



Aerial view of Casandro Wash Dam near its peak impoundment at approximately 7:15 pm; Courtesy of ABC15 News

Flood Control District of Maricopa County

Engineering Division, Flood Warning Branch

Storm Report : July 18, 2015

Vicinity of Wickenburg, AZ

Revision 1 - Sep. 4, 2015

- Revised the discharge hydrograph for Hassayampa River at I-10 (#5283)
- Added Figure 34 - Where Did All The Wickenburg Water Go?
- Added Appendix A - Indirect Flood Discharge Measurement for Cemetery Wash



TABLE OF CONTENTS

Meteorology	3
<u>Precipitation</u>	8
<u>Runoff</u>	13
<u>Event Timeline</u>	25
<u>Selected Data Sources</u>	28

TABLES

Table 1	FCDMC Hourly Quantitative Precipitation Forecast	4
Table 2	Peak Rainfall Amounts and Calculated Return Periods	8
Table 3	Summary of Measured Peak Discharges at FCD Stream Stations	13
Table 4	Summary of Measured Peak Stages at FCD Impoundment Stations	13
Table 5	Travel Times between Various Stream Gages in the Wickenburg Area	19

FIGURES

Figure 1	True-color Visible Satellite Photo of Arizona	5
Figure 2	True-color Visible Satellite Photo of the Eastern Pacific	5
Figure 3	4-Panel Synoptic Setup - 5:00 PM MST 07/18/2015	6
Figure 4	Observed Skew-T/log P Diagram for Phoenix, 7/18/15 5:00 PM	7
Figure 5	Rainfall Hyetograph for Twin Peaks Rain Gage	9
Figure 6	Rainfall Hyetograph for Vulture Mine Rd. Rain Gage	9
Figure 7	Rainfall Hyetograph for Casandro Wash Rain Gage	9
Figure 8	Rainfall Hyetograph for Powder House Wash Rain Gage	9
Figure 9	Rainfall Map - Isohyetal and Point Values	10
Figure 10	Sea Surface Temperatures, Eastern Pacific, 7/1/2015	11
Figure 11	The MCSSI Scale	12
Figure 12	MCSSI Calculation Template	12
Figure 13	MCSSI Storm Map	12
Figure 14	Antelope Creek Hydrograph	14
Figure 15	Box Wash Hydrograph	14
Figure 16	Casandro Wash Hydrograph	15
Figure 17	Casandro Dam Hydrograph	15
Figure 18	Flying E Wash Hydrograph	16
Figure 19	Hartman Wash Hydrograph	16
Figure 20	Hassayampa R. @ Box Canyon Hydrograph	17
Figure 21	Hassayampa R. @ US 60 Hydrograph	17
Figure 22	Hassayampa R. near Morristown Hydrograph	18
Figure 23	Hassayampa R. @ I-10	18
Figure 24	Plot of Hassayampa River Peaks & Travel Times	19
Figure 25	Martinez Creek Hydrograph	20
Figure 26	Powder House Wash Hydrograph	20
Figure 27	Sols Wash near Matthie Hydrograph	21
Figure 28	Sunnycove FRS Hydrograph	21
Figure 29	Sunset FRS Hydrograph	22
Figure 30	Vulture Mine Road Hydrograph	22
Figure 31	Photo - Box Wash, Left Bank, 5/14/2015	23
Figure 32	Photo - Box Wash, Left Bank, 7/20/2015	23
Figure 33	Photo - Debris Flow on Vulture Mine Rd.	24
Figure 34	Hydrographs - Where Did All The Wickenburg Water Go?	24
Appendix A	- Indirect Flood Discharge Measurement for Cemetery Wash	28

METEOROLOGY

An unstable atmosphere largely aided by tropical moisture associated with the remnants of Hurricane Dolores led to the development of an organized thunderstorm complex which dropped torrential rains over northwestern Maricopa County during the evening of Saturday July 18th. These storms produced anywhere from 2.00"-5.00" of rain over a three hour period with many gages registering the bulk of that rainfall during a brief 60-90 minute window. Heavy rain from this event ultimately led to significant flash flooding in and around the Town of Wickenburg.

Synopsis:

In the days leading up to the event, District staff as well as many other Federal agencies began keeping close tabs on the track of the 4th named tropical system, Dolores, to develop in the eastern Pacific. Dolores organized into a tropical storm early the morning of July 12th, quickly intensified into a hurricane the following afternoon, and became the third major hurricane of the season on July 15th. Forecast tracks projected the hurricane to move northwest toward the southern tip of Baja California (BC) by Friday July 17th before continuing northwest and weakening well off the west of coast of the BC Spur (geographical feature on the west coast of the BC peninsula) on Saturday July 18th. A loop of all forecasts tracks produced by the National Hurricane Center (NHC) can be viewed [here](#). While the circulation center of Dolores was never forecast to make landfall in the southwestern US, numerical weather guidance continued to favor a deep surge of tropical moisture to move north out of the Gulf of California into southern AZ/CA Friday into Saturday.

The synoptic setup on the evening of the event is shown in Figure 3 (page 6). The upper level images (C and D) depict the Monsoon ridge suppressed across southeastern TX and a large scale trough off the western coast of CA; meanwhile the remnants of Dolores are seen off the west coast of BC in each of the four images. It's worth noting that this persistent upper-level pattern was evident days before the event and was one of the main drivers helping to draw the tropical system and subsequent moisture north. Looking at the mid-levels, moist south/southwesterly flow was evident in both the 700mb and 850mb maps. Surface moisture values were rather high with area dewpoints running in the mid to upper 60s across much of west central AZ, [image](#) (courtesy of NWS Storm Prediction Center at 00Z, 5:00pm MST). Precipitable water values were measured throughout the day as the deep surge of tropical moisture moved north into southern AZ/CA. A value of 1.73" was observed on the 00Z, 5:00pm MST, KPSR sounding (Figure 2, below) which according to the Storm Prediction Sounding Climatology page (can be viewed [here](#)) was a period of record daily max.

Mesoanalysis data across CA/AZ in the near storm environment on Saturday afternoon revealed a favorable setup for scattered to widespread heavy rain producing thunderstorms. Evidence of this is shown by the 23Z (4:00pm MST) RAP model mesoanalysis images shown [here](#) (gathered from NWS Storm Prediction Center archives). Thermodynamic variables/indices of note are included in images A and B: the high CAPE/low CIN profile maximized across southwestern AZ and largely negative lifted indices. The wind profile, shown in image C, was characterized by effective bulk shear values in the 20-35 knot range out of the southwest across the lower Colorado River Valley and extending into west-central AZ. The distribution of precipitable water is shown in image D. Further description of the favorable setup for heavy rain and flash flooding potential was conveyed an hour earlier by the Weather Prediction Center through its 2:59pm MST mesoscale precipitation discussion [here](#). Table 1 shows values from the District's hourly Convective Quantitative Precipitation Forecast (QPF) at 5:06pm MST which was generated just as the complex of storms moved into the Wickenburg area. Of note are the abnormally large 1-hr, 30-min, and 10-min potential rainfall rates within the two forecast zones encompassing northwestern Maricopa County. The QPF with multiplier values, which indicate a severe storm

able to utilize the full moisture profile, were remarkably accurate when compared to rain gage observations around the region.

Storm Summary and Radar Imagery

Strong downdraft winds from elevated t-storms over northern portions of the Sierra Estrella Mountains (web cam and radar [image](#)) kicked off a northward propagating outflow boundary around 3:00pm MST. Over the next hour this gust front helped initiate several rounds of weaker convection as it traversed the West Valley before generating a line of stronger storms just north of the White Tank Mountains extending northeast across Hwy74 in the Northwest Valley ([image](#)). After 4:30pm MST, the line strengthened as it continued to move north/northwest along US 60/93 dropping brief heavy rain along with pea-sized hail and severe downburst winds toppling power poles in and around the Morristown area. Resulting damage ultimately led to the brief closure of US 60 between mile posts 122-124.

The severe complex of thunderstorms continued to propagate north/northwest into a highly favorable environment for rapid intensification just after 5:00pm MST. Storm updrafts were further enhanced from upslope propagation over the higher terrain as well as from a strong area of low-level convergence associated with outflow boundary interaction from a large line of organized storms moving east out of the Lower Colorado River Valley into the region. From 5:00-6:00pm MST, torrential rain fell in and around the Town of Wickenburg with most District rain gages picking up 2.00" to more than of 4.00" ([image](#)). Significant flash flooding was underway as area washes, some of which were already moistened by rain the prior evening, began conveying runoff downstream into larger waterways. Residents living along Cemetery and Powder House Washes were hit particularly hard as runoff spilled onto area roadways and into neighborhoods. The heavy rain began to taper off after 7:00pm MST, though larger streams such as the Hassayampa River continued to register flows well into the overnight hours. A radar loop spanning the entire event, courtesy of the NWS Phoenix WFO, can be viewed using the following links (regional [loop](#), Maricopa County [loop](#)); also local NWS storm reports can be viewed [here](#).

TABLE 1: Hourly Quantitative Precipitation Forecast, Valid 05:06 pm MST 07/18/15			
	Convective QPF (in)		
MSP Weather Station	1-hr	30-min	10-min
Wickenburg	1.99	1.39	0.84
Upper Centennial	2.19	1.53	0.92
	Convective QPF w/multiplier (in)		
MSP Weather Station	1-hr	30-min	10-min
Wickenburg	3.98	2.79	1.67
Upper Centennial	4.38	3.07	1.84

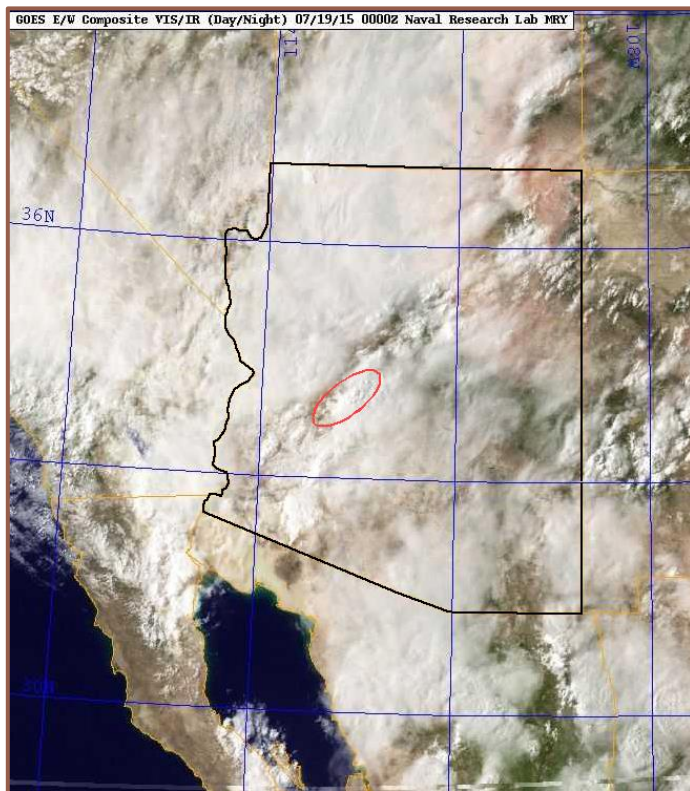
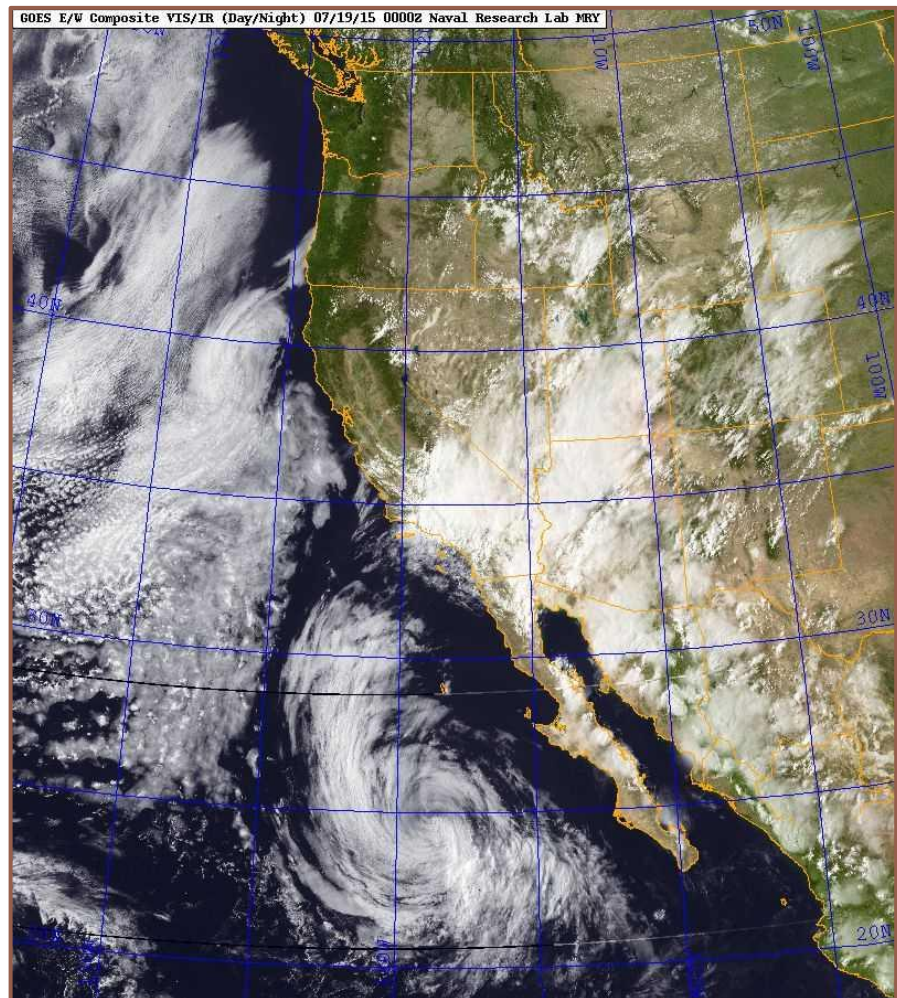


FIGURE 1

True-color visible satellite photo of AZ from GOES West - 5PM MST on July 18th. Red ellipse denotes the location of the Wickenburg storm.

FIGURE 2



True-color visible satellite photo of the eastern Pacific from GOES West - 5PM MST on July 18th. Note position and influence of Hurricane Delores.

4-Panel 00Z Synoptic Setup 07/19/2015 (5:00 PM MST 07/18/2015)

FIGURE 3

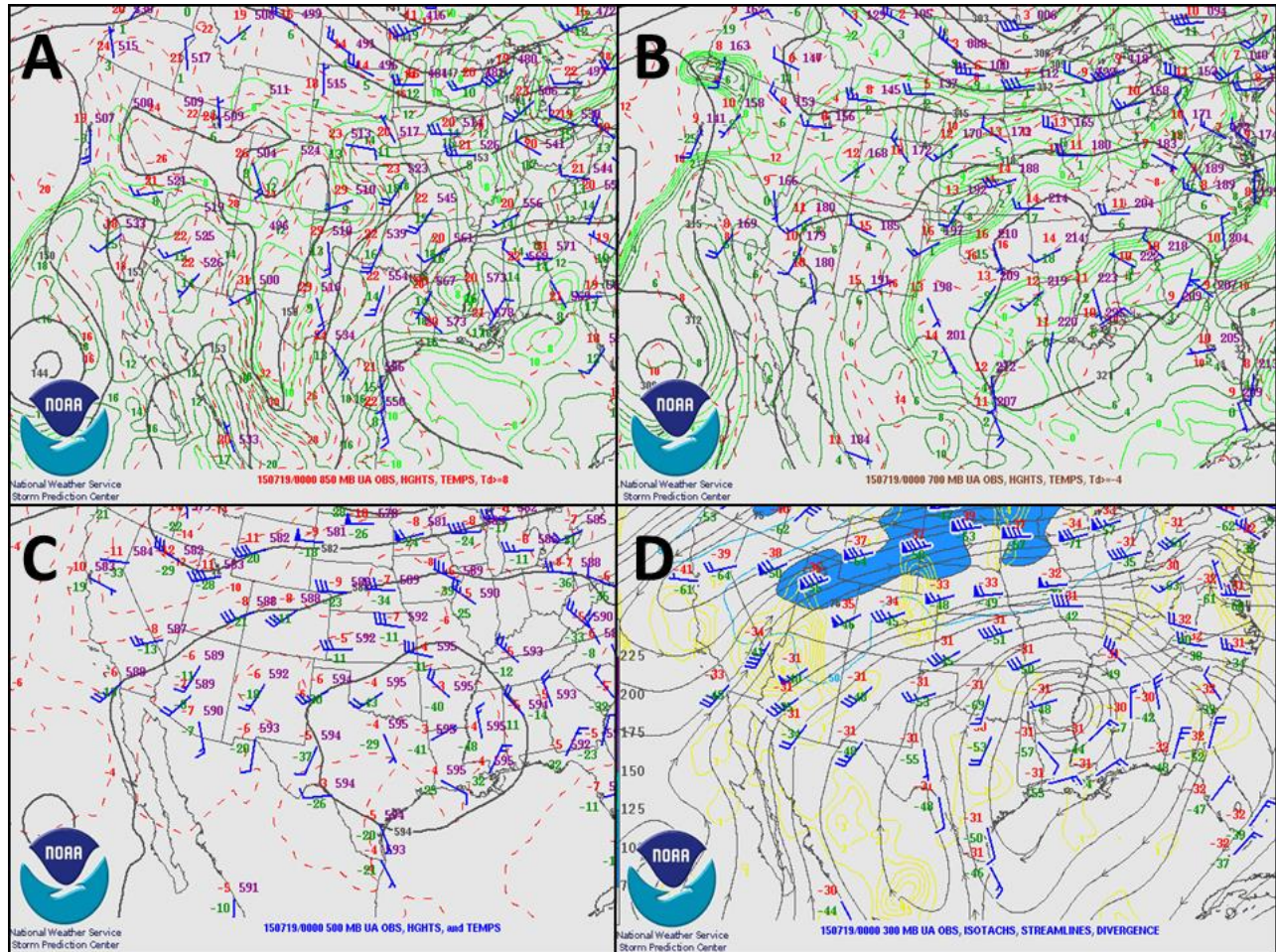


Figure 3 depicts the synoptic setup at 5:00 PM MST on July 18th 2015. The images are from the Storm Prediction Center upper air maps archive. **A)** is the 850mb map: the black lines are heights, the red dashed lines are isotherms, the green lines are isodrosotherms, blue barbs are wind speed, and station observations are plotted at each available location. **B)** is the 700mb map: variables colored the same as A. **C)** is the 500mb map: variables colored the same as in A. **D)** is the 300mb map: the black lines are stream lines, the yellow lines are divergence, and station observations are plotted at each available location.

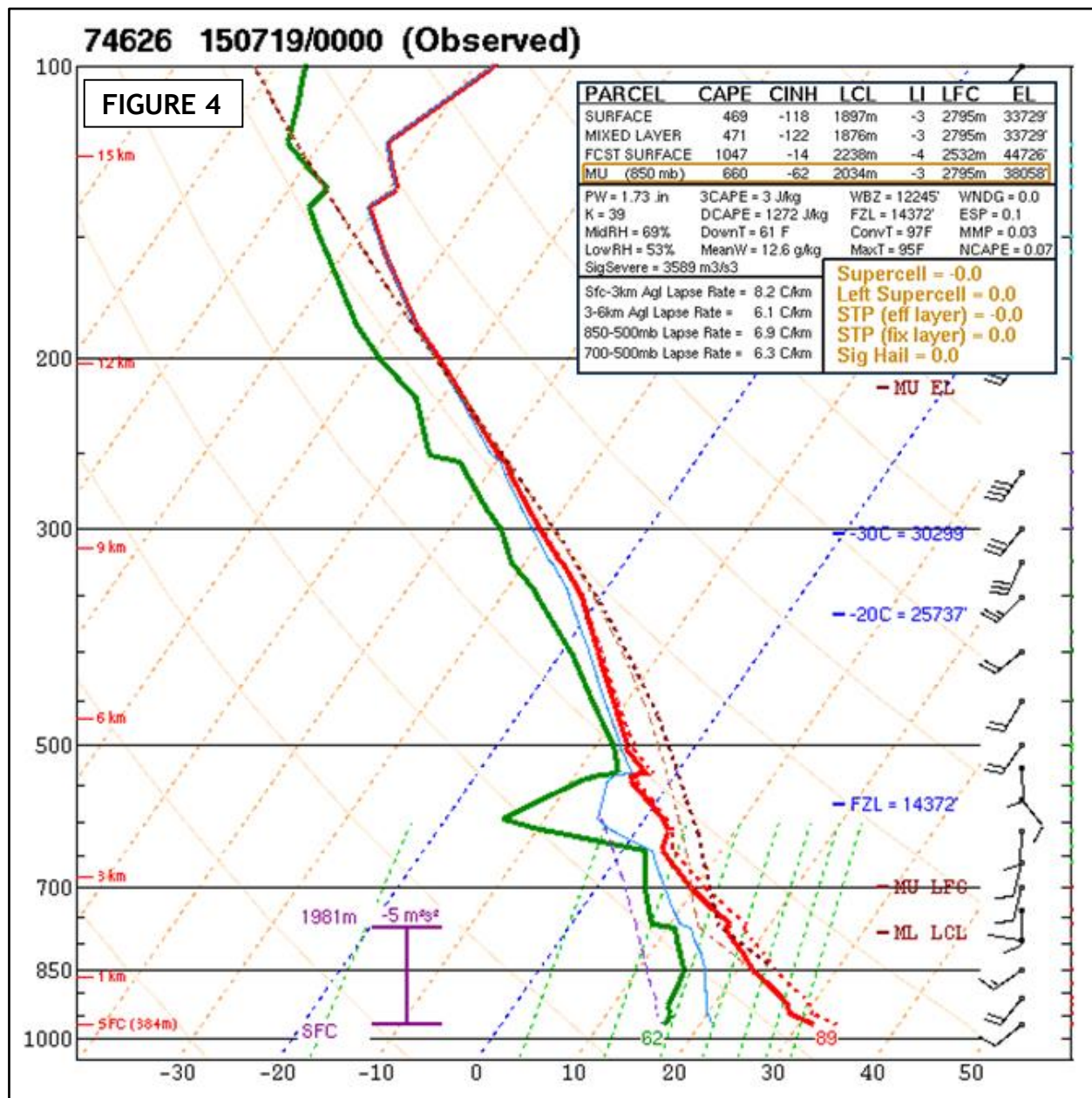


Figure 4: Observed Skew-T/log P (vertical profile of the atmosphere above Phoenix) diagram at 5:00pm MST on July, 18th, 2015. Sounding generated from NOAA/SPC. The vertical axis is pressure in (hPa) and the horizontal axis is temperature in (°C). The thick solid red line is the temperature profile. The thick solid green line is the moisture profile. The dashed red lines are the atmospheric parcel profiles. The vertical axis on the right displays the wind speed and direction at each level in knots. Thin solid brown lines sloping from upper left to lower right are constant potential temperature (°K). Thin dashed brown and blue lines sloping from right to left are isotherms (°C). Thin dashed green lines sloping from right to left are mixing ratio (g/kg). The table in the top left displays various parcel attributes and thermodynamic indices.

PRECIPITATION

Table 2 presents rainfall as recorded by area FCDMC ALERT rain gages - peak amounts and return periods for selected durations. These 3-hour totals match the values displayed on Figure 9:

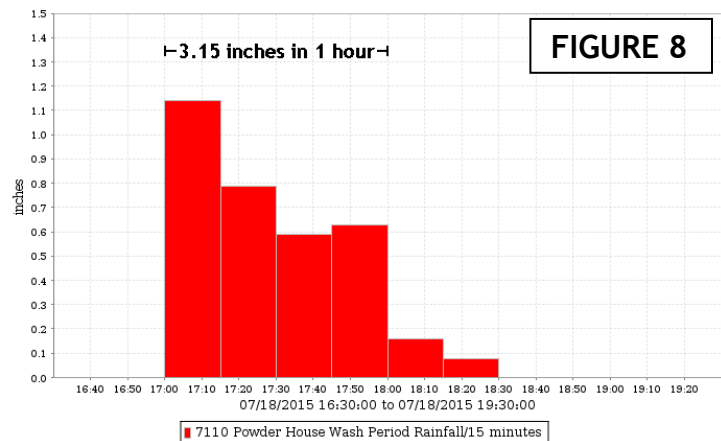
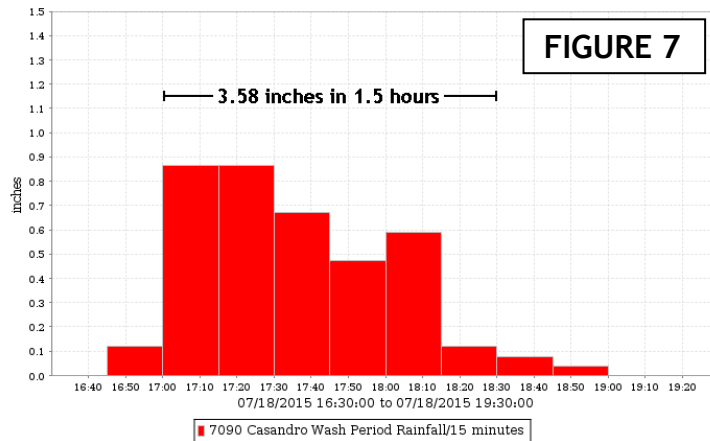
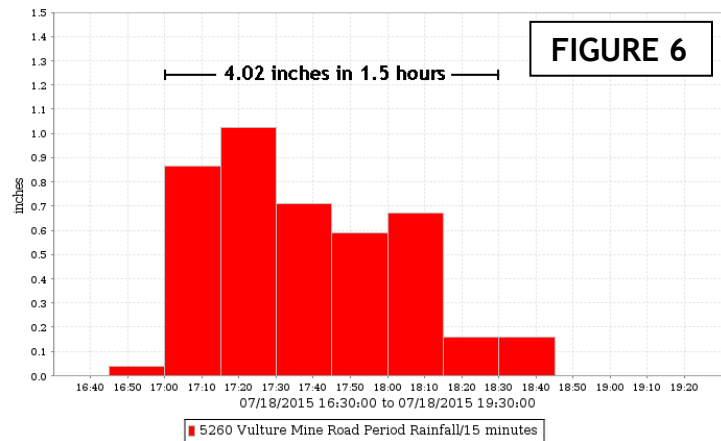
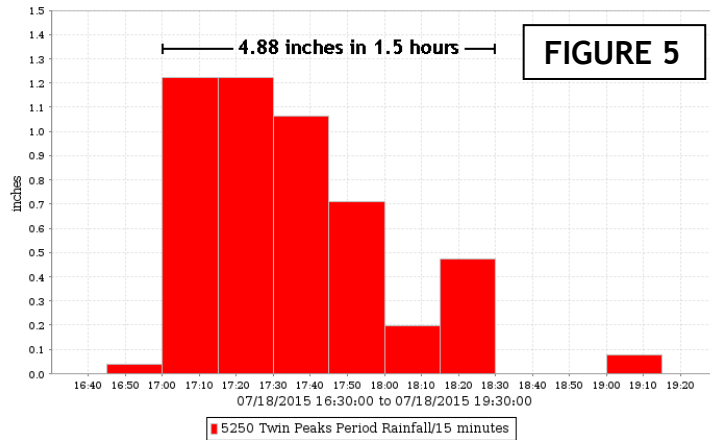
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W																			
Flood Control District of Maricopa County ALERT Rain Gages																																									
Wickenburg Storm of July 18, 2015																																									
GageID	Station Name / Year Installed	Elev.	Jurisdiction	Lat.	Long.	Rain (in)	Peak Rainfall Amounts (inches)						Heaviest Rain			Return Period (years)						Log Ave.																			
						Prior 72h	5m	15m	30m	1h	2h	3h	Start	End	Duration	5m	15m	30m	1h	2h	3h		30m-2h																		
5225	Hassayampa R. @ US 60 / 1994	2,030	Wickenburg	33.9703	112.7270	0.08	0.47	1.02	1.65	2.68	3.82	3.82	16:58	19:00	2:02	8	13	31	159	850	451	161																			
7110	Powder House Wash / 1995	2,130	Wickenburg	33.9808	112.7173	0.08	0.75	1.61	2.24	3.35	3.46	3.46	17:00	18:17	1:17	69	157	194	857	368	225	394																			
5230	Sunset FRS / 1989	2,140	Wickenburg	33.9650	112.7425	0.12	0.43	0.83	1.42	2.52	3.03	3.03	16:55	18:45	1:50	6	6	15	105	168	114	64																			
5245	Sunnycove FRS / 1986	2,150	Wickenburg	33.9573	112.7398	0.16	-----	-----	-----	-----	-----	3.07	16:55	?	-----						125																				
7130	Casandro Dam / 1996	2,165	Wickenburg	33.9674	112.7485	0.12	0.83	1.50	2.28	3.27	3.94	3.94	16:55	18:45	1:50	132	100	227	698	1000	582	541																			
7040	Sols Wash near Matthie / 1995	2,220	Maricopa County	33.9874	112.7930	0.08	0.51	0.91	1.30	2.01	2.52	2.52	17:17	18:50	1:33	10	8	10	28	51	39	24																			
7090	Casandro Wash / 1994	2,240	Wickenburg	33.9621	112.7653	0.08	0.71	1.34	2.13	3.23	3.98	3.98	16:55	18:45	1:50	50	50	137	610	1000	648	437																			
5305	Hassy R. @ Box Canyon / 1983	2,245	Yavapai County	34.0450	112.7101	0.28	0.39	0.91	1.46	2.17	2.48	2.48	17:12	18:35	1:23	4	8	16	40	40	31	29																			
7100	Constellation Road / 1994	2,260	Wickenburg	33.9759	112.7036	0.16	0.63	1.30	1.77	3.07	3.27	3.27	17:00	18:20	1:20	26	42	46	408	245	159	166																			
7080	Flying E Wash / 1994	2,305	Wickenburg	33.9623	112.7829	0.12	0.59	1.26	1.93	3.19	3.98	3.98	17:05	18:45	1:40	18	34	70	526	1000	590	333																			
5260	Vulture Mine Road / 1981	2,315	Maricopa County	33.9524	112.7718	0.12	0.71	1.42	2.32	3.74	4.41	4.41	16:55	18:40	1:45	50	75	200	1000	1000	1000	585																			
7120	Wickenburg Airport / 1994	2,385	Wickenburg	33.9649	112.8040	0.04	0.47	1.06	1.73	2.87	3.39	3.39	17:15	18:50	1:35	7	14	37	228	310	190	138																			
7165	Antelope Creek / 2003	2,400	Yavapai County	34.0488	112.7794	0.51	0.35	0.79	1.10	1.18	1.97	1.97	17:25	19:05	1:40	3	5	6	4	14	11	7																			
7010	Martinez Creek / 1994	2,410	Yavapai County	34.0283	112.7922	0.12	0.39	0.83	0.98	1.06	1.85	1.85	17:25	19:10	1:45	4	6	4	3	11	9	5																			
7060	Hartman Wash / 1994	2,460	Maricopa County	33.9628	112.8280	0.08	0.47	0.91	1.50	2.09	2.64	2.68	17:25	19:00	1:35	7	7	17	31	59	47	31																			
7070	Flying E Tank / 1995	2,540	Maricopa County	33.9367	112.8170	0.24	0.43	0.94	1.61	2.68	3.66	3.66	17:10	18:55	1:45	5	8	22	119	435	247	104																			
5250	Twin Peaks / 2003	2,675	Maricopa County	33.8836	112.8229	0.12	0.67	1.54	2.60	4.25	4.92	5.00	16:58	19:07	2:09	26	85	468	1000	1000	1000	776																			
5320	O'Brien Gulch / 1981	2,960	Yavapai County	34.1033	112.5751	0.35	0.59	1.02	1.22	1.42	1.65	1.69	17:00	18:26	1:26	16	11	7	6	6	6	6																			
7000	Stanton / 1994	3,465	Yavapai County	34.1647	112.7293	1.89	0.35	0.91	1.38	1.77	1.85	1.93	17:30	18:20	0:50	3	6	10	11	8	8	10																			
Notes:																																									
• Rainfall recurrence intervals calculated by station latitude/longitude from NOAA Design Rainfall Atlas 14, Version 5																																									
• Columns N & O, Start and End times for the storm represent the duration of most intense rainfall. Many stations had light rain until 10 PM.																																									
• In Columns Q-V, a value of "1000" means 1000 years or more.																																									
• Column W is the logarithmic average of the 30-min, 1-hour and 2-hour return period values.																																									
• Gage 5245, Sunnycove FRS, had a plugged funnel during the event - accurate intensities could not be calculated.																																									
• Bold/Lt. Orange 15 min., 1-hour and 3-hour Peak Rainfall Amounts are highest-in-record for that gage (30m & 2h values were not calc'd for this report).																																									
• Bold/Yellow 1-hour and 3-hour Peak Rainfall Amounts are all-time records for all FCD rain gages.																																									
Old records were 3.58" in 1 hour at Vulture Mine Road, 7/21/1986 and 4.21" in 3 hours Waterman Wash / Rainbow Valley, 9/8/2014.																																									

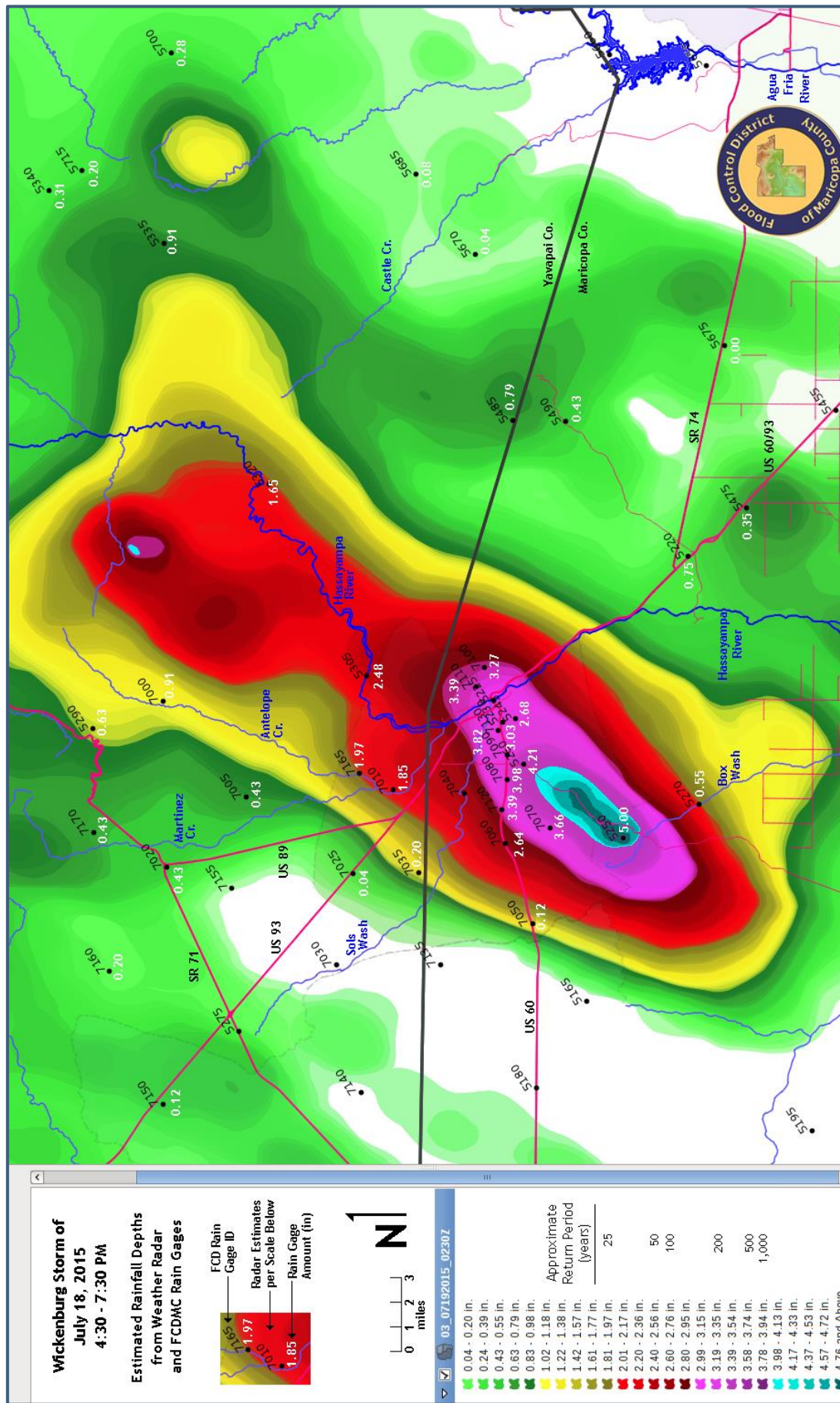
TABLE 2

Rain Gage Names and Locations, Links to Station History Pages (also see Figure 9):

- [5225](#) - Hassayampa River @ US 60; southwest corner of the old bridge.
- [7110](#) - Powder House Wash; 0.8 miles NE of confluence with Hassayampa R., 0.3 mi. N of Constellation Rd.
- [5230](#) - Sunset FRS; 0.2 miles SE of the intersection of US 60 and Mariposa Dr.
- [5245](#) - Sunnycove FRS; 0.2 miles NW of the intersection of Kellis Rd. and Turtleback Ln.
- [7130](#) - Casandro Wash Dam; 0.2 miles NW of the intersection of US 60 and Mariposa Dr.
- [7040](#) - Sols Wash near Matthie; 1.3 miles NNW of Sols Wash crossing of Vulture Mine Rd.
- [7090](#) - Casandro Wash; US 60 at Lazy Fox Drive.
- [5305](#) - Hassayampa River at Box Canyon; 5.3 miles NNE of Wickenburg.
- [7100](#) - Constellation Road; at Sportsman's Gun Club, 1.4 miles ENE of Hassayampa R. at US 60.
- [7080](#) - Flying E Wash; 250 ft. west of Park Ave. on US 60.
- [5260](#) - Vulture Mine Road; Vulture Mine Rd. at Duffy Drive.
- [7120](#) - Wickenburg Airport; 125 yards west of the Airport entrance road.
- [7165](#) - Antelope Creek; 2.3 miles NNE of the US 93 / US 89 junction.
- [7010](#) - Martinez Creek; 0.9 miles NE of the US 93 / US 89 junction.
- [7060](#) - Hartman Wash; 1.4 miles west of Wickenburg Airport
- [7070](#) - Flying E Tank; 2.1 miles SSW of Wickenburg Airport.
- [5250](#) - Twin Peaks; off Vulture Mine Road; 6.2 miles SSW of Vulture Mine Rd. at US 60
- [5320](#) - O'Brien Gulch; 12.8 miles NE of Wickenburg
- [7000](#) - Stanton; at Stanton RV Park, 6.6 miles east of Congress

15-minute time distributions for selected rain gages are shown in Figures 5-8 below:





This map was developed using local gage-corrected radar rainfall estimates from our weather vendor – WDT, Inc. Point rainfall readings from FCDMC rain gages are shown as white numbers. Discrepancies between the radar and gage values are likely due to the radar's inability to resolve very steep intensity gradients. The maximum rainfall depth reported by the radar product was just under 4 inches. For this figure the authors chose to estimate and add the cyan colors to match the gage readings.

FIGURE 9

Precipitation Synopsis

Table 2 presents precipitation frequency statistical estimates from NOAA Atlas 14 at nineteen precipitation measuring points. All are FCDMC ALERT-format rain gages using 1mm tipping buckets. The gages transmit an incremented count for each recorded millimeter of rain during an event. Some of the increment counts are lost during an event of this magnitude due to collision of transmissions occurring at the same time, or when more than one ‘tip’ occurs in the 30 second hold-off time for transmission. When subjecting the data to QA/QC editing prior to development of this report, it appeared that data loss was on the order of 20-30%. This can lead to slight inaccuracies in the calculation of intensities, but overall the intensity calculations, and therefore the frequency calculations, can be considered good. The 20-30% data loss will be reduced to nearly zero as these stations are converted to the ALERT2 format in the coming year.

Of the nineteen gages analyzed for this report, 13 of them set new records for 30-minute, 1 hour or 3 hour durations. Their record lengths range from 20 to 34 years. Two all-time records were set for FCDMC rain gages - both at the Twin Peaks gage. Its 1-hour total was 4.25 inches and its 3-hour total was 5.00 inches. The old records were 3.58” at Vulture Mine Road on 7/21/1986 and 4.21” at Waterman Wash @ Rainbow Valley Road on 9/8/2014 respectively. Together with the 15-minute record of 1.77” at Congress on 9/9/2006, it is interesting that all these short-term records occurred within about 20 miles of each other.

In reviewing Table 2, for durations from 30 minutes to 2 hours:

- 11 gages had return periods of 100 years or more,
- 7 gages had return periods of 500 years or more,
- 5 gages had return periods of 1,000 years or more.

As was experienced in Maricopa County during several storms in the summer of 2014, 1,000-year return period rainfall amounts were measured in this storm. This is undoubtedly the result of entrained tropical moisture from Hurricane Delores, but an unusual phenomenon during the month of July. Warmer-than-normal sea-surface temperatures in the Eastern Pacific courtesy of El Niño are a likely contributor to these early-season tropical storms and their ability to influence weather so far north of their origin.

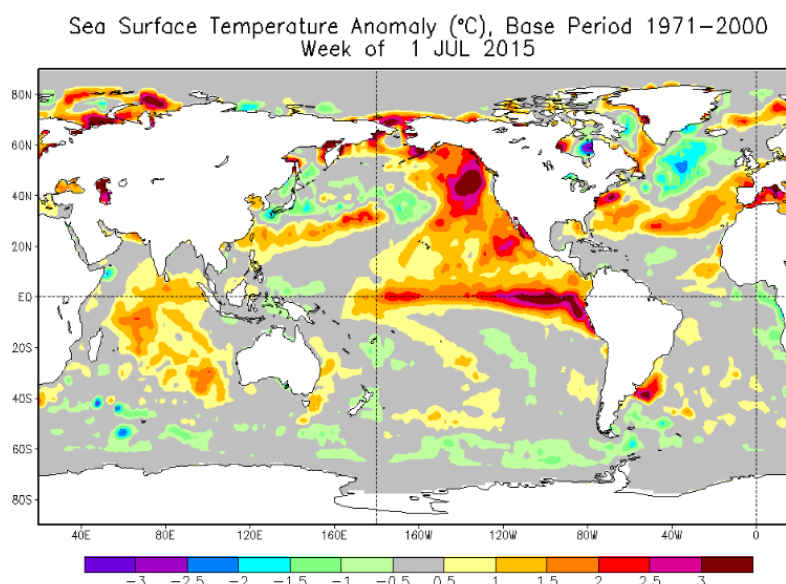
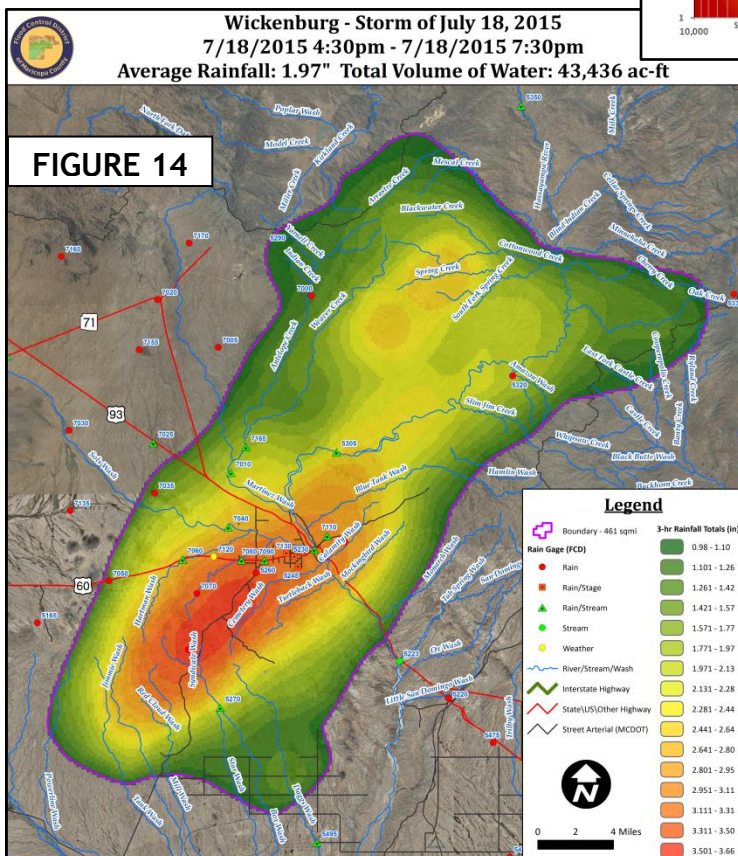
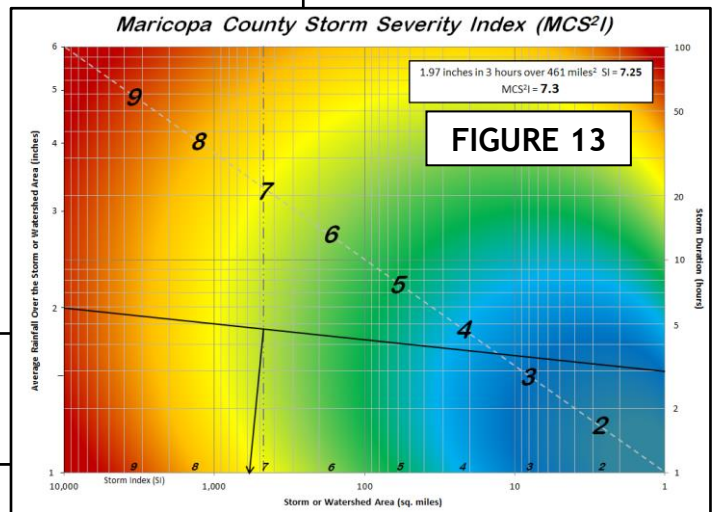
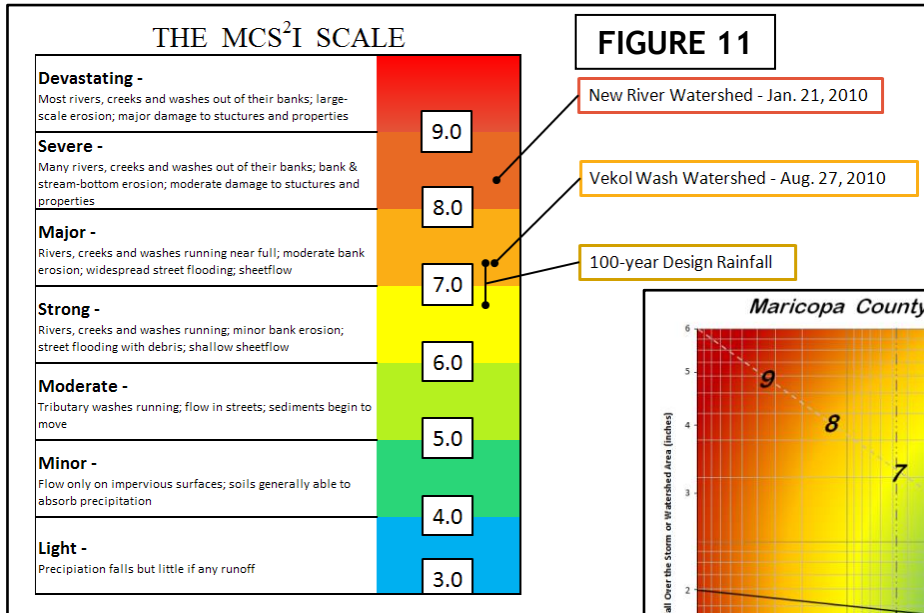


FIGURE 10

Maricopa County Storm Severity Index (MCS²I), developed by FCDMC

MCS²I is an index that classifies the severity of a storm based on the area covered, the average rainfall over that area (from gage-adjusted radar estimates), and the storm duration. For this storm, we chose the area inside the 1-inch contour on the 3-hour duration storm map. The storm scores an MCS²I of 7.3, categorized as **Major** on the MCS²I Scale. If a smaller area near the most intense portion of the storm had been selected, say to the southwest of US 93, it would have certainly scored more than an 8.



RUNOFF

Very intense rainfall occurred on Saturday July 18, 2015 from remnants of Hurricane Dolores. Table 3 below gives a summary of the streamgages affected by the heavy rainfall in and around the Wickenburg area. The peaks in the two tables below have been verified in the field by either verifying high water marks from staff gages, crest-stage gages, or surveying of high water marks. Values highlighted in yellow are period-of-record peaks. "Peak Q" is discharge in cubic feet per second and "GH" is gage height in feet from an arbitrary datum, often (but not always) the bottom of the stream bed.

TABLE 3

Site	ID	Peak Q	Peak GH	Time / Date
Antelope Creek	7168	4,430	4.79	07/18/2015 18:48
Box Wash	5273	4,160	5.65	07/18/2015 18:33
Casandro Wash	7093	670	8.01	07/18/2015 18:18
Flying E Wash	7083	5,250	7.07	07/18/2015 19:03
Hartman Wash	7063	2,465	6.62	07/18/2015 18:55
Hassayampa River at Box Canyon	5308	9,601	10.80	07/18/2015 19:05
Hassayampa River at US60 Bridge	5228	9,123	3.45	07/18/2015 18:22
Hassayampa River near Morristown	5223	15,606	14.19	07/18/2015 21:00
Hassayampa River at I-10 Bridge	5283	6,456	3.22	07/19/2015 02:36
Martinez Creek	7013	10,562	11.43	07/18/2015 19:07
Powder House Wash	7113	2,300	2.42	07/18/2015 17:36
Sols Wash near Matthie	7043	5,240	4.40	07/18/2015 19:26
Vulture Mine Road	5263	102	2.83	07/18/2015 17:35
Cemetery Wash east of 323 rd Ave.	None	-10,000	6.40	Time Unknown

Additionally, the three impoundment structures in Wickenburg also experienced record levels from this precipitation event. All structures were empty prior to this storm.

TABLE 4

Site	ID	Peak GH (feet)	Peak Vol (ac-ft)	% Full	Time / Date of Peak	Time from empty to Peak
Casandro Dam	7133	18.64	113	85.2	07/18/2015 19:16	125 minutes
Sunnycove FRS	5248	31.85	145	66.9	07/18/2015 20:21	195 minutes
Sunset FRS	5233	16.78	64	74.8	07/18/2015 19:19	136 minutes

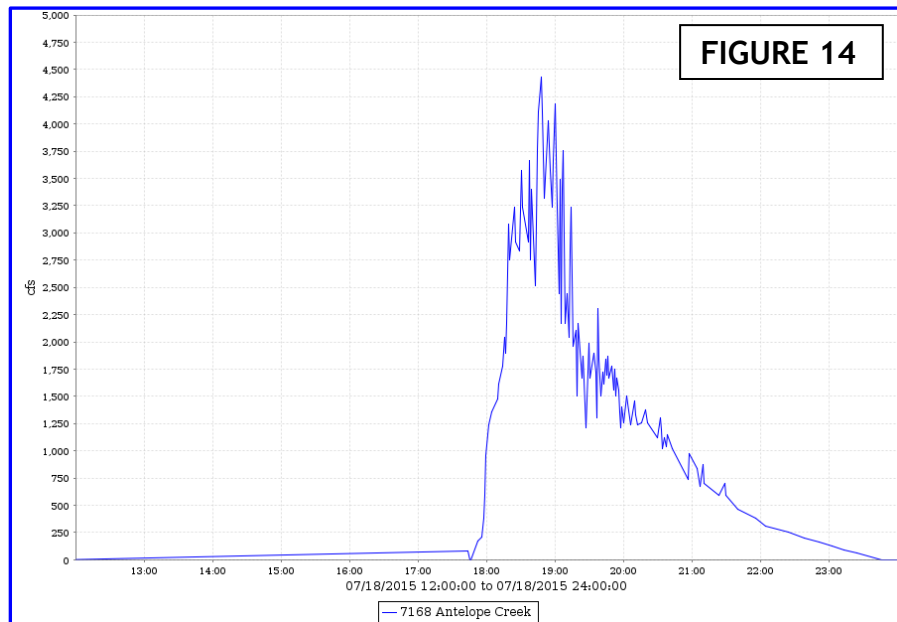
Previous to this event, none of these structures had filled to a capacity of 50 percent. Casandro Dam previously reached 48.8 percent full and Sunset FRS reached 39.5 percent full during the 1997 Hurricane Nora storm. Sunnycove FRS had had a maximum of 24.5 percent in 1992. Using design studies and anecdotal information, the authors believe that Casandro Wash Dam's pool and spillway were designed to impound the 6-hour, 100-year storm (3.35 inches) at a future condition which included a 35% impervious watershed - much higher than existed in 1995 or even today. Sunset and Sunnycove were designed by the (then) Soil Conservation Service to impound the 10-day, 100-year rainfall of 6.50 inches, also using Curve Numbers to simulate rainfall losses that represented a future-condition watershed.

Discussion

All the gaged washes in Wickenburg flowed in response to the large amount of rainfall that occurred on Saturday July 18, 2015. Five of these washes experienced their highest-ever recorded peak discharge. Following are hydrographs for each of the gaged washes and impoundment structures, in alphabetical order:

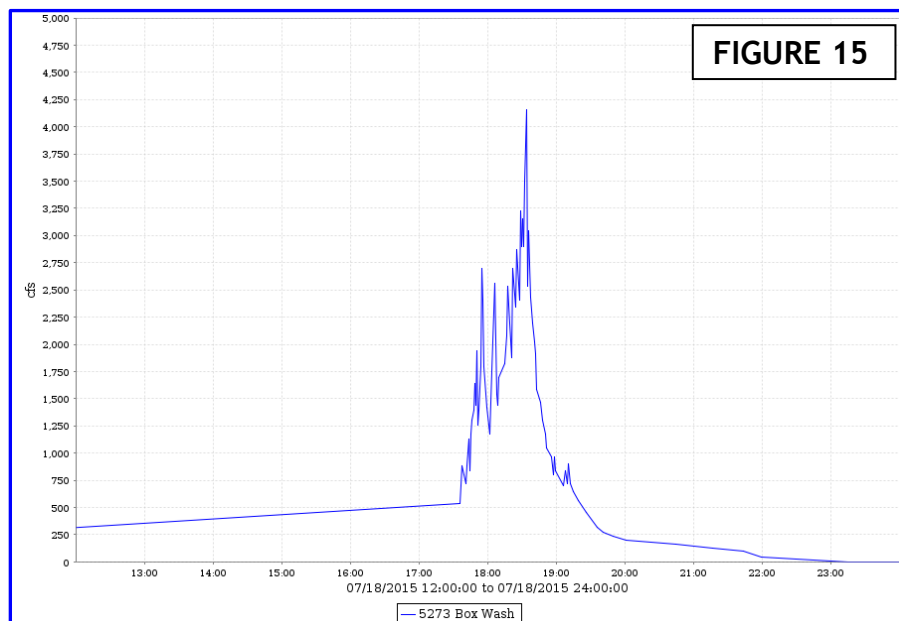
Antelope Creek (ID #7168)

This gage is located about 1.7 miles upstream from the Martinez Creek gage (7013). It flows into Martinez Creek about one quarter mile upstream from the Martinez Creek gage station. The flow here was the second largest flow of record since installation in 2003 - probably the result of rain and streamflow the previous day. Peak discharge high water marks were verified by survey.



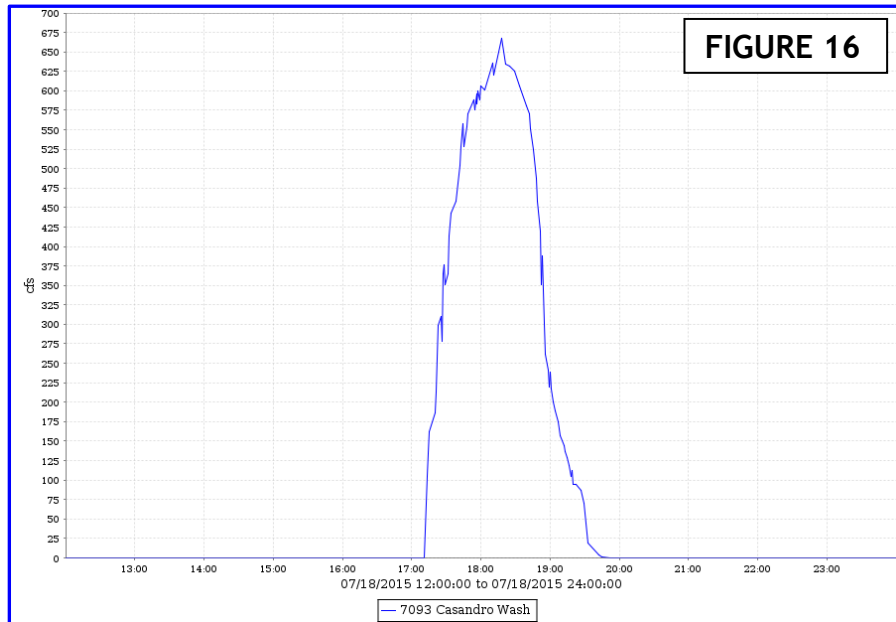
Box Wash (ID #5273)

Box Wash is located south of Wickenburg, but its watershed is adjacent to those for Flying E Wash and Hartman Wash. It experienced similar high flows for the event. The flow here was 4,160 cfs at 5.65 feet gage height. It is by far the largest discharge recorded since installation in 2003. Peak discharge high water marks were verified by survey.



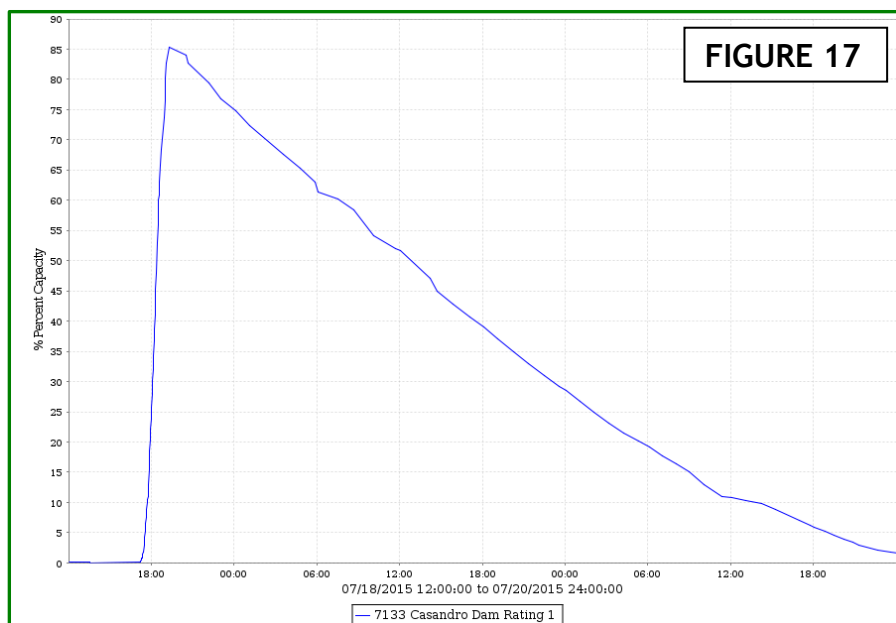
Casandro Wash (ID #7093)

This gage is located on the upstream side of the US60 culverts about one half mile east of Vulture Mine Road. The culverts are two 6-foot high by 6-foot wide boxes. The water level in the channel at the entrance to the culvert exceeded the top of the culvert but did not overtop the roadway. The rating was developed using an HY-8 culvert analysis and is considered good. Peak stage was a record 8.01 feet gage height, and the peak discharge was a record 668 cfs. Peak stage was verified using high water marks on the upstream side of the bridge. The crest-stage gage was overtopped during the event.



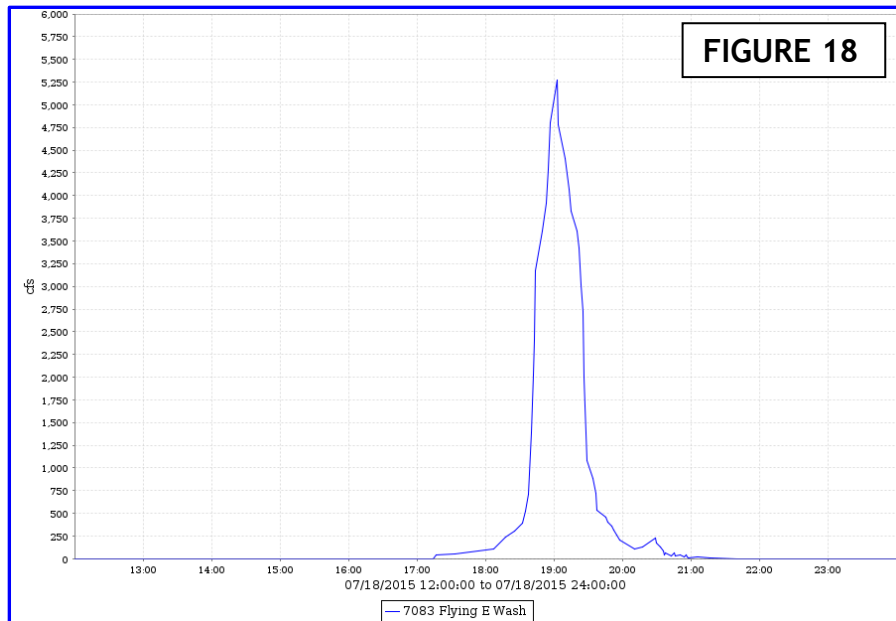
Casandro Dam (ID #7133)

This dam downstream from the Casandro Wash stream station received a record amount of inflow and had a peak impoundment that reached 85% capacity, within 1.6 feet of the emergency spillway crest, and the highest recorded since its construction in 1996.



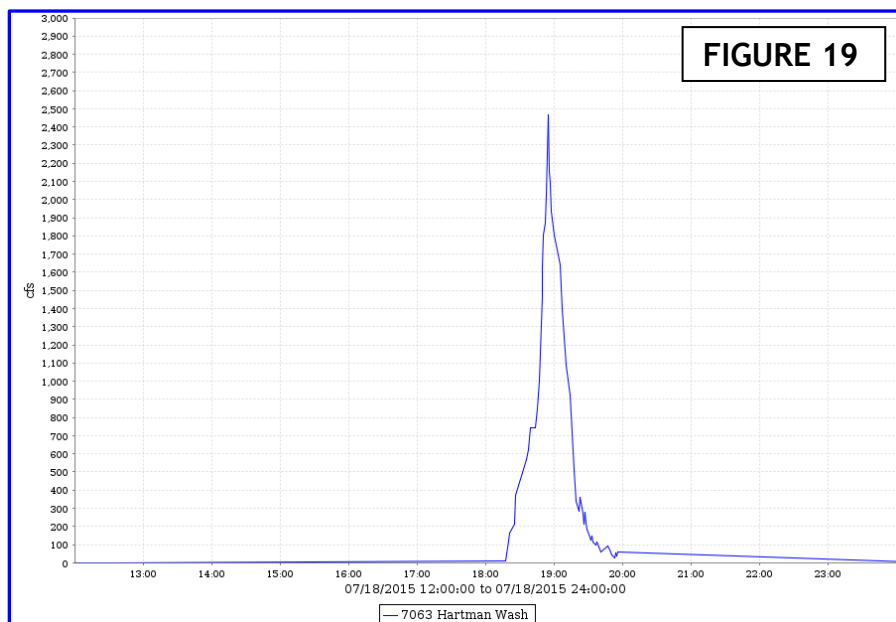
Flying E Wash (ID #7083)

This gaged wash is located about one-half mile west of Vulture Mine Road on US 60. The watershed had high intensity rainfall, but the transducer gage failed to measure the peak. High water marks were recovered from the crest-stage gage and from a survey of the site. Peak discharge was an estimated 5,250 cfs at 7.07 feet gage height. This is the highest flow recorded since installation in 1994.



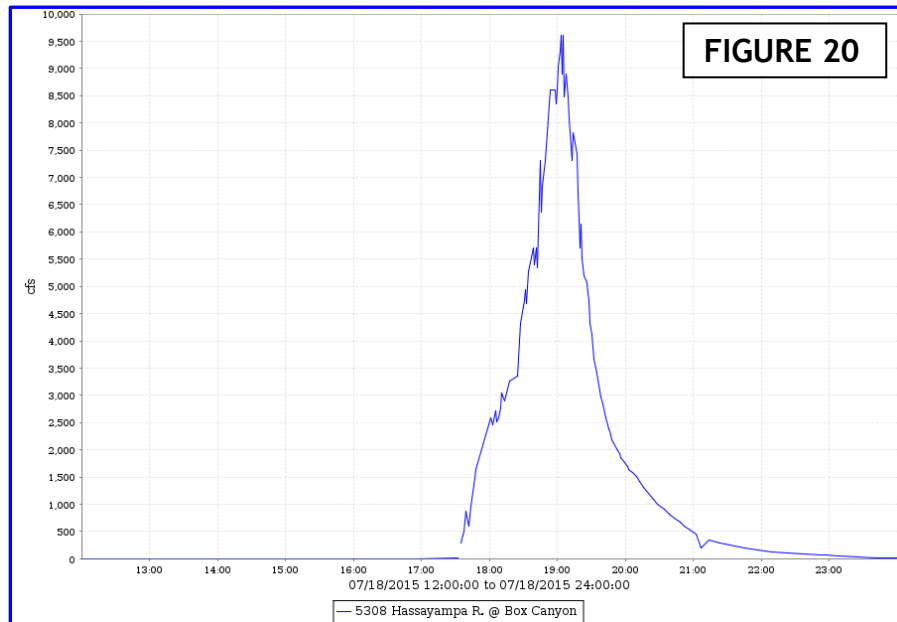
Hartman Wash (ID #7063)

This wash is located about 2 miles west of Flying E Wash, also along US60. This point on the wash is also monitored by the USGS. The transducer gage at this location also did not work correctly. High water marks were recovered from crest-stage gages and a survey. Best estimate is that the peak stage was at about 6.5 feet gage height upstream, and about 5.0 feet in the culvert. The discharge for this water level is 2,490 cfs.



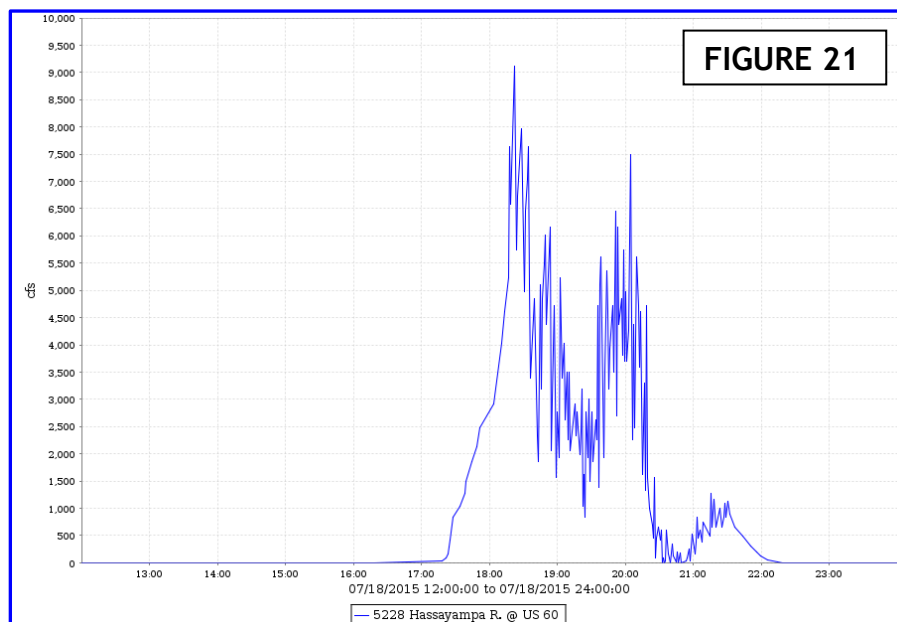
Hassayampa River at Box Canyon (ID #5308)

This station is upstream of the town and all major tributaries. It is about 8 miles upstream from the US60 bridge. This station recorded a flow of 9,601 cfs at 10.80 feet gage height. There have been a number of flows of greater magnitude over the long period of record for this gage. Peak stage was not verified for this event.



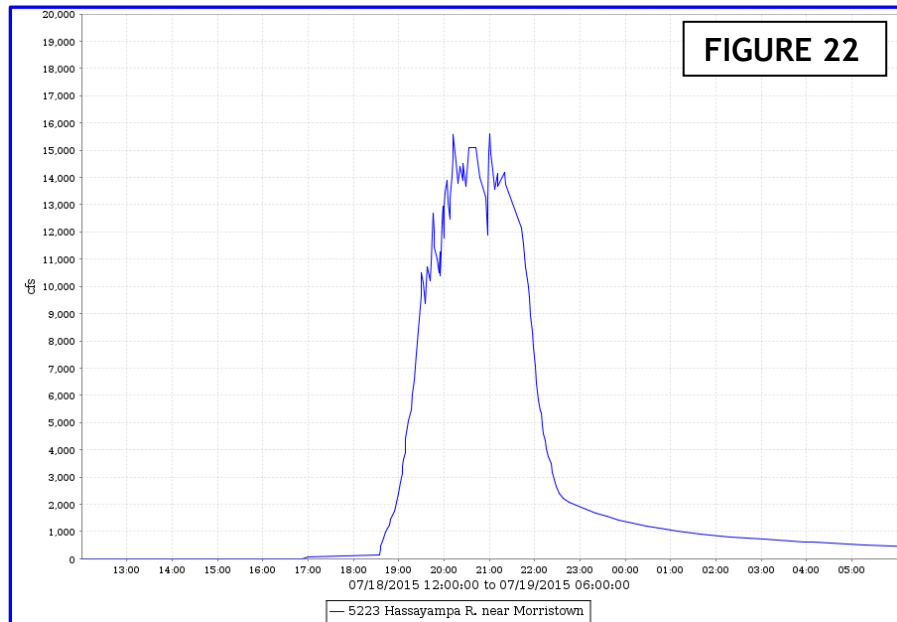
Hassayampa River at US60 (ID #5228)

This gage is located near the center of the town of Wickenburg and is downstream of tributary inflow from the upper watershed including Antelope Creek, Martinez Creek, Hartman Wash, Flying E Wash, Sols Wash near Matthie, and Powder House Wash. This gage had a peak discharge of 9,123 cfs at 3.45 feet gage height. The peak stage could not be verified as of publication of this report. However, analysis of peak discharge and time of peaks for the upstream stations would indicate this peak discharge to be reasonable.



Hassayampa River near Morristown (ID #5223)

This station is approximately 7.4 miles downstream from the US 60 bridge. The USGS also operates a gage at this location. The peak at this station was 15,606 cfs and a stage of 14.19 feet gage height. The peak occurred about 2.5 hours after the peak passed the US 60 bridge.



Hassayampa River at I-10 (ID #5283)

This last station on the Hassayampa River is about 20 miles downstream from the Morristown gage. This station received a small flow, likely as a result of the flows upstream. Using an average velocity and channel distance, the flow was estimated to arrive at this station at 07/19/2015 03:00. The actual arrival time was 07/19/2015 at 02:36, which confirmed that the flow originated from the Wickenburg event. Much of the flow from Morristown did not go the full 20 mile trip - it soaked into the river bottom. The peak at I-10 was 6,456 cfs and 3.22 feet gage height.

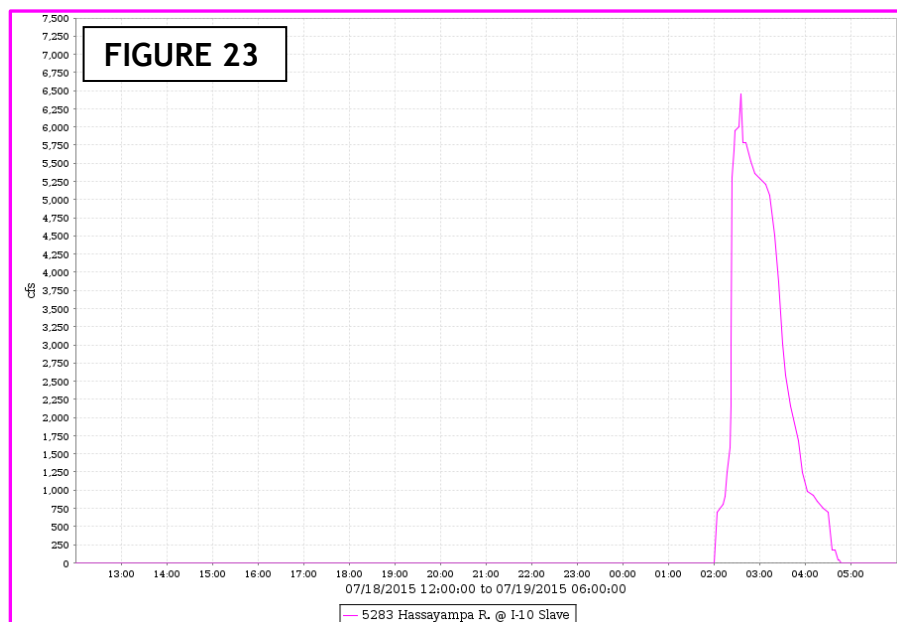


TABLE 5

From Station [A]	To Station [B]	Drainage Area (mi ²)	Distance (mi.)	Ave. Velocity from HEC-2 (ft/sec)	Travel Time (hours)	Actual Time of Peak at [A]	Estimated Time of Arrival at [B]	Actual Time of Arrival at [B]	Difference (hr:min)
Hassayampa R. at Box Canyon	Hassayampa R. at US60	417.0	7.78	9.0	1.27	7/18/2015 19:05	7/18/2015 20:21	7/18/2015 18:22	1:59
Antelope Creek	Martinez Creek	62.0	1.68	4.1	0.60	7/18/2015 18:48	7/18/2015 19:24	7/18/2015 19:07	0:17
Martinez Creek	Hassayampa R. at US60	105.0	6.43	8.0	1.18	7/18/2015 19:07	7/18/2015 20:17	7/18/2015 19:07	1:10
Hartman Wash	Sols Wash	5.4	3.80	8.0	0.70	7/18/2015 18:55	7/18/2015 19:36	7/18/2015 18:55	0:41
Flying E Wash	Sols Wash	8.5	2.02	8.2	0.36	7/18/2015 19:03	7/18/2015 19:24	7/18/2015 19:03	0:21
Sols Wash near Matthie	Hassayampa R. at US60	121.0	4.57	9.0	0.75	7/18/2015 19:26	7/18/2015 20:10	7/18/2015 19:26	0:44
Powderhouse Wash	Hassayampa R. at US60	1.8	0.93	11.0	0.12	7/18/2015 17:36	7/18/2015 17:43	7/18/2015 17:36	0:07
Hassayampa R. nr Morristown	Hassayampa R. at I-10	796.0	20.24	5.0	5.94	7/18/2015 21:00	7/19/2015 2:56	7/19/2015 02:36	0:20

Table 5 shows distances and travel times between various stream gages in the Wickenburg area. The average velocity was taken from HEC-2 and HEC-RAS hydraulic models. Since US 60 peaked before Box Canyon, the peak could not have come from there. US 60 peaked before every other contributing gage except Powder House, so its peak likely came from Powder House and other small upstream washes, plus a contribution from Sols Wash and its tributaries below the Matthie gage. The estimated arrival and actual times over the 20.24 miles from Morristown to I-10 were remarkably close - the actual average velocity was 5.3 feet/second.

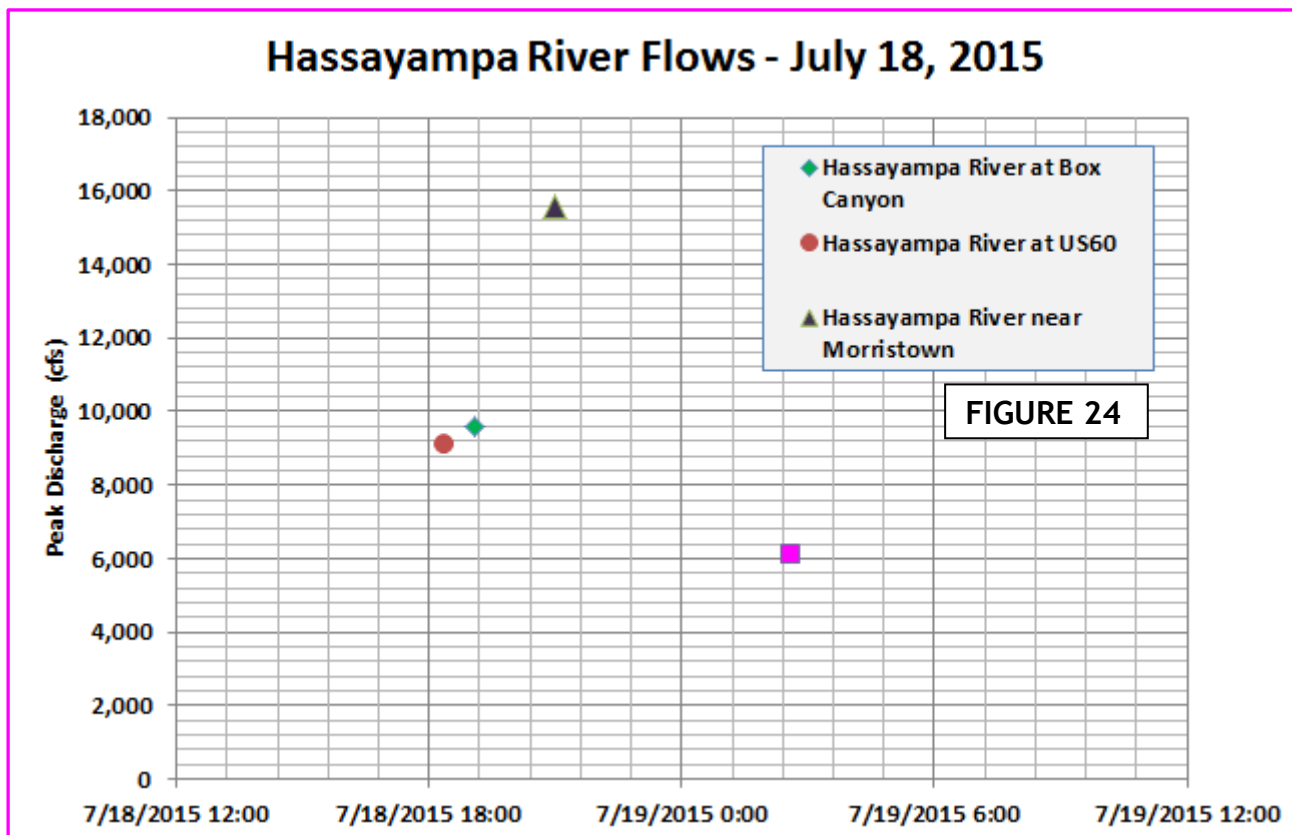
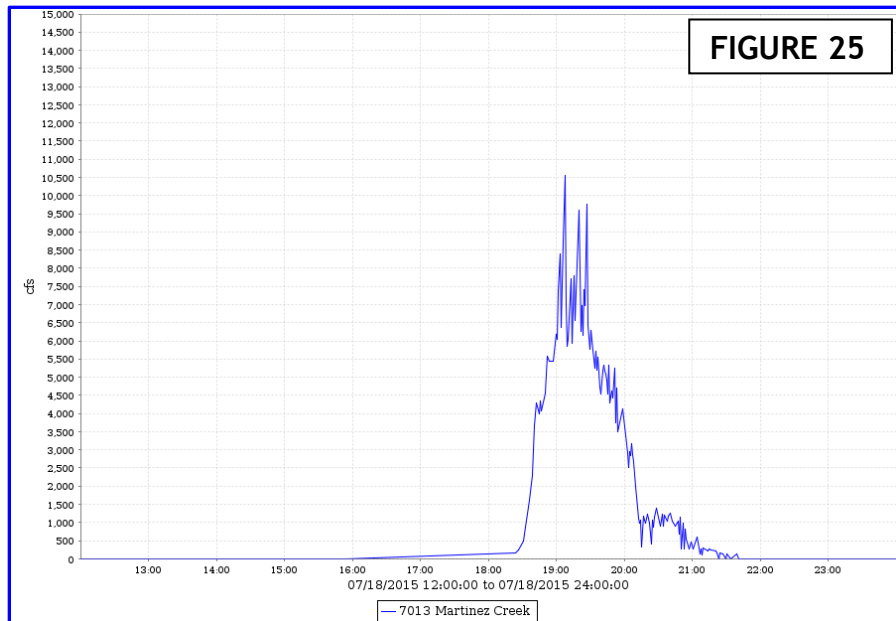


Figure 24 shows the peaks at the four Hassayampa River gages and when they occurred in time. Inflow from ungaged washes downstream of US 60, especially Cemetery Wash, contributed to the much higher peak at Morristown.

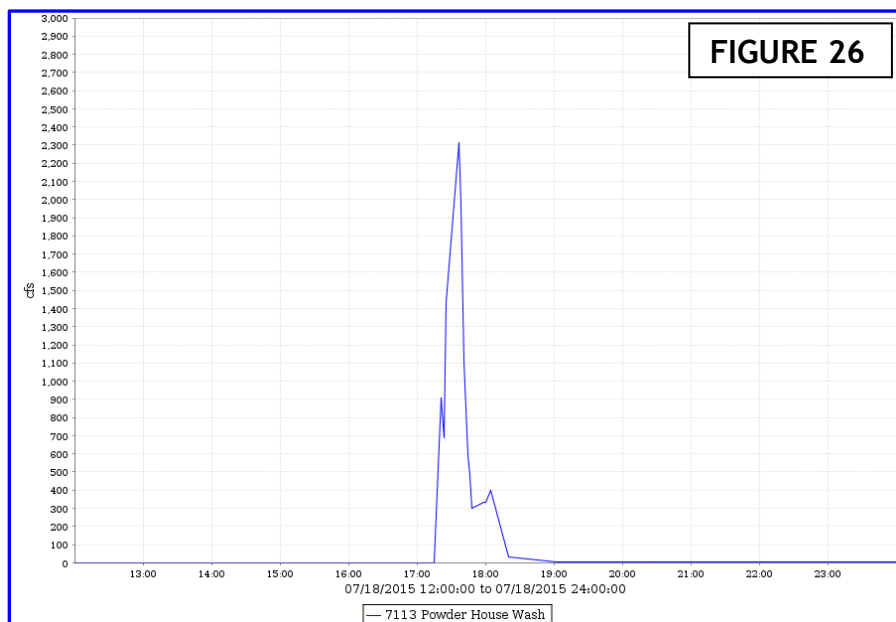
Martinez Creek (ID #7013)

The Martinez Creek gage is located about one mile upstream of Scenic Loop Road. Flow at this gage is from Martinez Creek and Antelope Creek, both of which have large watersheds. Peak stage values tend to be very large here due to a 90 degree bend the water must make at the gage location. The peak discharge was estimated in a contraction about 300 feet upstream from the level gage. Peak discharge for this event is 10,300 cfs which is the highest recorded to date.



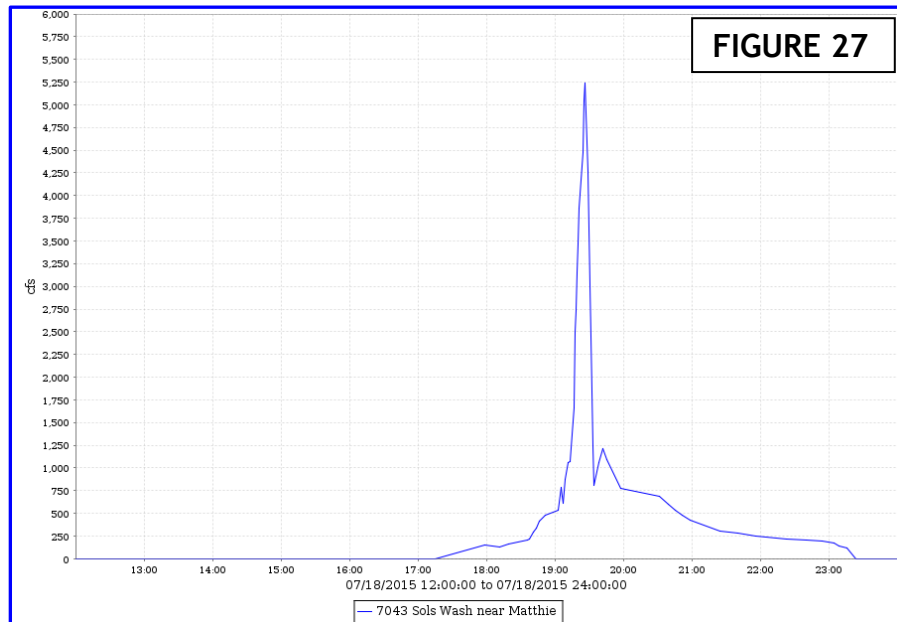
Powder House Wash (ID #7113)

This gage is on a small watershed east of the Hassayampa River. It is a very steep wash that discharges into the Hassayampa River just above the US 60 bridge. Runoff from the event produced the largest flow of record since 1995 when the gage was installed. The peak stage was 2.42 feet, with a computed discharge of 2,300 cfs. High water mark data were verified with a survey and from the crest-stage gage.



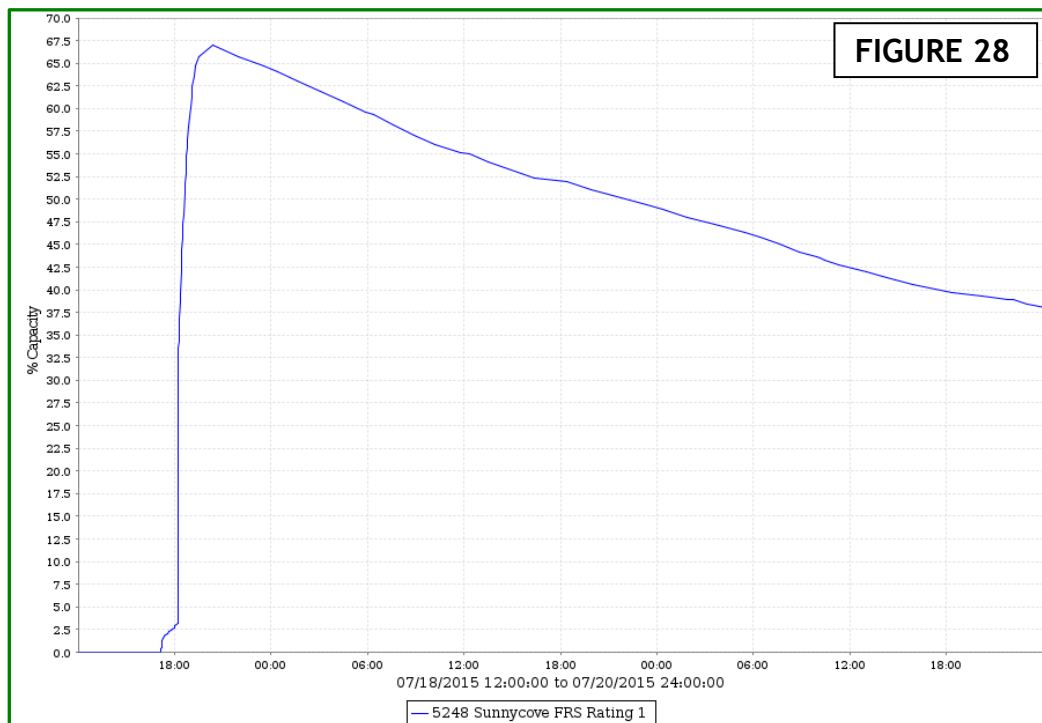
Sols Wash near Matthie (ID #7043)

This gage is located about one mile upstream from Vulture Mine Road, and about 4.5 miles upstream from the US 60 bridge. The peak discharge at this station was 5,240 cfs at 4.40 feet gage height. High water marks were verified from a survey of the site following the event.



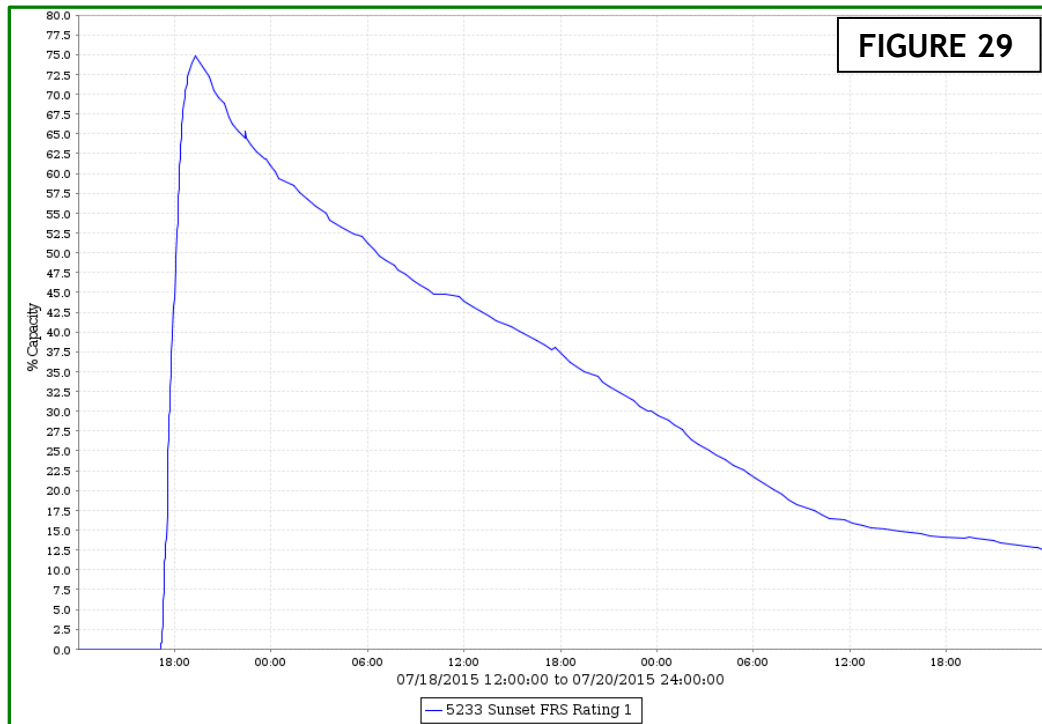
Sunnycove FRS (ID #5248)

This dam is located southwest of the downtown area of Wickenburg, near the town cemetery. Sunnycove FRS recorded a record impoundment, reaching a peak of 31.85 feet gage height, or about 67% of spillway capacity, which is the highest known impoundment.



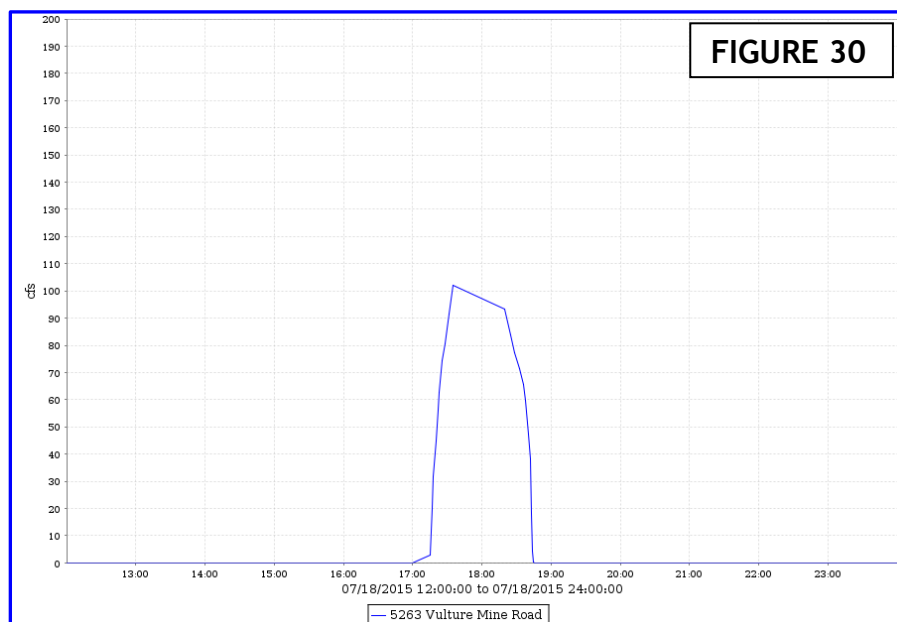
Sunset FRS (ID #5233)

Sunset FRS is located on the south side of US 60 west of downtown Wickenburg. This dam also recorded its highest known impoundment. Records have been kept since 1989. The peak stage was 16.78 feet gage height - about 75% of spillway capacity.



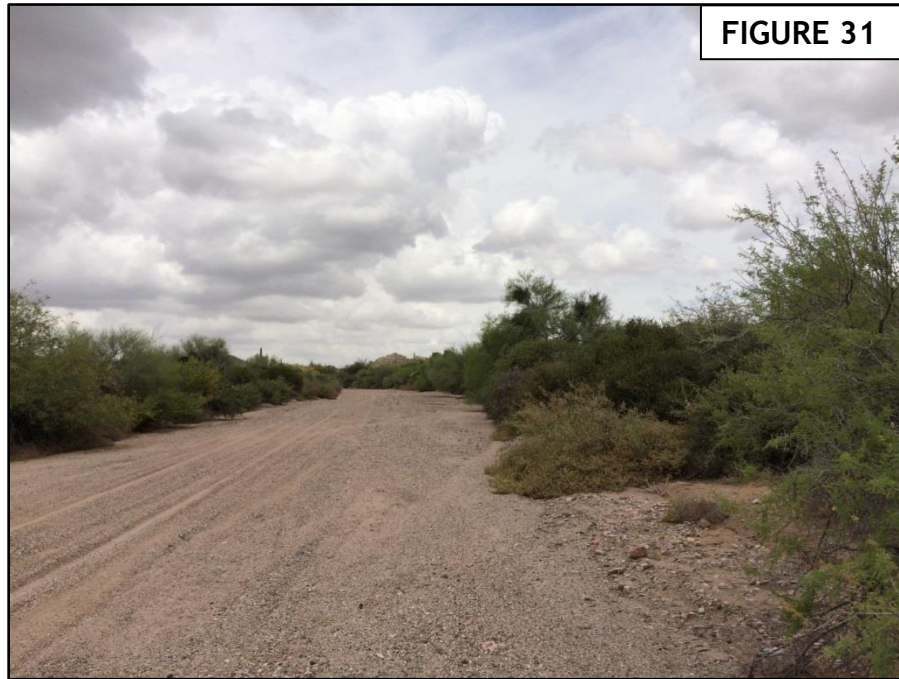
Vulture Mine Road (ID #5263)

This gage is located on a part of Casandro Wash on a small upper watershed. It had a small flow during the event, 102 cfs. There have been larger flows in the past.



Additional Information of Interest

Significant changes to streams occur as a result of high flows. At Box Wash, a significant amount of vegetation was destroyed. The photos below show the scour power of water. The top picture shows the left bank of Box Wash upstream from the gage, taken in May 2015. The bottom photo is the same left bank upstream of the gage, taken on July 20, 2015. Much of the vegetation has been removed and the bank scoured.



Box Wash, Left bank, May 14, 2015



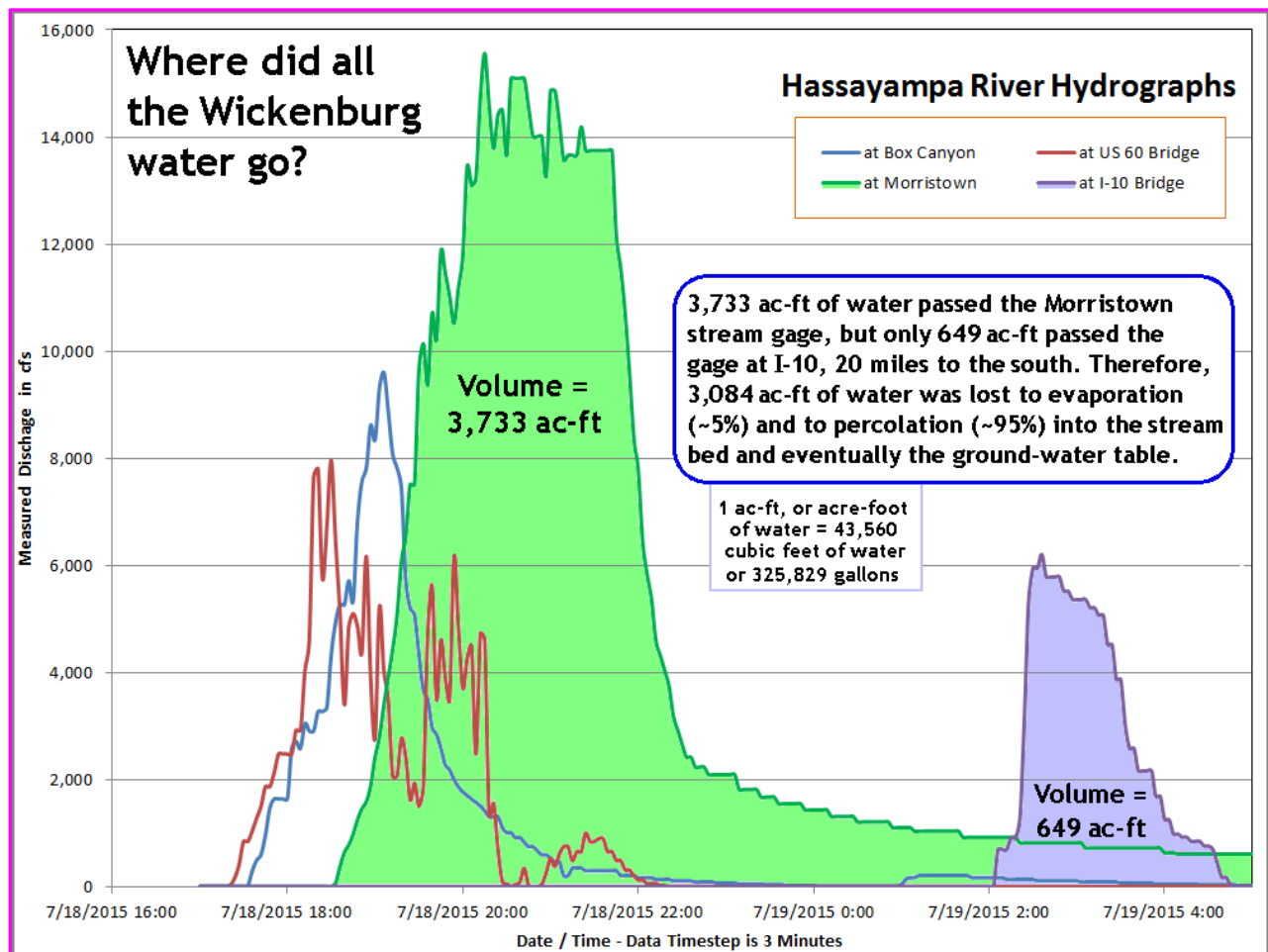
Box Wash, Left bank, July 20, 2015

The photo below shows a large debris flow that occurred on a tributary wash to Box Wash that crosses a paved portion of Vulture Mine Road. Notice the large boulder in the center of the road. The boulder is about 2.5 feet wide and over a foot in height.



FIGURE 33

Debris Flow on Vulture Mine Road, south of Box Wash crossing, July 19, 2015



EVENT TIMELINE

Friday, 7/17/2015

- 11:10 AM FCDMC MSP issues a Message 2 Flash Flood Watch for all MSP Forecast Zones from 5pm Friday 7/17 through 11pm Saturday 7/18.
- 6:10 PM FCDMC MSP issues a Message 1 Alert for the Wickenburg Forecast Zone.
- 8:00 PM FCDMC MSP issues a Message 3 Flash Flood Warning for Antelope Creek and Martinez Creek.
- 8:03 PM Flow at Antelope Creek gage peaks at 2,830 cfs.
- 8:08 PM FCDMC ALERT Room called Wickenburg Police Dispatch - "Expect flow to come down Martinez Creek and into the Hassayampa River".
- 8:23 PM Flow at Martinez Creek gage peaks at 4,700 cfs.
- 9:36 PM Flow at Hassayampa River at US 60 peaks at 1,170 cfs.

Saturday, 7/18/2015 (not all rain / stream alarms are included)

- 1:52 PM FCDMC MSP issues a Message 1 Alert for the Gila Bend Forecast Zone.
- 3:00 PM FCDMC MSP issues a Message 1 Alert for the Rainbow Valley Forecast Zone.
- 3:12 PM FCDMC MSP issues a Message 1 Alert for the West Valley Forecast Zone.
- 4:01 PM FCDMC MSP issues a Message 1 Alert for the Northwest Valley Forecast Zone.
- 4:40 PM FCDMC MSP issues a Lake Alert for Lake Pleasant.
- 4:55 PM Heavy rain begins falling in Wickenburg.
- 5:00 PM FCDMC MSP issues a Message 1 Alert for the Wickenburg Forecast Zone.
- 5:04 PM Impoundment begins at **Sunset FRS**.
- 5:07 PM Impoundment begins at **Sunnycove FRS**.
- 5:10 PM First of the Wickenburg rainfall alarms activated - Casandro Dam. Five more rainfall alarms sound before 5:13 PM.
- 5:12 PM Impoundment begins at **Casandro Dam**.
- 5:13 PM First Wickenburg stream gage alarm activated - Casandro Wash reached 1.9 ft. / 50 cfs.
- 5:20 PM FCDMC MSP issues a Message 3 Flash Flood Warning for the Wickenburg Forecast Zone.
- 5:22 PM Powder House Wash stream gage alarm activated - reached 0.8 ft. / 220 cfs.
- 5:23 PM FCDMC ALERT Room called Wickenburg Police Dispatch - "Be sure to keep an eye on Powder House Wash, gage is showing flow".
- 5:24 PM **Sunset FRS** 10% alarm activated, stage is 6.48 feet (10% filled in 20 minutes).
- 5:30 PM **Casandro Dam** 10% alarm activated, stage is 4.54 feet (10% in 18 minutes).
- 5:32 PM Twin Peaks 20-min. rainfall alarm sounds - 1.77 inches
- 5:33 PM FCDMC ALERT Room called MCDOT Barricade Section - "Send a crew to Wickenburg via Vulture Mine Rd".
- 5:35 PM Vulture Mine Road stream gage (above Sunnycove FRS) peaked at 2.8 feet / 102 cfs.
- 5:36 PM **Sunset FRS** at 25%, stage is 9.83 feet (15% filled in 12 minutes, 25% full in 32 minutes).
- 5:37 PM Box Wash stream gage alarm - above 2.73 feet / 700 cfs.
- 5:37 PM Powder House Wash stream gage peaks at 2.42 feet / 1,800 cfs.
- 5:40 PM FCDMC ALERT Room notified FCD O&M - "**Sunset FRS** at 25%".
- 5:50 PM FCDMC ALERT Room notified FCDMC AOC Chief
- 5:55 PM Flying E Wash stream gage alarm - 1.90 feet / 315 cfs
- 6:00 PM Antelope Creek stream gage alarm - 3.00 feet / 750 cfs
- 6:01 PM **Casandro Dam** at 25%, stage is 10.5 feet (15% filled in 31 minutes, 25% full in 49 minutes).

6:02 PM Hassayampa R. @ Box Canyon stream gage alarm - 7.25 feet / 1,600 cfs.

6:08 PM **Sunset FRS** at 50%, stage is 14.1 feet (25% filled in 32 minutes, 50% full in 64 minutes).

6:12 PM Major flash flood hits **Sunnycove FRS**. In three minutes the stage goes from 9.2 feet (3%) to 24.6 feet (34%).

6:14 PM Twin Peaks 1-hour rainfall alarm sounds - 3.23 inches.

6:17 PM Hassayampa R. @ US 60 stream gage alarm - above 2.80 feet / 5,245 cfs.

6:18 PM Casandro Wash stream gage peaks at 8.0 feet / 665 cfs.

6:23 PM Hassayampa R. @ US 60 peaks at 3.45 feet / 9,100 cfs.

6:26 PM **Casandro Dam** at 50%, stage is 14.6 feet (25% filled in 25 minutes, 50% full in 74 minutes).

6:30 PM FCDMC AOC Chief arrives at AOC.

6:31 PM Flying E Tank 1-hour rainfall alarm sounds - 2.44 inches.

6:32 PM Hartman Wash stream gage alarm - 3.0 feet / 730 cfs.

6:37 PM **Sunnycove FRS** at 50%, 28.6 feet (50% full in 90 minutes).

6:37 PM Martinez Creek stream gage alarm - 4.90 feet / 1,900 cfs.

6:48 PM Wickenburg Airport 1-hour rainfall alarm sounds - 2.48 inches.

6:59 PM Hassayampa R. near Morristown stream gage alarm - 10.1 feet / 2,415 cfs

6:59 PM **Casandro Dam** at 75%, 17.6 feet (25% filled in 33 minutes, 75% full in 1 hour 47 minutes).

7:03 PM Sols Wash near Matthie stream gage alarm - 1.75 feet / 500 cfs.

7:03 PM Hassayampa R. @ Box Canyon stream gage peaked at 10.8 feet / 9,600 cfs.

7:04 PM Martinez Creek stream gage peaks at 11.4 feet / 10,562 cfs.

7:17 PM **Casandro Dam** peaks at 18.64 feet, 85.2% (10% filled in 18 minutes, 85.2% full in 2 hours 5 minutes). ALERT gage does not check in for 1 hour and 35 minutes. A level pool was assumed because at this time the Casandro Wash stream gage had dropped to 100 cfs.

7:20 PM **Sunset FRS** peaks at 75%, 16.8 feet, (25% filled in 72 minutes, 75% full in 2 hrs. 16 min.).

7:38 PM First FCD staff (our MCSO Deputy) arrives at **Casandro Dam**, reports a staff gage reading of 19.0 feet.

8:13 PM Hassayampa R. near Morristown stream gage peaks at 14.2 feet / 15,600 cfs.

8:22 PM **Sunnycove FRS** peaks at 67%, 31.85 feet (17% filled in 105 minutes, 67% full in 3 hours 15 minutes).

8:32 PM **Casandro Dam** - MCSO Deputy reports a staff gage reading of 18.5 feet - this value was entered manually into the ALERT database.

8:42 PM **Casandro Dam** pool gage finally sends a reading of 18.34 feet / 82.%.

9:11 PM Patton Rd. @ Hassayampa River flashing warning signs activate.

10:00 PM FCDMC AOC closed.

Sunday, 7/19/2015

0:00 AM **Sunset FRS** has dropped to 15.1 feet / 60%, **Sunnycove** has dropped to 31.4 feet / 64.5%, and **Casandro Dam** has dropped to 17.4 feet / 75%.

2:36 AM Hassayampa River @ I-10 stream gage alarm peaked at 3.22 feet / 6,456 cfs.

Monday, 7/20/2015

5:38 AM Hassayampa R. near Morristown stream gage drops to zero; Patton Rd. @ Hassayampa River flashing warning signs deactivate.

SELECTED DATA SOURCES

1. National Atmospheric and Oceanic Administration, National Climatic Data Center, Asheville, NC - Radar Data Archive and Climate and Weather Toolkit:
<http://www.ncdc.noaa.gov/oa/radar/radardata.html>
2. Strong winds and Heavy Rain in Wickenburg Saturday 18 July 2015: National Weather Service, Phoenix, AZ WFO:
<http://www.wrh.noaa.gov/psr/pns/2015/July/18JulyStorms.php>
3. National Weather Service, Storm Prediction Center, Norman, OK:
<http://www.spc.noaa.gov/obs wx/maps/>
4. Flood Control District of Maricopa County, Phoenix, AZ:
<http://www.fcd.maricopa.gov>
5. National Weather Service, National Hurricane Center, Miami, FL:
<http://www.nhc.noaa.gov/?epac>
6. National Weather Service, Weather Prediction Center, College Park, MD:
<http://www.wpc.ncep.noaa.gov/>
7. US Naval Research Laboratory, Marine Meteorology Division; NEXSAT NRL/NPOESS Next-Generation Weather Satellite Demonstration Project
<http://www.nrlmry.navy.mil/>
8. National Weather Service, Hydrometeorological Design Studies Center, Silver Spring, MD - Precipitation Frequency Data Server for Arizona:
http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=az



Cemetery Wash Indirect Flood Discharge Measurement

Flood Date: 18 July 2015
Survey Date: 04 August 2015

Summary

A significant flood event occurred on Cemetery Wash in Wickenburg, AZ on July 18, 2015. The wash is not gaged at any location. Field data were collected on August 4, 2015. Data collected included high water marks on left and right banks, and cross section geometry. High water marks were of fair to excellent quality.

Based on analysis of the collected data, the peak discharge for the event is computed to be an estimated 10,000 cubic feet per second. The most recent estimate of the 1% chance flood discharge at the surveyed location on the wash is 7,561 cfs.

Introduction

A large precipitation event occurred on the late afternoon of Saturday July 18, 2015 in and around Wickenburg. Precipitation in the 7.6 square mile Cemetery Wash watershed was in the range of 3.5 to 4.5 inches in about 2 hours. Rain in this quantity and short duration will produce significant runoff. Runoff in Cemetery Wash was significant, and it was desired to determine the peak discharge of the runoff. Cemetery Wash is not gaged at any location along its watercourse.

Discussion

A survey was conducted to acquire data to determine the peak discharge from the July 18 event. First a suitable reach was examined from aerial photos. It was decided to survey a part of the wash that was accessible from Ocotillo Drive. The specific site was about one half mile downstream from 323rd Drive. The approximate coordinates are latitude 33.9466, longitude -112.7494. An aerial of the surveyed area is below.



The channel in this section has a well-defined main bed composed of fine sand. There was only a small left over-bank with a wide, heavily vegetated right over-bank. The photo below is of the channel downstream from the furthest upstream cross section surveyed.



It was desired to select three cross sections to survey. However, due to significant variability of the channel (expanding, contracting, bends, etc.) only two cross sections were surveyed in this fairly straight, and somewhat uniform section of the channel. The reach length between the two cross sections is about 215 feet.

Data were collected, analyzed, plotted, and used to create a Slope Area Computation (SAC) model. Channel roughness values (n-values) were selected in the field based on observation and experience of the hydrologist. For the main channel, n-values of 0.028 to 0.030 were used. In the over-banks, the n value selected was 0.065 to 0.090 due to heavy vegetation.

The SAC program was run with various parameters. The table below summarizes the findings.

RUN	WSEL US	WSEL DS	MAIN N	RB N	LB N	US - DS COMPUTED FROUDE #	COMPUTED DISCHARGE
1	96.40	93.50	0.03	0.065	0.08	1.31-1.39	10,683
2	96.40	93.50	0.03	0.075	0.08	1.26-1.37	10,048
3	96.40	93.50	0.028	0.075	0.08	1.32-1.44	10,383
4	97.06	92.91	0.028	0.09	0.09	0.94-1.52	8,648
5	96.36	93.16	0.03	0.075	0.08	1.17-1.39	9,191
6	96.40	93.50	0.028	0.075	0.09	1.32-1.45	10,403

Run 4 used the actual high water marks as surveyed, whereas the first 3 runs and run 6 used water surface slope among all the high water marks on each bank. Run 5 used average high water marks between the left and right banks. At the upstream cross section, the left bank high water mark was higher by 1.4 feet, whereas at the downstream cross section the right bank high water mark was about 0.9 feet higher than

the left bank. Furthermore, no previous information was available about past runoff events or the amount of channel scour that occurs. For this analysis, the scour is not considered significant, though that may be in error.

A hand computation for the main channel at the downstream cross section only, gives velocities of 19.7 feet-per-second ($n=0.03$) to 21.1 fps ($n=0.028$). Either n value is reasonable, but the lower one is probably justified for use in this case. These high velocities produced nearly 7,000 cfs in the main channel alone (hand calculation).

Given both the SAC results and the hand calculation showing a high discharge, it is not unreasonable to conclude that the peak discharge was about 10,000 cfs. More likely, the peak discharge was in the range of 9,500 - 10,500 cfs for this event. The most recent estimate of a 1%, or 100-year discharge for Cemetery Wash @ 323rd Ave., based on a 100-year, 24-hour rainfall of 4.5 inches, is 7,571 cfs.

