MONUMENT FIRE

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Post-Burn Increased Flash Flood Risk Analysis

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USFS Image of rain falling over Miller Canyon, Monument Fire Burn Area, on July 10, 2011.

Abstract.

In the desert southwest of the United States, wildfire alters the hydrologic response of watersheds greatly increasing the magnitudes and frequency of flash floods. The NOAA National Weather Service is tasked with the issuance of flash flood warnings to save life and property. Basins impacted by the Monument Fire are expected to see 5-year peak flows that range from 1,393 to 18,773 cfs. These post-burn 5-year peak flows are 7 to 61 times greater than pre-burn flows. The storm duration for the NWS post-burn peak flows is equal to the time of concentration for each basin evaluated. For these basins, the time of concentration ranged from 15 to 41 minutes. The study also presents the results for the 2-year and 10-year post-burn peak flows.

INTRODUCTION

This report is an assessment of the impact on the future hydrologic response of basins burned by the 2011 Monument Fire in Cochise County, Arizona. These impacts are possible during the next few years, prior to the hydrologic recovery of the watersheds. Empirical equations developed by NWS using post-burn data from fires that have occurred in the mountainous terrain of Southeast Arizona are used to estimate the 2-year, 5-year, and 10-year post-burn peak flows and the associated increased flash flood risk. The basins selected for analysis (Figure 1) are a subset of those defined by the Monument Fire BAER Team. This report does not address areas burned in Mexico or impacts in Mexico.

This report provides an estimate of potential flows after a burn with an emphasis on the first significant flash flood that could "likely" occur in each of the studied basin. It is the experience of the authors that these "first flush" peak flows are often hyper-concentrated flows. Thus the peaks from each basin are essentially sediment carrying water flows with entrained post-burn debris. The 5-year return interval is used for this study because the calculated peaks then have a 67% chance of being equaled or exceeded one or more times during an assumed burn recovery period of five years. The 2-year and 10-year post-burn flows are also presented to help better define flash flood risk. By convention, the storm duration for these events is equal to or greater than the time of concentration of the basins. These are not debris flows and the equations are not suitable for forecasting post wildfire debris flow hazards.

Flash floods pose a significant threat to life and property in and downstream of burned areas. This report does not seek to determine if a given structure is at risk of damage or destruction. Such a determination is beyond the scope of this report or the expertise of the authors. Any statements about increases in post-burn flash flood risks are general in nature and based on a comparison of pre- and post-burn peak flows.

METHODOLOGY

In studies of post-burn peak flows throughout southeast Arizona, Reed and Schaffner (2007 and 2008) have demonstrated that peak flows can be estimated for burned basins using a multivariate runoff index defined by several watershed characteristics. Therefore, a series of empirical equations were developed by Reed to estimate peaks flows with 2-year through 10-year recurrence intervals from both small and larger sized burned basins. The basin properties used are 1) the hyper-effective drainage area, the area of the basin with moderate and high severity burn, in square miles, 2) the modified channel relief ratio, and 3) the mean basin elevation, in thousands of feet above mean sea level.

For the Monument Fire, an analysis of 10 watersheds using the Reed-Schaffner Equation 3 was performed. Equation 3 is a best-fit curve that uses a multivariate runoff index. For the purpose of this study the hyper-effective drainage area was redefined to be the area of moderate plus high severity burn for hydro soil groups C and D only. This was done because the BAER Team soil specialist report stated “soil water repellency was mostly weak and intermittent within the fire area…” The post-burn flows were calculated for the 2-year, 5-year and 10-year storms with duration equal to or greater than the watershed's time of concentration (ranged from 15 to 41 minutes). The data used in these calculations were provided by the Monument BAER Team, with the exception of the modified channel relief ratio that required additional basin analysis by the authors.

The Reed-Schaffner equations apply where: 1) the storm duration is greater or equal to the basin's time of concentration, 2) the event is the first major flush after the fire, 3) water repellent soils are assumed present, and 4) the core of the storm moves over at least a portion of the hyper-effective drainage area. The Reed-Schaffner equations were not used for watersheds with: 1) drainage area less than 1 square mile, 2) elevation change less than 1500 feet, 3) no hyper-effective hydro soil group D, and/or 4) no hyper-effective hydro soil group C unless hydro soil group D coverage was significant.

Since equation 3 only calculates runoff from the hyper-effective drainage area, the pre-burn 2-year, 5-year or 10-year runoff from the remaining portion of the basin was added to the results of equation 3. The pre-burn 2-year, 5-year, and 10-year runoffs were calculated using the USGS equations for region 14, Thomas (1997). Final results reflect the 2-year, 5-year, and 10-year post-burn runoffs from the entire basin.

The calculated flash flood generated peak flows from each basin are essentially sediment carrying water flows with entrained post-burn debris, often referred to as hyper-concentrated flows. In order to provide an estimated of % water for calculated peaks, the 2-year post-burn flows where compared to the 100-year pre-burn flows (Figure 6) and the multivariate index was ranked (Figure 7). With regard to the 2-year post-burn / 100-year pre-burn ratio, the basins with the four highest values were assigned 40%, the next four highest were assigned 60%, and the remaining 2 basins were assigned 80%. The same process was repeated for the multivariate index. Both methods assigned the same values. These values are estimates only. As previously stated, hyper-concentrated flows are not debris flows and the equations are not suitable for forecasting post wildfire debris flow hazard.

Projected hydrologic recovery for the 5-year peak flows were estimated by reducing the flows over the assumed five year recovery period. A simple model for hydrologic recovery was used. The difference between post-burn and pre-burn flows was divided by 5. Year 0 started with the post-burn flow then to obtain the next year (Year 1) the above calculated value was subtracted from the previous year (Year 0). This was repeated until Year 5. Year 5 is the pre-burn flow.

Selected basin data are presented in Figure 2. Study results including the calculated post-burn peak flows are presented in Figures 3-5. Estimates of percent water for the calculated hyper-concentrated flows are presented in Figure 6 and 7. Projected hydrologic recovery for 5-year peak flows is presented in Figure 8. As stated previously, a hydrologic recovery period of five years was assumed. The projected flows are for first flush flows from a basin. Once an event has occurred subsequent flows for the same rainfall will most likely be reduced as the sediment concentration of the flows decreases. Relative increase in flash flood risk is provided in Figures 9-17.

FINDINGS

PEAK FLOWS: The 10 basins selected for analysis (Figure 1) are a subset of those defined by the Monument Fire BAER Team. These basins impacted by the Monument Fire are expected to see 2-year peak flows that range from 653 to 9,177 cfs (Figure 3). These post-burn 2-year peak flows are 10 to 95 times greater than pre-burn peak flows. The basins are expected to see 5-year peak flows that range from 1,393 to 18,773 cfs (Figure 4). These post-burn 5-year peak flows are 7 to 61 times greater than pre-burn peak flows. The basins are expected to see 10-year peak flows that range from 2,463 to 32,266 cfs (Figure 5). These post-burn 10-year peak flows are 6 to 47 times greater than pre-burn peak flows. The storm duration for the NWS post-burn peak flows is equal to the time of concentration for each basin evaluated. For these basins, the time of concentration ranged from 15 to 41 minutes.

ESTIMATED PERCENT WATER FOR HYPER-CONCENTRATED FLOWS: As previously stated, the calculated peaks from each basin are essentially sediment carrying water flows with entrained post-burn debris. The estimated percent water for the flows from the 10 selected basins is expected to range from 40 to 80 percent (Figures 6-7).

INCREASED FLASH FLOOD RISK: To evaluate the relative increase in flash flood risk, the 10 basins were ranked by post-burn yield and assigned a relative increased flash flood risk. This was done for the 2-year, 5-year, and 10-year events as is shown on Figures 3, 4, and 5. This relative increase in flash flood risk is shown spatially in Figures 9-17.

CONCLUSIONS

Storms with time of concentrations from 15 to 41 minutes over the burn area will cause significant increases in peak flows from the impacted basins during the recovery period. The short duration storms will impact the steeper basins on both sides of the hydrologic divide of the Huachuca Mountains, and the larger duration storms will impact all basins. The basins with relative increased flash flood risk have been identified and are shown on Figures 9-17. To help better define the risk, the risk is shown for 2-year, 5-year, and 10-year events. Four basins of particular interests are

- **Carr Canyon near Admin.**
- **Miller Canyon near B&B**
- **Ash Canyon**
- **Hunter Canyon**

These four basins were selected due to the potentially high impacts with elevated post-burn flows. This is true provided the core of the storm passes over the hyper-effective burn area and the duration of the storm is equal to or greater than the time of concentration. For theses four basins post-burn flow results are:

Carr Canyon near Admin. (Storm Duration: 30 Minutes)
5-Year Post-Burn Flow (Eq. 3): 10,039 cfs

Estimated % Water: 60 %
2-Year Relative Increased Flash Flood Risk: High
5-Year Relative Increased Flash Flood Risk: Extreme
10-Year Relative Increased Flash Flood Risk: Extreme
2-Year Precipitation: 1.31 inches
5-Year precipitation: 1.70 inches
10-Year Precipitation: 1.97 inches

Miller Canyon near B&B (Storm Duration: 30 Minutes)
5-Year Post-Burn Flow (Eq. 3): 5,394 cfs
Estimated % Water: 60 %
2-Year Relative Increased Flash Flood Risk: Moderate
5-Year Relative Increased Flash Flood Risk: High
10-Year Relative Increased Flash Flood Risk: Extreme
2-Year Precipitation: 1.27 inches
5-Year precipitation: 1.65 inches
10-Year Precipitation: 1.91 inches

Ash Canyon (Storm Duration: 15 Minutes)
5-Year Post-Burn Flow (Eq. 3): 18,773 cfs
Estimated % Water: 40 %
2-Year Relative Increased Flash Flood Risk: Extreme
5-Year Relative Increased Flash Flood Risk: Extreme
10-Year Relative Increased Flash Flood Risk: Extreme
2-Year Precipitation: 1.00 inches
5-Year precipitation: 1.29 inches
10-Year Precipitation: 1.50 inches

Hunter Canyon (Storm Duration: 15 Minutes)
5-Year Post-Burn Flow (Eq. 3): 13,420 cfs
Estimated % Water: 40%
2-Year Relative Increased Flash Flood Risk: Extreme
5-Year Relative Increased Flash Flood Risk: Extreme
10-Year Relative Increased Flash Flood Risk: Extreme
2-Year Precipitation: 0.96 inches
5-Year precipitation: 1.25 inches
10-Year Precipitation: 1.45 inches

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ACKNOWLEDGEMENTS

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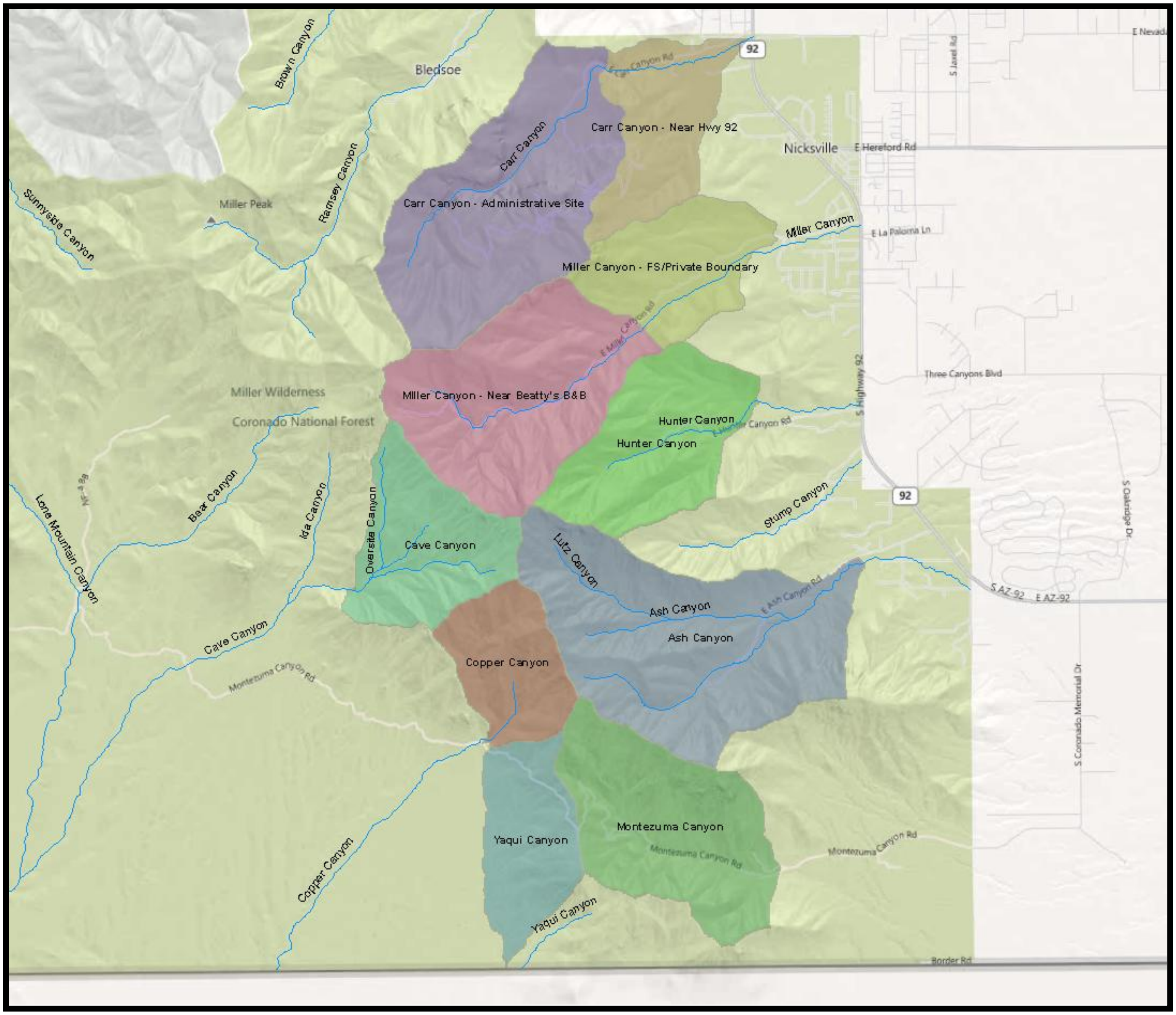


MONUMENT FIRE FIGURE 1. SELECTED BASINS

MONUMENT FIRE FIGURE 2. SELECTED BASIN VALUES

	Drainage Area (sq. mi.)	Hyper-Effective Drainage Area (sq. mi.)	Modified Hyper-Effective Drainage Area (sq. mi.)[1]	Maximum Basin Elevation (ft.)	Mean Basin Elevation (ft./1000)	Modified Channel Relief Ratio	Storm Duration (minutes)
Hunter Canyon	2.0	1.74	0.20	9422	7.4	0.26	18
Ash Canyon	4.1	3.74	2.27	9460	7.3	0.16	20
Copper Canyon	1.2	0.60	0.24	8738	7.4	0.22	15
Cave Canyon	1.7	0.21	0.02	9322	7.8	0.23	15
Montezuma Canyon	2.7	1.06	0.73	7666	6.6	0.12	27
Carr Canyon near Admin.	3.5	0.61	0.54	9204	7.2	0.17	29
Carr Canyon	5.0	1.18	1.04	9204	7.0	0.13	41
Yaqui Canyon	1.3	0.07	0.07	7598	6.5	0.09	23
Miller Canyon near B&B	3.0	2.35	0.11	9461	7.4	0.19	24
Miller Canyon	4.5	3.56	1.09	9461	7.1	0.15	37

MONUMENT FIRE FIGURE 3. RESULTS FOR 2-YEAR FLASH FLOODS

	Pre-Burn USGS Eq. (cfs)	Post-Burn Eq. 3 (cfs)	Post-Burn / Pre-Burn Ratio	Post-Burn Basin Yield (cfs/sq. mi.)	Relative Increased Flash Flood Risk
Hunter Canyon	69	6542	95	3283	extreme
Ash Canyon	107	9177	86	2225	extreme
Copper Canyon	52	4889	94	3967	extreme
Cave Canyon	59	1610	27	939	moderate
Montezuma Canyon	95	3281	35	1226	high
Carr Canyon near Admin.	100	4879	49	1380	high
Carr Canyon	127	4448	35	889	moderate
Yaqui Canyon	65	653	10	490	moderate
Miller Canyon near B&B	87	2599	30	860	moderate
Miller Canyon	117	5850	50	1294	high

[1] Note: used only soil groups C & D, moderate + high burn area.

MONUMENT FIRE FIGURE 4. RESULTS FOR 5-YEAR FLASH FLOODS					
	Pre-Burn USGS Eq. (cfs)	**Post-Burn Eq. 3 (cfs)**	**Post-Burn / Pre-Burn Ratio**	**Post-Burn Basin Yield (cfs/sq. mi.)**	**Relative Increased Flash Flood Risk**
Hunter Canyon	219	13420	61	6734	extreme
Ash Canyon	322	18773	58	4552	extreme
Copper Canyon	170	10030	59	8138	extreme
Cave Canyon	195	3360	17	1960	high
Montezuma Canyon	277	6755	24	2525	extreme
Carr Canyon near Admin.	302	10039	33	2840	extreme
Carr Canyon	368	9163	25	1832	high
Yaqui Canyon	195	1393	7	1043	high
Miller Canyon near B&B	271	5394	20	1785	high
Miller Canyon	344	12019	35	2658	extreme

MONUMENT FIRE FIGURE 5. RESULTS FOR 10-YEAR FLASH FLOODS					
	Pre-Burn USGS Eq. (cfs)	**Post-Burn Eq. 3 (cfs)**	**Post-Burn / Pre-Burn Ratio**	**Post-Burn Basin Yield (cfs/sq. mi.)**	**Relative Increased Flash Flood Risk**
Hunter Canyon	497	23128	47	11606	extreme
Ash Canyon	697	32266	46	7823	extreme
Copper Canyon	398	17289	43	14028	extreme
Cave Canyon	464	5892	13	3436	extreme
Montezuma Canyon	570	11656	20	4358	extreme
Carr Canyon near Admin.	649	17331	27	4903	extreme
Carr Canyon	762	15821	21	3163	extreme
Yaqui Canyon	413	2463	6	1845	high
Miller Canyon near B&B	603	9385	16	3106	extreme
Miller Canyon	727	20719	28	4582	extreme

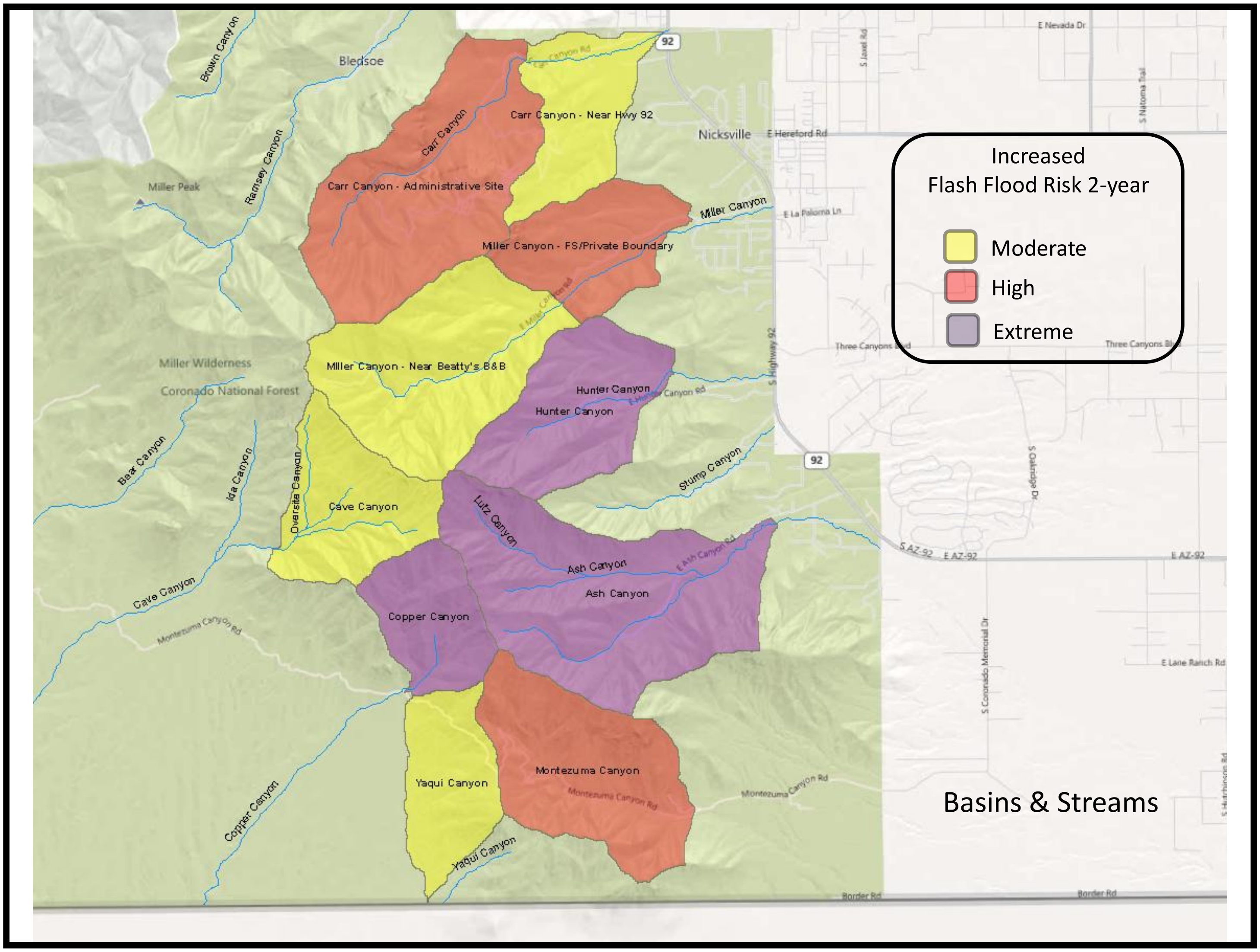
MONUMENT FIRE FIGURE 6. ADDITIONAL RESULTS

	USGS Equation 100-Year Pre-Burn (cfs)	EQ 3 2-Year Post-Burn (cfs)	2-Year Post-Burn / 100-Year Pre-Burn Ratio	est. % water
Hunter Canyon	1390	6542	4.7	40
Ash Canyon	1946	9177	4.7	40
Copper Canyon	1113	4889	4.4	40
Cave Canyon	1296	1610	1.2	80
Montezuma Canyon	1593	3281	2.1	60
Carr Canyon near Admin	1812	4879	2.7	60
Carr Canyon	2128	4448	2.1	60
Yaqui Canyon	1155	653	0.6	80
Miller Canyon near B&B	1685	2599	1.5	60
Miller Canyon	2031	5850	2.9	40

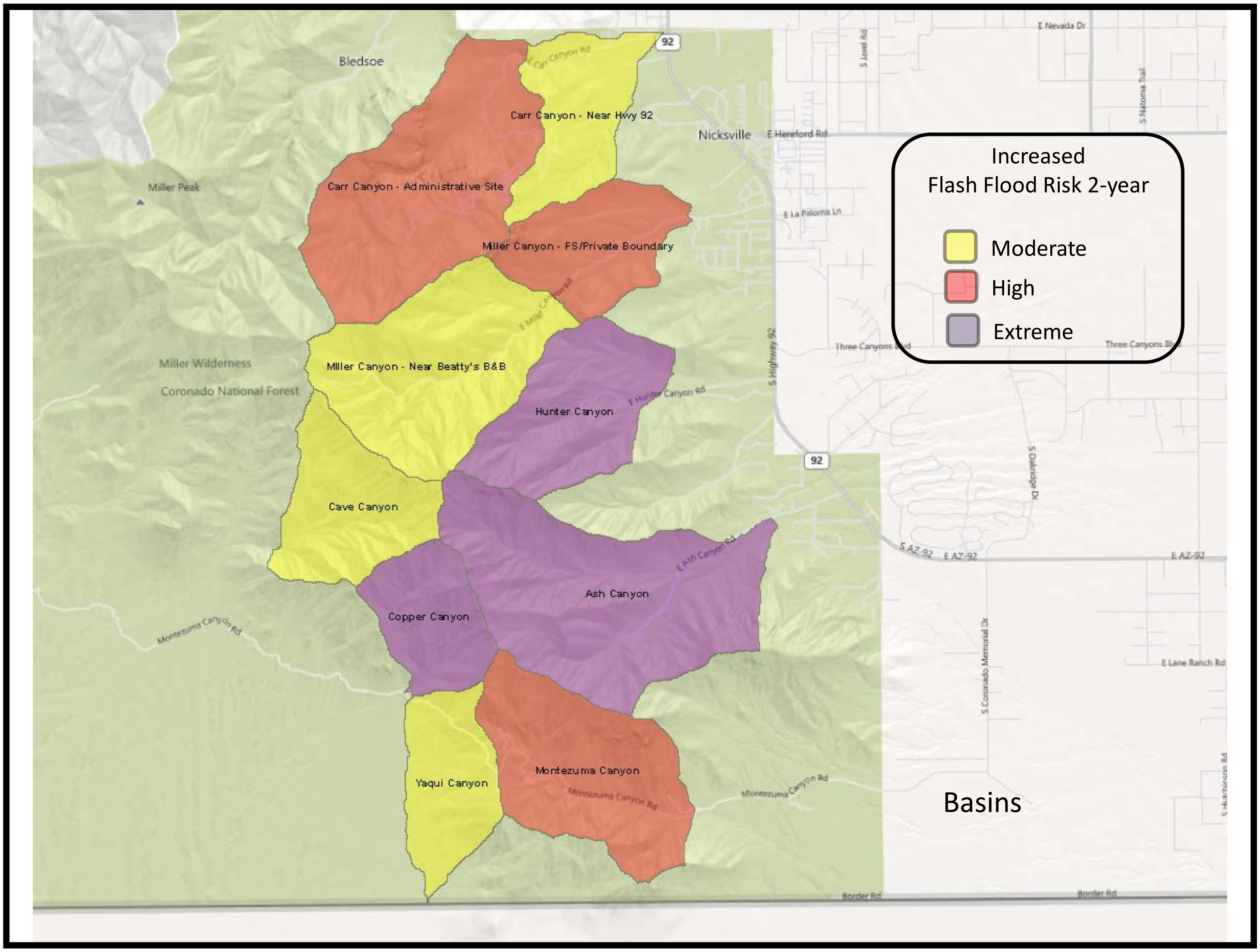
MONUMENT FIRE FIGURE 7. HYPER-CONCENTRATED FLOWS

	Multivariate Index	est. % water
Ash Canyon	13.16	40
Hunter Canyon	9.34	40
Miller Canyon	8.30	40
Copper Canyon	6.98	40
Carr Canyon near Admin.	6.90	60
Carr Canyon	6.26	60
Montezuma Canyon	4.62	60
Miller Canyon near B&B	3.62	60
Cave Canyon	2.23	80
Yaqui Canyon	0.85	80

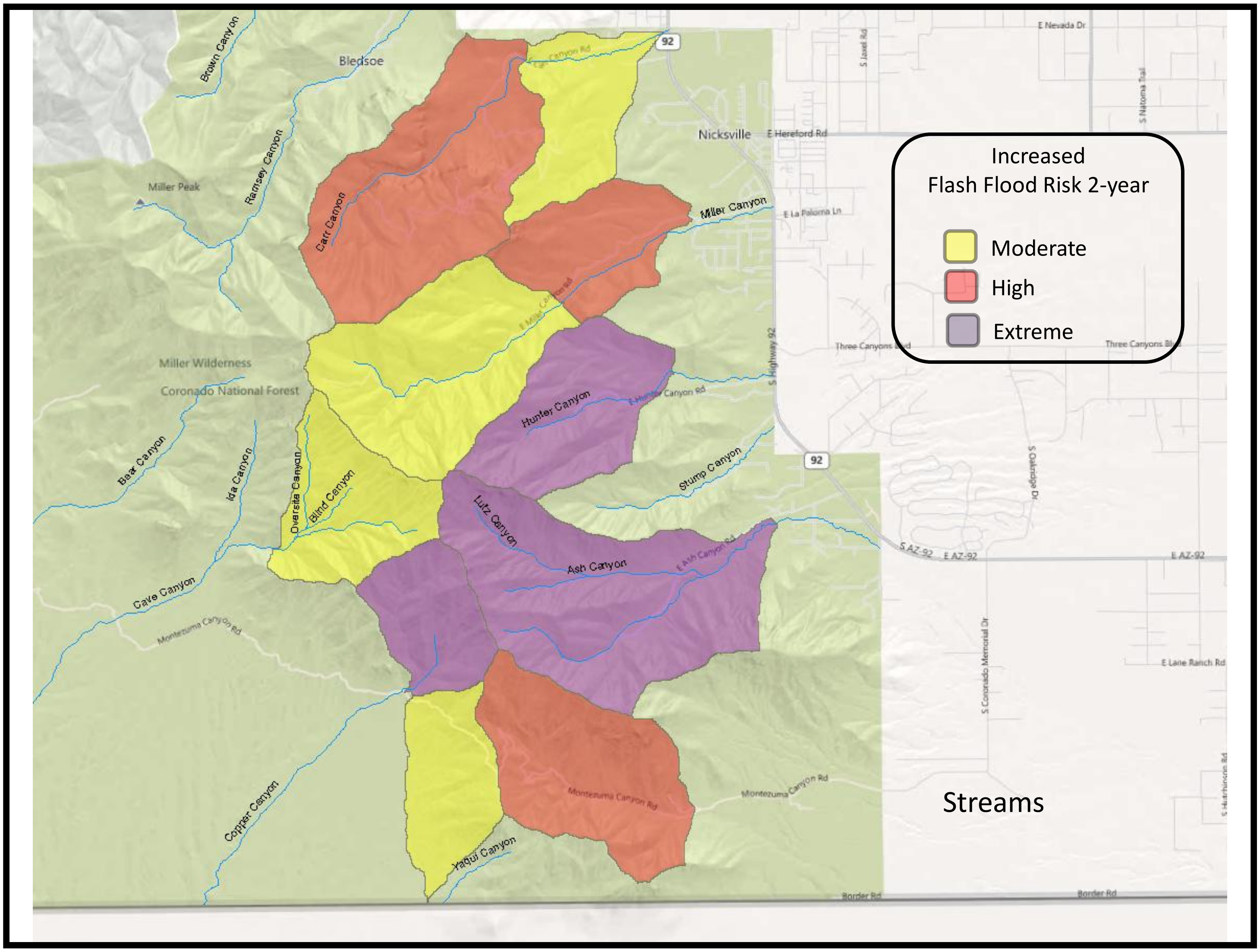
MONUMENT FIRE FIGURE 8. PROJECTED RECOVERY FOR 5-YEAR RETURN FLOWS						
	Year 0 (cfs)	**Year 1 (cfs)**	**Year 2 (cfs)**	**Year 3 (cfs)**	**Year 4 (cfs)**	**Year 5 (cfs)**
Hunter Canyon	13420	10780	8140	5499	2859	219
Ash Canyon	18773	15083	11393	7702	4012	322
Copper Canyon	10030	8058	6086	4114	2142	170
Cave Canyon	3360	2727	2094	1461	828	195
Montezuma Canyon	6755	5459	4164	2868	1573	277
Carr Canyon near Admin.	10039	8092	6144	4197	2249	302
Carr Canyon	9163	7404	5645	3886	2127	368
Yaqui Canyon	1393	1153	914	674	435	195
Miller Canyon near B&B	5394	4369	3345	2320	1296	271
Miller Canyon	12019	9684	7349	5014	2679	344



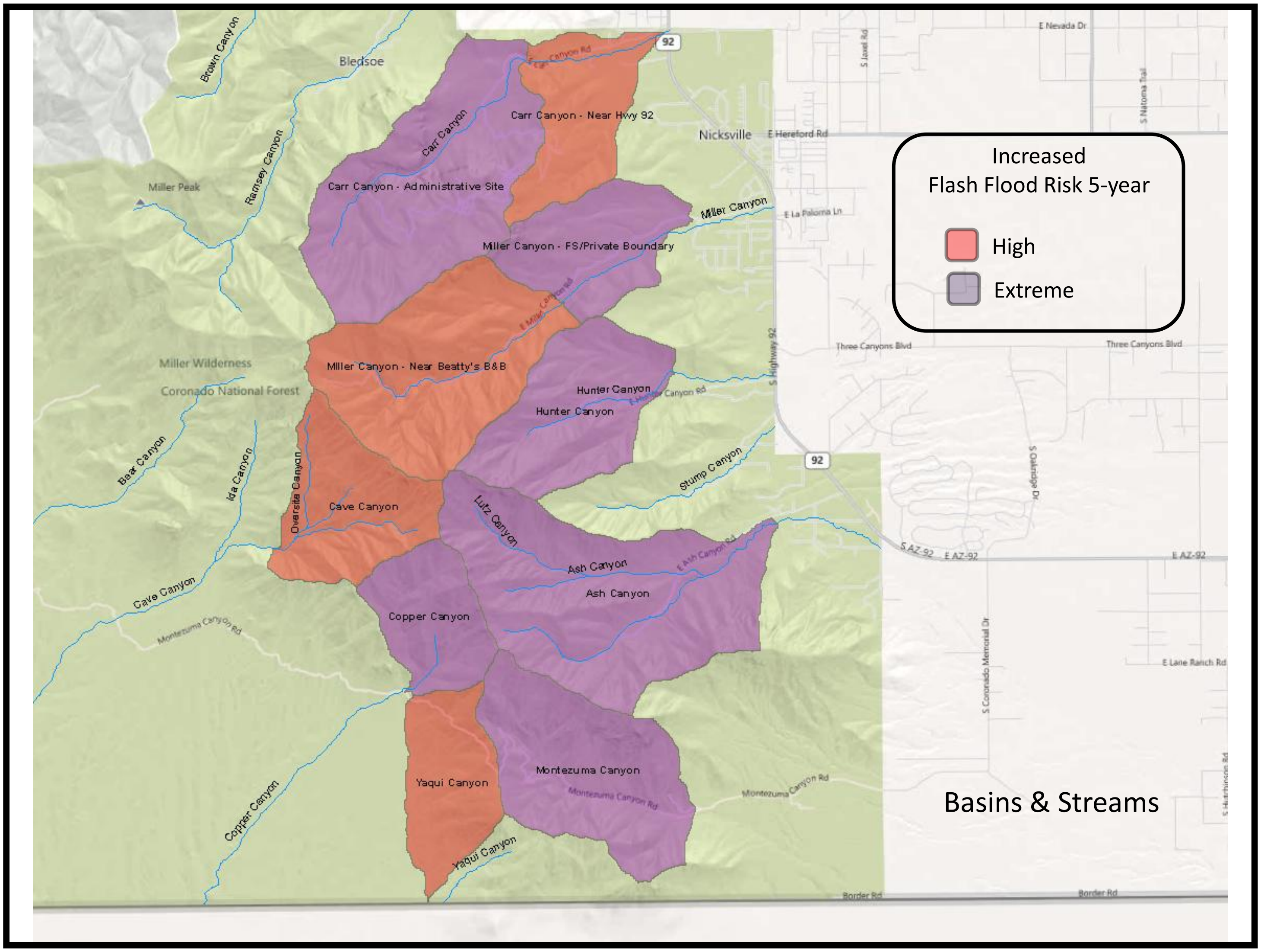
MONUMENT FIRE FIGURE 9. INCREASED FLASH FLOOD RISK 2-YEAR RETURN, BASINS & STREAMS



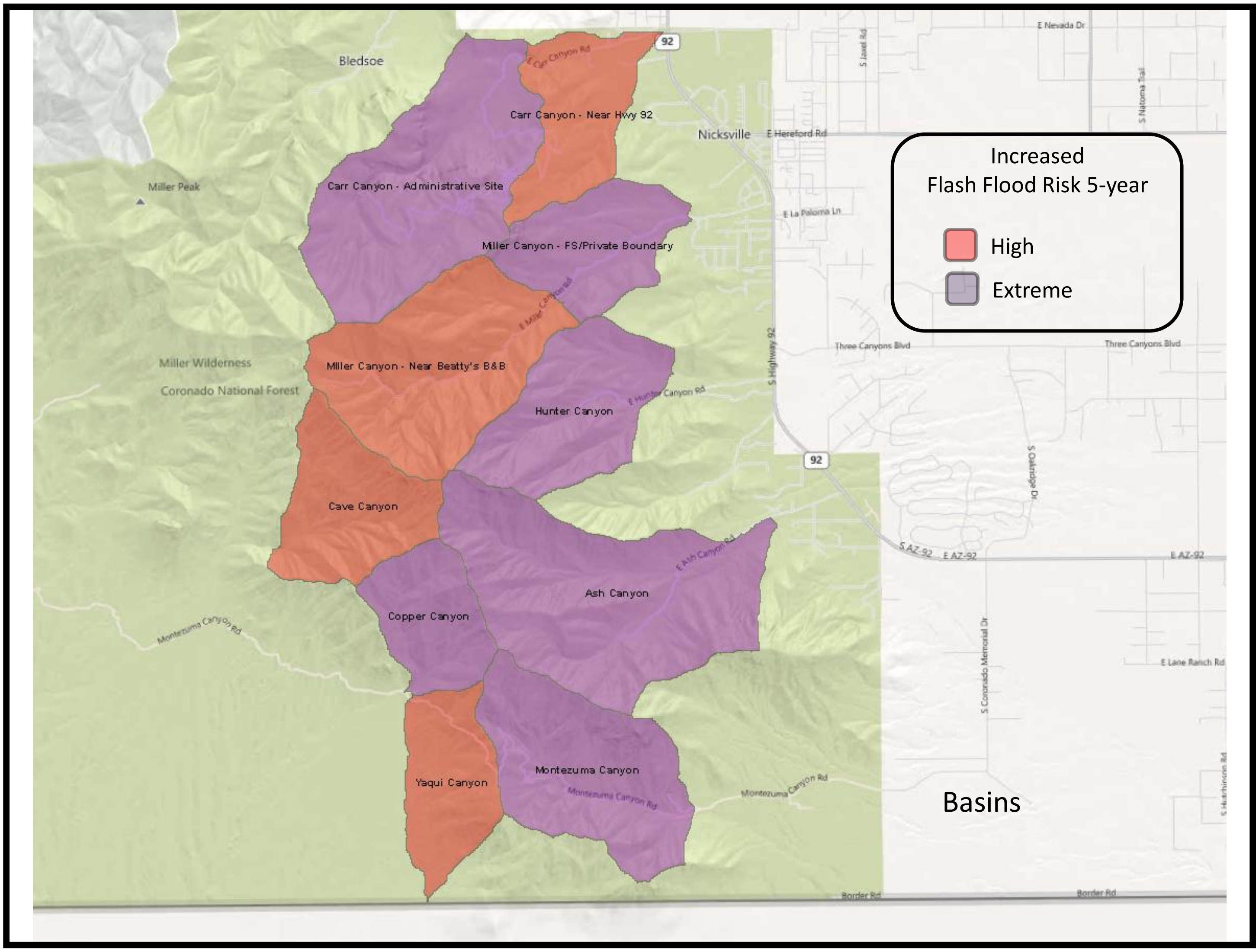
MONUMENT FIRE FIGURE 10. INCREASED FLASH FLOOD RISK 2-YEAR RETURN, BASINS



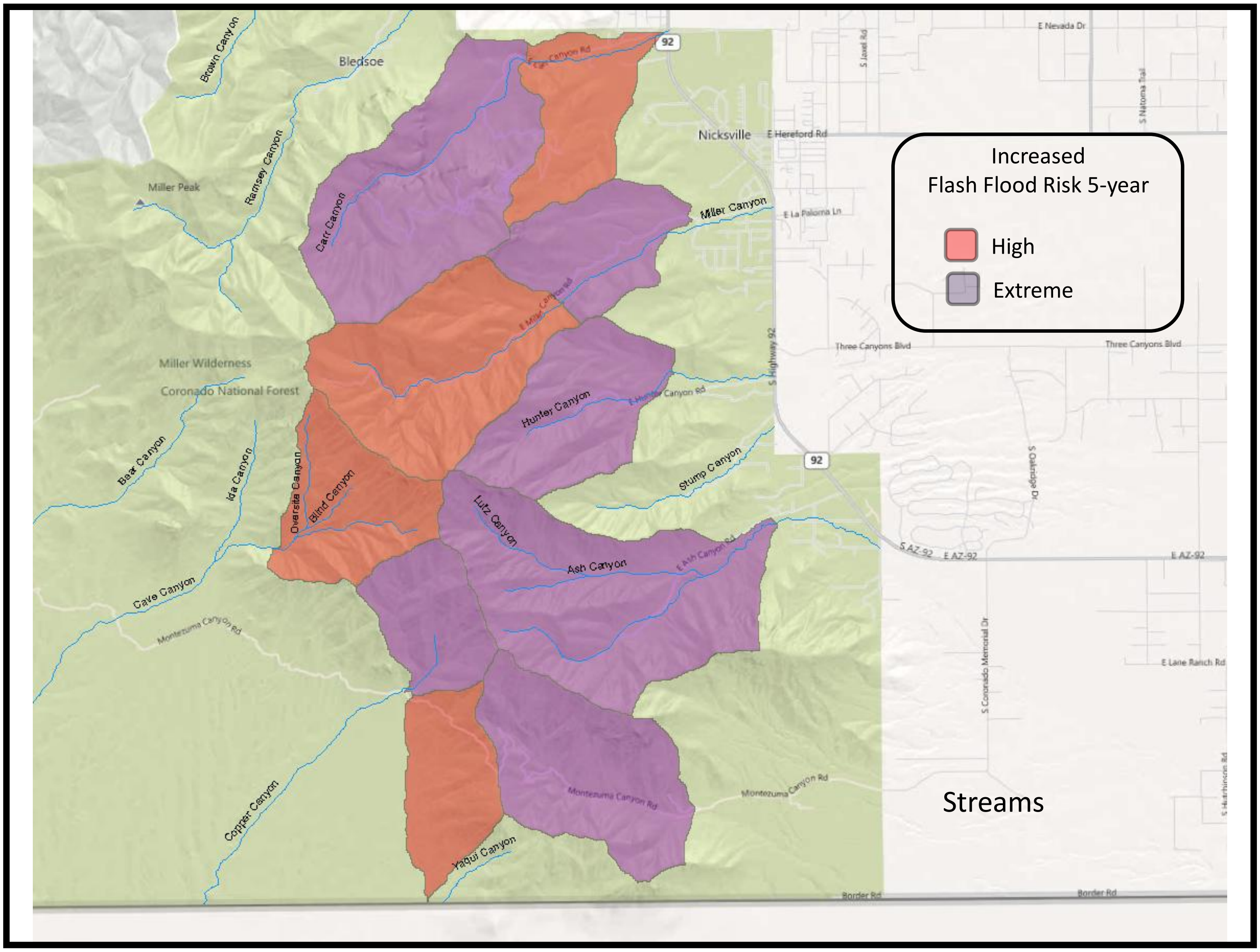
MONUMENT FIRE FIGURE 11. INCREASED FLASH FLOOD RISK 2-YEAR, STREAMS



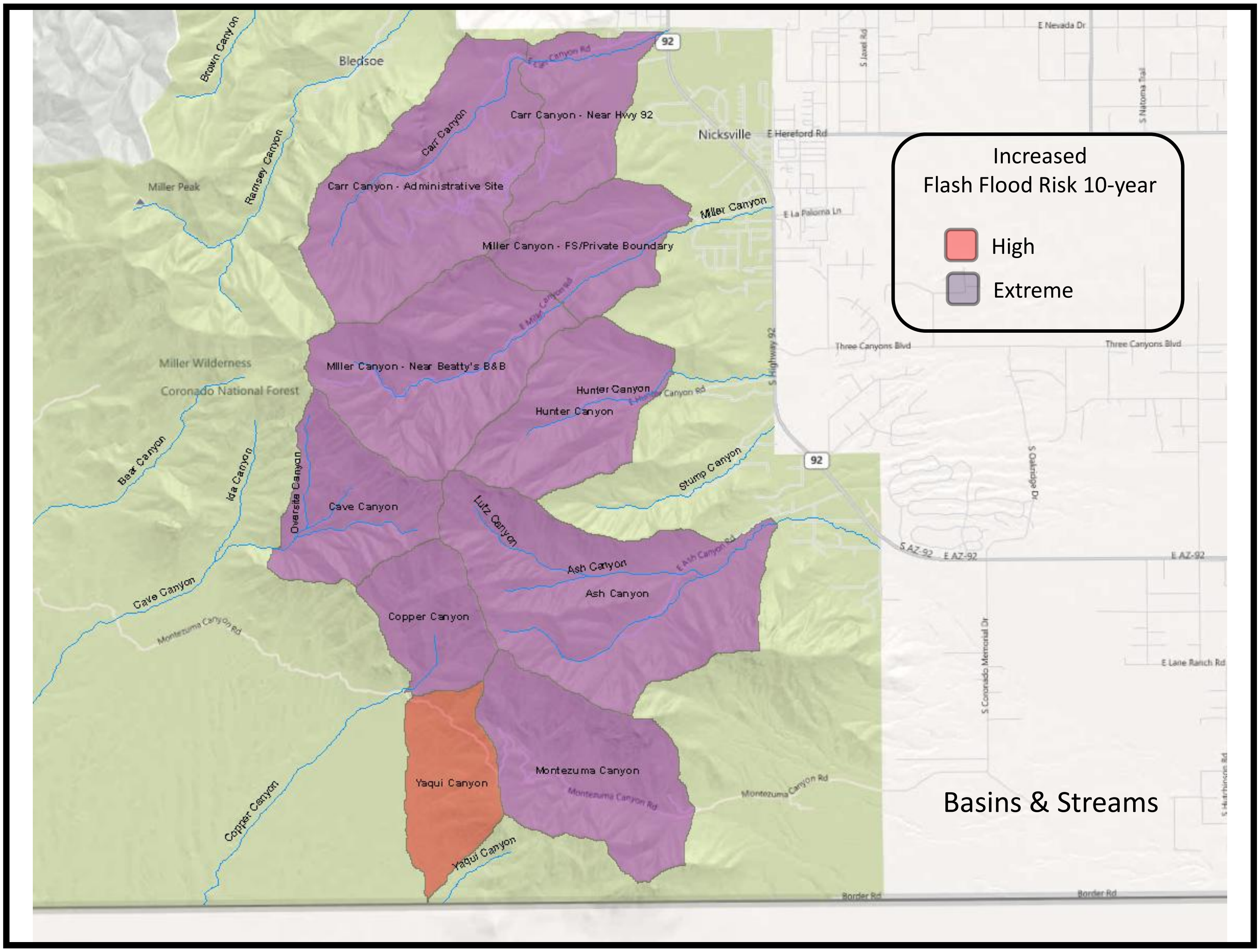
MONUMENT FIRE FIGURE 12. INCREASED FLASH FLOOD RISK 5-YEAR, BASINS & STREAMS



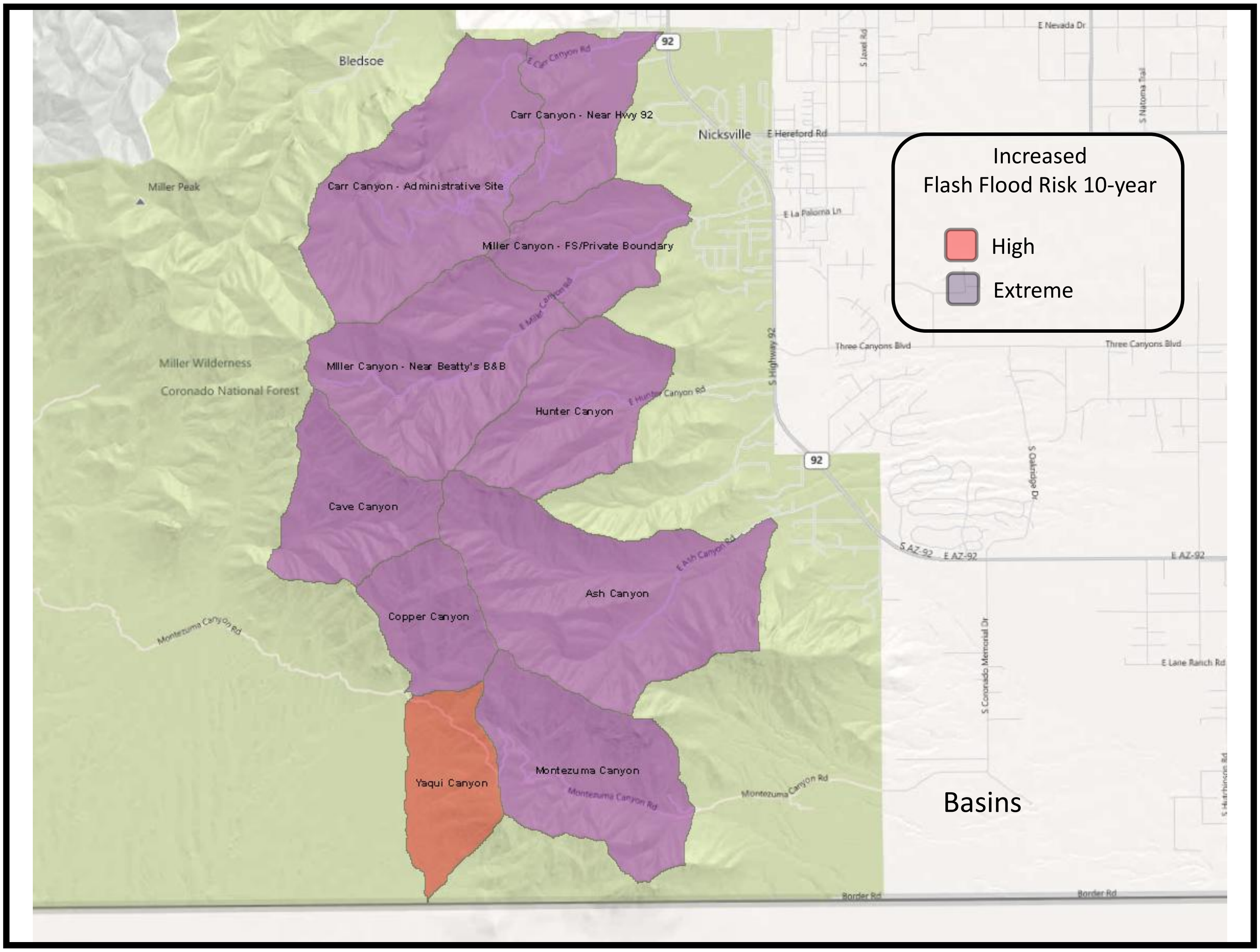
MONUMENT FIRE FIGURE 13. INCREASED FLASH FLOOD RISK 5-YEAR, BASINS



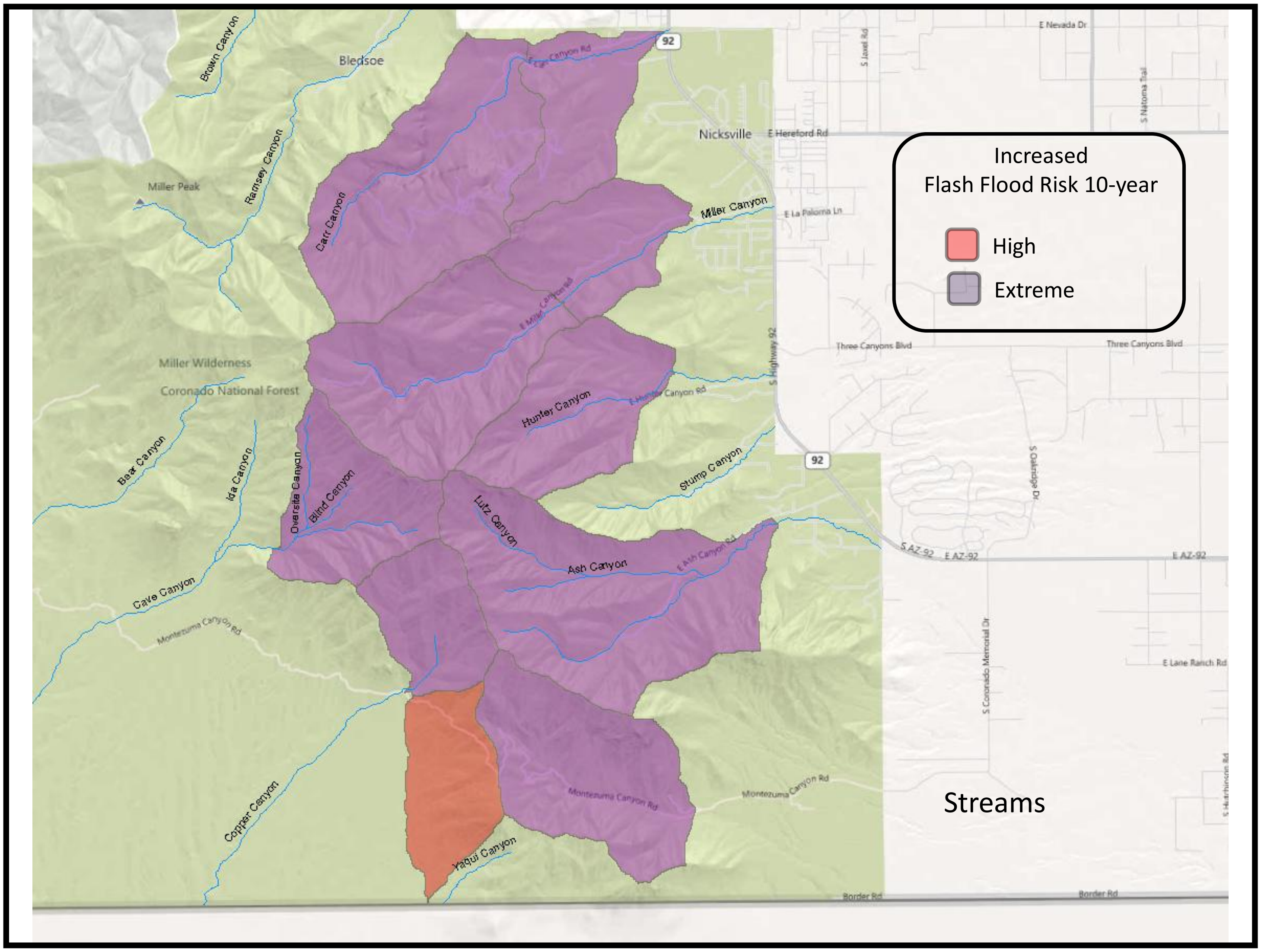
MONUMENT FIRE FIGURE 14. INCREASED FLASH FLOOD RISK 5-YEAR, STREAMS



MONUMENT FIRE FIGURE 15. INCREASED FLASH FLOOD RISK 10-YEAR, BASINS & STREAMS



MONUMENT FIRE FIGURE 16. INCREASED FLASH FLOOD RISK 10-YEAR, BASINS



MONUMENT FIRE FIGURE 17. INCREASED FLASH FLOOD RISK 10-YEAR, STREAMS