Bush Fire – Mesa and Tonto Basin Ranger Districts

Tonto National Forest

June 13th -July 6th 2020

Watershed Specialist Report

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Objectives

- Assess watershed threats to human life and safety have developed as a result of the Bush Fire while minimizing field work due to concerns related to spread of COVID-19.
- Where possible, identify watershed threats property, critical natural resources, and critical cultural and heritage resources.
- Prescribe treatments to prevent, mitigate, or reduce the severity of the threats to human life and safety. Although the COVID environment has restricted our ability to implement treatments for property, critical natural resources, and critical cultural and heritage resources, recommendations from specialists based on the results in this report will be provided where possible.

Initial Concerns

Threats to downstream life and property exist as a result of moderate to high soil burn severity in greater than 35% of the watershed for Cottonwood Creek, Rock Creek, Lambing Creek-Tonto Creek, Mesquite Wash, Mud Springs-Rock Creek, and Slate Creek. Additionally, within Cottonwood Creek, Rock Creek, Mesquite Wash, and Mud Springs-Rock Creek over 85% of the total watershed area is within the burn scar. All of these watersheds contain forest service roads and trails that are at risk as well as recreation sites (Cottonwood Creek-Cottonwood Camp and Saguaro Lake, Mesquite Wash/Mud Springs-Rock Creek – Sycamore OHV area, Rock Creek – Cholla Campground) Threats are derived from the increased likelihood of hyper-concentrated flows, flash floods, and debris flows that have developed from the loss of vegetative ground cover and development of water repellant soils in the burned watersheds.

The primary threats that exist are to:

- Life and safety of users of roads and trails
- Life and safety for users of developed and dispersed recreation sites
- Property for roads and trails
- Cultural resources within and below the burned area.

Resource Condition Assessment

The burned area lies within portions of 22 HUC12 watersheds (Table 1 and Figure 1).

TABLE 1:WATERSHEDS WITHIN BURNED AREA (WATERSHEDS WITH >75% OF THEIR AREA WITHIN THE BURNED AREA HIGHLIGHTED IN GREY)

HUC #	Watershed Name	Total Acres	Acres Burned[1]	% Watershed in Burned Area
150601060103	Apache Lake-Salt River	29,454	11,684	44.1%
150601050409	Ash Creek-Tonto Creek	13,919	1,832	15.7%
150601060102	Buckhorn Creek-Salt River	18,337	8,298	47.6%
150601060302	Bulldog Canyon-Salt River	41,854	587	1.5%
150601050503	Bumblebee Creek-Tonto Creek	17,966	7,581	44.0%
150601060109	Cane Springs Canyon	8,107	6,219	84.2%
150601060110	Cottonwood Creek	32,628	24,645	83.3%
150601050311	Hardt Creek-Tonto Creek Total	17,417	2,127	17%
150601060112	Jones Canyon	12,000	3,584	31.1%
150601050406	Lambing Creek-Tonto Creek	33,398	16,713	60.2%
150602030605	Lower Sycamore Creek	28,327	4,997	19.8%
150602030603	Mesquite Wash	12,666	11,212	97.7%
150602030604	Middle Sycamore Creek	32,885	11,388	37.7%
150601050504	Mills Canyon-Tonto Creek	21,348	7,529	37.0%
150602030602	Mud Springs-Rock Creek	9,851	8,543	98.4%
150601050403	Packard Wash-Tonto Creek	23,721	6,623	32.8%
150601060113	Saguaro Lake-Salt River	12,344	22	>1%
150601050501	Rock Creek	13,861	11,190	83.5%
150601060108	Salt River-Canyon Lake	18,188	971	5%
150601050402	Slate Creek	18,390	11,633	63.0%
150601050407	Sycamore Creek	11,885	4,418	41.9%
150602030601	Upper Sycamore Creek	39,506	15,007	41.5%

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[1] Low, moderate and high severity combined

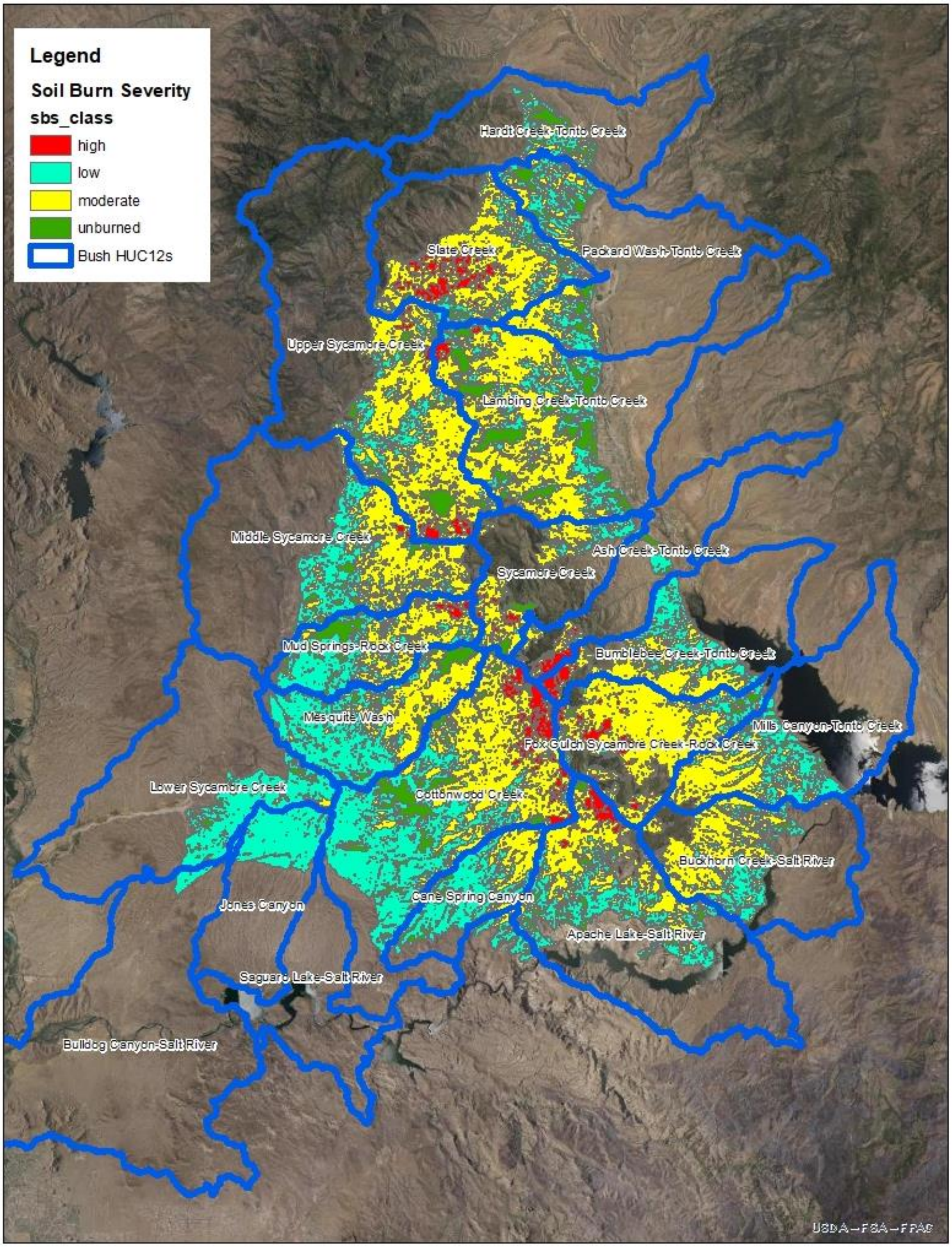

FIGURE 1: HUC 12 WATERSHEDS WITHIN THE BUSH FIRE BURN SCAR AND SOIL BURN SEVERITY

Sixteen of these watersheds have more than 25% of their area within the burn area: Apache Lake-Salt River, Buckhorn Creek-Salt River, Bumblebee Creek-Tonto Creek, Cane Spring Canyon, Cottonwood Creek, Rock Creek, Jones Canyon, Lambing Creek-Tonto Creek, Mesquite Wash, Middle Sycamore Creek, Mills Canyon-Tonto Creek, Mud Springs-Rock Creek, Packard Wash-Tonto Creek, Slate Creek, Sycamore Creek, and Upper Sycamore Creek.

TABLE 2: WATERSHEDS WITH >25% OF AREA IN BURNED AREA AND SOIL BURN SEVERITY (WATERSHEDS WITH >35% MODERATE AND HIGH BURN SEVERITY HIGHLIGHTED IN GREY)

Watershed Name	Acres w/in Burned Area	Outside Burn Perimeter %	Unburned/ Very Low %	Low Burn Severity %	Moderate Burn Severity %	High Burn Severity %
Apache Lake-Salt River	12,986	56%	4%	19%	18%	3%
Buckhorn Creek-Salt River	8,728	52%	2%	18%	26%	>1%
Bumblebee Creek-Tonto Creek	7,910	56%	2%	20%	20%	3%
Cane Spring Canyon	6,830	16%	8%	52%	25%	>1%
Cottonwood Creek	27,174	17%	8%	37%	32%	7%
Rock Creek	11,580	16%	3%	14%	60%	7%
Jones Canyon	3,728	69%	1%	30%	0%	0%
Lambing Creek-Tonto Creek	20,091	40%	10%	18%	31%	>1%
Mesquite Wash	12,372	2%	9%	54%	34%	>1%
Middle Sycamore Creek	12,391	62%	3%	16%	18%	>1%
Mills Canyon-Tonto Creek	7,905	63%	2%	17%	18%	>1%
Mud Springs-Rock Creek	9,690	2%	12%	47%	37%	3%
Packard Wash-Tonto Creek	7,786	67%	5%	16%	12%	0%
Slate Creek	12,242	33%	3%	3%	39%	9%
Sycamore Creek	4,979	58%	5%	12%	22%	3%
Upper Sycamore Creek	16,380	59%	3%	10%	26%	2%

Watershed conditions following a fire, such as loss of stabilizing vegetation, decreased soil porosity, and increased hydrophobicity in soils, are all factors that can increase the magnitude, timing, and volume of stormwater runoff. Additionally, the volume of sediment and ash that these flows can transport can cause aggradation, down cutting, and/or widening of stream channels that can significantly reduce the functioning condition of these channels. The increased peak flows pose a threat to life, property and resources within and below the burned area.

To evaluate threats to Values at Risk as a result of the Bush Fire, watersheds were delineated using USGS Streamstats.[2] The resulting watersheds fall into three categories: 1) finer scale than the HUC 12 watershed, 2) identical or almost identical to the HUC 12 watershed, and 3) aggregation of multiple HUC 12 watersheds. The model used to estimate increase in flows was based on the watershed size. Watersheds smaller than a HUC 12 (and less than 5 square miles) were modeled with Wildcat5 and watersheds larger than 5 square

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[2] https://streamstats.usgs.gov/ss/

miles were modeled with HEC HMS, so that additional sub-basins could be delineated within the larger watershed area. A smaller set of watersheds were also evaluated for initial post fire flash flood estimates using empirical formulas developed by The National Weather Service (NWS) to estimate the magnitude of the initial post fire peak flows for southeastern and central Arizona (Reed, et al. 2012) Assessment methods are described in Appendix A and detailed modeling results are provided in Appendix B. The science of predicting post fire peak flows is not well advanced and the estimates provided in the following tables should be considered ballpark estimates only.

Names of the models, the HUC 12 watersheds they include or are within and soil burn severity are listed in Table 3 and modeled watersheds and HUC 12s are shown on Figure 2.

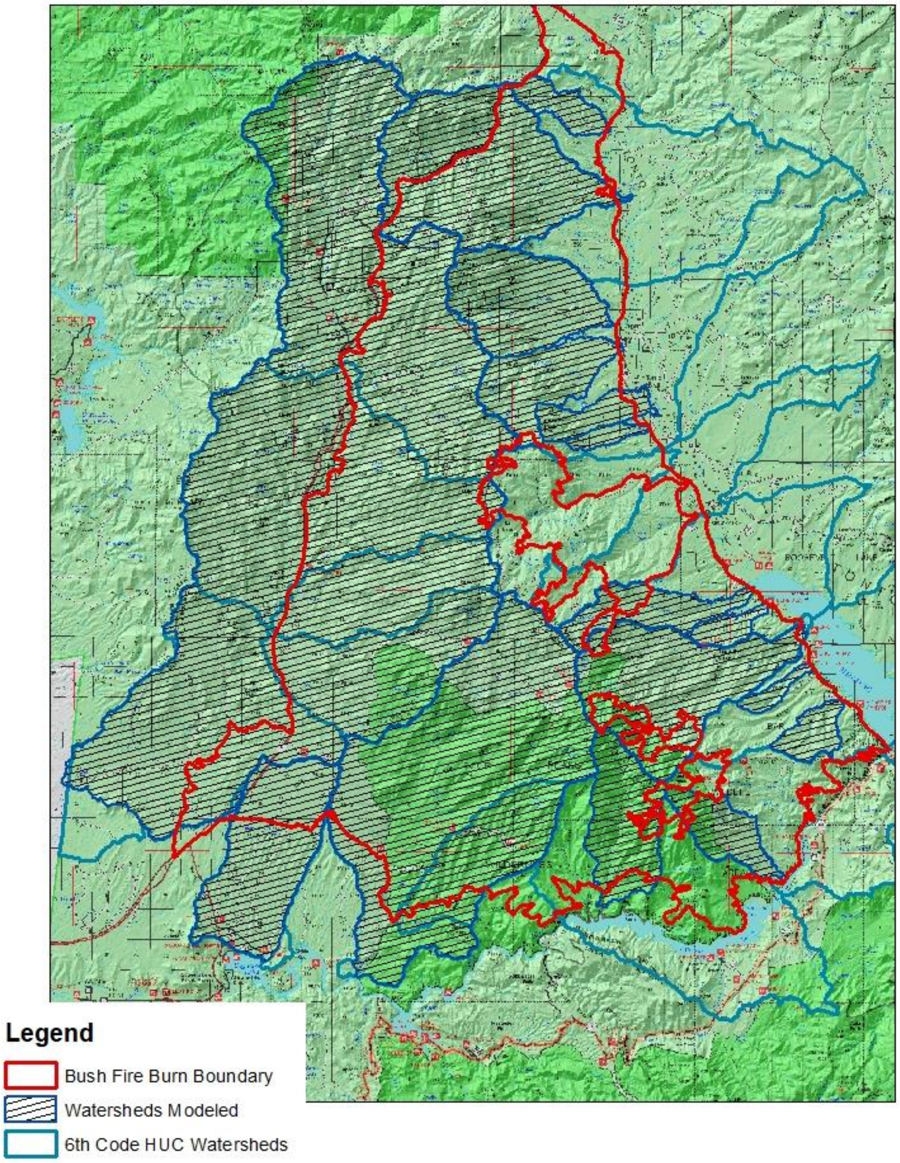


FIGURE 2: OVERVIEW OF MODELLED WATERSHEDS

TABLE 3: MODELED WATERSHEDS AND SOIL BURN SEVERITY

Model Name	HUC12 Name	Total Acres in Model	Total Acres Burned	Acres of Unburned/ Low SBS	% model with Unburned/ Low SBS	Acres of Moderate SBS	Acres of High SBS	% model with Mod/High SBS
Alder CK	Salt River-Apache Lake	6,763	5,036	2,541	38%	2,278	714	44%
Bachelor Rec Area	Mills Canyon	807	739	420	52%	385	0	48%
Bermuda Flat Rec Area	Bumblebee CK	1,211	1,192	287	24%	924	0	76%
Bronco CK	Buckhorn CK	3,287	2,775	867	26%	1,971	14	60%
Bumblebee CK	Bumblebee CK	4,102	2,947	1,052	26%	1,567	519	51%
Burro CK	Lambing CK	805	723	375	47%	429	0	53%
Cottonwood CK (Saguaro Lake)	Cottonwood CK	40,566	30,866	19,249	47%	12,445	2,312	36%
	Cane Spring							
Cottonwood CK (Tonto Basin)	Packard Wash	1,993	1,486	1,454	73%	504	0	25%
Park CK	Lambing CK	5,571	4,381	2,492	45%	2,899	8	52%
Reno CK	Lambing CK	8,815	7,814	3,475	39%	5,064	276	61%
Rock CK	Rock CK	13,805	11,227	3,425	25%	8,262	1,035	67%
Slate CK	Slate CK	18,390	11,633	3,425	19%	7,122	1,695	48%
Sycamore CK	Upper Sycamore CK	119,157	51,364	30,819	26%	24,462	1,384	22%
	Middle Sycamore CK							
	Mud Springs							
	Mesquite Wash							
	Lower Sycamore							
The Rolls	Jones	11,642	3,585	3,694	32%	35	0	0%
Vineyard Rec Area	Mills Canyon	1,776	1,761	1,049	59%	728	0	41%
Walnut Canyon	Lambing CK	2,320	1,528	1,041	45%	895	1	39%

Table 4 displays pre-fire flood flows derived from US Geological Survey regression equations (Paretti, et al, 2014). The peak flood values listed below are derived using data from stream gage stations and therefore do not reflect flows derived from storms of specific intensities or return intervals. However, this table does provide a basis for comparing the magnitude of pre and post fire peak flows from one-hour thunderstorms using rainfall runoff models.

TABLE 4: PRE-FIRE FLOOD ESTIMATES FOR SELECTED INDIVIDUAL WATERSHEDS AFFECTED BY THE BUSH FIRE

Sub-watersheds	2 Year Peak Flood	5 Year Peak Flood	10 Year Peak Flood	25 Year Peak Flood	100 Year Peak Flood
Alder CK	262	1,160	2,150	4,110	8,470
Bachelor	62.8	350	653	1,240	2,510
Bermuda Flat	83.5	485	903	1,710	3,420
Bronco CK	162	754	1,390	2,660	5,440
Bumblebee	188	947	1,780	3,440	7,110
Burro	63.8	384	738	1,450	3,010
Cottonwood CK – Tonto Basin	109	572	1,050	1,980	3,960
Cottonwood CK – Saguaro Lake	837	4,060	7,130	12,700	24,100
Park CK	231	1,110	2,090	4,080	8,540
Reno CK	313	1,550	2,900	5,570	11,500
Rock CK	415	1,940	3,570	6,790	13,900
Slate CK	508	2,360	4,320	8,140	16,500
Sycamore	1,660	8,270	14,700	26,700	51,600
The Rolls	376	2,090	3,560	6,050	10,800
Vineyard	107	579	1,060	1,970	3,880
Walnut Canyon	136	770	1,460	2,830	5,820

Post fire peak flows often begin with an initial flush of water, sediment, ash, and entrained post-burn debris that are sometimes characterized as hyper-concentrated flows (Reed, et al. 2012). The first post fire flows can be substantially higher than the post fire peak flows predicted with typical rainfall runoff models (i.e., Wildcat5 and HEC HMS). Post fire flows have greater energy to scour channels and transport material than do regular rainfall runoff events that occur over unburned landscapes. These flows can cause substantial damage to channels and structures and are a threat to life and property. The magnitude of these flows should decline as ash and debris are transported from the watershed. Once the initial flush of burned material has been washed from the watershed, peak flows are governed more by watershed condition than by post fire ash, sediment and post burn debris.

The National Weather Service (NWS) has developed empirical formulas to estimate the magnitude of the initial post fire peak flows for southeastern and central Arizona (Reed, et al. 2012). These formulas, called the Reed-Schaffner equation, were used to model the immediate post fire environment. The first few high intensity storms following the fire pose the greatest flash flood hazard to downstream areas. National Weather Service equations are suited for watersheds that range from one square mile to twenty square miles in size and have an elevation change of greater than 1500 feet, therefore only some of the watersheds within the burned area were able to be modeled for hyper-concentrated flows due to the limitations of the NWS equations.

Table 5 displays flash flood risks from select watersheds draining the burned area. The risk ratings are based on criteria developed in Reed, et al (2012) and represent risks based on peak flows per square mile. Table 5 is not a comprehensive list of areas with flash flood risk, it is likely that flash flood risks exist at areas other than that shown on the Table 5.

TABLE 5: HYPERCONCENTRATED FLOWS AND FLOOD RISK FOR SELECT WATERSHED AREAS

Flash Flood Risk					
Selected Sub-Watersheds	**Drainage Area (sq mi)**	**Peak Flow/Square Mile (cfs/sq. mi)**			
		Storm Recurrence Interval (yrs)			
		1	**2**	**5**	**10**
Butcher Hook Wash at SR 188	1.3	179	308	633	1101
Chalk Springs Creek at SR 188	1.4	751	1301	2720	4817
Hardt Creek at Jakes Corner	6.8	26	44	90	156
Reno Creek at Tonto Basin (SR 188)	14.3	352	628	1405	2706
Rock Creek above Cholla Campground	21.3	104	183	390	711
Sycamore OHV - SR 87 at Mesquite Wash (Picadilla Ck Drainage)	19.7	187	331	725	1361
Sycamore OHV - SR 87 at Mesquite Wash (Great Western Rd/Rock Ck Drainage)	15.1	177	311	670	1233
Walnut Canyon at SR 188	3.6	453	788	1666	2994

Risk Rating

Low Risk	< 100 cfs/sq. mi
Moderate Risk	100-1000 cfs/sq. mi
High Risk	1000-2000 cfs/sq. mi
Extreme Risk	>2000 cfs/sq. mi

Hydrologic response from the burn scar will be significant (>100% increase) for 72% of the sub-watersheds modelled in the 2-year storm event and 66% of modelled sub-watersheds for the 10-year storm. For the 2-year storm event 23 of the 108 burned sub-basins modelled (21%) have increases of greater than 500% and an additional 32 sub-basins (30%) have increased from no runoff pre-fire to some amount of runoff post fire. For the 10-year storm event 30 of the 108 sub-basins modelled (28%) have increases of greater than 500% and an additional 5 sub-basins (5%) have increased from no runoff pre-fire to some amount of runoff post fire. Table 6 displays changes in peak flows predicted for select sub-basins from the Bush burned area following the initial flushing flows represented by the hyper-concentrated flow estimates. Figure 3 displays increase in flows for all modelled sub-basins. While numerical flows are generated as part of the models (in cubic feet per second, cfs) the volumes should not be assumed to be what was produced by these watersheds prior to the fire or what they will be post-fire. Although the model is uncalibrated, the percent change should provide a good approximation of how peak flows will change due to post-fire soil and vegetation conditions. The table suggests that all watersheds will see a significant increase in flows in some years for some basins except for Packard Wash – Tonto Creek, Buckhorn Creek – Salt River, Mills Canyon, Jones Canyon and Lower Sycamore.

TABLE 6: CHANGE IN PEAK FLOWS DUE TO POST FIRE CONDITIONS FOR SELECT SUB-BASINS (BASINS WHERE A % INCREASE CANNOT BE CALCULATED BECAUSE THERE WERE WOULD NOT HAVE BEEN FLOWS FOR A GIVEN EVENT THAT POST FIRE HAVE FLOWS ARE MARKED WITH + AND ++)

HUC #	**Watershed Name** Subwatershed	**Total Acres**	**Acres w/in Burned Area**	**2 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**10 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**25 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**100 yrs Event Post Fire (cfs)**	**% Increase from Pre Fire**	**Model Type**
150601050403	**Packard Wash-Tonto Creek**	**23,721**	**6,623**									
	Cottonwood Creek Tonto Basin	*1,993*	1,486	742	60%	1,790	60%	2,554	60%	3,917	60%	Wildcat5
150601060102	**Buckhorn Creek-Salt River**	**18,337**	**8,298**									
	Bronco Creek	*3,287*	2,775	1,706	74%	3,762	55%	5,138	48%	7,307	41%	Wildcat5
150601050503	**Bumblebee Creek-Tonto Creek**	**17,966**	**7,581**									
	Bermuda Flat	*1,211*	1,192	586	99%	1,339	69%	1,835	60%	2,688	50%	Wildcat5
	Bumblebee Creek	*4,102*	2,947	2,332	105%	4,962	78%	6,690	68%	9,442	59%	
150601050406	**Lambing Creek-Tonto Creek**	**33,398**	**16,713**									
	Burro	*805*	723	405	80%	916	63%	1,250	57%	1,824	50%	Wildcat5
	Walnut Canyon	*2,320*	1,528	902	80%	2,051	69%	2,818	64%	4,160	57%	
	Park Creek_FSR422	*5,571*	4,381	2,164	304%	4,883	218%	6,734	187%	9,935	155%	
	Eagle Peak	*995*	817	140	++	551	725%	879	467%	1,140	578%	HEC HMS
	Sycamore Canyon Drainage	*1,201*	1,162	224	776%	767	253%	1,186	202%	1,487	191%	
	Punkin Center Transfer Station	*539*	401	30	138%	145	45%	250	40%	311	42%	
150601050504	**Mills Canyon-Tonto Creek**	**21,348**	**7,529**									
	Vineyard Canyon	*1,776*	1,761	973	48%	2,204	36%	3,006	32%	4,340	27%	Wildcat5
	Bachelor Cove	*807*	739	394	64%	918	45%	1,264	39%	1,845	33%	
150601050402	**Slate Creek**	**18,390**	**11,633**									
	SE Baker Mountain	*864*	*853*	273	++	649	1087%	883	505%	1,253	281%	HEC HMS
	Dipper Spring	*1,371*	*1,273*	163	508%	560	116%	841	83%	1,316	61%	
	FS626 Gila	*1,000*	*917*	259	++	666	1460%	927	575%	1,351	296%	
	NorthSR87	*793*	*499*	124	101%	400	44%	586	33%	890	24%	

HUC #	**Watershed Name** *Subwatershed*	**Total Acres** *Acres drained by basin*	**Acres w/in Burned Area**	**2 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**10 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**25 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**100 yrs Event Post Fire (cfs)**	**% Increase from Pre Fire**	**Model Type**
150602030601	**Upper Sycamore Creek**	**39,506**	**15,007**									
	Crabtree Spring	*2,537*	2,109	34	+	379	++	688	++	1,250	++	HEC HMS
	Boulder Creek Trail	*2,253*	2,115	252	++	813	925%	1,204	438%	1,850	244%	
	Juniper Spring	*1,423*	1,394	151	++	520	++	781	++	1,209	402900%	
	Kitty Joe Canyon	*2,752*	1,763	19	+	310	2912%	589	545%	1,107	230%	
150602030604	**Middle Sycamore CK**	**32,885**	**11,388**									
	Mud Springs FSR 1704	*1,042*	1,035	174	++	518	++	746	++	1,112	556050%	HEC HMS
	Ballantine Trail	*5,764*	4,386	484	193%	1,544	77%	2,294	59%	3,531	44%	
150602030602	**Mud Springs-Rock Creek**	**9,851**	**8,543**									
	Ballantine Trail	1,207	1,174	155	++	492	574%	724	304%	1,102	181%	HEC HMS
	Mud Center	2,321	2,254	684	92%	1,582	47%	2,143	37%	3,010	28%	
	FSR11	3,024	2,560	581	38%	1,461	22%	2,035	18%	2,940	14%	
150602030603	**Mesquite Wash**	**12,666**	**11,212**									
	Picadilla Creek - FSR143	5,857	5,037	523	207%	1,534	86%	2,235	66%	3,379	50%	HEC HMS
	Mine Mtn - FSR143	4,459	4,241	978	42%	2,250	25%	3,053	20%	4,304	16%	
150602030605	**Lower Sycamore**	**28,327**	**4,997**									
	FSR 1835	2,706	2,090	534	37%	1,326	21%	1,841	17%	2,652	13%	HEC HMS
	Outlet (All Sycamore Basins)	119,115	51,364	2,632	69%	13,222	67%	22,043	61%	37,911	49%	
150601060109	**Cane Springs Canyon**	**8,107**	**6,219**									
	Cane Springs Canyon	1,657	1,633	468	77%	1,111	43%	1,510	34%	2,136	26%	HEC HMS
	South Moderate Burn	1,288	1,047	153	109%	490	45%	719	34%	1,093	25%	
150601060110	**Cottonwood Creek**	**32,628**	**24,645**									
	North Soldier Trail	4,391	4,356	970	10223%	2,379	415%	3,261	252%	4,720	163%	HEC HMS
	Cold Water Spring/ FSR143	3,347	2,970	227	657%	840	136%	1,278	96%	2,016	67%	
	Outlet to Saguaro Lake	40,735	30,864	3,509	70%	12,295	68%	18,768	70%	28,657	56%	

HUC #	**Watershed Name** *Subwatershed*	**Total Acres** *Acres drained by basin*	**Acres w/in Burned Area**	**2 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**10 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**25 yr Event Post-Fire (cfs)**	**% Increase from Pre Fire**	**100 yrs Event Post Fire (cfs)**	**% Increase from Pre Fire**	**Model Type**
150601050501	**Rock Creek**	**13,861**	**11,190**									
	Big Oak Flat	2,663	2,147	299	++	1,075	878%	1,705	457%	2,810	290%	HEC HMS
	South Three Bar Cabin	755	754	204	376%	613	204%	893	158%	1,361	115%	
	Cholla Campground	351	286	32	+	134	244%	234	210%	421	181%	
150601060103	**Apache Lake-Salt River**	**29,454**	**11,684**									
	Amethyst Spring	1,511	1,401	445	++	1,359	6193%	1,989	1634%	2,993	847%	HEC HMS
	Middle Trail	1,071	866	216	246%	719	135%	1,082	105%	1,678	76%	
	Alder Trail	677	576	224	47%	555	28%	774	24%	1,116	20%	
150601060112	**Jones Canyon**	**12,000**	**3,584**									
	FSR 1832	1,321	1,081	198	45%	538	25%	769	21%	1,149	17%	HEC HMS
	FSR 1343	2,104	804	220	19%	647	12%	941	10%	1,430	8%	

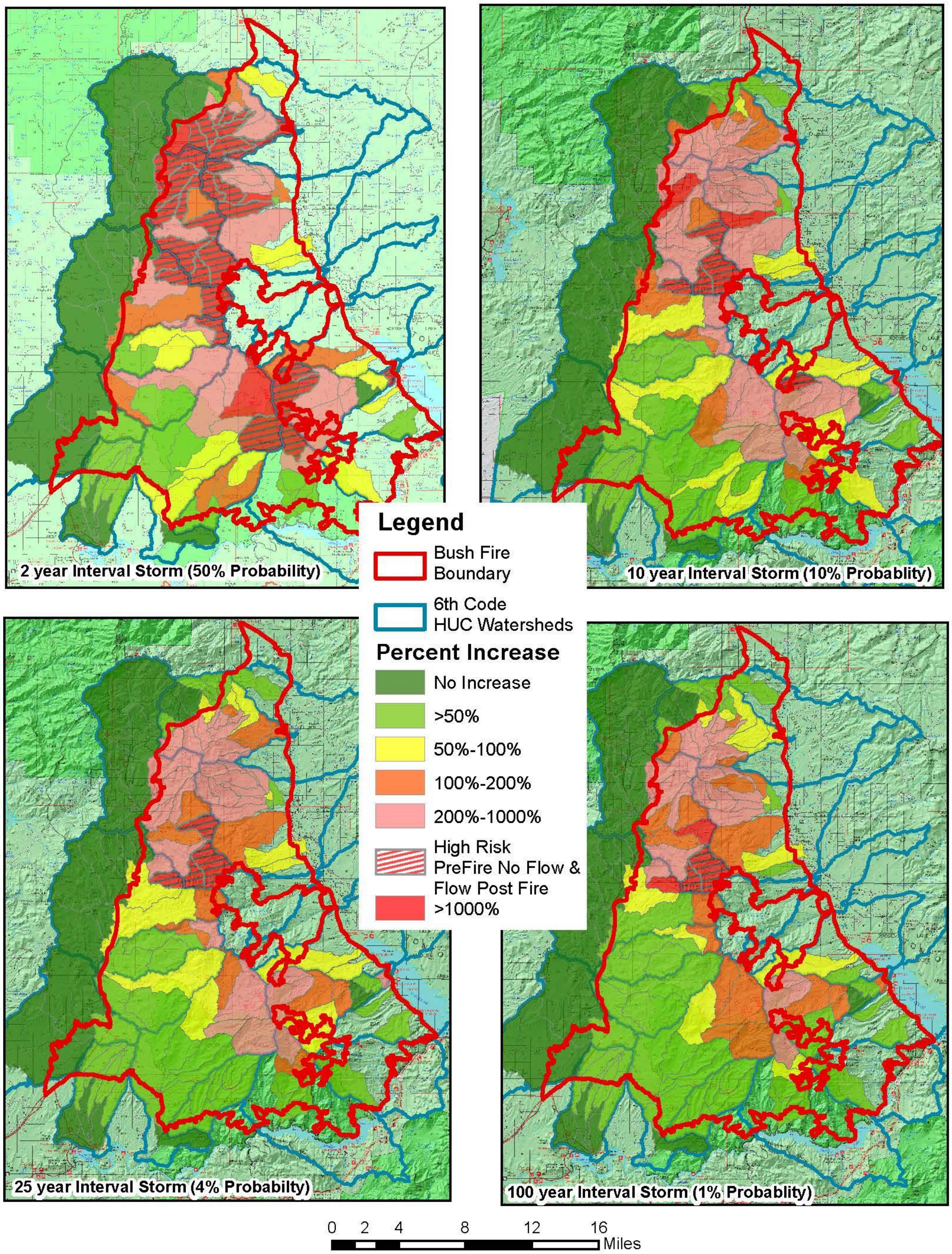


Figure 3 Percent increase in peak flows for the 2, 10, 25 and 100 year storm events

The US Geological Survey has estimated the probability and magnitude of debris flows within and from the burned area and developed a debris flow hazard rating from the combination of these factors for various rainfall intensities for watersheds within the burned area. They have developed debris flow hazard ratings for both watersheds and stream channels. The ratings are displayed on a public website that can be found at: (https://landslides.usgs.gov/hazards/postfire_debrisflow/). This site assesses debris flow hazard for a storm with a peak 15-minute intensity of 24 mm/hr (approximately one inch per hour). They have also developed hazard estimates for storms ranging from 15-minute intensities of from 12 to 40 mm/hr in 4 mm increments. Shapefiles of basin and segment debris flow can be downloaded from the site. According to their analysis most of the perimeter of the burn area is estimated to have a low to moderate level of debris-flow hazard at the modeled rainfall intensities. A smaller number of stream reaches and watersheds on the interior of the burn area have a greater than 50% likelihood of producing debris flows at modest 15-minute rainfall intensities between 12 and 24 mmh-1. The stream segments with the greatest likelihood of debris flows (>60%) occur in the southeastern portion of the burn area in the vicinity of Browns Peak and Four Peaks. Most watersheds are estimated to produce debris-flow volumes between 10,000 and 100,000 m^3. The three largest watersheds in the southern half of the burn area are estimated to produce debris-flow volumes between 10,000 and 100,000 m^3, including most of the high probability stream segments and basins on the burn area interior. Figure 4 provides a visual representation of debris flow risk for the 12mm per hour and 24 mm per hour events.

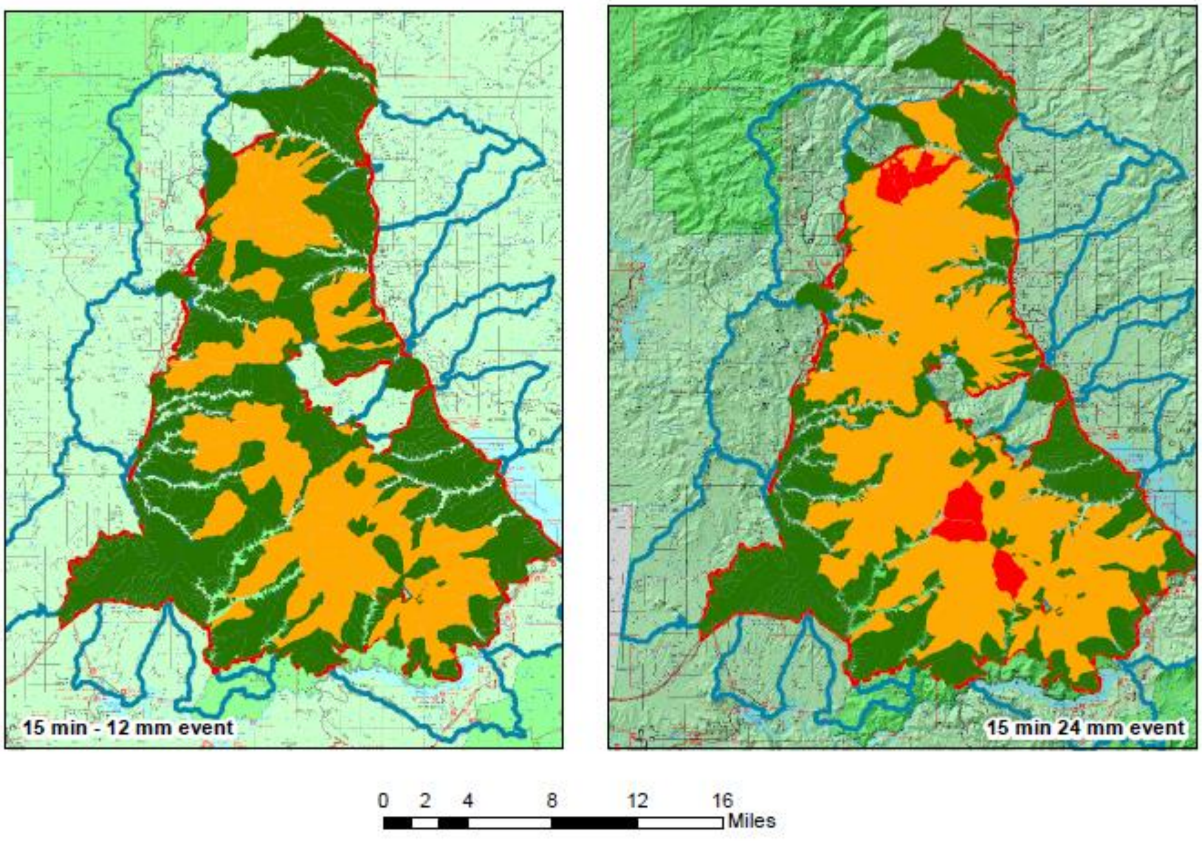


FIGURE 4: DEBRIS FLOW HAZARD FOR BUSH BURN SCAR

Emergency Determination

1. Threats to downstream life and property from post-fire watershed conditions (increased peak flows, potential hyper-concentrated flows, and debris flows).
2. Threats to hydrologic function (magnitude, timing, and volume of storm water runoff) and changes in the condition of stream channels from post fire runoff and sediment.
3. Threats to life and property on forest service roads, trails, and developed and dispersed recreation sites from increased peak flows (flash flooding), hyper-concentrated flows and debris flows and from rolling rocks, and falling limbs and trees.
4. Threats to forest service infrastructure (roads, trails, and recreation sites) from post-fire watershed conditions.
5. Threats to life and property for users of Forest Service recreation facilities, particularly Cottonwood Camp and Sycamore Creek OHV area and washes adjacent to recreation sites on Roosevelt Lake, due to post fire watershed conditions.
6. Threats to cultural resources from post-fire watershed conditions.

Treatments to Mitigate the Emergency

1. Given the focus on human life and safety the primary recommendation is to restrict access where increased flows are anticipated through November of 2020. This will ensure public health and safety during the monsoon season and during the time when Arizona receives tropical storms. Opening these areas should be revaluated in November based on damage from storms. If no significant rainfall has occurred by November it is advisable to keep these areas closed until at least one seasons worth of vegetative recovery has occurred. Specific recommendations for areas to be closed can be found in the recreation specialist report.
2. Restrictions on field work have prevented verification of areas to remove floatable debris from stream channels to prevent development and failure of debris jams that can increase the magnitude of peak flows and threaten downstream NFS property and other downstream resources. The following are a list of areas based on a desktop review of road proximity to channels in areas with moderate to high soil burn severity, modelled increase in flows >100% and intermittent streams that would have burned riparian vegetation that could be good candidates for floatable debris removal.
    - Mesquite Wash for 2 miles from crossing with SR 87 to protect Sycamore Creek OHV area and FSR 11
    - Picadilla Creek for ¼ mile upstream where it crosses the FSR 143 at approx. -111.417 33.729
    - Un-named intermittent streams for ¼ mile where they cross the FSR 143 at -111.381 33.71, -111.371 33.711, and -111.37 33.71
    - Fox Gulch for a ¼ mile above the crossing with FSR 445 (-111.29 33.728) and Rock Creek for a ¼ mile above crossing with FSR 445 (-111.299 33.72)
3. Improve drainage (ditches, culverts, sloping of road surface) on Forest Roads within and below the burned area to reduce potential damage to road infrastructure. See engineering and roads specialist report for specific recommendations.
4. Improve drainage on Forest Trails within the burned area (water bars, drains, grade dips, strategic mulching where effective) to protect trail infrastructure. See recreation specialist report for specific recommendations for trail treatments.

5. Place warning signs on roads and trails traveling through or beneath the burned area to warn forest users of the potential for flash floods, rolling rocks, and falling limbs. See recreation and roads specialists reports and treatment area map for specific locations for warning signs.
6. Provide for storm inspection and response on roads within and below the burned area to ensure drainage structures are functioning properly and to clear accumulated sediment and debris from the road surface.
7. Provide information to other agencies (local, state, and federal) about the potential hazards from the burned area so they can prepare for post-fire emergency conditions off-forest.
8. Assist other agencies with development of emergency warning systems by streamlining the permitting process to place necessary emergency equipment on NFS lands.
9. Recommend evaluating allotments within the burn area prior to authorizing grazing. Areas should not be grazed until damaged infrastructure to prevent riparian grazing where applicable is repaired and evaluation of vegetation and soil conditions indicate that watershed conditions to have recovered. See Apache-Sitgreves NF protocol for allotment evaluation post-fire for a recommended process for determining recovery.

Summary

The Bush Fire burned with primarily low severity in the Sonoran desert and Sonoran grassland ecosystem types, but included significant areas of moderate and smaller areas of high soil burn severity in the chaparral, ponderosa pine, evergreen oak and pinyon juniper vegetation types. Clearing floatable debris from stream channels is proposed to reduce the likelihood of debris jams forming and failing which could increase peak flows above those generated by the watershed itself and damage downstream structures as well as threaten life and property.

Consultations and Findings

1. Jaime Kostelnik and Dennis Staley and of the US Geological Survey conducted modeling of debris flow potential from the burned area and provided shapefiles of debris flow probability and volume for watersheds and channel segments draining the burned area.
2. Mike Schaffner with the National Weather Service discussed the rainfall intensities that could be used for setting flash flood warnings.
3. David Callery, hydrologist in Region 1 and BAER team hydrologist provided review of modeling and advice on approach to BAER hydrology generally.

References

Hawkins, R.H. and Barreto-Munoz, A., 2016. Wildcat5 for Windows, a rainfall-runoff hydrograph model: user manual and documentation. Gen. Tech. Rep. RMRS-334. Fort Collins, Co: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 68 p.

Paretti, N.V., Kennedy, J.R., Turney, L.A., and Veilleux, A.G., Methods for estimating magnitude and frequency of floods in Arizona, developed with unregulated and rural peak-flow data through water year 2010: U.S. Geological Survey Scientific Investigations Report 2014-5211, 61 p.,

Reed, William, Michael Schaffner, Chad Kahler, and Erin Boyle, 2012. 2011 Wildfire in the Mountainous Terrain of Southeast Arizona: Verification of Empirical Formulas used to Estimate from

1-Year through 10—Year Peak Discharge from Post-Burn Watersheds and Associated Increased Flash Flood Potential of Post-Burn Hyper-Concentrated Flows. NOAA Technical Memorandum NWS WR-285.

NOAA National Weather Service Hydrometeorological Design Studies Center, Precipitation Frequency Data Server, NOAA Atlas 14 Point Precipitation Frequency Estimates: Az. website https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=az accessed 5/28/2017

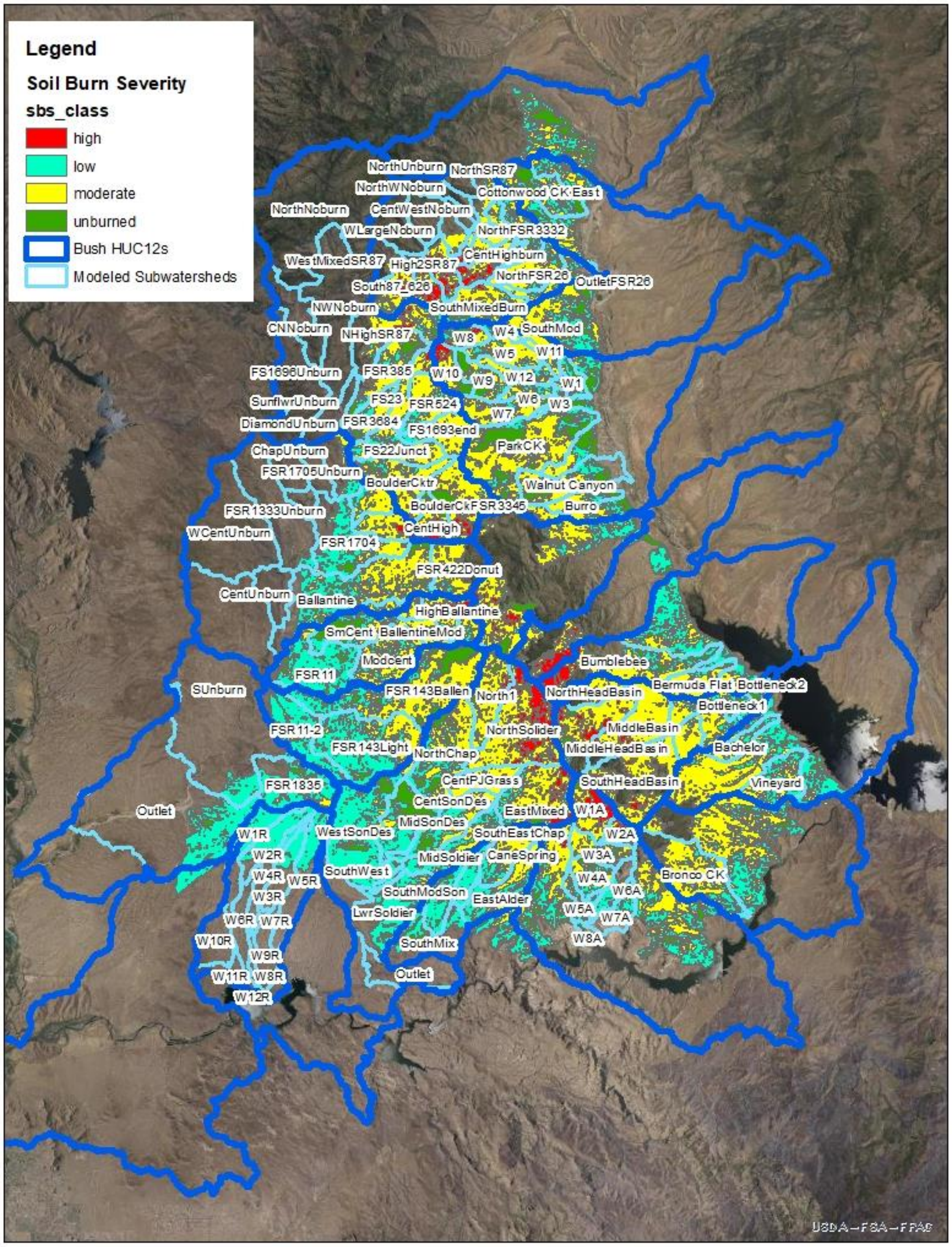
US Geological Survey StreamStats Website: https://ssdev.cr.usgs.gov/ss3/ Accessed 6/6/2017

Appendix A

Assessment Methodology

Fifteen models were created based on values at risk – primarily human safety concerns. models were created in HEC-HMS and the remaining nine were created in Wildcat5. See Figure A1.

Figure A1



For Wildcat5 watersheds (Bachelor Recreation Area, Bermuda Flat Recreation Area, Bronco Creek, Bumblebee Creek, Burro Creek, Cottonwood Creek (Tonto Basin), Park Creek, Vineyard Recreation Area, and Walnut Canyon) the area of analysis was delineated using StreamStats, these boundaries were brought into ArcGIS, and then acres by severity were determined for each watershed. Partial duration series based precipitation frequency estimates for the burned area were downloaded from NOAA and estimates for the 60-minute duration storm, which is similar to a monsoon storm, were used for the analysis. A custom storm distribution was created in Wildcat5 using NOAA Atlas-14 data percentages. Dunne and Leopold's (1978) equation based on measurements of stream length made through StreamStats was used to calculate time of concentration. Pre-fire curve numbers were determined based on Terrestrial Ecological Unit Inventory identification of the hydrologic soil group, vegetation type, and condition (Casillas personal communication 06/2020). Post-fire curve numbers were determined based on soil burn severity and applying the following general curve numbers based: light = +5 to the pre-fire CN, moderate = 87, high = 92. These post-fire CNs were adjusted when the pre-fire CNs were over 87 to start with to just add 2 CNs to for each severity type, e.g., original of 87 would equal light = 89, moderate = 90 and high 92.[3] The rainfall, time of concentration, and curve number data were entered into Wildcat5 (Hawkins and Barreto-Munoz, 2016) for each watershed and the 2, 5, 10, 25, and 100 year storms were run for pre and post fire conditions. The simple triangular unit hydrograph was used for all model runs. Results for each watershed were saved into an excel file with tabs for the different model runs.

For HEC-HMS watersheds (Sycamore Creek, Alder Creek, Cottonwood Creek, Reno Creek, Rock Creek, Slate Creek and Jones Canyon) an updated draft version of R3 white paper was used to create the model. Briefly, model parameters were established using ArcHydo and GEO-HMS. Watersheds were deliniated within GEO-HMS based on selected pour points, which were all at or near the outlet of the HUC12 watershed, or in the case of the 5 HUC 12 watersheds modeled for Sycamore Creek and the 2 for Cottonwood Creek ath outlet of these systems. A CN-grid was created for the HEC HMS models to calculated the weighted average of CNs for each sub-basin pre and post fire. The basins were deliniated to create hydrologic response units based on TEUI unit and the soil burn severity. Post-fire CNs were determined using the same methodology as that of the Wildcat5 watersheds. Lag time was determined using Dunne and Leopold's equation based on the longest flow path calcuation in ArcGIS and the elevations at the outlet and most upstream points on the longest flow path. Transform method used was the SCS unit hydrograph and it was assumed that there was 0% impervious area in the watershed. Routing method was Muskingum-Cunge with length and slope of the channel determined through GEO-HMS, bottom width and side slope through measurements of NAIP imagry, and index of flow based on gauge data where available or bankfull discharge from regional curves within Moody 2007 report where gauge data were not available.[4]

Metorologic models for HEC-HMS were built for 2, 5, 10, 25, and 100 year storms using NOAA Atlas 14 partial duration series based precipitation frequency estimates for the burned area. Storm

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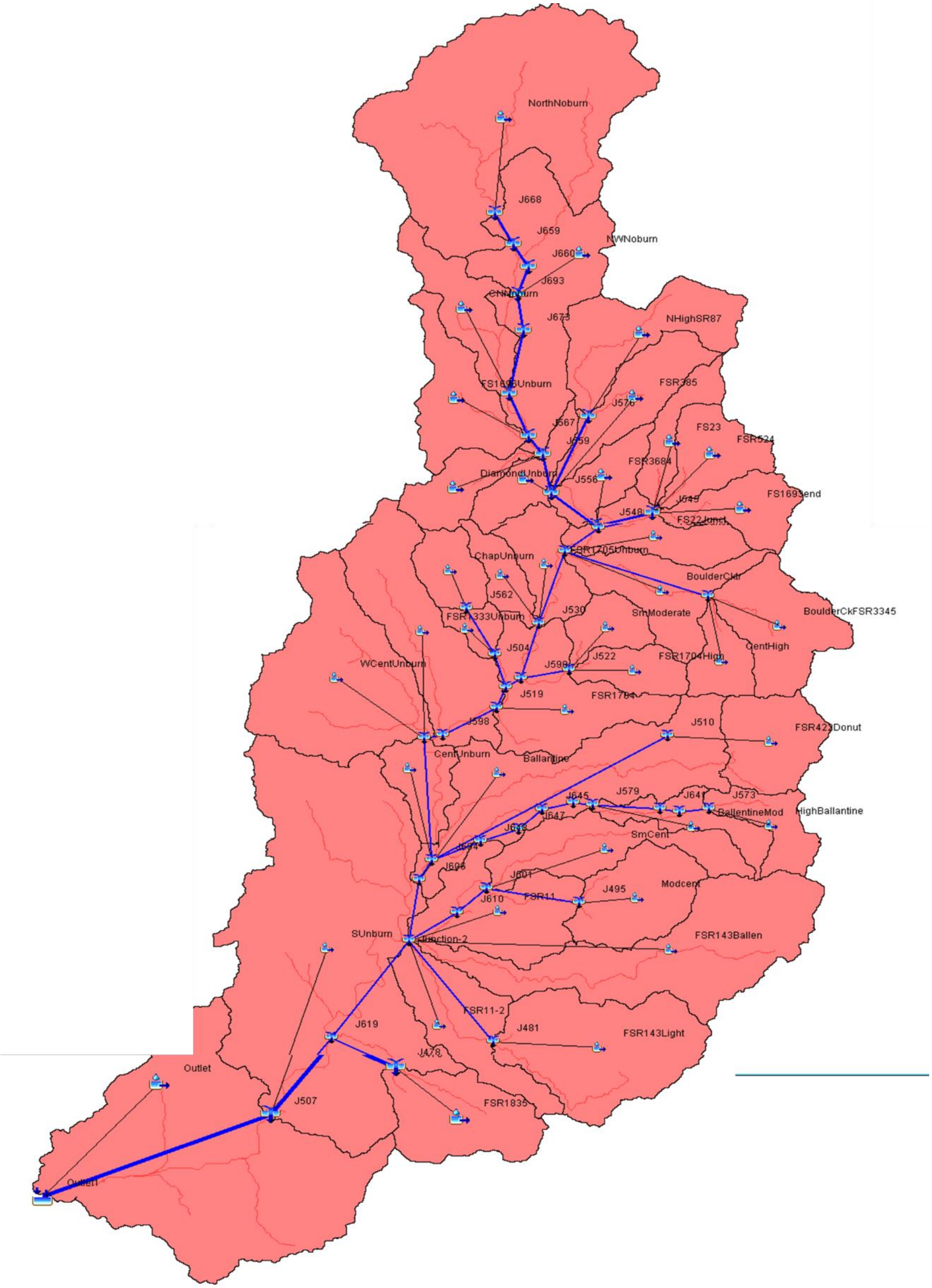
[3] Post-fire CNs were based on advice from Greg Kuyumjian where moderate soil burn severity acreage was assumed to be ½ hydrophobic and high was assumed to be all hydrophobic.

[4] A sensitivity test of the index flow parameter preformed during the Woodbury BAER assessment in 2019 where peak flow gauge data were available showed minimal (+/- 10 cfs) difference in using actual peak flow data compared to bankfull discharge data, despite peak data being >10x the bankfull discharge. It was therefore determined to be acceptable to use bankfull discharge data for this parameter.

duration was 60 minutes, with an intensity duration of 5 minutes, intensity position of 33%, and data from NOAA Atlas 14 entered for the 5, 15, and 60-minute rainfall. Because these watersheds were all over five square miles, storm area reduction using TP40 was used by entering the total watershed size into the meteorological model. The resulting discharge from each basin mimics a thunderstorm, however, the overall discharge for the larger basins (e.g., outlet of Sycamore or Cottonwood Creeks) would be more like a one hour frontal storm that covered the entire watershed area because the flows are cumulative from each basin and the model has “rained” over each basin.

Simulation runs were then created for each year pre and post fire. An visual example of a HEC-HMS watershed model is shown in Figure A2. Results for each watershed were saved in a separate excel workbook, with tabs for each pre-post fire event and raw data exported from ArcGIS used to calculate routing, time of concentration, and pre/post fire CNs.

Figure A2 Visualization of Sycamore Creek HEC-HMS Watershed Model



Methods for estimating peak flows in StreamStats and through Wildcat5 or HEC-HMS are different, however, using StreamStats as a comparision for pre-fire conditions can be a useful metric to determine relative confidence in the model. Model, either Wildcat5 or HEC-HMS, concurrence with StreamStats figures is show in Table A1.

Table A1 Model Concurrence

Model Name	Model Type	Concurrence with StreamStats
Cottonwood CK East	Wildcat5	Fair
Burro	Wildcat5	Good
Walnut Canyon	Wildcat5	Good
Park CK	Wildcat5	Good
Reno CK	HEC HMS	Poor (~75% low)
Rock CK	HEC HMS	Fair
Bermuda Flat	Wildcat5	Good
Bumblebee CK	Wildcat5	Good
Bachelor	Wildcat5	Good
Vineyard	Wildcat5	Poor (100+ high)
Bronco CK	Wildcat5	Poor (100+ high)
Alder CK	HEC HMS	Good
Slate CK	HEC HMS	Poor (~75% low)
Sycamore	HEC HMS	Fair (~50% low)
Cottonwood	HEC HMS	Good
	HEC HMS	Good
The Rolls	HEC HMS	Good

Very Good < 20% difference w/5yr and 10 yr. StreamStats for watershed

Good 20% - 30% difference w/5 yr. and 10 yr. StreamStats for watershed

Fair 30%-50% difference w/5 yr. and 10 yr. StreamStats for watershed

Poor 50%-70% difference w/5 yr. and 10 yr. StreamStats for watershed

Very Poor >70% difference w/ 5yr and 10 yr. StreamStats for watershed

Hyper-concentrated flow modeling

Equations for modeling hyper-concentrated flows are from:

William Reed, Michael Schaffner, Chad Kahler, and Erin Boyle, 2012. 2011 Wildfire in the Mountainous Terrain of Southeast Arizona: Verification of Empirical formulas used to

Estimate from 1-year through 10-year peak discharge from Post-burn Watersheds and Associated Increased Flash Flood Potential of Post-Burn Hyperconentrated Flows, NOAA Technical Memorandum NWS WR-285

Equation 12 from this reference was the method used to estimate these flows. It is:

$Qt = 55.819(mvi1)^{2} + 2138.9(mvi1)$.

Where the multivariate runoff index (mvi) for 1 to 10 year events is
$(mvi1) = 1000(\alpha\psi)^{0.51}\beta^{1.91}\phi^{-1.99}\lambda^{0.78}$

α = fraction of total watershed with moderate or greater burn severity (square miles/square miles)
ψ = total drainage area (square miles)
β = modified channel relief ratio (feet/feet);

The modified channel relief ratio in feet/foot is the average slope of the basin along the first order channel measured from 1,250 feet below the ridge to the basin basin outlet.

φ = average basin elevation above mean sea level (thousands of feet)
λ = recurrence interval of rainfall (t-years).

Equation 12 applies 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 present
4) the core of the storm moves over at least a portion of the hyper-effective drainage area

Caution should be used when applying Reed-Schaffner Equation 12 to watersheds with
1) drainage area less than 1 square mile
2) drainage area greater than 20 square miles
3) elevation change less than 1500 feet
4) lower mean basin elevations where vegetation recovery may occur quickly
5) higher mean basin elevations with predominately shallow soils and impermeable rock outcrops.

The range of watersheds used to develop equation 12 is from 1.5 square miles to 21.6 square miles.

- The original equations were developed in Southeast Arizona
- The unmodified channel relief ratio was used for burned areas within the Central Arizona Highlands (Wallow Fire Area)

Both the modified and unmodified channel relief ratios were used in the Bush Fire analysis to develop a range of flow estimates. The highest estimates using the unmodified channel relief ratio were used in the analysis to provide a conservative estimate of the flows that might be expected.

Appendix B – Detailed Model Outputs