Hydrology Resource Report
Waldo Canyon Fire BAER Assessment – Pikes Peak Ranger District
Pike National Forest
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Objectives

1. Identify Values at Risk downstream and down slope from the high severity burn areas.
2. Assess watershed changes caused by the fire, particularly those that pose substantial threats to human life, property and critical natural and cultural resources.
3. Assess the potential for post-fire effects to downstream values at risk.

Initial Concerns

- Threats to human health and life within and downstream of the burned area.
- Threats to the structures, roads and other improvements within the burn area.
- Threats to the urban areas and residences adjacent to the Highway 24 corridor and along the foothills on the east flank of the fire.
- Threats to roads, stream crossings, or other man-made developments or property that are downstream of the fire and are at risk of being removed or damaged from future storm events.
- Threats to water quality.

I. Resource Condition Assessment

A. Resource Setting

The Waldo Canyon Fire burned approximately 18,247 acres within the foothills and mountains of the Rampart Range immediately northwest of Colorado Springs, Colorado in El Paso County. The fire perimeter in a general sense can be delineated by State Highway 24 on the southwest, Rampart Reservoir and West Monument Creek on the north and the foothills (in and around Centennial Expressway) along the east flank of the burned area. Table 1 summarizes the acres burned by land ownership.

Table 1: Area Burned and Percent of Burned Area by Land Ownership

Land Ownership	*Acres*	*Percent of Burned Area*
USDA Forest Service (NFS lands)	14,422	79.0%
Private	3,678	20.2%
DOD (U.S. Air Force Academy)	147	0.8%

The National Forest System (NFS) lands which burned are managed by the Pikes Peak Ranger District of the Pike & San Isabel National Forests and the Cimarron and Comanche National Grasslands (PSICC). Unfortunately, 346 private residences were destroyed in the fire. Fire ignition occurred on June 23, 2012, and it was contained on July 10, 2012. The fire burned primarily Ponderosa Pine and mixed-conifer stands.

The burn area covers multiple tributaries to the Fountain Creek and Monument Creek watersheds that are tributary to the Arkansas River drainage. Table 2 lists the five sixth-level watersheds affected by the fire.

Table 2: Sixth-level Watersheds within the Burned Area

6th Level Watershed	*Watershed Name*
110200030103	West Monument Creek
110200030107	Lower Monument Creek
110200030201	Headwaters Fountain Creek
110200030203	Cascade Creek-Fountain Creek
110200030204	Garden of the Gods

Within these 6th-level watersheds, multiple sub-watersheds (smaller watersheds) were affected by the fire. Sub-watersheds were delineated to evaluate the values-at-risk at a larger scale within each of these 6th-level watersheds. A pour point was identified at the mouth of each of these sub-watersheds, and this point was utilized to delineate the drainage area above that point. Tables 3 through 7 summarize the pour points and names for each of those sub-watersheds:

Table 3: Sub-watersheds for Headwaters Fountain Creek

Pour Point Designation	*Sub-watershed Name*
A	Sand Gulch
B	Wellington Gulch
C	Unnamed (Mud across Hwy 1)
D	Unnamed (Mud across Hwy 2)

Table 4: Sub-watersheds for Cascade Creek-Fountain Creek

Pour Point Designation	*Sub-watershed Name*
E	Unnamed (Cascade)
F	Unnamed (Marygreen Pines)
G	Unnamed
H	Waldo Canyon
I	Cavern Gulch
J	Fountain Creek above Manitou Springs

Table 5: Sub-watersheds for Garden of the Gods

Pour Point Designation	*Sub-watershed Name*
K	Williams Canyon
L	Camp Creek (aka Queens Canyon)
Y	Camp Creek above Eagle Lake Camp 1
Z	Camp Creek above Eagle Lake Camp 2

Table 6: Sub-watersheds for Lower Monument Creek

Pour Point Designation	*Sub-watershed Name*
M	Unnamed (Alpine)
N	S. Douglas Creek
O	N. Douglas Creek
P	Dry Creek

Table 7: Sub-watersheds for West Monument Creek

Pour Point Designation	*Sub-watershed Name*
Q	W. Monument Creek above Filtration Plant
R	Unnamed (N. Blodgett Gulch)
S	Unnamed (Devils Kitchen)
T	Unnamed (d/s Northfield Reservoir)
U	Unnamed (Nichols Reservoir)
V	Wildcat Gulch
W	Unnamed (Rampart Reservoir Shore 1)
X	Unnamed (Rampart Reservoir Shore 2)

Nearly all of the burned area is comprised of shallow, weathered soils from the Pikes Peak batholith. The landscape is highly dissected in the upland forested portion of the burn, and annual precipitation is comprised of snowfall during the winter and high intensity rainfall events during the summer.

Perennial tributaries directly affected by the burn include Fountain Creek, West Monument Creek, and Camp Creek. Camp Creek is the only perennial stream within the burned area. Ninety-six miles of intermittent channels and 4 miles of perennial drain the Waldo Canyon Fire burn area. While Fountain Creek and Monument Creek are not directly within the burned area, all of the sub-watersheds are tributary to either of these larger perennial streams.

Vegetation that existed prior to the burn is summarized in Table 8. The general vegetative type and approximate percent of cover are displayed.

Table 8: General Vegetative Type and Percent of Cover

Vegetation Type	*Percent of Cover*
Ponderosa Pine	50.2%
Mixed Conifer	28.3%
Aspen	6.8%
Shrub	8.7%
Riparian	4.5%
Pinyon-Juniper	1.1%
Bristlecone/Limber Pine	0.3%
Spruce-Fir	0.1%

B. Summary of Findings, On-the-Ground Survey

1. Identify Values at Risk

Table 9 identifies the values at risk in the primary watersheds (HUC 6) of the Waldo Canyon Fire. The primary threat to the values at risk is flooding and sedimentation. Mobilization of woody debris and refuse within stream channels is an additional threat in areas of stream constriction where debris can build up with sediment and spread floodwaters and sediment into residential and urban areas. See soils report for information on sedimentation.

Table 9: Watershed Related Values at Risk in the watersheds of the Waldo Canyon Fire (a)

6th-level Watersheds and Sub-watersheds	*Values at Risk from Flooding and Sedimentation*	*Comments*
***West Monument Creek (6th-level)*:** Sub-watersheds include: W. Monument Creek above Filtration Plant, Unnamed (N. Blodgett Gulch), Unnamed (Devils Kitchen), Unnamed (d/s Northfield Reservoir), Unnamed (Nichols Reservoir), Wildcat Gulch, Unnamed (Rampart Reservoir Shore 1), and Unnamed (Rampart Reservoir Shore 2).	***USFS values*** NFS roads and trails (FSRs: 303, 303A, Rampart Reservoir Roads, 304, and FSTs: 700, 700.A, and 700.B). Loss of soil and cover from hillslopes. Preble's mouse riparian habitat. West Monument Creek riparian and fisheries. Spread of noxious weeds. ***CSU values*** Temporary impacts to water quality from ash and sediment. Potential loss of human life and water supply and related infrastructure as a result of major flooding.	With the expected increases of sediment and runoff during large storms (post-fire) from the burned watersheds, channel sections in lower gradient stream reaches have the potential to accumulate excess sediment and debris deposition that could cause peak flows to overwhelm channels and flood adjacent areas and streamside terraces. Increased peak flows have the potential to cause damage to CSU's water supply and related infrastructure.
Lower Monument Creek (6th-level): Sub-watersheds include: Unnamed (Alpine), S. Douglas Creek, N. Douglas Creek, and Dry Creek.	***USFS values*** Loss of soil and cover from hillslopes. West Monument Creek riparian. Spread of noxious weeds. ***NRCS values*** Life and properties associated with North and South Douglas Creeks, Dry Creek, Flying W Ranch, and Sub-basin M (unnamed, Alpine)	With the expected increases of sediment and runoff during large storms (post-fire) from the burned watersheds, channel sections in lower gradient stream reaches have the potential to accumulate excess sediment and debris deposition that could cause peak flows to overwhelm channels and flood adjacent areas and streamside terraces. Hazmat issues, loss of infrastructure, increased flooding and sediment deposition.
Headwaters Fountain Creek (6th-level): Sub-watersheds include: Sand Gulch, Wellington Gulch, Unnamed (Mud across Hwy 1), and Unnamed (Mud across Hwy 2).	***USFS values*** NFS road (FSR: 300). Non-system roads. Loss of soil and cover from hillslopes. Sand Gulch and Wellington Gulch riparian. Spread of noxious weeds. Historic mine site. ***NRCS values*** Life and properties associated with Sand and Wellington Gulches, Chipita Park, Ute Pass Elementary School, Rampart Terrace, Crystola Circle, Cascade. Pond in Wellington Gulch. ***CDOT values*** Highway 24 infrastructure.	With the expected increases of sediment and runoff during large storms (post-fire) from the burned watersheds, channel sections in lower gradient stream reaches have the potential to accumulate excess sediment and debris deposition that could cause peak flows to overwhelm channels and flood adjacent areas and streamside terraces. Hazmat issues, loss of infrastructure, increased flooding and sediment deposition. Sediment deposition, rilling and flooding are already occurring. Potential loss of ingress and egress. CDOT has already had to remove debris between pour points C and D.

Table 9 **Cont.**: Watershed Related Values at Risk in the watersheds of the Waldo Canyon Fire (a)

6th-level Watersheds and Sub-watersheds	*Values at Risk from Flooding and Sedimentation*	*Comments*
Cascade Creek-Fountain Creek (6th-level): Sub-watersheds include: Unnamed (Cascade), Unnamed (Marygreen Pines), Unnamed, Waldo Canyon, Cavern Gulch, and Fountain Creek above Manitou Springs.	***USFS values*** NFS road (FSR: 300) and the Waldo Canyon Trail. Loss of soil and cover from hillslopes. Waldo Canyon riparian. Spread of noxious weeds. ***NRCS values*** Life and properties associated with East Cascade and Manitou Springs. ***CDOT values*** Highway 24 infrastructure. ***County values*** Life and property associated with Manitou Springs.	With the expected increases of sediment and runoff during large storms (post-fire) from the burned watersheds, channel sections in lower gradient stream reaches have the potential to accumulate excess sediment and debris deposition that could cause peak flows to overwhelm channels and flood adjacent areas and streamside terraces. Hazmat issues (burned cabin), loss of infrastructure, increased flooding and sediment deposition. Tourists not aware of inherent dangers.
Garden of the Gods (6th-level): Sub-watersheds include: Williams Canyon, Camp Creek (aka Queens Canyon), Camp Creek above Eagle Lake Camp 1, and Camp Creek above Eagle Lake Camp 2.	***USFS values*** NFS roads: FSR: 300 and FSR 302, and the trails along Williams Creek and Camp Creek. Loss of soil and cover from hillslopes. Williams Creek and Camp Creek riparian (potential associated Mexican Spotted Owl habitat). Fisheries in Camp Creek. Spread of noxious weeds. ***NRCS values*** Life and properties associated with Cave of the Winds, Manitou Springs, Glen Eyrie, Pleasant Valley/31st, Eagle Lake Campground, and the general area from Williams Canyon to Canon Avenue/Little Switzerland. Manitou mineral water springs. ***CDOT values*** Highway 24 infrastructure. ***County values*** Life and property associated with Manitou Springs.	With the expected increases of sediment and runoff during large storms (post-fire) from the burned watersheds, channel sections in lower gradient stream reaches have the potential to accumulate excess sediment and debris deposition that could cause peak flows to overwhelm channels and flood adjacent areas and streamside terraces. Hazmat issues (burned cabin), loss of infrastructure, increased flooding and sediment deposition. Tourists not aware of inherent dangers. Potential groundwater concerns.

(a) Note: For a more comprehensive list of the values at risk, see the appendix of the FS-2500-8, Burned-Area Report plus the individual specialists reports prepared to support this document. Values called out in table 9 have a very high to high risk, and these values were taken from the VARs table.

II. Synopsis of Post –Fire Watershed Conditions of the Waldo Canyon Fire

The BAER Team performed a rapid ground and air reconnaissance of the burned area to produce a soil burn severity map. The criteria for the soil burn severity map can be found in the Soil Scientists Specialist Report.

The BAER Team Hydrologists began the limited BAER watershed survey on Friday July 6, 2012 by conducting an on-the-ground reconnaissance within the burn area. On Friday and Saturday, July 7, 2012 BAER watershed team initiated a helicopter reconnaissance and mapped the burn severity on 1:24,000

scale topographic maps. The BAER team soil scientists used the air and ground reconnaissance to create the burn severity map for the burned area.

The BAER Team continued to conduct limited watershed surveys in key areas of interest between July 8 and July 9, 2012 by conducting an on-the-ground rapid reconnaissance within the burn area.

The BAER Team assessment identified the overall soil burn severity for the Waldo Canyon fire as 18.5% High, 39.9% Mod, and 41.6% Low/Unburned. The team conducted numerous hydrophobicity tests and found that the burned area had few areas of strongly hydrophobic soils.

Table 10: Burn Severity by Land Ownership (acres)

Burn Severity	*DOD*	*PRI*	*USFS*	*Grand Total*
High		118	3,257	3,375
Moderate		1,419	5,867	7,286
. Low	147	2,142	5,298	7,587
Grand Total	147	3,678	14,422	18,247

Watershed conditions in the burned watersheds have changed significantly as compared to pre-fire conditions. Vegetation and underlying organic matter slows runoff and protects soils from direct raindrop impact, assists with water infiltration to soil and releases runoff at slower rates. Consumption of organic material and high soil heating can promote the formation of water repellent layers, at or near the soil surface, which can result in significant amounts of soil loss. The strength and depth of water repellency varies greatly by the duration and intensity of soil heating, type of organic matter consumed by the wildfire, and soil texture and moisture content. A "buried" water repellent layer was observed beginning at a depth of one inch to three or four inches below the soil surface based on the burn intensity and duration driving the water repellent layer deeper into the soil where the gases cooled, condensed on soil particles and remained buried. As a result of the Waldo Canyon Fire, the above described hydrologic function has been adversely affected and rates of runoff and sediment outputs are now significantly increased, particularly the first year after the fire.

Watershed Post-Fire Response

Post-fire conditions have been assessed to determine how fire-induced changes to hillslope hydrology and soil conditions will impact the values at risk. The results of a peak flow analysis show that pre-fire area weighted flows were on average 112.4 cfs /mi^2 for a 10-year, 1-hour storm, and 237.2 cfs /mi^2 for post-fire flows. Table 11 summarizes these data along with other hydrologic design factors.

Table 11: Hydrologic design factors

A. Estimated Vegetative Recovery Period	5-7 years
B. Design Chance of Success	50 %
C. Equivalent Design Recurrence Interval	10 years
D. Design Storm Duration	1 hours
E. Design Storm Magnitude	1.75 inches
F. Design Flow	112.4 cfs / mi^2
G. Estimated Reduction in Infiltration	60%
H. Adjusted Design Flow	237.3 cfs / mi^2

As previously mentioned, the post-fire flows could lead to plugged culverts, flow over road surfaces, rill and gully erosion of cut and fill slopes, erosion and deposition along road surfaces and relief ditches, loss of long-term soil productivity, and threats to human safety. Some sedimentation of the ephemeral channels is likely to occur at an accelerated rate until vegetation establishes itself and provides ground cover.

Due to the steepness of these drainages and the amount of moderate and high burn severity and with large areas now devoid of vegetation and groundcover after the fire, large runoff producing storms will likely create increased surface flow volumes and velocities that can transport available sediment from the slopes and along the channel bottoms. This scenario coupled with existing wet antecedent soil conditions from previous storms could trigger a severe flood event with high sediment volumes.

Initial erosion of ash and surface soil during the first storm events will reduce slope roughness by filling depressions above rocks, logs, and remaining vegetation. The ability of the burned slopes to detain water and sediment will be reduced accordingly. This will aid in the potential for flashy floods and will increase the distance that eroded materials are transported. However, several factors favor a quick recovery in terms of normal hydrologic response of some hillslopes. The existence of fine roots in the low and moderate severity burn areas just below the surface will likely aid plant recovery, and suggests there still might be a seed source for natural vegetation recovery. The major concern for vegetative recovery and in turn hydrologic recovery is in the high severity burn areas.

Field observations of the slopes and drainages in the burned area show loose soil, rock and burned organic matter over large areas of the watersheds that will be available for transport when heavy rainfall occurs. In addition, large amounts of loose soils are presently moving off slopes as a result of gravity (dry ravel) and are accumulating within drainage channels, increasing the amount of transportable materials. The highest amounts of sediment yields from the burned watersheds are expected during the first several years after the fire.

An analysis of pre- and post-fire peak flows was completed by the BAER team. Peak flows are expected to be one to two times higher than normal where less than 50% of the sub-watershed burned at a moderate or high burn severity. Peak flows are expected to be three to four times higher than normal where more than 50% of the sub-watershed burned at a moderate or high burn severity. Regardless, the amounts of sediment and debris delivered to the lower depositional areas could be substantial.

With intense rainfall and the expected increases in runoff, the slope materials could easily move into drainages, accumulate and move downstream and increase exponentially further down the watershed. Along with sediment bulking, it is expected that burned wood and other organic materials in the watersheds will be entrained in the flows. If a sustained and intense runoff event occurs, it is likely sediment and debris bulked runoff may be substantial and large sediment/debris deposits could cause channel aggradation within the lower gradient reaches. If channel capacities are limited along these reaches due to channel constriction points or areas of dense in-channel vegetation and sediment deposits are large enough, peak flow runoff and debris may be able to overwhelm channel banks and flow outward onto NFS, state, county and private roadways. This may be more concentrated at the low water crossings and downstream residential areas possibly causing significant property damage and the potential threat to human life and safety.

Many of the lower reaches of the streams and associated streamside vegetation within major drainages were burned with a lower burn severity; much of the existing vegetation that lined the channels is still intact. Along with well-vegetated channels below the fire area, this condition will help to reduce floodwater energy and help to capture and slow sediment and debris during peak flow events. The channel bottoms are mostly comprised of some large boulders and cobble that should resist some channel scour and slow peak flows.

Image 1: Waldo Canyon Fire with high and moderate burn severity slopes. Sources of excess surface sediment as a result of the Waldo Canyon Fire exist ready for storm runoff transport. These areas as seen in the above photo and in similar areas of the other burned watersheds are typically subject to high precipitation rates and intensity during large storms that could trigger large volumes of sudden runoff.

III. Emergency Determination

1. Threats to Human Life, Property and Infrastructure

- Roads within and below the fire area that have low-water crossings may be flooded and covered in debris and could be a safety hazard to motorists and could restrict critical access to local residents. Roads, culverts and bridge infrastructure could be damaged or destroyed. There is a possibility if flood water moves onto the roadways, flooding could occur preventing the ingress and egress of downstream residences.

- Large peak flows and sediment/debris have the potential to flood into downstream residential structures, outbuildings and agriculture land adjacent to main drainages in the Waldo Canyon fire which may cause severe property damage and loss and a possible threat to human health and safety.

- Trails and existing roads in the mountainous areas of the fire will be subject to excessive erosion and degradation during large runoff producing storm events with the possibility of sections of trail tread being destroyed or made partially impassable. Travelers on trails and roads could be subject to injury or death during a large storm event from flooding, possible landslides or rock fall.

The above threats will be the most acute during the first few years of post-fire rain season from June through August with a lower level of hazard during the following years until burn areas experience new vegetative growth and become more stabilized. Research indicates that the post-fire watershed threat normally is reduced measurably after five to seven years with favorable precipitation.

Image 2: Debris Flow heading towards Highway 24 with vehicles passing by.

2. Threats to Water Quality

Surface waters in the fire area will be bulked by ash, debris and other floatable and transportable material during storm events. It is likely that stream flows from the post-fire runoff producing rain events will see high concentrations of ash and fine sediment that will cause considerable turbidity and degradation of water quality and the beneficial uses of water. Beneficial uses of water are identified and protected by the Colorado Department of Public Health and Environment.

Burned Residence Debris

In addition, burned residence debris in the watersheds could contribute contaminants to waterways as well if not removed or contained. The California Integrated Waste Management Board (CIWMB) has stated that ash and debris from residential structures consumed by wildfires may contain concentrated amounts of heavy metals, such as arsenic, barium, beryllium, copper, chromium, cadmium, lead and zinc (CIWMB, 2007). Further, according to the CIWMB, the occurrence of these metals in burned residential debris has been demonstrated in the "Assessment of Burned Debris Report for the Cedar and Paradise Fires, San Diego County, CA" dated December 2003. It is also known that asbestos remains are found in burned debris and pose a threat when disturbed and airborne. In addition, debris from burned household products and vehicles found in burned structures such as pesticides, fertilizers, paints and thinner, automobile products and other petroleum based products can affect water quality. Steep drainages found within the areas of the burned structures increase the probability off-site migration of contaminants into local

waterways. Domestic and other water sources located in the areas of burned residential structures are at high risk.

IV. Treatments to Mitigate the Emergency

a. Treatment Type – The primary treatment recommended for implementation is aerial mulching (application of woodshred and agricultural straw) of upland slopes that are 60 percent or less.

b. Treatment Objective: The treatment objectives focus on the reduction of potential soil erosion/sediment yield and runoff onto oversteepened mid-elevation slopes that, despite containing elevated high and moderate burn severity, have little to no treatment options. This may lessen the overall threat to downstream life and property from increased sediment load and flows.

   If additional acres on non-federal land in the burn areas are treated as well, a decrease in flows and sediment can be expected. This treatment's primary benefit is for the protection of life with secondary benefits to protect Forest Service infrastructure and natural and cultural resources.

c. Treatment Description: The prescribed treatment is an aerial application of woodshred and agricultural straw on upland slopes of the burn area. The woodshred would be produced onsite with recently burnt trees that are dead or will be dying off in the next 3-5 years. Because of the potential for high wind in the area (based on local knowledge), woodshred would be used on the steeper slopes and ridge tops of wind prone areas. Ag straw will fill in the remainder of the treatment polygons.

Aerial application of woodshreds and agricultural straw will be applied to hillslopes between 25% and 60% were such treatments can be most effective. These treatments will facilitate stabilization by dissipating raindrop impact, trapping sediment and water, improving infiltration, increasing the flowpath distance of water occurring as overland flow, and providing a seedbed and improved microclimate for revegetation.

References

USDA Forest Service Handbook (FSH) 2509.13. Burned Area Emergency Handbook. Effective January 12, 1995.

National Oceanic Atmospheric Administration website – Precipitation Frequency Data Server for Southern California.

California Integrated Waste Management Board, 2007 "Pre-and Post-Removal Activity Results, Angora Fire, South Lake Tahoe, California" (document 003-09285-00).

USGS, Surface Water for California Peak Stream flows.

USDA Forest Service - Willows Fire BAER Watershed Report, San Bernardino National Forest, 1999.