-19


Paige Boulder Creek Flow
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Discharge (CMS)
10/3/2018 21:49, 26.0
11/29/2018 3:19, 13.7
1/16/2019 18:34, 14.9
2/27/2019 2:49, 33.5
3/6/2019 15:34, 16.1
4/5/2019 20:59, 50.6
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Time
Discharge

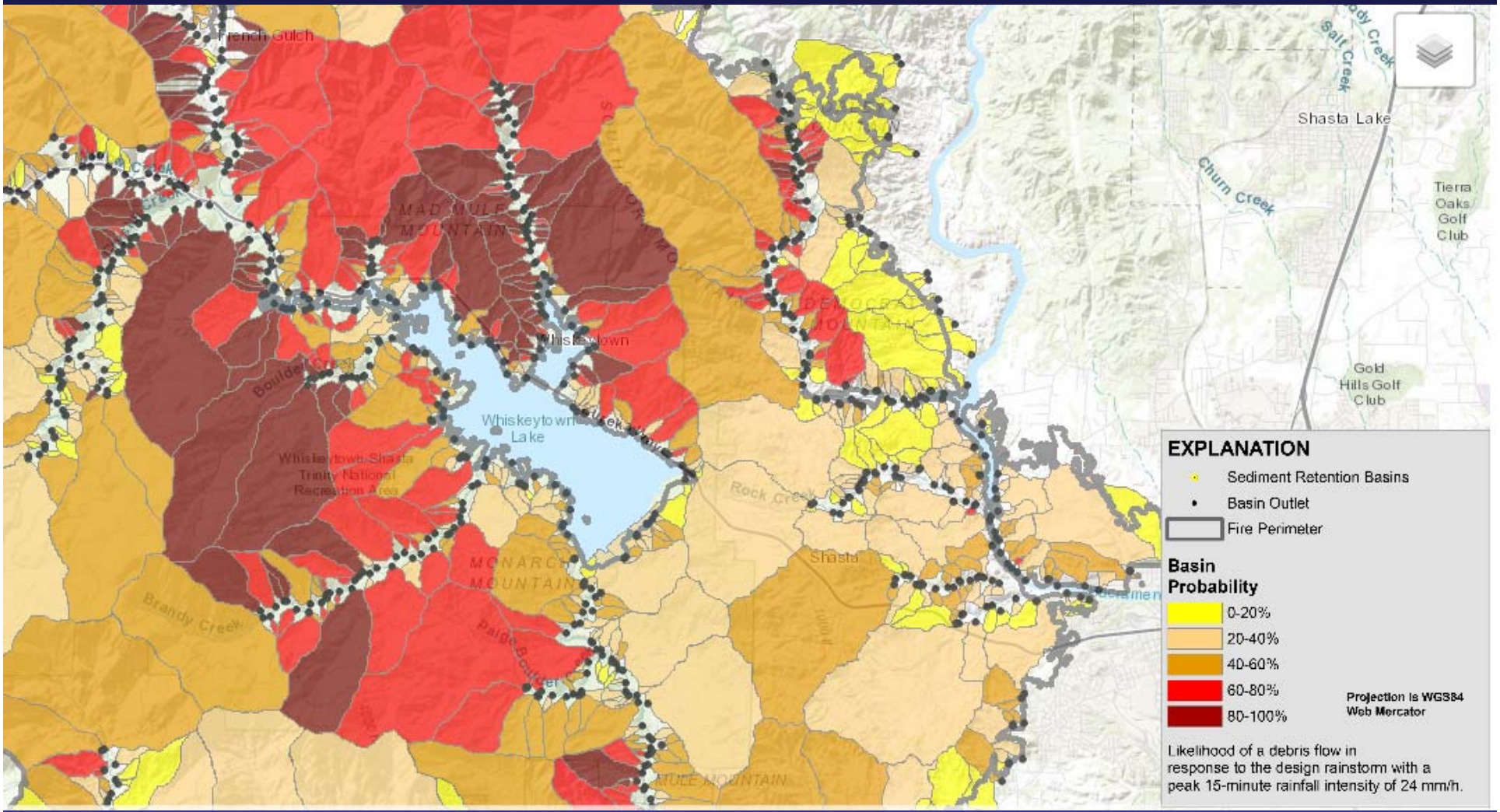

4-6-19

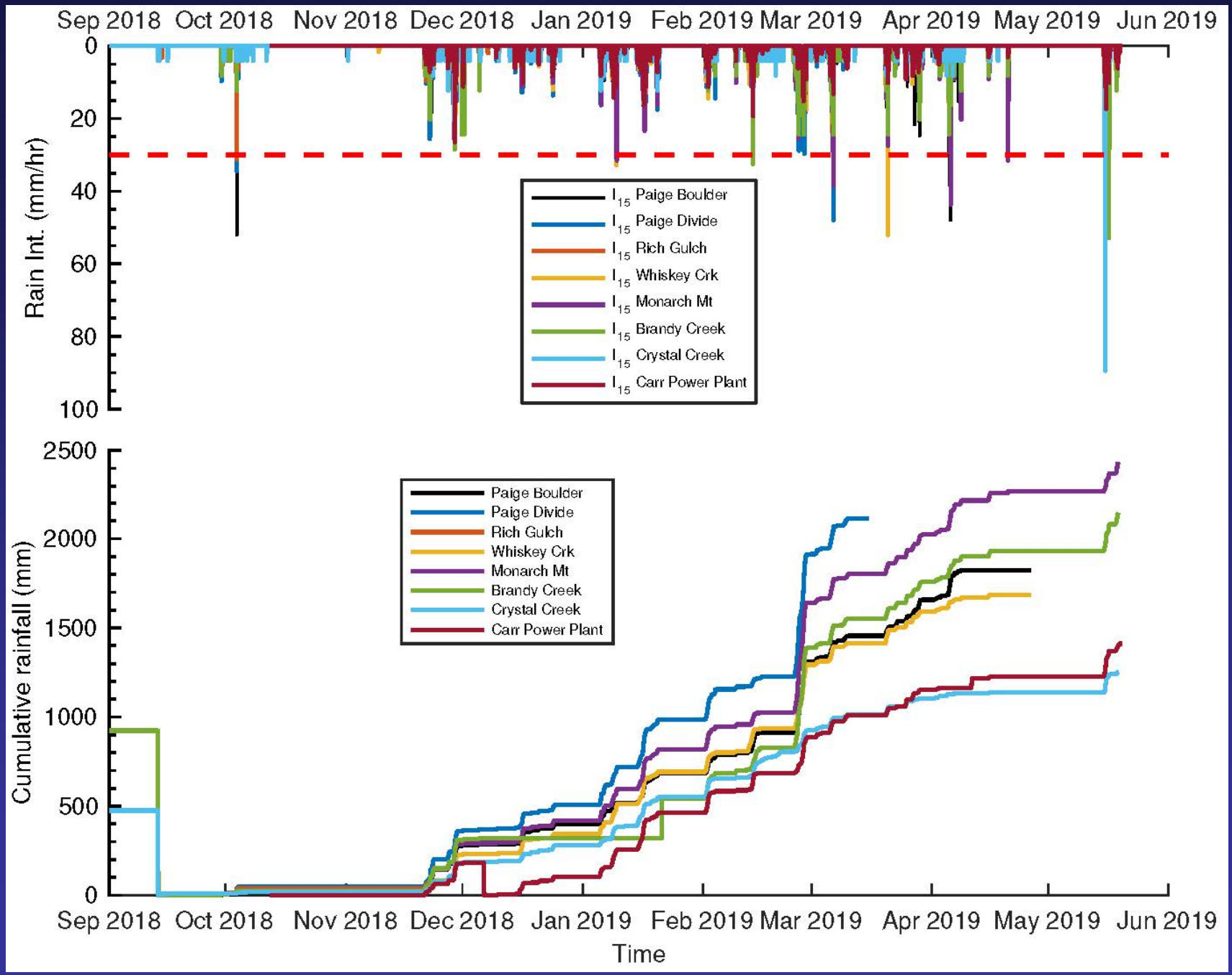
Paige Boulder Creek



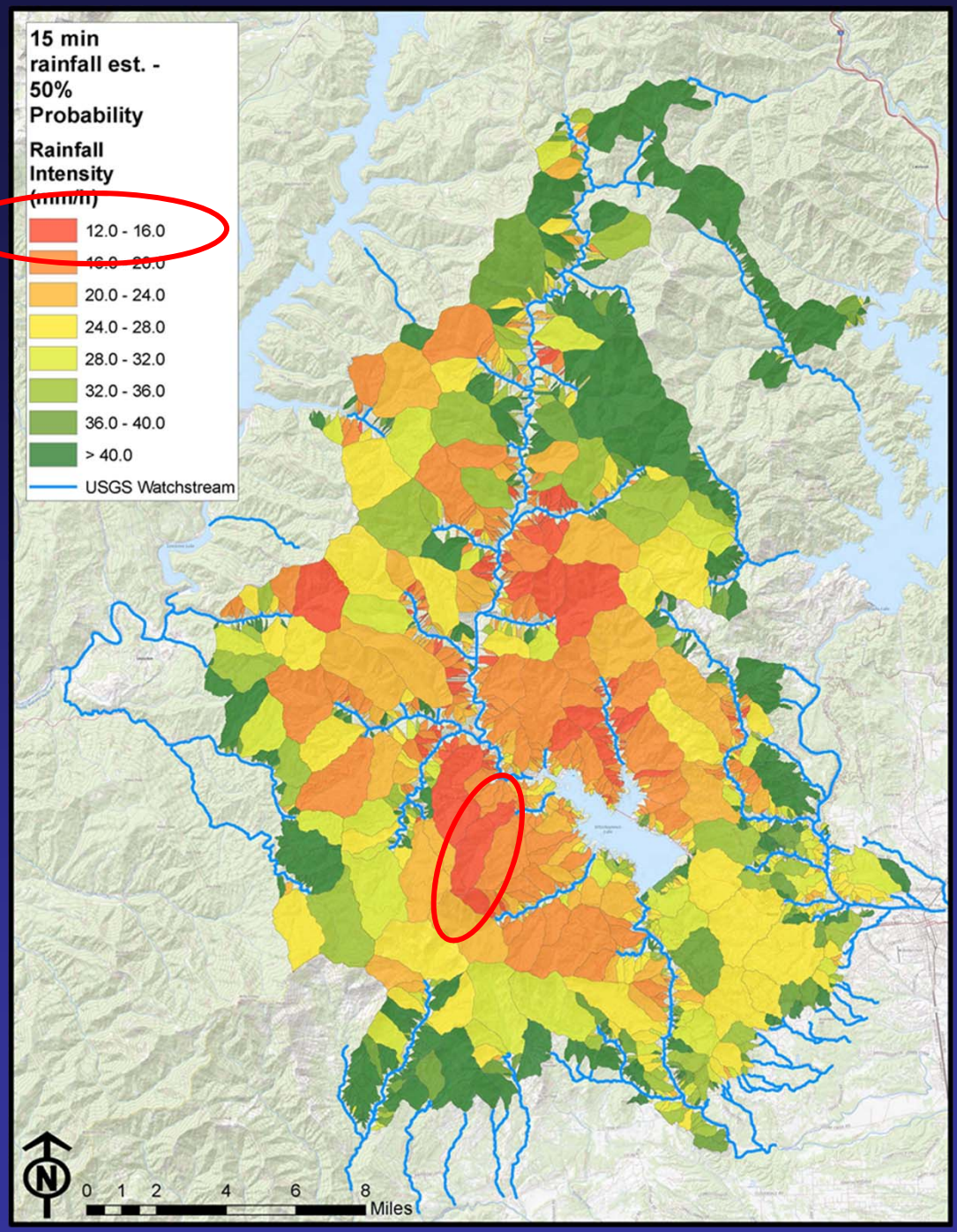

Paige Boulder Creek Flow
2-yr RI flow =13 cms
MP = post-fire multiplier
3.9<MP<5*
2.6<MP<3.5
2<MP<3
1.2<MP<2
4/5/2019 20:59, 50.6
2/27/2019 2:49, 33.5
10/3/2018 21:49, 26.0
11/29/2018 3:19, 13.7
1/16/2019 18:34, 14.9
3/6/2019 15:34, 16.1
Discharge (CMS)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Discharge
* I30 rainfall on 4/5/19 was close to a 5-yr RI event, thus the MP based on a 5-yr flow could be as low as 2.2

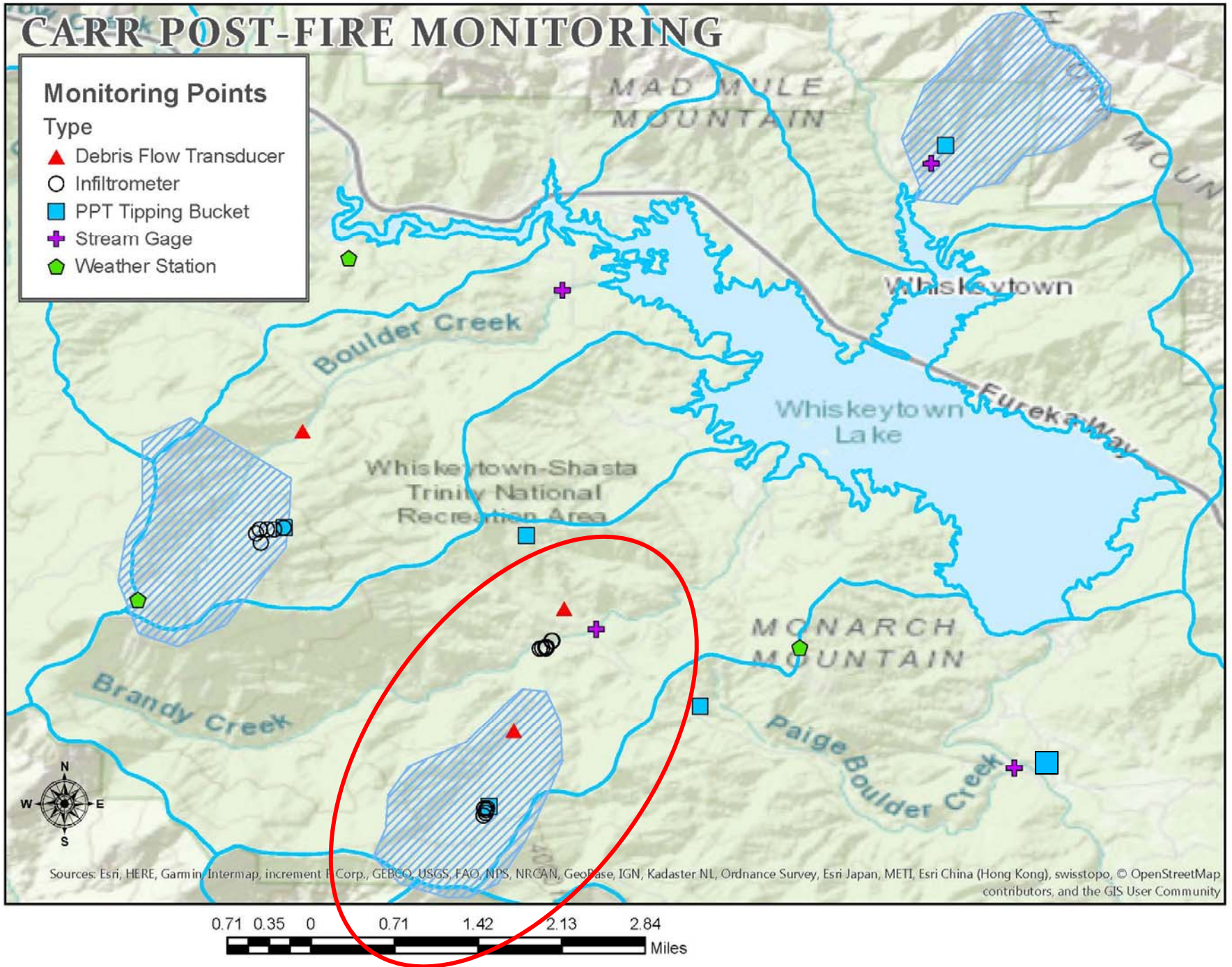
2018 Carr Fire




Sep 2018
Oct 2018
Nov 2018
Dec 2018
Jan 2019
Feb 2019
Mar 2019
Apr 2019
May 2019
Jun 2019
Rain Int. (mm/hr)
0
20
40
60
80
100
I15 Paige Boulder
I15 Paige Divide
I15 Rich Gulch
I15 Whiskey Crk
I15 Monarch Mt
I15 Brandy Creek
I15 Crystal Creek
I15 Carr Power Plant
Cumulative rainfall (mm)
2500
2000
1500
1000
500
0
Paige Boulder
Paige Divide
Rich Gulch
Whiskey Crk
Monarch Mt
Brandy Creek
Crystal Creek
Carr Power Plant
Time

Experienced rainfall intensities ~3.5 times modelled value




CARR POST-FIRE MONITORING
Monitoring Points
Type
Debris Flow Transducer
Infiltrometer
PPT Tipping Bucket
Stream Gage
Weather Station
MAD MULE MOUNTAIN
Whiskeytown
Boulder Creek
Whiskeytown Lake
Whiskeytown-Shasta Trinity National Recreation Area
MONARCH MOUNTAIN
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N
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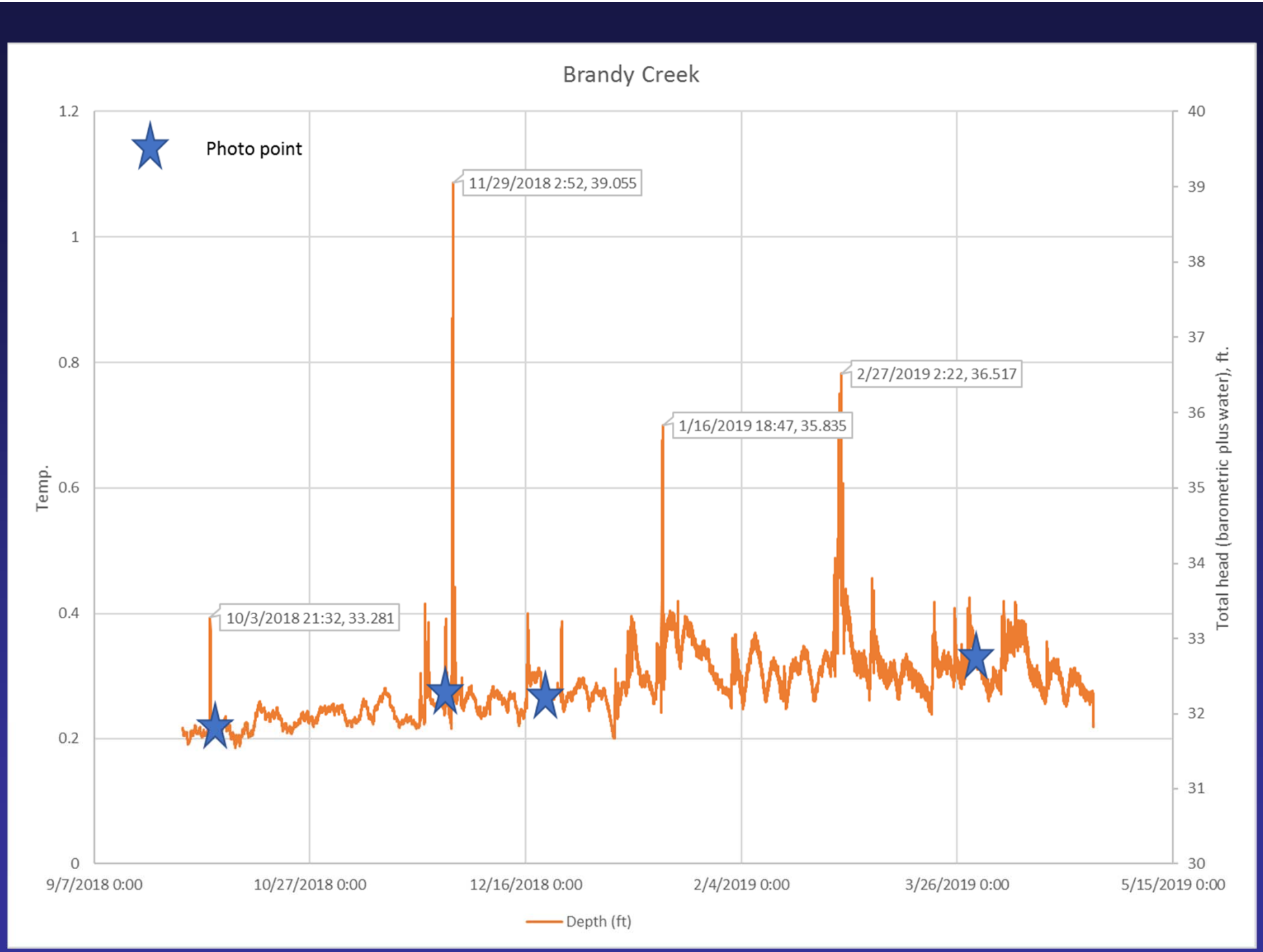
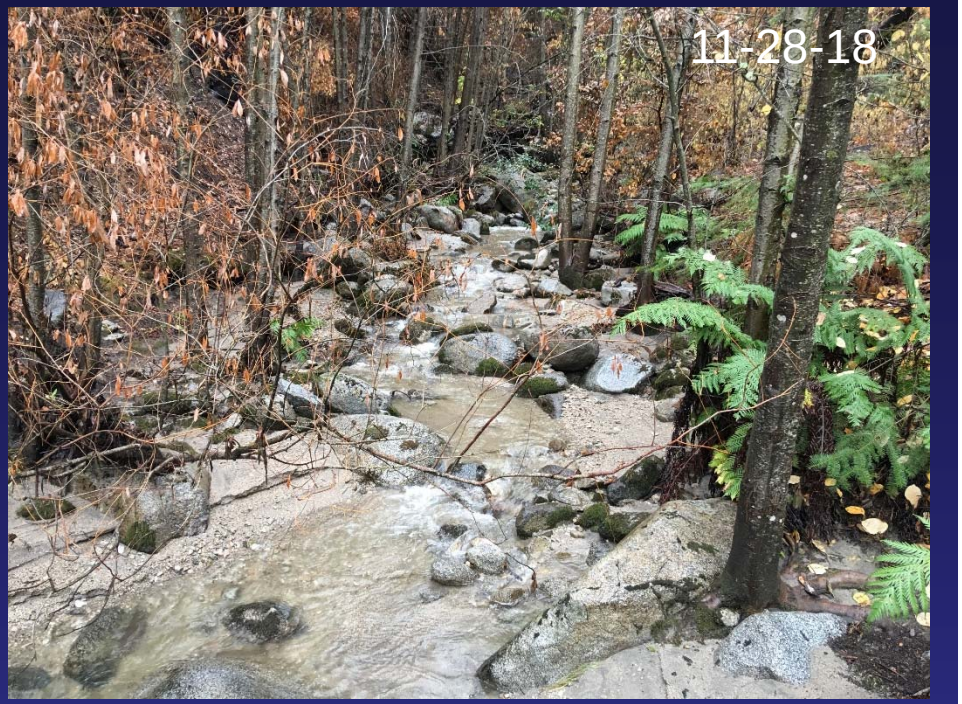
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
0.71 0.35 0 0.71 1.42 2.13 2.84
Miles


Brandy Creek
Photo point
11/29/2018 2:52, 39.055
2/27/2019 2:22, 36.517
1/16/2019 18:47, 35.835
10/3/2018 21:32, 33.281
Temp.
Total head (barometric plus water), ft.
1.2
1
0.8
0.6
0.4
0.2
0
40
39
38
37
36
35
34
33
32
31
30
9/7/2018 0:00
10/27/2018 0:00
12/16/2018 0:00
2/4/2019 0:00
3/26/2019 0:00
5/15/2019 0:00
Depth (ft)


10-5-18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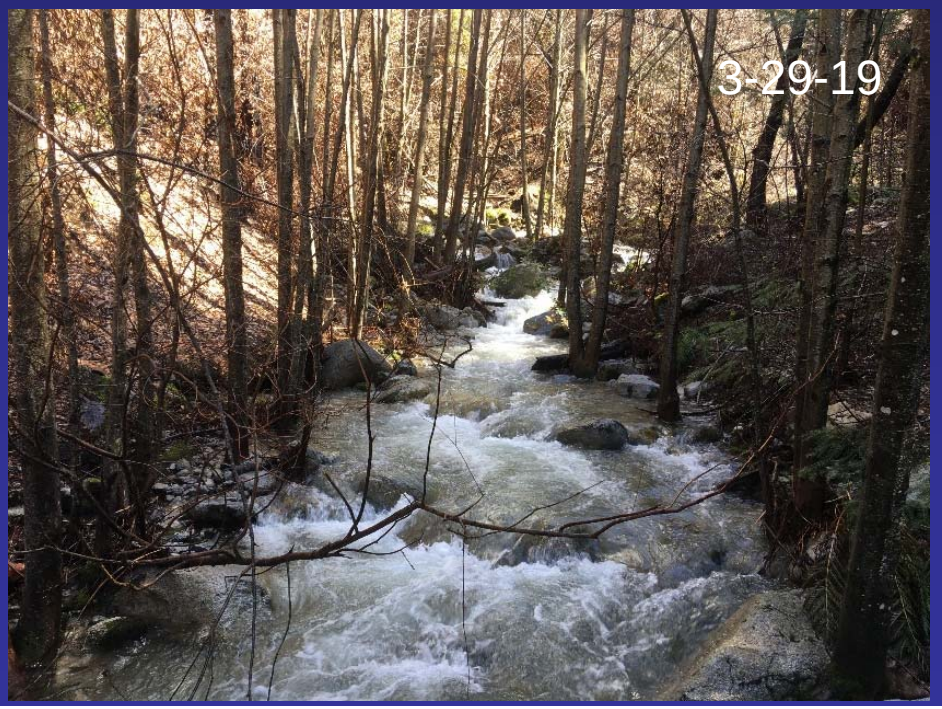
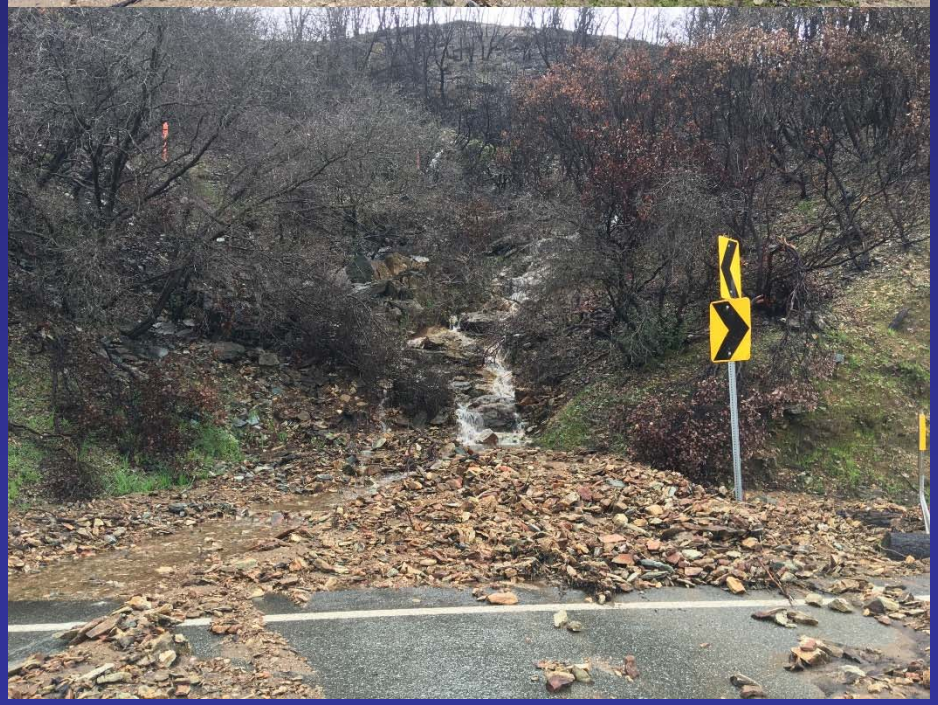
12-20-18


3-29-19



Conclusion

Preliminary results suggest that in areas with similar physiographic and climatic conditions as those present in the Carr Fire, we could expect:

- Post-fire bulking multipliers in excess of 2, and can range between 2.5 and 5 for 2-year RI events; and
- Post-fire debris flow triggering thresholds may be increased over modelled predictions. However, additional testing is required prior to implementation.

Based on preliminary observations, these findings appear applicable to the Camp Fire.

CGS
CALIFORNIA GEOLOGICAL SURVEY

Thank You!

Questions?