Hydrology Resource Assessment
Mad River Complex

Humboldt and Trinity Counties, California

Six Rivers and Shasta-Trinity National Forests

Angela Coleman (Hydrologist –Chugach National Forest)

September 8, 2015

1. Objectives

The objective of this assessment is to evaluate the effects of the Mad River Complex Fire on watershed hydrologic processes and function including changes in runoff, soil conditions and watershed response to precipitation events. This assessment focuses on fire-induced changes in hydrologic processes and functions that pose a significant threat to human life and safety, property, and critical natural and cultural resources on National Forest System Lands. Values at risk are identified and a determination of the probability of damage or loss and the magnitude of consequences has been made for each value. Treatments recommendations have been developed for resources where critical resources at risk have been identified exist.

2. Burned Area Characterization

Hydrologic Setting
The Mad River Complex began on July 30st, when a large storm system produced numerous lightening strikes in Trinity, Shasta and Humbolt Counties causing over 150 fires. The Mad River Complex is composed of 5 fires including the Lassic, Gobbler, Pickett, Pine, and Blueford Fires. The five fires totaled approximately 39,200 acres (approximately 61 square miles). The fires burned in watersheds tributary to the South Fork Trinity River, Mad River and Van Duzan River. The burned areas included numerous tributaries to perennial fish bearing streams. Many of these perennial fish bearing streams downstream of the fire perimeter which are anadromous.

Geologic Setting
The Mad River Fire Complex is located within the Klamath Mountains. The area is largely composed of metasediments, limestone, ultramaphic rocks, metavolcanics, basic intrusives and granitic intrusives.

Climate
The climate of the fire area is typified by warm, dry summers and cool wet winters. Substantial variation in temperature and precipitation occurs with elevation. The average maximum and minimum temperatures in the summer are 95 and 50 degrees Fahrenheit, respectively. Winter temperatures range from lows in the 20s to highs around 50 degrees F. Annual precipitation in the fire area ranges from 55 - 75 inches with more precipitation occurring in high elevation areas. The majority of winter precipitation falls as snow at higher elevations. Almost all of the precipitation occurs between October and May.

Hydrology
Hydrologic features found within the Mad River Complex include the South Fork Trinity River, Mad River, Van Duzan River and it tributary streams. Elevations within the area ranges from 2100 feet down near the South Fork Trinity River to over 5600 feet near Black Lassic Peak.The burn area contains approximately 190 miles of ephemeral streams, 73 miles of intermittent streams and 48 miles of perennial streams. Intermittent streams differ from ephemeral streams in that they flow for several months a year while ephemeral streams only flow during precipitation events. Wet meadows, lakes and springs are also prevalent throughout the Mad River Complex particularly in high elevation areas. The drainage density for the Mad River Complex burn area is 5.1 miles of stream channel per square mile[1]. The Trinity River, Mad River and Eel River are all currently listed for for water quality impairment

(303d list) by the Environmental Protection Agency for sediment impairment. All of the streams within and downstream of the fire perimeter drain into these listed streams.

3. Hydrology Resource Assessment

Reconnaissance of the burn area was conducted using a rapid approach described as a burned area emergency assessment. The burned area emergency assessment is an immediate and rapid assessment of the burned area that is conducted in order to identify post-fire threats, critical values at risk, and need for emergency stabilization measures. The burned area emergency assessment is not a comprehensive evaluation of all fire damage or long-term rehabilitation or restoration needs (FSM 2500, 2004).

Reconnaissance of the burned area was conducted by helicopter overviews, driving roads, hiking on trails and cross-country through the burn and interviewing people familiar with the burned area. Specialists that the hydrologists worked with and/or consulted during the field assessments included soil scientists, fisheries biologist, geologist, botanist, archaeologist, GIS specialists and roads engineers.

The Mad River Complex burned a total of 39,200 acres within portions of 19 Hydrologic Unit Codes (HUC) 7 drainages (Figure 1). BAER soil scientists' determined the burn severity for the fire based on burn intensity information from the BARC and field surveys of the burned area (see Table 1 for definitions).

Term	Definition
Burn Intensity	The intensity of the fire's effect on the watershed vegetation. Low severity indicates ground fire only with only small areas of canopy burned. Moderate severity indicates hot ground fire with frequent scorching of canopy. Tree mortality is high but needles and leaves are not consumed. High severity indicates ground and canopy fire with complete consumption of the forest canopy. Burn intensity is determined based on imagery of the burned area reflectance classification (BARC) as refined by ground surveys.
Burn Severity	Rating of fire impacts on soil hydrologic function (e.g. infiltration capacity, erodability, etc.). Burn severity is determined by refining the burn intensity information from the BARC with additional field surveys. Classes of burn severity are high, moderate, low, and very low/ unburned.
Watershed Response	A qualitative degree and/or modeled measure of how a watershed will respond to precipitation. Parameters include pre-existing soil moisture; amount of soil cover; amount and distribution of impermeable surfaces (rock outcrop, hydrophobic soils), amount, duration, and intensity of rainfall; watershed area and slope, and lag time between initiation of storm and peak flow runoff. Response is generally measured as peak-flow discharge and sediment yield. Changes in the characteristics of watershed brought about by a fire will increase the efficiency with which waters runs off, thus increasing peak flows and decreasing lag times.

Table 1: Severity and response definitions.

[1] Drainage densities based on the Six Rivers National Forest NHD streams layer clipped to the fire perimeters.

Figure 1: Map of the Mad River Complex fire severity and HUC 7 watershed locations.

Watershed Steamflow Analysis

Fire effects on runoff were determined by modeling pre-fire and post-fire discharges for all HUC 5, 6, 7 watersheds affected by the Mad River Complex (Table 2). Increases in runoff were assumed to be due to hydrophobic soils and the loss of vegetation and ground cover (i.e. interception, evapotranspiration, ground cover storage). Elevated streamflows can be expected to occur in the burned watersheds, with greater flow increases in those drainages having higher percentages of high burn severity. The percentage of each HUC 5, 6, and 7 burned at high, moderate, low and very low/ unburned burn severity is also shown in Table 2.

Estimated pre-and post-fire peak flows were modeled for HUC 5, 6 and 7 level watersheds using the United States Geological Survey (USGS) Regional Flood Frequency method (Gotvald, et. al., 2012), utilizing a GIS-based approach developed on the Shasta-Trinity National Forest (Lotkeff, 2009). The Peak flow equations were calculated in relation to regional hydrologic characteristics (Gotvald, et. al., 2012). Pre-fire peak flows were calculated for the full range of recurrence intervals defined in the regional equations, between 2 and 100 years, for all watershed scales between 5th- and 7th-field Hydrologic Unit Codes (HUCs) that intersect the burned area. Post-fire peak flows for all complete watersheds intersecting the burned area were calculated for the lower recurrence intervals, between 2 and 10 years. Pre- and post-fire peak flows for the burned area alone were calculated only for 7th-field HUCs, in order to characterize the design flow increase from the burned area. The post-fire peak flow increase estimates are based on a factor of three (300%) increase in flow from areas of high burn severity, a factor of 1.5 (50%) increase from areas of moderate burn severity, and factor of 1.1 (10%) increase from areas of low burn severity. These factors were adopted from ratios used for similar areas in Southern California where intense rainstorms are the most likely type of damaging storm. It should be noted that the regional flood frequency estimates describe linear post-fire increases in peak flow magnitude with increased recurrence intervals. Field studies in Southern California have demonstrated that as recurrence interval increases, the effects of fire or other vegetation losses on peak flows is reduced (Rowe, Countryman and Storey, 1949). Therefore, estimates for longer recurrence interval post-fire peak flows were not calculated. Additionally, a sediment/ debris bulking factor was added to the high severity burn acreages following the the methods outlines in Gusman, 2011.

Because high and moderate burn severity areas were widely scattered and relatively isolated thoughout the fire the burn severity was further stratified by smaller subwatersheds/drainages of interest to more closely examine impacts to water resources and values at risk. These smaller subwatersheds/drainages were identified as being at risk to fire induced impacts based on values at risk. These subwatersheds were dilineated utilizing the USGS StreamStats Program (http://water.usgs.gov/osw/streamstats/california.html). Projected flow increases resulting from increases in runoff from the burn areas are shown in Table 3.

Projected runoff increases for a 2-year recurrence interval storm within the HUC 5, 6, and 7 analysis ranged from a low factor of 1.0 to 1.21 in the West Fork of the Van Duzan and Shanty Creek watersheds (Table 2 and Figure 2). The results show minimal increase in flows at these watershed levels. This is likely due to the patchy, lower severity burn and a high percentage of the watersheds being unburned. The analysis of the smaller subwatersheds with higher percentages of moderate and high burn severity resulted in higher ranges with the maximum of 2.6 in the headwaters of Glen Creek (Table 3 and Figure 2). Other areas with high ratios included much of the headwaters along the east side of Ruth Lake, Glenn

Creek draining into the South Fork of the Trinity River and the Shanty Creek, Black Lassic Creek, and Red Lassic areas draining into the Van Duzan River.

Watersheds			HUC 5-7	Watershed Area	Mean Precip.	Pre-Fire (Entire Watersheds)				Burn Severity (%)			Burned Area	Post-Fire (Entire Watersheds -HUC 7)			Ratios		
HUC 5	HUC 6	HUC 7		(acres)	(inches)	Qp2	Qp5	Qp10	Qp25	Sever	Moderate	Low	Total Acres	Qp2	Qp5	Qp10	Qp2	Qp5	Qp10
Dobbyn Creek			1801010503	47,925	60	5,040	8,797	11,411	14,786	0	0	2	974	5,070	8,849	11,479	1.01	1.01	1.01
	North Dobbyn Creek		180101050301	10,865	60	1,318	2,359	3,091	4,042	0	1	3	455	1,339	2,396	3,140	1.02	1.02	1.02
		Upper North Dobbyn Creek	18010105030101	2,848	70	457	810	1,059	1,382	1	5	10	435	484	859	1,123	1.06	1.06	1.06
		Lower North Dobbyn Creek	18010105030103	7,974	62	1,029	1,839	2,409	3,148	0	0	0	20	1,029	1,839	2,410	1.00	1.00	1.00
	Conley Creek-Dobbyn Creek		180101050303	11,589	60	1,397	2,497	3,272	4,276	0	1	3	374	1,408	2,518	3,299	1.01	1.01	1.01
		South and North Forks Conley Creek	18010105030302	3,569	66	529	946	1,240	1,622	0	2	8	374	543	971	1,273	1.03	1.03	1.03
		Conley-Dobbyn	18010105030304	8,059	54	899	1,656	2,194	2,897	0	0	0	0	899	1,656	2,194	1.00	1.00	1.00
	South Dobbyn Creek		180101050302	25,471	60	2,846	5,021	6,542	8,510	0	0	1	144	2,848	5,025	6,547	1.00	1.00	1.00
		Bluford-Mud	18010105030203	7,802	62	1,009	1,803	2,363	3,089	0	0	2	144	1,011	1,807	2,368	1.00	1.00	1.00
Larabee Creek			1801010506	56,268	68	6,590	11,172	14,338	18,404	0	0	0	0	6,590	11,172	14,338	1.00	1.00	1.00
	Upper Larabee Creek		180101050601	30,546	68	3,793	6,498	8,375	10,790	0	0	0	0	3,793	6,498	8,375	1.00	1.00	1.00
Lower Van Duzen River			1801010509	131,791	65	13,607	22,953	29,384	37,641	0	1	2	3,498	13,715	23,136	29,618	1.01	1.01	1.01
	Little Van Duzen River		180101050902	26,375	73	3,562	6,026	7,733	9,923	0	3	9	3,498	3,704	6,266	8,041	1.04	1.04	1.04
		Blanket Creek	18010105090202	2,685	75	464	811	1,055	1,370	0	3	14	458	479	838	1,090	1.03	1.03	1.03
		Upper Little Van Duzen River	18010105090201	7,055	75	1,111	1,910	2,469	3,188	2	12	30	3,040	1,262	2,171	2,806	1.14	1.14	1.14
Middle Mad River			1801010203	56,462	65	6,324	10,822	13,937	17,944	0	1	2	1,767	6,368	10,898	14,034	1.01	1.01	1.01
	Bear Creek-Mad River		180101020302	31,033	65	3,681	6,364	8,230	10,635	0	2	4	1,767	3,728	6,446	8,335	1.01	1.01	1.01
		Hale-Olsen	18010102030201	8,768	60	1,085	1,950	2,559	3,351	0	6	14	1,767	1,134	2,038	2,675	1.05	1.05	1.05
Middle South Fork Trinity River			1801021204	145,690	55	12,642	22,053	28,572	36,996	0	0	2	2,629	12,694	22,143	28,689	1.00	1.00	1.00
	Smoky Creek-South Fork Trinity River		180102120402	27,021	65	3,248	5,629	7,286	9,423	0	0	0	71	3,249	5,631	7,289	1.00	1.00	1.00
		Cable Creek-Farley Creek	18010212040203	9,538	65	1,267	2,235	2,914	3,793	0	0	1	71	1,268	2,237	2,917	1.00	1.00	1.00
	Little Bear Wallow Creek-South Fork Trinity River		180102120404	26,515	62	3,048	5,337	6,934	8,998	0	1	8	2,558	3,116	5,456	7,089	1.02	1.02	1.02
		Cave Creek-Swift Creek	18010212040401	9,538	63	1,229	2,182	2,852	3,719	1	4	20	2,366	1,302	2,312	3,022	1.06	1.06	1.06
		Little Bear Wallow Creek-Hidden Valley	18010212040402	9,794	61	1,219	2,179	2,854	3,730	0	0	2	192	1,222	2,184	2,860	1.00	1.00	1.00
Upper Mad River			1801010202	77,107	60	7,747	13,413	17,340	22,406	1	2	2	3,630	7,955	13,774	17,807	1.03	1.03	1.03
	Ruth Lake-Mad River		180101020203	20,247	60	2,313	4,096	5,346	6,963	2	6	9	3,630	2,550	4,516	5,893	1.10	1.10	1.10
Upper Van Duzen River			1801010507	54,646	70	6,603	11,132	14,258	18,269	1	6	7	7,466	7,027	11,846	15,173	1.06	1.06	1.06
	West Fork Van Duzen River-Van Duzen River		180101050701	15,215	70	2,079	3,581	4,628	5,976	1	8	10	2,956	2,265	3,902	5,042	1.09	1.09	1.09
		Headwaters Van Duzen River	18010105070103	5,910	65	822	1,462	1,913	2,496	0	0	0	1	822	1,462	1,913	1.00	1.00	1.00
		West Fork Van Duzen River	18010105070102	6,439	70	955	1,670	2,171	2,818	3	18	24	2,947	1,157	2,023	2,630	1.21	1.21	1.21
		Big Meadow Creek	18010105070101	2,893	70	464	821	1,074	1,401	0	0	0	8	464	822	1,075	1.00	1.00	1.00
	Shanty Creek-Van Duzen River		180101050702	23,143	65	2,824	4,906	6,358	8,230	1	8	10	4,510	3,085	5,361	6,947	1.09	1.09	1.09
		Waggit Spring	18010105070201	4,607	70	706	1,241	1,617	2,103	1	16	16	1,554	802	1,411	1,838	1.14	1.14	1.14
		Black Lassic-Red Lassic	18010105070202	5,957	70	891	1,559	2,028	2,633	3	14	18	2,069	1,041	1,822	2,370	1.17	1.17	1.17
		Shanty Creek	18010105070203	2,434	75	424	743	968	1,258	4	15	17	884	513	899	1,170	1.21	1.21	1.21
		Crooks-Senteney	18010105070205	7,074	70	1,040	1,816	2,359	3,060	0	0	0	3	1,040	1,816	2,359	1.00	1.00	1.00

Table 2: Pre-fire runoff and post-fire predicted flows for HUC 5, 6, and 7 watersheds in the Mad River Fire Complex.

Watersheds			Drainage Area	Watershed Area	Mean Precip.	Pre-Fire (Entire Watersheds - HUC 7)				Burn Severity (%)			Post-Fire (HUC 7) (cfs)			Ratios		
5	6	7		(acres)	(inches)	Qp2	Qp5	Qp10	Qp25	High	Moderate	Low	Qp2	Qp5	Qp10	Qp2	Qp5	Qp10
Upper Mad River	Ruth Lake-Mad River		Hobart Creek	1,079.95	73	198.21	354	465	608	5	10	10	254	454	596	1.28	1.28	1.28
Upper Mad River	Ruth Lake-Mad River		Choptoy Creek	640.72	69.4	117.64	214	283	373	12	31	23	197	359	475	1.68	1.68	1.68
Upper Mad River	Ruth Lake-Mad River		Upper Picket Creek (above mid-slope rd)	319.80	73.5	66.41	121	160	211	24	20	33	142	259	342	2.14	2.14	2.14
Upper Mad River	Ruth Lake-Mad River		Bailey Canyon Campground	279.77	68.2	54.68	101	135	179	10	32	27	89	164	219	1.62	1.62	1.62
Upper Mad River	Ruth Lake-Mad River		Fir Cove Campground	483.71	68	89.43	164	218	288	7	44	32	138	254	337	1.55	1.55	1.55
Upper Mad River	Ruth Lake-Mad River		Sherrif's Cove	431.67	66	78.36	145	193	256	16	42	29	149	276	367	1.90	1.90	1.90
Little Bear Wallow Creek-South Fork Trinity River	Cave Creek-Swift Creek		Glen Creek	1,515.61	74.7	275.43	487	636	829	4	11	38	353	623	815	1.28	1.28	1.28
Little Bear Wallow Creek-South Fork Trinity River	Cave Creek-Swift Creek		Glen Creek Headwaters (above the 1S04 rd)	219.28	81.3	52.14	94	123	161	28	32	21	123	220	290	2.36	2.36	2.36
Shanty Creek-Van Duzen River	Black Lassic-Red Lassic		Red Lassic Creek	1,227.61	75.8	230.95	408	534	696	7	78	30	396	700	916	1.71	1.71	1.71
Shanty Creek-Van Duzen River	Black Lassic-Red Lassic		Black Lassic Creek	1,833.64	84.4	368.91	633	819	1,057	7	34	20	550	944	1221	1.49	1.49	1.49
Shanty Creek-Van Duzen River	Shanty Creek		Shanty Creek Headwaters (above rd 01S07)	325.14	105	95.73	162	208	267	23	53	10	216	365	470	2.26	2.26	2.26
Shanty Creek-Van Duzen River	Shanty Creek		Culvert waypoint 96	181.70	70.5	38.24	71	94	125	0	11	36	41	75	100	1.06	1.06	1.06

Table 3: Pre and post-burn flow analysis for selected HUC 8 and smaller drainages in the Mad River Complex Fire area.

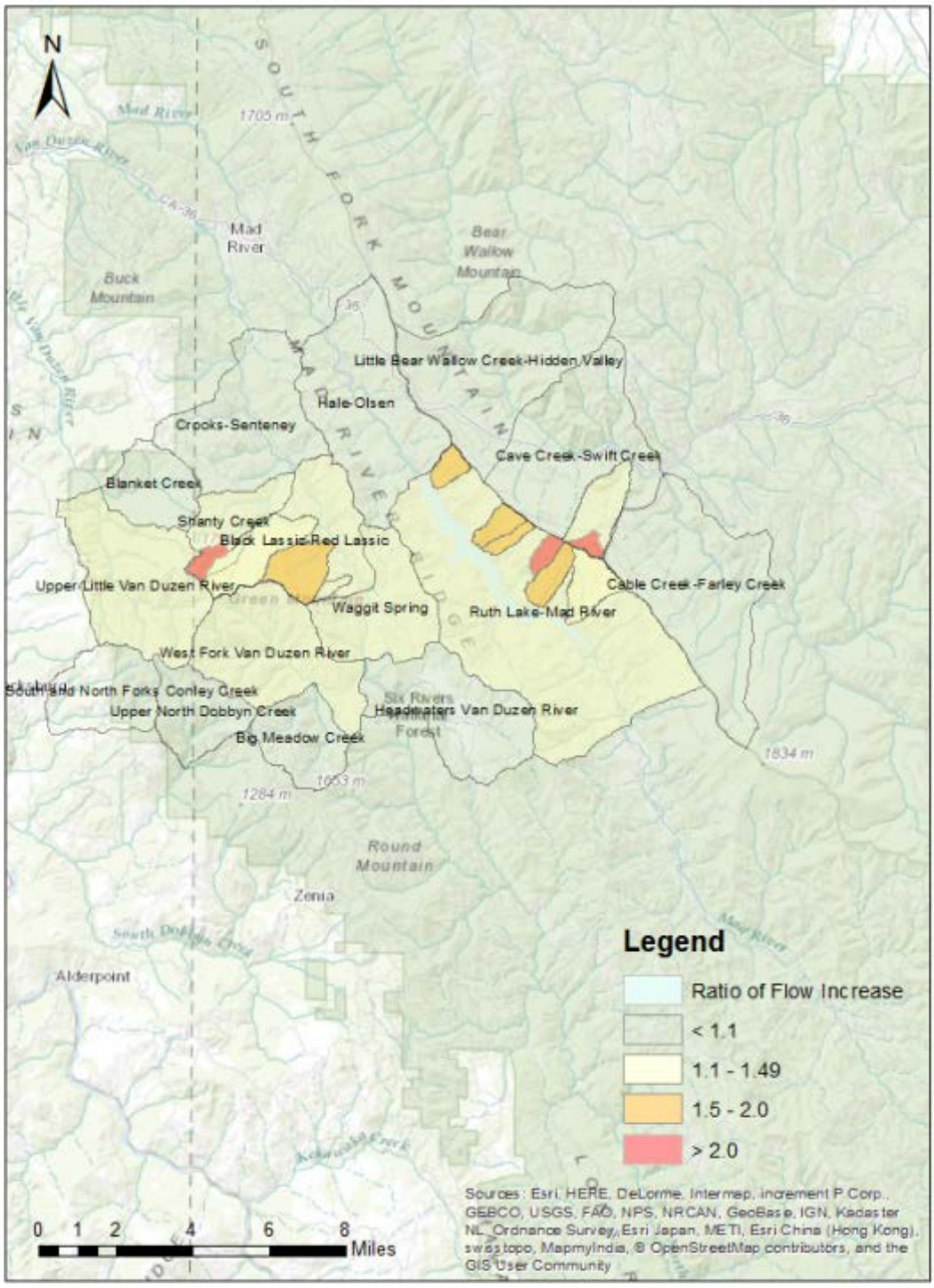

Figure 2: Map of the HUC 7 watersheds and smaller subwatersheds of interest post-fire predicted streamflow ratio increases.

4. Values at Risk and Threats

The Burn Area Emeregency Response (BAER) team identified several categories of issues, threats and resource concerns for the Mad River Complex. Threats to human life and safety, downstream effects to water quality and aquatic habitat, erosion of transportation and facilities facilities (roads, recreational cabins, campgrounds) and water supplies are the principal values at risk related to hydrologic effects of the Mad River Complex. Values at risk for water quality, fisheries and domestic water supplies are presented below. Refer to the Mad River Complex 2500-8 for a complete summary of all values at risk.

Glen Creek Area– Picket Fire (tributary to South Fork Trinity River) Headwaters burned hot with high to moderate soil burn severity, water repellency up to 8 inches in a deep to moderate gravelly loam. These gravelly loams have a high erosion rating and could erode significantly. The fire activity may produce accelerated surface erosion, debris flow activity, loss of soil productivity and increased runoff. All of these threats may affect the following values at risk:

- Midslope road segments of road 1S04 and the Forest Glen road and bridge – These roads may be susceptible to increased flows and debris flows.Streamflow analysis indicate that the headwaters of Glen Creek will have a 136% increase in stream flow comparable to a Q10 event. Undersized, plugged or damaged culverts on these roads have a likely risk failure (Refer to the Engineers report for locations of undersized culverts). There is an estimated 28% increase for flows for Glen Creek, comparable to less than a Q5 event, at the Forest Glen bridge.
- The South Fork of the Trinity River water quality and aquatic habitat – Glen Creek is a tributary into the South Fork of the Trinity River. The river has critical coho habitat.Glen Creek is likely to experience high erosion rates and transport large quantities of sediment to the South Fork Trinity River.
- Private domestic water systems on Forest Service lands – These water systems are surface cathments and spring boxes located downslope of moderate and high severity burn. Some of the water tanks and hoses were damaged in the fire. Several appear to have been already replaced or fixed. These systems will be likely be susceptible to higher rates of erosion and sedimentation following the fire (Figure 3).
- Forest Service Glenn Creek Recreational Cabin – This cabin is located along Glen Creek near the confluence with the South Fork of the Trinity River. It is possible the cabin may be susceptible to debris flows or extremely high magnitude floods.
- Forest Service Glenn Creek Recreational Cabin water system – The water system site is a groundwater well located in a location not susceptible to floods or debris flows.

Figure 3: Private domestic water systems with sources on Forest Service lands within or adjacet to the Pickett fire that were damaged and/or will be susceptible to erosion and sedimentation.

<u>Black Lassic, Red Lassic and Shanty Creek areas – Lassic Fire</u> Headwaters burned hot with high to moderate burn severity near the ridgetops of Black Lassic and Red Lassic peaks. Water repellency was up to 7 inches in deep to moderate gravelly loam with moderate erosion rating. There is an actively eroding slide (Mule Slide) in the vacinity. The fire activity may produce accelerated surface erosion, debris flow activity, loss of soil productivity and increased runoff. All of these threats may affect the following values at risk:

- Vernal pools near Red Lassic Peak – High and moderate burn severity surrounding these vernal pools. One pool has steeper ground surrounding it and is likely susceptible to sedimentation from surface erosion.
- Road segments with undersized culverts downhill of high and moderate severity burn areas (01S07, 01S11 and spurs G & F) – these areas will likely have increased runoff and surface erosion increasing the risk of plugging and overtopping culverts. Refer to the engineers report for locations of undersized culverts.
- Road 01S11 near the Mule Slide – This area has high burn severity and is susceptible to debris flows and landslide failure (Figure 4).
- Private homes in the Rutland Opening area near Black Lassic and Red Lassic Creeks – This area is susceptible to accelerated surface erosion and minor flooding (< Q5 event).
- Water Quality – Black Lassic, Red Lassic and Shanty Creek are all headwater tributaries to the Van Duzan River. Each of these creeks is likely to experience acclerated erosion rates and transport increased sediment to the Van Duzan River.
- Private domestic water systems in the Rutland Opening area (located off NFS lands) near Black Lassic and Red Lassic Creeks - These areas will likely be susceptible to flooding, erosion, sedimentation and debris flows if they are located in close vacinity to the drainages.

Figure 4: Photos of vernal pool susceptible to sedimentation (left) and the high severity burned head scarp of the deep seated landslide near the Mule slide off of the 01S11 road (right).

Figure 5: Photos of the high to moderate burn severity at the headwaters of Shanty Creek just upstream of the 01S07 road.

<u>Headwaters of the East Side of Ruth Lake - Pickett Fire</u> – Headwaters burned hot with high to moderate burn severity, water repellency up to 8 inches in a deep to moderate gravelly loam. These gravelly loams have a high to moderate erosion rating. and could erode significantly. The fire activity may produce accelerated surface erosion, debris flow activity, loss of soil productivity and increased runoff. All of these threats may affect the following values at risk:

- Private homes near Hobart, Choptoy and Pickett Creeks and the Sheriff Cove Area – These areas are likely susceptible to accelerated surface erosion and minor flooding (< Q5 event) if they are located in close vacinity to the drainages.
- Water Quality of Ruth Lake –Headwater tributaries that burned with moderate to high burn severity will likely experience acclerated erosion rates and transport increased sediment to the Ruth Lake. This may affect the Humbolt Bay Municipal Water Supply filters and the Ruth Lake Hydropower Facility.

- Private domestic water systems (located off NFS lands) near Hobart, Choptoy, and Pickett Creeks and Sheriff's Cove- These areas will likely be susceptible to flooding, erosion, sedimentation and debris flows if they are located in close vacinity to the drainages.
- Bailey Canyon and Fir Cove Campground water supply systems - Threats to public water supply from sediment and debris originating from flood source areas on the east side of Ruth Lake (Pickett, Hobart, Choptoy, Sheriff's Cove Creeks). In these drainages the headwaters burned at moderate to high severity. Inreased runnoff and surface erosion is expected.
- Bailey Canyon and Fir Cove Campground facilities - Threats to Fir Cove and Bailey Canyon Campground facilities from flooding, sedimentation and debris flows is likely. Expected flood flows will overtop the banks of the channel and extend out onto the floodplain. It will likely inundate low lying and flat areas nearby the channel. The Qs rate it out to be less than a 5 year storm event.
- Road segments with undersized culverts downhill of high and moderate severity burn areas (02S27 road) will likely have increased runoff and surface erosion increasing the risk of plugging and overtopping culverts. Refer to the engineers report for locations of undersized culverts.

5. Assessment of Values at Risk

The assessment of values at risk utilized a 2 year equivalent design recurrence interval storm for determining calculated risk for the Mad River Complex. This design storm was chosen because it is likely that this event will occur within six months of the fire. Both design storm durations of 12 and 24 hours were evaluated for watersheds affected by the fire. The most common type of flood generating storms are long-duration winter rainfall events caused by Pacific Ocean frontal systems (Levitan, et. al., 2015). Occassional rain-on-snow events produce the highest peak flows and pose the greatest erosion risk. The design storm magnitude for the 2 year, 12 hour rainfall event was determined to be 3.48 inches and the 2 year, 24 hour rainfall event was determined to be 5.16 inches. These values was derived from National Oceanic Atmospheric Association's National Weather Service Meteorological Design Studies Center, Precipitation Frequency Data Center, accessed September 7. The pre-event design flow was calculated for each HUC 7 watershed according to methodology developed by Gotvald, et. al., 2012. The total pre-fire runoff from a 2 year recurrence interval storm was calculated to be 88 cubic feet per second per square mile. The adjusted design flow was calculated based on the reduction of infiltration from both high and moderate intensity burn areas. Increases in runoff were generally very low due to the small amount of total watershed acreage affected by high and moderate severity burns. The total post-fire runoff in response to a 2 year recurrence interval storm was calculated to be 93 cubic feet per second. This value shows an overall increase in total runoff of by 5 cfs or a 5.7% as a result of the fire. More localized high severity burn areas (subwatersheds smaller than HUC7s) did show increases up to 236% in specific locations (Table 3 and Figure 2).

Value Catagory	Value at Risk	Description of Threat	BAER Critical Value	Probability	Magnitude	Risk
Property	Private Domestic Water Supply Systems on	Threats to water systems located on NFS lands that supply water to adjacent land owners from flooding, erosion, sedimentation and debris flows.	N			

	Forest Service Lands					
Property	Forest Glen Rental Cabin water system	Threats to the Forest Glen Rental Cabin water system/ well from flooding, erosion, sedimentation and debris flows.	Y	Unlikely	Moderate	Low
Property	Forest Glen Rental Cabin	Threats to the Forest Glen Rental Cabin from accelerated surface erosion, incvreased streamflows, and debris flow activity.	Y	Possible	Minor	Low
Property	Forest Glen Bridge	Threats to road infrastructure at the Forest Glen bridge across Glen Creek from flooding and debris flows.	Y	Possible	Moderate	Low
Property	Forest Roads	Threats to undersized culverts from flooding and debris flows are expected to plug or overtop and severly damage road infrastructure with loss NFS investment. Areas of concern include the 1S04, 01S07, 01S11 and 02S27 roads (Refer to Engineers report for locations of undersized crossings).	Y	Likely	Moderate	High
Property	Bailey Canyon and Fir Cove Campgrounds	Threats to Fir Cove and Bailey Canyon Campground facilities from flooding, sedimentation and debris flows.	Y	Likely	Minor	Low
Property	Fir Cove and Bailey Canyon Campgrounds Public Water Supply (Ruth Lake)	Threats to public water supply from sediment and debris originating from flood source areas on the east side of Ruth Lake (Pickett, Hobart, Choptoy, Sheriff's Cove Creeks). In these drainages the headwaters burned at moderate to high severity. Inreased runnoff and surface erosion is expected.	Y	Likely	Minor	Low
Property	Humboldt Bay Municipal Water District (Ruth Lake)	Threats to public water supply from sediment and debris originating from flood source areas on the east side of Ruth Lake (Pickett, Hobart, Choptoy, Sheriff's Cove Creeks). In these drainages the headwaters burned at moderate to high severity. Inreased runnoff and surface erosion is expected.	N			
Property	Private Domestic Water Supplies located off of NFS lands	Threats to private domestic water systems not located on NFS lands from flooding, erosion, sedimentation and debris flows.	N			
Natural Resource	Vernal Pools	Increased erosion and sediment delivery are threats that can decrease the capacity of the vernal pools.	N			
Natural Resource	Water Quality	Threats to 303d – listed streams from increased sediment delivery. Impacts to watershed proccesses and functions that regulate erosion, large wood recruitment and sediment delivery in areas that burned at moderate and high severity. Threats to water quality can potentially impact beneficial uses such as habitat for	Y	Very Likely	Moderate	Very High

		ESA-listed aquatic species, domestic water supply systems, and capacity and productivity og hydropower facilities.				
Natural Resource	Seeps and Springs	Threats from Increased erosion and sediment can alter the morphology and functionality of groundwater dependant ecosystems (GDEs)	N			

6. Response Actions Recommended to Mitigate the Risk

Road Treatments
Replace plugged and damaged culverts with functional culverts. Replace undersized culverts or add rolling dips to improve road drainage for roads located within or below high severity burn areas, in particularly along the 1S04, 01S07, 01S11 and 02S27 roads (Refer to Engineers report for locations of undersized crossings and treatment recommendations). These areas will likely experience increased runoff as a result of the fire. Please refer to Table 4 for more detailed flood flow ratio increases. Use storm patrols to monitor undersized pipes located in moderate and high severity burn areas where no culvert upgrades are planned and access can occur safely.

Administrative Closures
It is recommended that administrative closures be considered on high risk roads that are not treated and at Forest Service campgrounds during times of predicted high precipitation events.

7. Consultations

It is recommended that USFS consult with the California Water board, Humboldt Bay Municipal Water District and the NRCS for mitigating risk to private values at risk.

8. References

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles, 2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl., available online only at *http://pubs.usgs.gov/sir/2012/5113/*.

Gusman, A.J., 2011, Sediment/Debris Bulking Factors and Post-Fire Hydrology for Ventura County Final Report, 184 p.

Levitan, F., Dresser, A. and Black, C., 2015, personal communication.

Lotkeff, R., 2009, Flood Frequency Analysis (unpublished manuscript and GIS model, on file at USDA Forest Service, Shasta-Trinity National Forest, Redding, CA).

National Oceanic and Atmospheric Administration (NOAA), 2015. Application listed in NOAA Atlas 2, Volume XI, Precipitation-Frequency Atlas of the United States, Volume XI---California.

http://hdsc.nws.noaa.gov/hdsc/pfds/other/nca_pfds.html

Rowe, P.B., Countryman, C.M., and Storey, H.C., 1949, Probable peak discharges and erosion rates from southern California watersheds as influences by fire: Berkeley, California, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service, (unpublished manuscript, on file at USDA Forest Service, Forest Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507).

USDA Forest Service, 2004. FSM 2500 – Watershed and Air Management, Chapter 2520 – Watershed Protection and Management, Amendment No.: 2500-2004-1. 44 p.