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The Campo Bonito Wash Flash Flood of August 14, 2003: A Heavy Rain Event on a Recent Burn

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Introduction

The Santa Catalina Mountains rise up from the valleys of the Tucson metro area (an elevation of about 3,500 feet, to several summits over 9,000 feet). The area is mostly within the Coronado National Forest. Several forest fires have impacted the Santa Catalinas since 2002. The Bullock Fire burned 30,563 acres in May and June, 2002. The Oracle Hill fire consumed 2,432 acres in July, 2002. The Aspen Fire burned over 84,000 acres in June and July, 2003.

During the 2002 monsoon season, Campo Bonito residents reported several high flows near bankfull of approximately 350 cfs. Although this was an increase in high flows from pre-Oracle Hill Fire conditions it was not a cause for alarm from local residents.

The Campo Bonito basin is two square miles (Figure 1) and includes about nine private in-holdings within the Coronado National Forest. Sixty percent of the basin is currently burned: 0.45 square miles being from the Oracle Hills Fire and 0.75 square miles from the Aspen Fire. Within the basin, the Aspen Fire burned approximately one-quarter high severity burn, one-half moderate severity burn, and one-quarter low severity burn while the Oracle Hill Fire was dominated by high severity burn (Figure 2 and 3). An early stage of recovery was noticed by the presence of new roots sprouting from the bases of burnt oaks within the Oracle Hill Fire burn area.

Event Overview

On the afternoon of Thursday, August 14, 2003, a number of storm cells converged and moved west from the Galiuro Mountains over the San Pedro Valley, near San Manuel, and through the northern Santa Catalina Mountains near Oracle in Pinal County (Figure 4). Storm motion was to the west-southwest or generally moving up basin.

KEMX Tucson radar estimated 1.60 to 1.75 inches of precipitation fell between 4:00 and 4:25 PM MST (Figure 5). A spotter in Oracle reported 1.8 inches over the same time period. A Pima County Flood Control ALERT gage, just to the west on Oracle Ridge, reported 1.54 inches between 4:07 and 4:36 PM MST. While spotters also reported small

hail with this storm, radar estimates approximately match rain gage data in the area. A rainfall of 1.59 inches in thirty minutes for the Oracle area (ORACLE 2 SE, ARIZONA (02-6119) 32.60.25ººN 110.73.44ººW 4399 feet) amounts to a 25 year rainfall according to the NOAA Atlas 14 http://hdsc.nws.noaa.gov/hdsc/pfds/sa/az_pfds.html. This rainfall resulted in an 8 to 12 foot wall of water in Campo Bonito Wash. Three homes and several other properties were damaged. A long-time resident of the Oracle area was killed when he was swept downstream from his residence. His body was located a half mile downstream the following morning.

While no one else was in the area to witness the event, a coworker reported talking to the deceased at 5:00 PM. This provided a minimum of 5 hours lead time on the flash flood watch issued at 12:05 PM and 34 minutes for the flash flood warning issued at 4:26 PM.

Flood Survey Findings

A flood survey was conducted within 24 hours of the event. The NWS Tucson Hydrologist and WCM, county officials, and state division of emergency management were present. Highwater marks were approximately 5 feet high on the residence of the deceased or about 9 feet high from the pre-flood channel bottom of Campo Bonito Wash. Pre-flood channel depth was based on conversations with neighbors. Campo Bonito Wash makes a greater than 45 degree turn near the residence. A large piling of debris can be seen up against the channel side of residence (Figure 6). A culvert and wooden beam bridge belonging to a neighbor 100 yards downstream was plugged and may have caused much of the channel sedimentation near the home (Figure 7). Further evidence of man-made channel modification was noted several hundred yards downstream including walls that constricted channel flow.

Slope-Area Measurement Findings

During a flood it is often impossible or impractical to measure peak discharges. This may be due to road closures, stressed resources during the event, and sites being ungaged. A slope-area measurement is a common indirect technique used by the USGS to estimate discharge after a flood event. The slope-area measurement makes use of the energy equation for computing streamflow. The energy equation makes use of the physical characteristics of the channel, water-surface elevations at time of peak discharge, and channel roughness coefficients. The data required for a slope-area measurement is obtained in a field survey of a reach of the channel. The survey includes the elevation and location of high-water marks corresponding to the peak stage, cross sections of the channel along the reach, and selection of a roughness coefficient.

The NWS Tucson hydrologist worked with the USGS Tucson water resources field office to make a slope-area measurement for the event. Two slope-area reaches were flagged and surveyed within less than a week of the event (Figure 8, 9, and 10). The upstream reach has an area of 1.25 square miles and the downstream reach an area of 2.0 square miles. The majority of the area burned is within the drainage area for the upstream reach. See

Table 1 for slope area results. Bill Reed from CBRFC also calculated pre and post-burn return flows for the site (Appendix A). Post-burn flows were now 2.5 times pre-burn flows for an equivalent rainfall event As a result; a pre-burn 100 year return flow now has a return interval of less than 25 years.

Conclusions

The combined influence of the Aspen and Oracle Hill Fires resulted in significantly increased runoff. Post-burn runoff was about 2.5 times pre-burn runoff for the area of interest. Based on the USFS (Burn Area Emergency Reaction (BAER) Meeting, July 7, 2003) and literature on the subject, it will take three to five years for the basin to recover to pre-burn conditions. The lack of debris dams, as seen by the USFS (Bonito Canyon USFS internal memo, August 21, 2003) and NWS/USGS, indicates that debris was not a significant issue in this particular flood event. Channel constrictions and plugging of local residence bridge culverts downstream of the residence may have contributed to storm damage. However the magnitude and velocity of the peak crest flow and the channel geometry adjacent to the residence seems to be the major cause of the damage.

Forecasters anticipated flash flood potential was very high due to recent fires. The Bullock Fire was the first exposure most forecasters had at WFO Tucson with post-burn flash flood forecasting. The Bullock Fire was on the sparsely populated backside of the Santa Catalinas and thus allowed our office to learn in a safe environment. We were fortunate that the backside of mountain did not experience any reported flooding. This was likely due to the low population density and the lack of rain and stream gages. An unpublished report entitled "Anticipated Flash Flood Impacts from the Aspen Fire" was also written by the NWS Tucson hydrologist. This report was distributed to the staff prior to the start of the 2003 monsoon season. Field work, such as slope-area measurements and flood surveys, revealed important details of post-burn flash floods for operational forecasters dealing with burn-related flash floods. An unpublished report entitled "Canada del Oro (CDO) Wash Flash Flood Survey of the August 1, 2003 Event" was distributed to the staff by the NWS Tucson hydrologist over a week prior to the August 14th event on Campo Bonito Wash. The CDO adjoins the Campo Bonito basin on its west side. A combination of situational awareness, and research both before and during the 2003 monsoon season, contributed to the extended lead times on both the watch and warning for the area.

Acknowledgements

Pinal County emergency manager, Pete Weaver, and department of public works project engineer John Rotter, facilitated the initial flood survey on Friday, August 15, 2003. In addition, John assisted in locating slope area reaches on August 18, 2003. The USGS responded quickly to the situation on Campo Bonito Wash. Within less than four days following the event, the author and Chris Smith (USGS AZ water resources division data chief) were able to walk much of the wash looking for slope area reaches. Two days following that, the USGS had a crew of three out to do the survey. This was a significant expenditure of resources for the USGS. Chris also reviewed this TA. Bill Reed, Colorado

Basin River Forecast Center (CBRFC) senior hydrologist and lower Colorado River focal point, calculated pre and post burn return flows. Bill has worked with previous burn areas including the Rodeo-Chediski in central Arizona of 2002. Bill also reviewed this TA and provided comments. The Tucson WFO SOO also reviewed this TA and provided direction. Salek Shafiqullah, a hydrologist with Coronado National Forest, provided the merged GIS burn severity map.

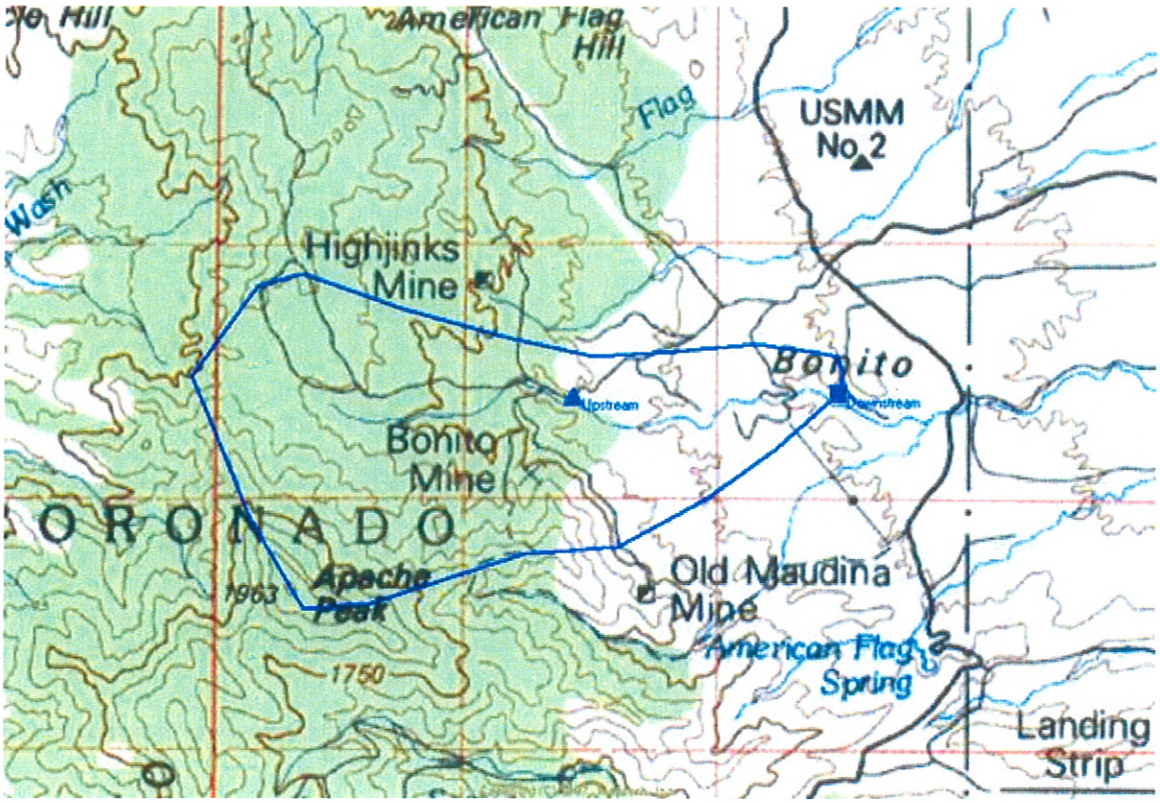

Figure 1. USGS topographic map showing downstream slope-area site and its associated 2 square mile drainage area. Upstream slope-area site also shown.

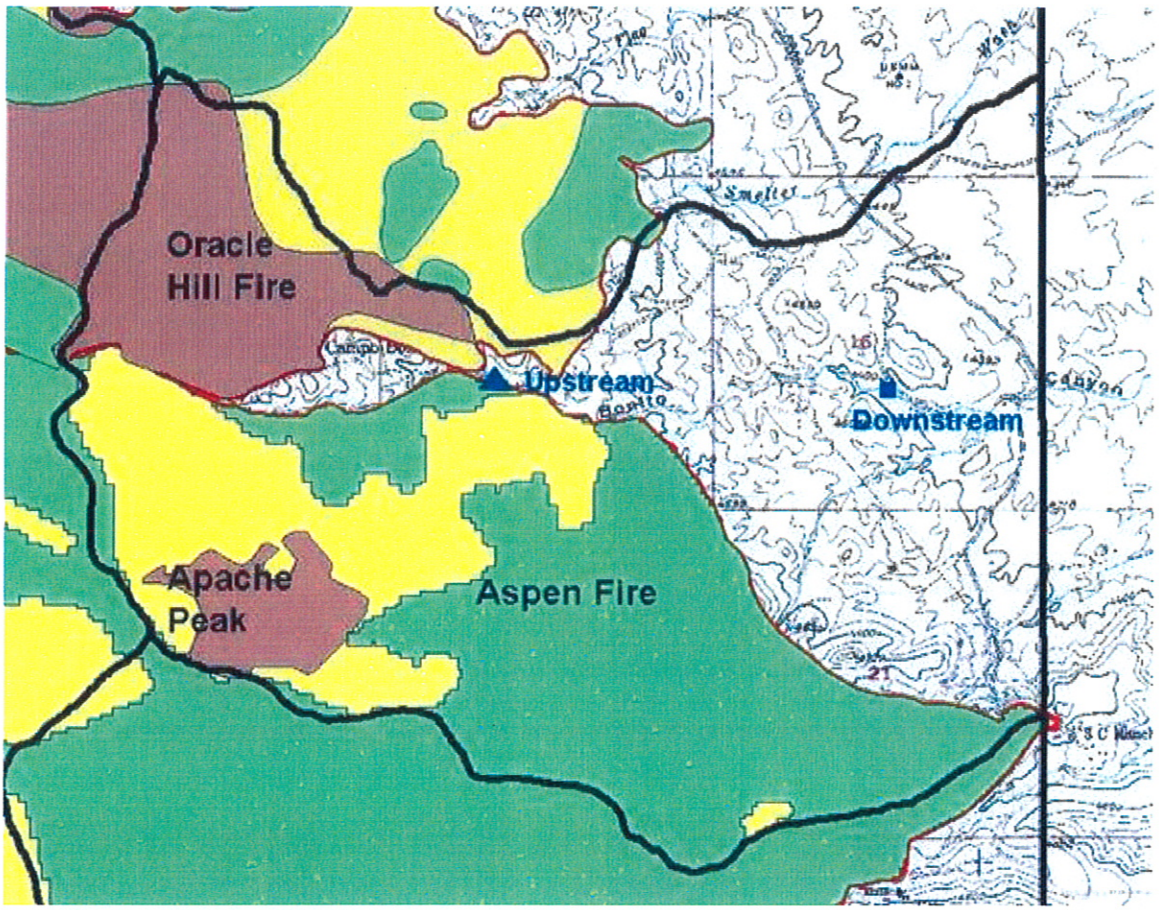

Figure 2. GIS burn severity map of the Oracle Hill and Aspen Fires courtesy of Coronado National Forest (09/29/03). Black lines represent USFS watershed boundaries. Red lines represent fire boundaries. Notice a large area of high severity burn in red within the Oracle Hill fire. The Aspen Fire contains an area of high severity burn on the eastern flanks of Apache Peak in red as well as the much larger area of moderate severity burn in yellow. Upstream and downstream slope-area sites shown.

Figure 3. Image of burned oaks, scrub brush, and soil near upstream slope-area site within the Aspen Fire burn area. Road in distance acted as a fire break for both the Oracle Hill and Aspen Fires.

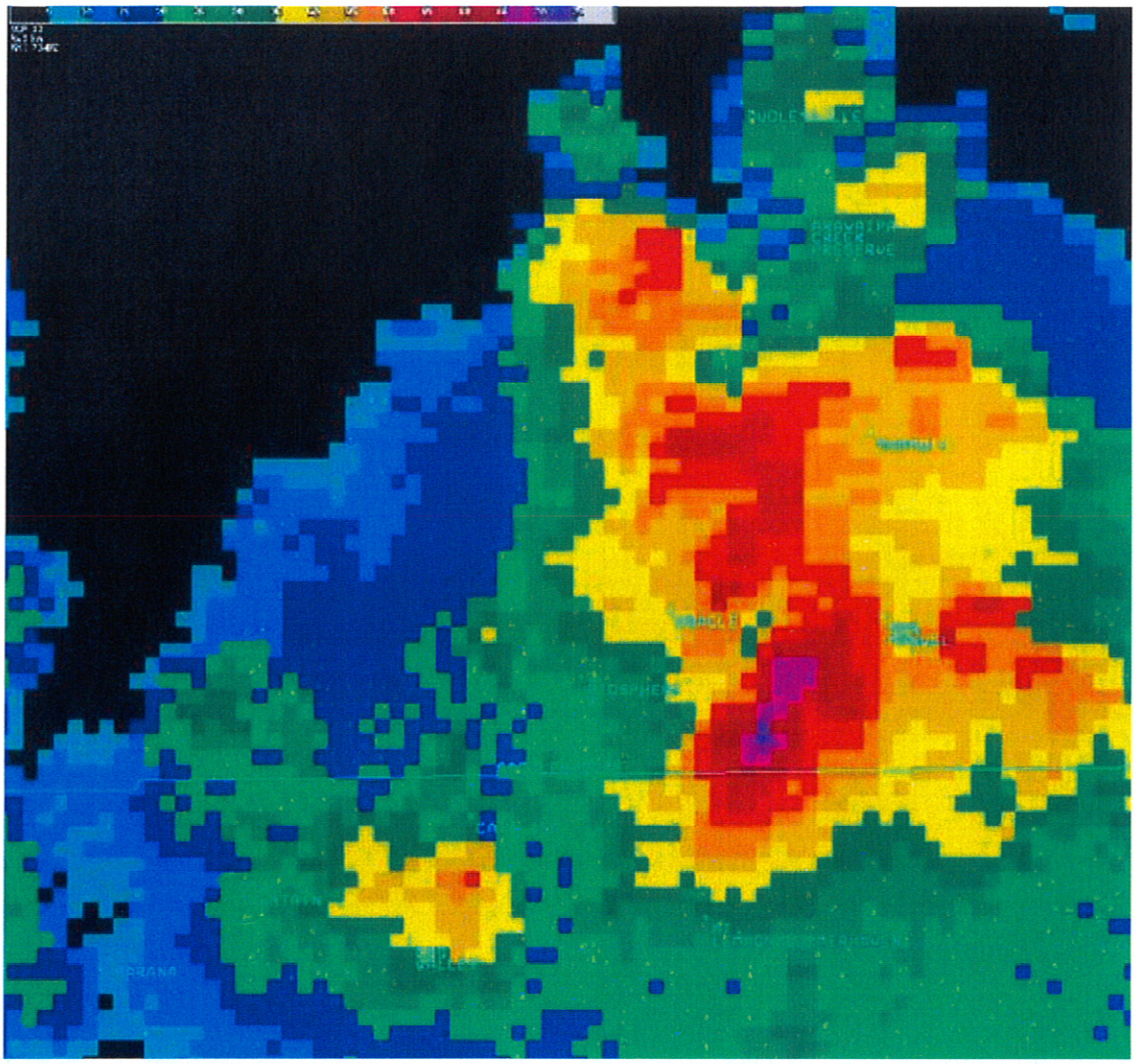

Figure 4. KEMX composite reflectivity image for August 14, 2003 from 3:58 PM MST. Storm is just entering the Campo Bonito Wash watershed at this time. The San Pedro River valley runs southeast to northwest from San Manuel to Dudleyville. The Galiuro Mountains are located east of San Manuel just off the image.

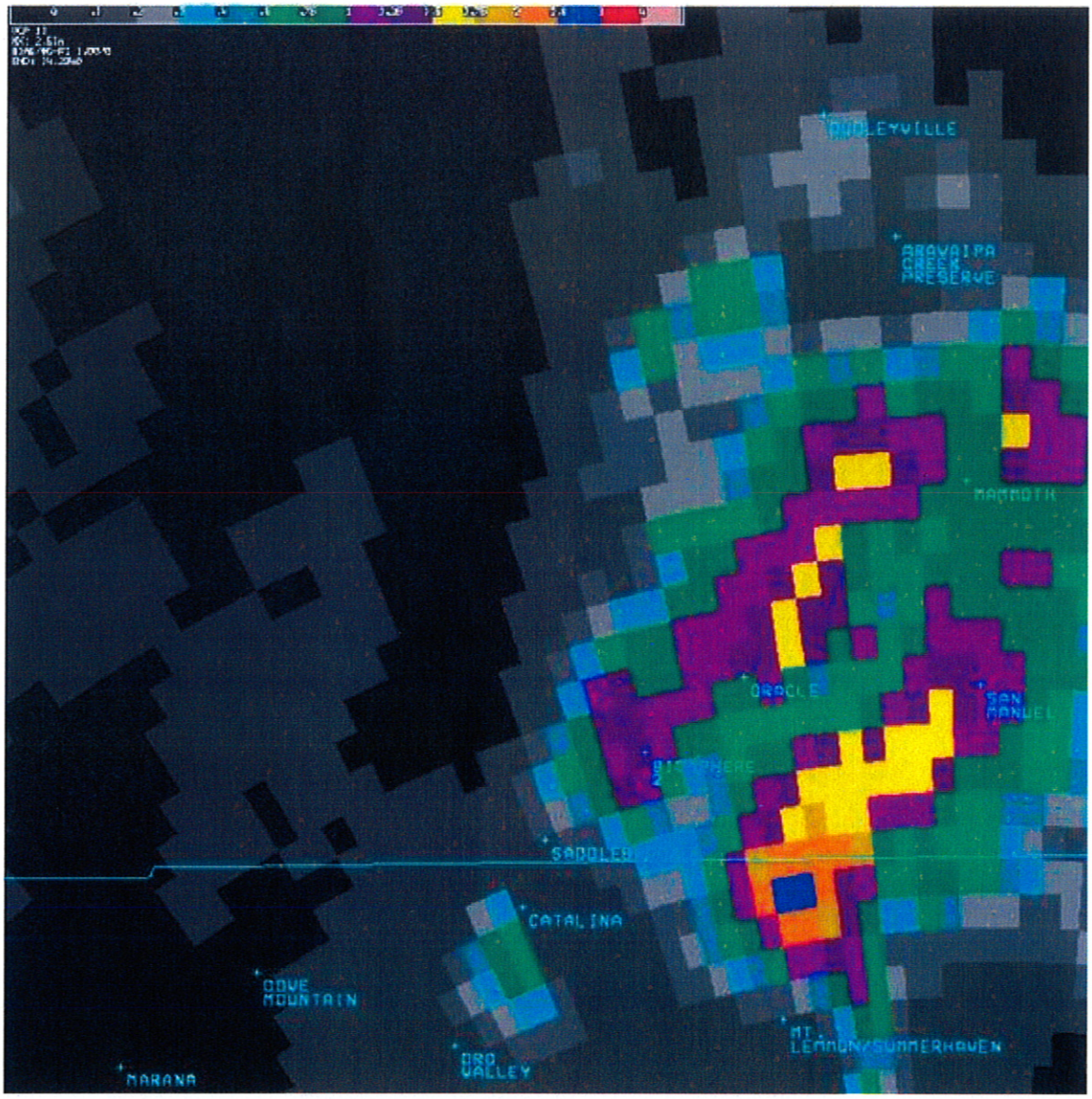

Figure 5. KEMX one hour precipitation estimate for August 14, 2003 ending at 23:38Z (4:48 PM MST). Note Campo Bonito area with 1.60 to 1.75 inch rainfall as indicated by light yellow color.

Figure 6. Large pile of debris near channel side of residence. Note highwater mark along side of residence.

Figure 7. Culvert and wooden beam bridge 100 yards downstream of residence. Note culverts blocked and channel deposition upstream.

Figure 8. USGS conducting slope-area survey in upper reach. Photo is taken looking downstream. Steve Wiele, a fluvial geomorphologist with the USGS in Tucson, is pictured in the foreground. Photo courtesy of the USGS.

Figure 9. NWS hydrologist Mike Schaffner pointing out a debris line in a tree located in the upper slope-area reach.

Figure 10. Image of lower slope-area reach looking downstream. Notice pink flagging on left bank indicating high water marks to be surveyed in. Photo courtesyof USGS.

	Upstream Site	Downstream Site
Average elevation of slope area section (feet above mean sea level)	4795	4400
Distance between sites (miles)		1.25
Drainage Area (square miles)	1.25	2.0
Area Burned (square miles)	1.0	1.0
Area burned by 2003 Aspen Fire (square miles)	0.65	0.75
Area Burned by 2002 Oracle Hills Fire (square miles)	0.40	0.45
% Area Burned	84%	60%
Preliminary slope area discharge (cfs) Subject to change	1900	1600

Table 1. Summary of USGS slope-area results. Drainage and burn area estimated by the NWS Tucson Hydrologist. Slope area results are preliminary and provided by Chris Smith via oral communication on August 25, 2003.

Appendix A

Aspen Burn Increased Flood Potential Bonito Wash Return Intervals
Prepared by William B. Reed, Colorado Basin River Forecast Center

Conditions	2-year	5-year	10-year	25-year	50-year	100-year
Pre-Burn	50 cfs	130 cfs	350 cfs	800 cfs	1300 cfs	1500 cfs
Post Burn	125 cfs	325 cfs	875 cfs	2000 cfs	3250 cfs	3750 cfs

Within Arizona post burn runoff has been observed to be 5 times greater than runoff during pre-burn conditions . In areas of sparse desert vegetation, shallow soils, and bare rock--the increase may not be as great--since runoff is already relatively high due to low initial abstractions. However, a value of 2.5 was used here, in an attempt to be conservative, and to reflect that only half of the watershed was burned.

The pre-burn 10-year return interval flow should be approximately the bankfull flow. The post burn 25-year return interval flow should be approximately the calculated event flow. This assumes the event was caused by a rainfall of 1.5 inches in 25 minutes, which has a return interval of approximately 25-years.

The above indicates that the pre-burn 100-year flood now has a return interval less than 25 years. These enhanced flood prone conditions will likely exists until such time as the watershed has recovered--perhaps 3 to 5 years. There is an 18 % chance or likelihood of one or more floods of equal or greater magnitude occurring in the next 5 years.

Please note that the site has not been visited by the author, and is an ungaged stream; therefore, this report should be considered preliminary and subject to revision (revised 8/25/2003).