Stickpin Fire BAER

Resource Report

Colville National Forest

Hydrology

Prepared by

John Rihs, Hydrologist, Apache-Sitgreaves NF's

With

Mike McConnell, Hydrologist, Gifford Pinchot NF

Bill Goodman, Hydrologist, Freemont-Winema NF's

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Objectives

A. Assessing the effects, through field reconnaissance and modeling, of overall watershed changes caused by the Stickpin Fire, particularly those that affect the following critical values at risk:

1. Human Life and Safety on or in close proximity to the burned NFS lands
2. Property: buildings, water systems, utility systems, road and trail prisms, dams, wells, or other significant investments on or in close proximity to the NFS lands
3. Natural Resources: a) Water used for community, domestic, hydropower, or agricultural supply or waters with special state or federal designations on or in close proximity to the burned NFS lands, b) changes to watershed conditions, hydrologic function, and watershed response to precipitation events.

B. Identify critical watershed areas and issues within the Stickpin Fire boundary.

C. Based on expected flow increases for water and debris prescribe emergency response action to protect and/or minimize effects to critical values at risk.

Inventory of Resource Values in Burned Area

Values at Risk (VAR) were identified in the priority of 1) Human Life and Safety, 2) Property, and 3) Critical Natural Resources. VAR assessment on the Stickpin Fire was divided up into eleven 6th code subwatersheds which served as focus areas for field and office inventories. Initial VAR assessment included review of the fire area through use of burn severity maps, drainage maps, 100-year floodplain delineations, Google Earth, and local knowledge to determine if life and property values were at risk. Field visits (documented via GPS, photographs, notes) were then made to areas with potential risk to life and property to further assess the severity of the risk. Incident specialists collected and analyzed local spatial data throughout the assignment.

An initial assessment of VAR was made based on potential values at risk within and immediately adjacent to the burn perimeter. There are three watersheds directly affected by the fire. These watersheds were separated into 6th code and smaller subwatersheds to evaluate the risk of flooding potential via the use of flow models. A complete list of VAR by basin, and subwatershed is included in the Stickpin Fire VAR Tracking Spreadsheet.

All known hydrology Values at Risk (VAR) within the eleven affected subwatersheds were field inspected including a small part of the Renner fire that shares a subwatershed (South Fork Boulder Creek) with the Stickpin fire. Of those eleven subwatersheds only eight have enough burn in them to be considered significant enough for modelling. Those not considered are Lambert Creek, La Fleur Creek – Kettle River, and Independent Creek. The burn areas in these subwatersheds are inconsequential. Both the Renner and Stickpin fires burned at the same time and are a part of the Kettle Complex.

Methodology and Assumptions

Information used in this assessment was generated from GIS databases, burn severity maps, field reviews, and Colville National Forest specialists.

The risk assessment relied heavily on the burn severity map and the assumption that it represented burn severity accurately. Prior to finalizing a burn severity map, field verification was conducted by the BAER Soils team and deviations from observations on the ground were adjusted. It was noted that few adjustments were needed beyond band gaps often associated with remote sensing from Landsat 7. For the modelling, a small part of the Renner Fire severity map was used because the two fires shared the same 6th code subwatershed (South Fork Boulder Creek).

Field visits to the Stickpin Fire area were conducted by the hydrology, engineering and soils teams for the period September 23 – September 27, 2015. Field reconnaissance consisted on-site inspection of all potential values at risk well as field assessment of watershed conditions.

Modeling of watersheds for predicting expected flow increases was accomplished using Wildcat 5 runoff predictions model. The Wildcat5 (Hawkins and Barreto No Date; BETA Test Release in cooperation with USDA Forest Service and STREAM Systems Technology Center) storm runoff model was used to predict peak flow runoff generated in key watersheds under pre- and post- burn conditions. Information generated by the Stickpin Fire BAER soils group was used to aid in the selection of curve numbers. Appendix A contains a description of the model and a table of inputs to the model.

The model is not precise therefore numbers are not meant to be interpreted as exact flows but rather as indicators of magnitude of change. These flow models are not intended for large subwatersheds where the VAR's are far from the uplands such as in Deer Ck, Long Alex, St Peter and Lone Ranch. Accuracy is improved when modelling smaller subsets of these watersheds higher in the subwatersheds.

Description of Resource Condition prior to Stickpin Fire

The Stickpin Fire over 56,329 Acres (includes part of the Renner fire) as well as all of the Kettle Complex lies east of the Cascade Mountain Range. This mountainous region lies within the Okanogan Highlands physiographic region. A central valley occupied by Curlew Lake, Sanpoil Lake, and the Sanpoil River serves as the trunk drainage for nearly all the area. Relief is nearly 5,000 feet, the highest point being Bald Mountain, which has an altitude of 6,933 feet (Muessig, 1967). The landscape of both adjacent fires where shaped by long periods of glaciation and river processes. The Mt. Mazama (present day Crater Lake) eruption around 7,700 years ago left an extensive ash mantle that is commonly present in the mountainous, forested areas today across this region in northeast Washington. The terrain varies from steep slopes to rolling hillsides, and flat river valleys. Drainages have been modified by several Pleistocene glaciations (Muessig, 1967). Bedrock is mainly composed of volcanic extrusive and intrusive igneous rocks.

Active geomorphological processes are evident throughout the burned area, including hillslope processes (i.e., soil erosion and rock fall) and fluvial processes (i.e. sediment and debris transport in stream channels, and stream downcutting and aggradation). For eample, a streatch of nonUSFS land above St Peter Creek show evidence of active hillslope erosion on a large scale as well as exhibiting the potential for slope failure. This area and others within the burn provide a good indication of the current erosion potential from this fire as well as direct threats to the road VAR's. Many areas within the fire perimeter have sandy loam soil textures with weak cohesion, making them very susceptible to erosion and likely to produce high rates of post-fire soil loss and sediment delivery to stream channels. For example, during and immediately after a fire, large amounts of sediment can be released that had accumulated over time behind trees and other woody vegetation resulting in pulses of sediment being delivered to ephemeral channels. Therefore, post-fire erosion and associated debris flows are likely a dominant natural process of geomorphic evolution in this Range.

Precipitation

Much of the climate in the burn area is influence by both maritime and continental air masses providing the necessary moisture to the area. Precipitation distribution in the area is characterized by approximately 80% of the annual precipitation falling as snow from September to as late as early May in the higher elevation from 4,000 to 5,000 feet. Lower elevation around 2,500 feet sees snow as early as October and as late as April. Heavy localized thunderstorms occur occasionally during the months of May and June briefly increase stream flow and then continues its attenuation throughout the months until October when precipitation begin to increase. Annual precipitation within the burn area ranges from 15 to as much as 20 inches with the lower precipitation amount along the Sanpoil River (approximately 2,000 ft. elevation)[3]

Elevation of the area impacted by the fire range from 2,700 to 5,300 feet limiting any warm snowpack zone (rain-on-snow flow regime) while most of the area are snowpack dominated. Snowpack melt drives much of the base flow in perennial streams from March to May.

The nearest long-term precipitation record is located in Republic, Washington (2,500 ft. elevation) located approximately 6 miles to the NNE of the North Star Fire. Rainfall season for the town of Republic, Washington typically occurs from January to June with precipitation amount between 1 and 2 inches. Summer season from July to September receive less rainfall precipitation with less than 1 inch before picking up again in October with December being the wettest month. The area receives an average rainfall of 30 inches per year, and snowfall with almost 50 inches a year. Period of record for the town of Republic from the Western Regional Climate Center is 115 years (Figure 1) .

The principal period of erosive precipitation events occurs from November through March when precipitation at higher elevations falls mainly as snow. The snow pack at this elevation generally develops continuously over this period but melts over a much shorter time span. Precipitation in the spring in these areas are rain-on-snow events often under saturated soil conditions. This rainfall period poses the a immediate threat of watershed and fisheries damage due to accelerated runoff and erosion, as well as from pulses of ash inputs to streams in the burned area.

This runoff produces the largest portion of the total yield of the watersheds and generally produces the highest annual peak flows than the short duration peak flows of the monsoon season. The second mode of a general bimodal precipitation distribution is summer thunderstorm precipitation events.

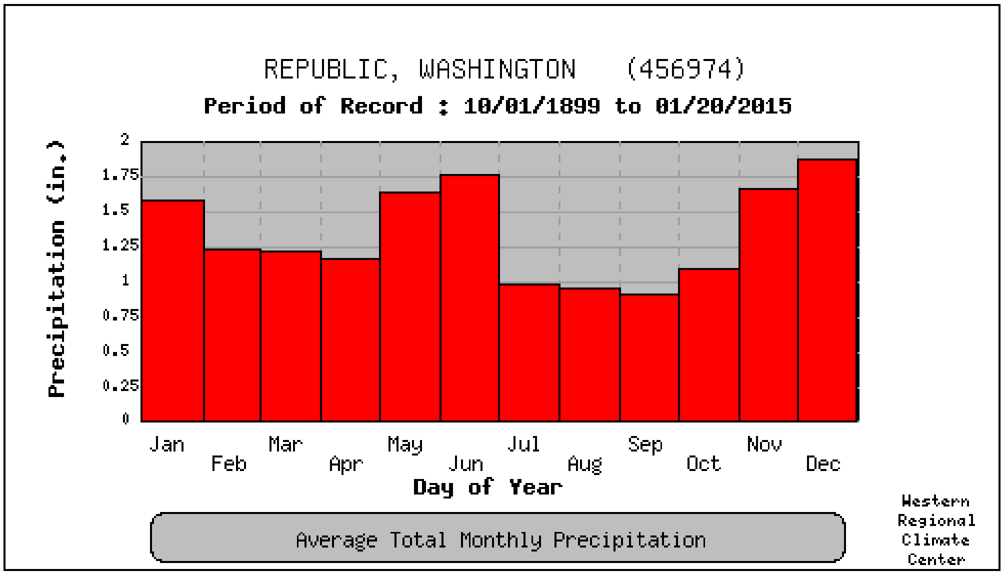

Figure 1. Average monthly precipitation for Republic, Washington (Western Regional Climate Center).

Outstanding Natural Resource Waters

Outstanding Resource Waters (ORW)s receive the highest level of protection under Washington's Water Quality Standards. The water quality and uses of these waters must be maintained and protected against all sources of pollution. This designation protects perennial rivers and streams, lakes, and wetlands within U.S. Forest Service Wilderness Areas. There are no ORW streams within the burn perimeter.

Municipal Watersheds

Orient Washington Water Supply

Orient is a small unincorporated community in northeastern Ferry County, Washington. The community of Orient is dependent on a historic water supply system that originates on the Colville National Forest. The Orient Watershed (facilitated by a historic weir (intake facility) is the domestic water source for the town, which has a population of ≈109 people (2015 census). There are ≈ 50 users including a historic 1910 school.

Orient is served by Orient School District No. 65. The district offers classes from kindergarten to grade 8. In October 2004, the district had an enrollment of 88 and a single school. The Orient School building is one of the oldest continuously used schoolhouses in Washington State.

The intake facility, located on the National Forest, is a mix of modern and historic structures. Historic structures include a Douglas-fir log with dimensional lumber, 12 inch wooden pipeline, and rock features supporting a weir gate and spillway.

The water system is comprised of modern pipe, valves, two sand lens filtrations systems with chlorination, and a 100,000-gallon holding tank. The system has the capability to shut down during high flow events, but the system lacks an automated system. So operating the system falls to a small group of volunteers who manually operate valves to reduce or shut off flow. These volunteers have daytime jobs, so response time to flow events is often slow resulting in exceeding water quality standards. The holding tank may only provide up to three days of water for the community should the facilities need to be shut down. Additionally, the historic intake structures is accessed by a foot trail, making cleaning of sediments captured by the weir system can only be done by hand.

The intake structure is at higher risk during normal storm events as they will have higher flows and sediment transport from burned areas in the upper drainage. For the 25-year storm event, a 150% increase in flow is estimated.

Figure 2: Historic weir intake structure for the Orient, WA, water municipal water system.

Water Supply Wells and Diversions

There were no wells identified within the fire perimeter. There are however several wells downstream of the burned area.

Impaired Waterbodies

No impaired water bodies occur within the burned area.

Description of Resource Values after the Stickpin Fire

The Stickpin Fire started on August 11, 2015 and burned approximately 56,329 acres. The fire pattern in the burn area resulted in high severity in the interior due to topography, vegetation types, and lower intensities east and north from mainly the dominant wind direction. Table 1 provides a summary of burn severity acres by river basin. The table is summarized by 6th level HUC subwatershed.

Subwatershed / Burn Severity	Acres	Burn Severity Acres	% Burn Total
East Deer Creek-Kettle River	**23,385**	**4,084**	**17.5**
Unburned-Very Low		519	2.2
Low Severity		1,007	4.3
Moderate Severity		701	3.0
High Severity		1,857	7.9
Little Boulder Creek	**13,829**	**2,661**	**19.2**
Unburned-Very Low		119	0.9
Low Severity		2,085	15.1
Moderate Severity		357	2.6
High Severity		99	0.7
Lone Ranch Creek	**14,706**	**7,202**	**49.0**
Unburned-Very Low		1,456	9.9
Low Severity		1,911	13.0
Moderate Severity		1,195	8.1
High Severity		2,640	18.0
Long Alec Creek	**11,669**	**5,429**	**46.5**
Unburned-Very Low		510	4.4
Low Severity		1,448	12.4
Moderate Severity		1,847	15.8
High Severity		1,625	13.9
North Fork Boulder Creek-Boulder Creek	**21,081**	**9,220**	**43.7**
Unburned-Very Low		2,680	12.7
Low Severity		2,361	11.2
Moderate Severity		2,170	10.3
High Severity		2,009	9.5
Saint Peter Creek	**17,634**	**6,198**	**35.1**
Unburned-Very Low		1,037	5.9
Low Severity		2,090	11.9
Moderate Severity		2,470	14.0
High Severity		601	3.4
South Fork Boulder Creek	**44,071**	**14,440**	**32.8**
Unburned-Very Low		3,286	**7.5**
Low Severity		4,995	**11.3**
Moderate Severity		3,424	**7.8**
High Severity		2,734	**6.2**
West Deer Creek	**13,662**	**7,095**	**51.9**
Unburned-Very Low		220	1.6
Low Severity		763	5.6
Moderate Severity		963	7.0
High Severity		5,149	37.7

Grand Total	56,329

Table 1. Severity and percent burn by subwatershed.

Vegetative ground cover, which is critical for maintaining soil stability, has been consumed in most areas where moderate and high severity wildfire has occurred. Areas that exhibit low burn severity have retained most of the effective ground cover, including live vegetation, unburned litter, and partially burned litter. An assessment of burn severity found the overall soil burn severity to be 27 % low, 23 % moderate, and 30 % high. Sixteen percent was either burned at very low severity or unburned. Soils that exhibit low burn severity have generally retained surface structure and porosity since fine and coarse roots of grasses, forbs, shrubs, and trees remain intact and larger woody species have generally survived. Where low severity wildfire has occurred, organic matter remains intact. This material covers and protects soil surfaces from raindrop impact and provides habitat for soil organisms that facilitate recovery of nutrient cycles. Soils subjected to low severity wildfire generally respond rapidly and in a positive manner as revegetation occurs, soil surfaces regain protective cover, and nutrient cycles are enhanced through deposition of ash and partially burned organic matter. Soils that are subjected to moderate and high soil burn severities have evidence of excessive soil heating in isolated patches; these areas typically exhibit longer term recovery with increased erosion potential. The most severely burned areas generally occur on steep terrain at higher elevations where pre-fire vegetation density and fuels accumulations were higher. Water repellency or soil hydrophobicity is present in some areas that burned at moderate severity within the fire perimeter, but was most evident in higher burn severity areas. The BAER Soil Resource Report contains a more detailed discussion of effects to soil resources.

Hydrologic features in each subwatershed are listed in table 2. Artificial paths are included however, no ephemeral channel inventory information could be found in terms of miles per subwatershed. Some channels were noted as being incised before the fire and this includes all channel types including ephemeral. All subwatersheds with VAR's were modeled using Wildcat 5.

The Stickpin Fire is contained within the Boulder Creek – Kettle River (HUC 1702000219), Curlew Creek watershed (HUC 1702000213), and the Vulcan Mountain – Kettle River watershed (HUC 1702000217). Eleven 6th code hydrologic were affected though only eight received enough burned acreage to be considered significant enough for analysis consideration (see table 1).

Subwatershed/StreamType	Miles
East Deer Creek-Kettle River (HUC 170200021907)	**29.3**
Intermittent	3.2
Perennial	19.3
Artificial Path	6.9
Little Boulder Creek 170200021903	**17.8**
Intermittent	0.8
Perennial	17.0
Lone Ranch Creek (HUC 170200021706)	**12.3**
Perennial	12.3
Long Alec Creek (HUC 170200021704)	**10.2**
Perennial	10.2

North Fork Boulder Creek-Boulder Creek (HUC 170200021906)	**29.0**
Intermittent	5.6
Perennial	23.4
Saint Peter Creek (HUC 170200021304)	**15.4**
Intermittent	1.0
Perennial	14.4
South Fork Boulder Creek (HUC 170200021905)	**50.3**
Intermittent	5.5
Perennial	44.9
West Deer Creek (HUC 170200021705)	**17.2**
Intermittent	2.3
Perennial	14.9
Artificial Path	0.1
Grand Total	**181.6**

Table 2. Miles of stream type in each subwatershed. No information on ephemeral channels was available.

Some private and state lands were burned in the fire (see table 2). Within the fire perimeter, approximately 16,657 (30%) acres burned at high severity, 12,900 (23%) acres burned at moderate severity, 15,310 (27%) acres burned at low severity and 8,852 (16%) acres burned remained unburned or burned at very low severity. The vegetated habitat in the Stickpin Fire area is a combination of Eastside (interior) Mixed Conifer Forest, Lodgepole Pine Dominated Forest and Ponderosa Pine Dominated Forest. It is composed of open to closed evergreen conifer tree canopies. Surface soil texture range from silty loam to loam to extremely cobbly fine sandy loam. Slopes range from low gradient valley bottoms and meadows to vertical where canyon walls and large outcrops occur.

Figure 3. Photo looking upstream in West Deer Creek. Private land in the fire perimeter.

Another key data set used for the assessment was prepared specifically for the BAER assessment by the U.S. Geologic Survey (USGS). It depicts spatially the probability of debris flows in small catchments and stream reaches in the fire given a storm of a specified recurrence interval. The model was developed by the USGS as a tool to help analyze the risk of post-fire debris flows. It was originally developed to assess the potential for debris flows after fires in southern California and the Rockies. Though not tested or calibrated for physiographic ecoregions in Washington, the model was applied to the Stickpin fire to see if it could be useful for identifying slopes and streams that may be prone to debris flows, and therefore the values potentially at risk. It was found that the data in the model applied to the Stickpin fire were generally useful for identifying potential impacts to resources and infrastructure. It may however, have underestimated the probability of risk because inherently, the stability of the decomposed volcanic ash mixed with granitics in the area is already comparatively low. None the less, the data has been useful in a relative sense because it identifies those areas or reaches where the density of highest probability is greatest. The debris flow model shows the highest concentration of debris flow probability in the upper Long Ranch subwatershed in the area of proposed treatments. The model was reviewed by local Hydrologist expert Bill Swartz who verified modeled problem areas. Overall the model was very helpful in designating priority treatment areas.

Water Quality

The fire burned along 75 miles of perennial streams and 117 miles of intermittent/ephemeral streams. There is one listed 303(d) stream (Category 5) waterbody on the Colville National Forest within the fire perimeter - a stream segment on the North Fork St Peter Creek (Listing ID: 38114 – WA State Dept of Ecology). Stream segment begins from inside the burn perimeter for 3,000ft to the edge of the Forest Service boundary for a total length of 7,000ft. Other listed stream segments found outside of the fire perimeter boundary include St. Peter Creek (Listing ID: 38119 & #46192) near the confluence with the SF St Peter Creek and Curlew Creek; SF Peter Creek (#8563); Lone Ranch Creek (#46271, #48934) near the junction of SF Lone Ranch Creek road and Lone Ranch Creek road, and East Deer Ck (#38056 at Hwy 395). Waterbodies are listed either for temperature exceedances, bacteria, or dissolved oxygen.

The greatest impacts of fire on water quality are increases in sediment and turbidity. Erosion rates and sediment yield can increase many fold in burned areas (NWCG 2001). Increases in sediment yield can last for several years. Eroded soil and ash can cause extremely high turbidity levels during runoff events that can be toxic to aquatic life and especially the Orient municipal watershed and their treatment facility. Estimated increases in sediment delivery for burned drainages within the Stickpin Fire are greatest within the first 3 to 5 years following the fire and can vary by drainage. Effects often last up to 25 years. More information on soil erosion can be found in the Stickpin Fire BAER Soils Specialist Report.

Stream temperatures can also increase following wildfire, primarily from removal of the vegetative canopy that shades the water surface. Elevated stream temperatures are detrimental to most cold water fish species (NWCG 2001).

Changes in water chemistry can also occur from wildfire. Chemical changes are due primarily to increases in nutrients carried to water courses from burned areas. Increases in various forms of nitrogen, phosphorous, and several cations are often observed in the first few storms following a fire (NWCG 2001). These nutrients are not hazardous to humans but can result in algae blooms and eutrophication in downstream receiving waters. Water quality normally returns to pre-burn levels within 1 to 2 years following fire (NWCG 2001).

Stream in the Fire perimeter and Burn Severity	
Severity/Owner	**Miles**
Intermittent	**117**
Unburned-Very Low	**19**
Private	*1*
State	*0*
USFS	*18*
Low Severity	**26**
Private	*2*
State	*2*
USFS	*23*
Moderate Severity	**24**
Private	*1*
State	*2*
USFS	*20*
High Severity	**47**
Private	*2*
State	*5*
USFS	*41*
Perennial	**75**
Unburned-Very Low	**19**
Private	1
State	0
USFS	17
Low Severity	**21**
Private	*2*
State	*2*
USFS	*18*
Moderate Severity	**16**
Private	*1*
State	*2*
USFS	*12*
High Severity	**20**
Private	*1*
State	*1*
USFS	*18*
Grand Total	**192**

Table 3. Stream type and owner within the fire perimeter.

Water Quantity

Schulz (NMED 2012b) summarizes post fire effects relevant to wildfires such as the Stickpin Fire. The resulting fire effects on watershed processes are a function of the burn size, severity, proportion of watershed burned at high severity, slope, and location. Burn severity is defined by fire intensity, duration, and consumption of vegetation and litter, and is determined by fuel load, fuel type, moisture content, and weather. For example, areas categorized as high severity typically have exposed mineral soil, ash accumulations, and most vegetation, surface litter, and soil organic matter consumed by fire. These extreme changes to soil structure can cause water-repellant (hydrophobic) soil conditions, and the resulting decreased infiltration can lead to amplified surface runoff, erosion, channel scour and instability, and sediment transport and deposition.

Figure 4. Upland stream channel.

Figure 5. Pre-fire erosion feature on private land above Long Alec Creek.

These watershed effects in Eastern Washington are exacerbated spring rain-on-snow events as well as by localized, high-intensity rainfall during the thunderstorm season (June-July) that often immediately follows the regular wildfire season (July-late September, depending on drought, snow pack, and weather).This combined with lack of vegetation and litter for soil stabilization and roughness to slow runoff can result in annual peak streamflow discharges of several orders of magnitude above normal, and mobilize combustion by-products, suspended, and dissolved material which affects the physical, chemical, and biological quality of the water. Post-fire sediment yield, or sediment outflow, can be up to several orders of magnitude greater than unburned areas depending on geology, soil, topography, vegetation, fire characteristics, weather patterns, and land use practices in the watershed.

Some watershed processes recover quickly after wildfire while others require decades or even longer. The rate of forest overstory and understory vegetation reestablishment generally determines the recovery rate of soil stabilization and water quality components. Understory vegetation generally regenerates faster than overstory vegetation. In widespread high severity burn areas, loss of seed banks, altered soil processes, and difficult conditions for recolonization significantly lengthens the time for forest establishment.

Changes to channel morphology from increased annual peak flows and runoff velocities include rill and gully erosion, debris flows in steep headwater basins, and scour and incision in low order channels. In contrast, further downstream the primary effect is aggradation due to decreased channel gradient. Erosion processes generally return to background levels 3 to 5 years after the fire, but the accumulated sediment in the downstream channels may take an order of magnitude longer to export due to decreased sediment transport capacity with annual peak flows returning to normal, which can have long term effects on channel morphology.

Burning of vegetation and litter cover, development of water repellent soils, and sealing of the soil surface from raindrop impact combine to result in increased runoff from the forest floor (Shakesby et al 2007). Increased runoff results increases the magnitude of post-fire peak flows. Next to the physical destruction of a fire itself, post-fire floods are the most damaging aspect of fire (Neary et al. 2005). Following wildfires, peak flows can increase dramatically and represent a serious threat to human life and safety from flooding and debris. Post-fire peak flows can change stream channel geomorphology through scouring and deposition. Aquatic habitat and biota and riparian ecosystems can also be severely impacted by unusual flood flows (Neary et. al. 2005).

Post-fire peak discharge increases tend to be most pronounced when short-duration, high-intensity rainfall of comparatively small volume occurs on steep, severely-burned catchments with shallow, skeletal, water-repellent soils (Robichaud et al. 2000, Neary et al. 2003 in Shakesby et al. 2007). These conditions exist in the area burned by the Stickpin Fire. Tremendous increases in peak flows have been reported following wildfires. Peak flow increases of 23 fold were found by Campbell et al (1977, in Shakesby et al. 2007) in a moderately burned ponderosa pine site in Arizona and increases of 200 fold were found in a severely burned site. Following the Rodeo-Chediski Fire of 2002, peak flows increased by orders of magnitude above pre-fire conditions. Often increased peak flows of up to 100 times those previously recorded have been measured after wildfires, but peak flow increases of as much as 2,300 times pre-fire levels have been recorded. Recovery to pre-fire peak flows normally occurs within 5 to 10 years following wildfire but can take many decades.

Soils in the uplands and drainages are characterized primarily as B hydrologic soil group soils. This group of soils exhibit low to moderate runoff rates. For a more detailed description of the soils within the burned area refer to the Soils Specialist Report for the Stickpin Fire BAER assessment.

Based on historic precipitation patterns, it can be expected that rain has a lower probability of occurring in the weeks following the Stickpin Fire than snow events. If rain events occur, they will probably be of short duration and low intensity storms which are not generally associated with flash flooding and high erosional events.

Peak flows have been estimated for watersheds above values at risk identified within and below the burned area. The Wildcat modeling is generally targeted at areas of high burn severity and areas with hydrophobic soils, as runoff from these areas are expected to be different from the unburned or low burn severity areas. Therefore, smaller basins that burned with a high severity are expected to display a larger magnitude response compared to a larger basin that contains a mosaic of unburned, low, moderate and high burn severities. Areas with hydrophobic soils further add to the predicted magnitude of runoff.

Wildcat 5 Results Summary

Estimated pre- and post-fire peak flows for the Wildcat 5 models are summarized in Table 5. A total of 20 Wildcat 5 runs were completed, a post- and pre-run for each VAR drainage. All VAR modeling runs were completed simulating a 25-year/3-hour storm event to maintain consistency with other modeling efforts on the North Star and Tunk Fires which occurred around the same time and in the same immediate area. The modeled storms precipitation was 1.5". Post-fire flows predicted by Wildcat5 show high variability in modeled runoff due to basin size and burn severity. Generally, post-fire peak flow increases are attributed to higher burn area acreages and higher burn severity. Because the data in Table 5 are derived from a numerical model, the runoff estimates should not be interpreted as absolute values. Small drainage basins with higher percentages of high burn severity showed the greatest increases in runoff potential. Peak flow per unit area described in cubic feet per second per square mile (cfs/mi^2) is another measurement used to evaluate the hydrologic response of a VAR watershed to a fire. The greatest increase was found for the Boulder Rd. crossing with a 1,713% increase in peak flow. The remainder of the smaller road crossing watersheds had similar peak flow increases well above 100% where high severity is uniform or nearly uniform throughout.

The flow model is not intended for large subwatersheds where the VAR's are far from the uplands such as Deer Ck, Long Alex, St Peter and Lone Ranch. Accuracy is improved when modelling smaller subsets of these watersheds higher in the subwatersheds. A map of VAR locations in relation to burn severity are included in Appendix A.

In addition to field inspection and modeling local experts and residents were consulted regard flooding history and past flooding effects. This vital exercise guided much of the field focus as well as final VAR selection and prioritization for modelling. A number of those interviewed referenced a significant storm and flooding events have occurred periodically but vivid memories of the flood in early 1998, along with field observations, helped in locating VAR's in West Fork Deer, Long Alec and Saint Peter drainages near Kettle River and Curlew Creek. Flooding in 1998 caused road, culvert and property damage in these areas due to a prolonged spring rain event in an area that now has a high percentage of high severity burns. Recent clear cutting timber activities in West Fork Deer Ck. have compounded storm runoff issues.

A historic wooden dam located in the East Deer Creek subwatershed is an important VAR. Other significant VAR's include occupied structures in the town of Malo and to a lesser degree in Curlew. However, these VAR's are a good distance downstream which lessens but not eliminates the risk. It is recommended that property owners and state agencies seek additional analysis. By far the most numerous VAR's were road and culvert related. Especially those in high severity burn and especially those at stream channel crossings within or below the burn (Table 4).

Table 4. Wildcat 5 Model Summary for individual VAR drainages*

Subwatershed	VAR	Lat. & Long.	pre-fire peak flow (cfs)	post-fire peak flow (cfs)	Percent Change
East Deer Ck. - Kettle R.	FSR 6100215	48 53' 11.54" 118 21' 49.35"	142	1,711	**1,105%**
East Deer Creek-Kettle R.	Orient Dam	48 51' 17.35" 118 13' 24.49"	1,140	2,851	**150%**
Lone Ranch Ck.	FSR 6120-500	48 54' 32.48" 118 25' 13.71"	158	2,135	**1,251%**
Lone Ranch Ck.	C-651 rd.	48 58' 35.03" 118 30' 33.01"	1,325	4,070	**207%**
Long Alec Ck.	Life and private properties. Long Alec Creek before Kettle River	48 53' 03.86" 118 35' 49.88"	740	3,039	**311%**
Long Alec Ck.	Road C-582	49 52' 51.24" 118.35' 51.36"	685	3,079	**349%**
Boulder Ck.	Hwy 395 & Railroad	48 50' 08.04" 118 11' 01.15"	1,515	5,298	**250%**
North Fork Boulder Ck.-Boulder Ck.	6113 FSR	48 50' 54.49" 118 21' 00.96"	216	2,546	**1,079%**
North Fork Boulder Ck.-Boulder Ck.	FSR 400 @ Butte Fork Creek	48 50' 44.72" 118 22' 54.92"	230	1,310	**470%**
North Fork Boulder Creek-Boulder Ck.	FSR 90 & wood bridge @ NF Boulder Ck.	48 49' 14.15" 118 16' 22.85"	1,555	3,829	**146%**
South Fork Boulder Ck.	Above-2030	48 45' 35.33" 118 25' 40.94"	80	738	**151%**
South Fork Boulder Ck.	2030 road	48 45' 32.55" 118 25' 28.28"	449	1,083	**141%**
South Fork Boulder Ck.	At Midget Creek	48 47' 43.30" 118 22' 40.79"	1,409	5,025	**257%**

South Fork Boulder Ck.	At Indian Ck.	48 45' 37.48" 118 24' 21.69"	626	2,021	**223%**
St. Peter Creek	Life and property HWY21	48 53' 14.19" 118 35' 48.18"	1,287	2,384	**85%**
St. Peter Creek	Culvert	48 46' 57.96" 118.34' 58.86"	1,457	2,346	**61%**
West Deer Creek	Road	48 53' 48.87" 118 33' 55.85"	1,255	6,595	**425%**
West Deer Creek	Boulder Creek Hwy	48 52' 03.85" 118 25'29.56"	107	409	**1,713%**
West Deer Creek	FSR 6100600	48 51' 49.09" 118 25' 51.85"	347	2,894	**734%**
West Deer Creek	FSR 6120	48 53' 02.66" 118 26' 10.50"	44	642	**1,359%**

Wildcat modeling was performed to predict the effects of post fire treatment on three representative or high priority subwatersheds. Changes to the model were based on the assumption that treatments would have a similar effect on runoff as the same acreage burnt at a low-moderate severity. The difference between the post-fire/no treatment percent changes and the post-treatment predicted percent changes over pre-fire conditions are significant. The West Deer pour point modeling results shows an order of magnitude change (Table 5). As mentioned previously, flow numbers are presented for informational purposes are not to be considered as exact or accurate, rather it is the percent change over pre-fire conditions that is important to consider.

Post Treatment Wildcat Modelling Results					
Subwatershed	**Pre-Fire Q_{pk} (cfs)**	**Post-Fire Q_{pk} (cfs)**	**Post Treatment Q_{pk} (cfs)**	**Post-Fire % Change**	**Post Treatment % Change**
Upper Lone Ranch at the 6120 Rd	158	2,135	1,455	**1,251**	**821**
West Deer at Boulder Rd and Third Creek	108	1,416	409	**1,223**	**282**
East Deer at Orient Dam	1,140	2,851	2,045	**150**	**79**

Table 5. Post treatment wildcat percent change predictions.

Hydrologic Design Factors

The analysis for pre- and post- fire hydrologic response and probability of flows is based on the probability of a 25-year storm occurring in the fire area. Vegetative recovery, which correlates with hydrologic response, is expected to be within 1 to 5 years. The 25-year design storm has a 4% chance of occurring in any given year and an 18.5% chance of occurring over the next five years. Conversely, there is an 81.5% chance that the 25 year storm event will not occur over the next 5 years (during the recovery period). The 25 year, 3 hour duration storm anticipated for the burned area is 1.5 inches (NOAA, 2015). Hydrologic design information is displayed in Table 5. It is important to note that any VAR found to be at risk during the 5 year event will still be at risk during greater events and may be at risk in smaller events as well.

Table 5. Hydrologic design factors	
A. Estimated Vegetative Recovery Period	1-5
B. Design Chance of Success	80%
C. Equivalent Design Recurrence Interval	25 years
D. Design Storm Duration	3 hours
E. Design Storm Magnitude	1.5 inches
F. Design Flow	34 cfs/mi^2
G. Estimated Reduction in Infiltration	35%
H. Adjusted Design Flow	46 cfs/mi^2

In analyzing the change in watershed response, the pre-fire discharge is calculated and estimated. The pre-fire design flow is the flow responsible for forming present day channel conditions and flows used to estimate proper performance of culverts and other drainage structures. Pre-fire design flows assume pre-fire infiltration and ground cover conditions. After a fire it is necessary to predict the increase in runoff that results from reduced water infiltration into the soil from soil hydrophobicity and lack of ground cover. Hydrophobic soils reduce water infiltration into the soil. Soil cover reduces soil erosion and subsequent sedimentation. High soil burn severity is characterized by less than 20% soil cover and extensive soil hydrophobicity. Moderate soil burn severity has non-continuous soil hydrophobicity and 20% to 50% existing soil cover with the potential for needle cast to increase the soil cover in the near future. Rainfall infiltrates into the soil with moderate soil burn severity better than high soil burn severity but is still reduced from pre-fire conditions. Increased flows provide a conduit for increased sediment delivery to streams or can initiate mass wasting events. Estimated reduction in infiltration is based on the percentage of hydrophobic soil and loss of soil cover in the burn area and was determined to be 35% for the Stickpin Fire.

Recommended Emergency Hydrology Response Actions (HRA)

Objectives

In response to the values at risk and affected resources, the objectives of the proposed response actions are to:

- Minimize threats to life and public safety.
- Reduce the impacts of high intensity runoff and erosion, debris flows, and to minimize loss of long-term site productivity, streambank stability and water quality

- Promote re-vegetation of the steep, severely burned areas.
- Minimize impacts to riparian habitat and aquatic resources.

Note: As an ancillary benefit of proposed response actions, downstream impacts from increased runoff and accelerated erosion may also be realized on non National Forest System Lands

Short Term Response Actions

Establishment of vegetative cover is critical to reducing erosion rates, improving hydrologic function, and maintaining site productivity. Mulching and/or seeding provide immediate or short-term cover which reduces erosion and runoff. Natural re-establishment of cover can require up to 5 or more years to reach pre-burn cover conditions resulting in natural runoff and erosion rates. If extreme rainfall events occur within the five-year period, extreme erosion events could occur resulting in a loss of hydrologic function and soil productivity. This would further delay natural cover re-establishment and cause longer term accelerated erosion and high runoff events.

The following response actions are recommended to meet objectives stated above:

- **HRA-1**: Aerial mulching areas of high and moderate burn severity to provide for re-establishment of vegetative ground cover.
    - Mulching alone can reduce sediment delivery to the stream channel by 70 to 80 percent of the sediment delivery from untreated areas over a one-year period. It takes 2 to 3 years for burned areas to naturally re-vegetate to match sediment delivery levels one year after treatment. Mulching with wood shred was selected as a recommendation by the BAER IDT as a potential treatment to help reduce hydrologic response, erosion, and protect soils. The correct type of mulch must be chosen for an area, as some may be more appropriate than others. Wood shred is more hardy, resistant, and less likely to contain a weed source. Utilizing wood shred would also allow the Forest Service to implement some cost savings by allowing them to exploit the large accumulation of biomass piles that already exist on the forest.
    - see Soil Specialist Report and the 2500-8 for details and cost estimate.
- **HRA-2**: Road and culvert maintenance is needed to minimize fire-related effects to water quality from increased runoff and sediment from road surfaces.
    - See engineering report for details and cost estimate

Long Term Response Actions

1. Coordinate with state agencies, county agencies, local communities, and other interested parties to identify concerns and opportunities for monitoring and evaluating the status of continuing threats to VAR, watershed conditions, and water quality. Utilize existing protocols to accomplish this monitoring. Establish watershed action plans for long-term improvement of severely burned watersheds and subwatersheds.

2. Conduct post-fire watershed evaluations to document conditions such as ground cover, rilling and gullying, sediment deposition, water quality, substrate composition, and to prioritize areas for long-term treatments. In watersheds where long-term response actions are implemented, monitoring plans should be developed to determine effectiveness of any treatments.

3. Grazing on the forest is regulated in part by range condition standards developed specifically by the forest. These standards will be implemented when determining stocking timing, intensity, and duration.

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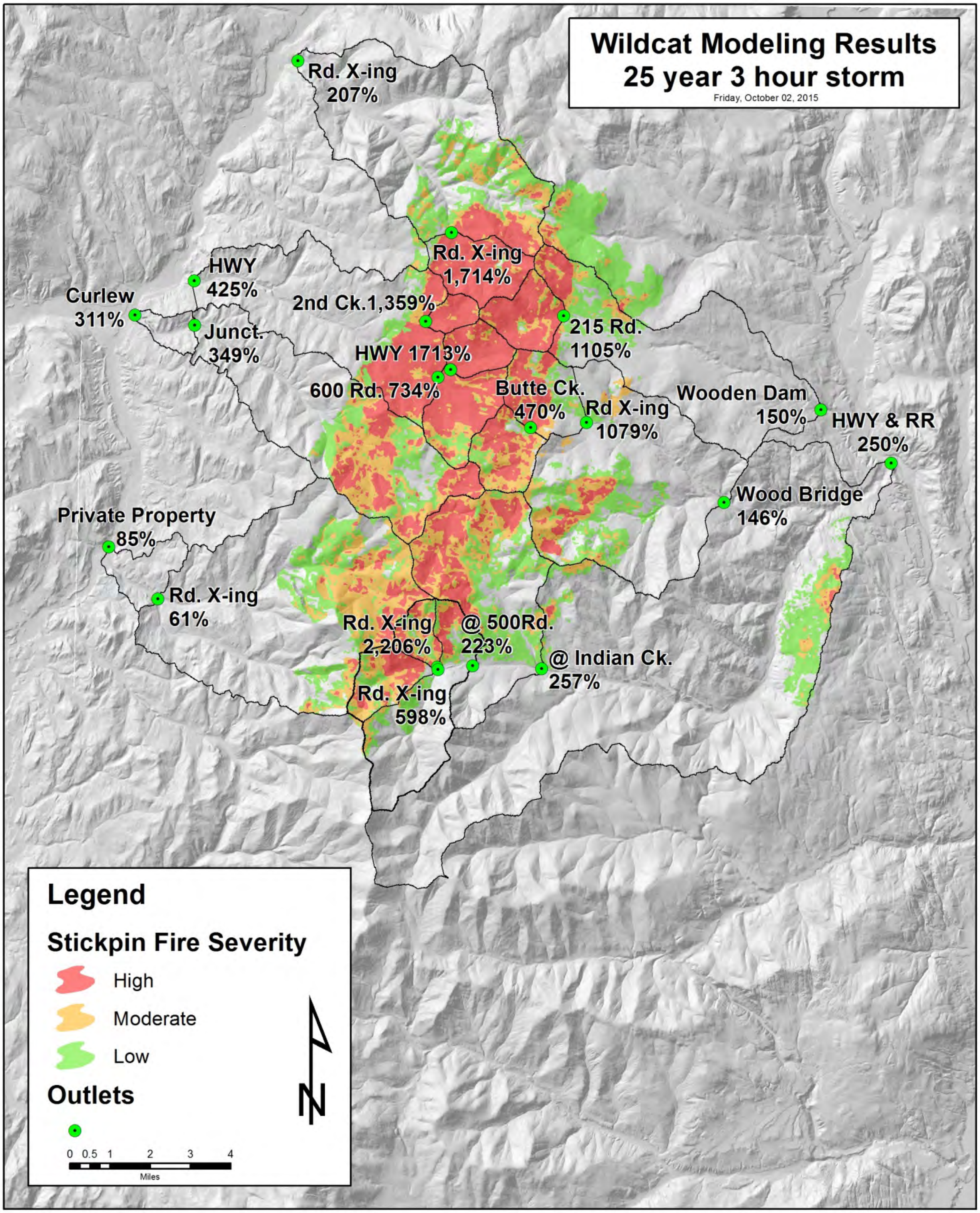
APPENDIX A

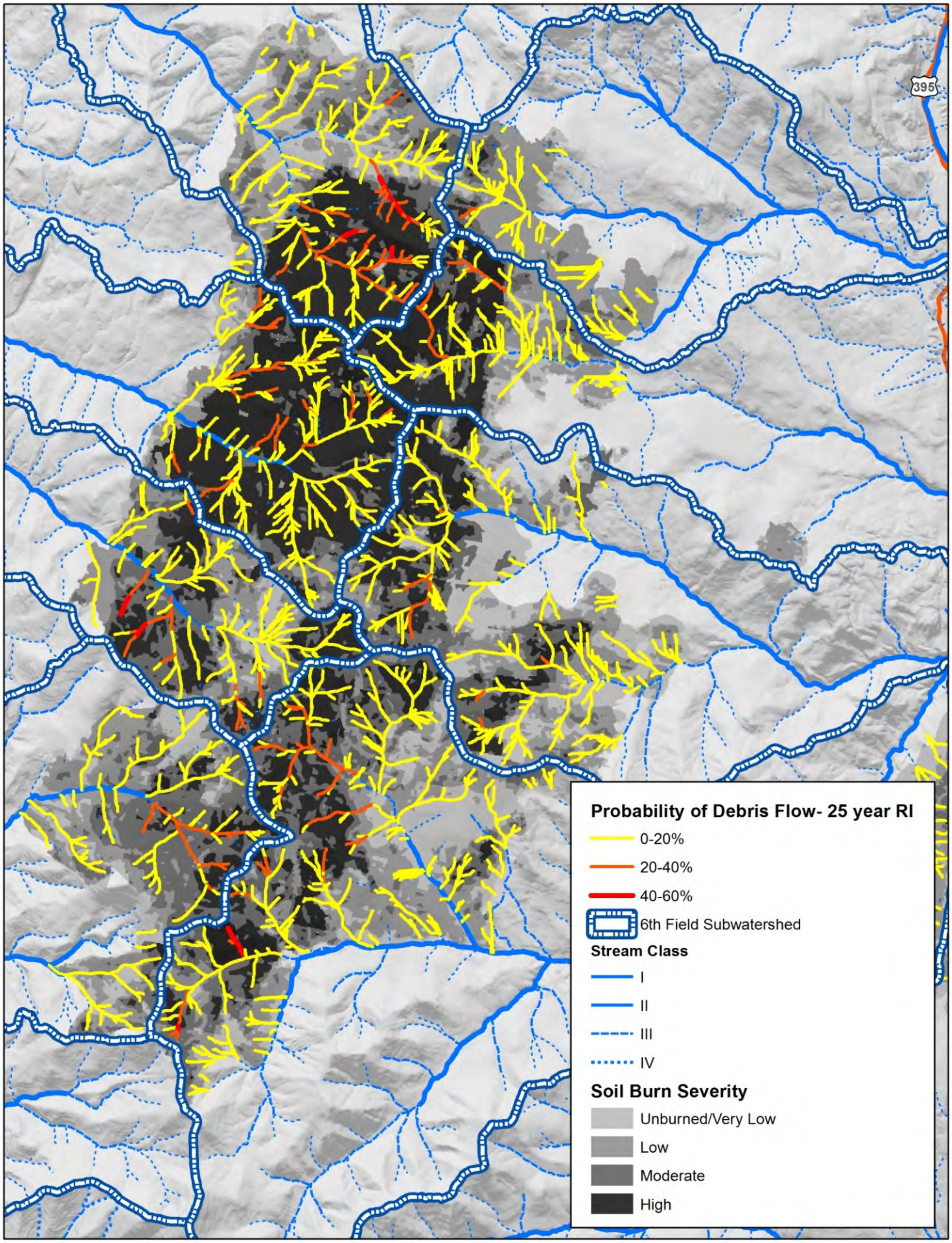
Wildcat Modeling Results



Wildcat Modeling Results
25 year 3 hour storm
Friday, October 02, 2015
Rd. X-ing 207%
Rd. X-ing 1,714%
HWY 425%
Curlew 311%
2nd Ck.1,359%
Junct. 349%
215 Rd. 1105%
HWY 1713%
600 Rd. 734%
Butte Ck. 470%
Rd X-ing 1079%
Wooden Dam 150%
HWY & RR 250%
Wood Bridge 146%
Private Property 85%
Rd. X-ing 61%
Rd. X-ing 2,206%
@ 500Rd. 223%
@ Indian Ck. 257%
Rd. X-ing 598%
Legend
Stickpin Fire Severity
High
Moderate
Low
Outlets
0 0.5 1 2 3 4
Miles
N

APPENDIX B

USGS Debris Flow Model



395
Probability of Debris Flow- 25 year RI
0-20%
20-40%
40-60%
6th Field Subwatershed
Stream Class
I
II
III
IV
Soil Burn Severity
Unburned/Very Low
Low
Moderate
High