

Memorandum

DATE: October 2, 2017

TO: Heather Gluski, Superintendent Hydrogeology, Resolution Copper Mining

FROM: Ted Lehman, PE, Hydrologist, JE Fuller

RE: USGS Regression Equation Computations for Queen Creek & Devil's Canyon

Dear Ms. Gluski,

At your request following meetings and discussions with you and your other consultants, JE Fuller has computed flood flow frequency and volume-duration-frequency values for points of interest on Queen Creek and Devil's Canyon. The intent is to quantify surface water hydrology in these two watersheds to assist Resolution Copper Mining (RCM) with assessment of potential impacts to surface water flows associated with the proposed mining and associated activities near Superior, Arizona.

To accomplish these goals, flood flow frequency and volume-duration-frequency were computed using two sets of regression equations recently published by the United States Geological Survey (USGS) – Scientific Investigations Reports (SIR) 2014-5211 (peak flow frequency) and 2014-5109 (volume-duration-frequency). These reports provide regression equations to estimate the magnitude and frequency of surface water hydrology for unregulated watersheds in Arizona. The statistical analyses presented in these reports were performed for streamflow data collected through 2010 for dozens of stream gaging stations with hundreds of years of cumulative streamflow records to develop regression equations to compute peak flow and volume frequency estimates. As such, they represent an excellent method to quantify surface water hydrology in central Arizona including the watersheds of Queen Creek and Devil's Canyon.

Significant variables used in the USGS regression equations include watershed drainage area, mean annual precipitation, and mean elevation. Equations are presented to compute annual exceedance probability (AEP) for the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent levels for un-gaged basins in Arizona. These reports also present standard error of prediction percentages for each set of equations for each AEP. Copies of these two USGS reports are provided with this memo for convenience.

Peak Discharge Flow Frequency (SIR 2014-5211)

Regression equations for unregulated watersheds in Arizona were developed by the USGS to estimate magnitude and frequency of floods using peak-flow data through Water Year 2010. Figure 1 shows a map from SIR 2014-5211 of the regions and stream gage locations used in the development of the peak-flow regression equations. Queen Creek and Devil's Canyon watersheds lie within Region 5 – Southeastern Basin and Range. Table 1 shows the regression equations developed for flood region 5. For each annual exceedance probability (AEP), the predicted peak discharge is computed solely as a function of drainage area (DRNAREA).

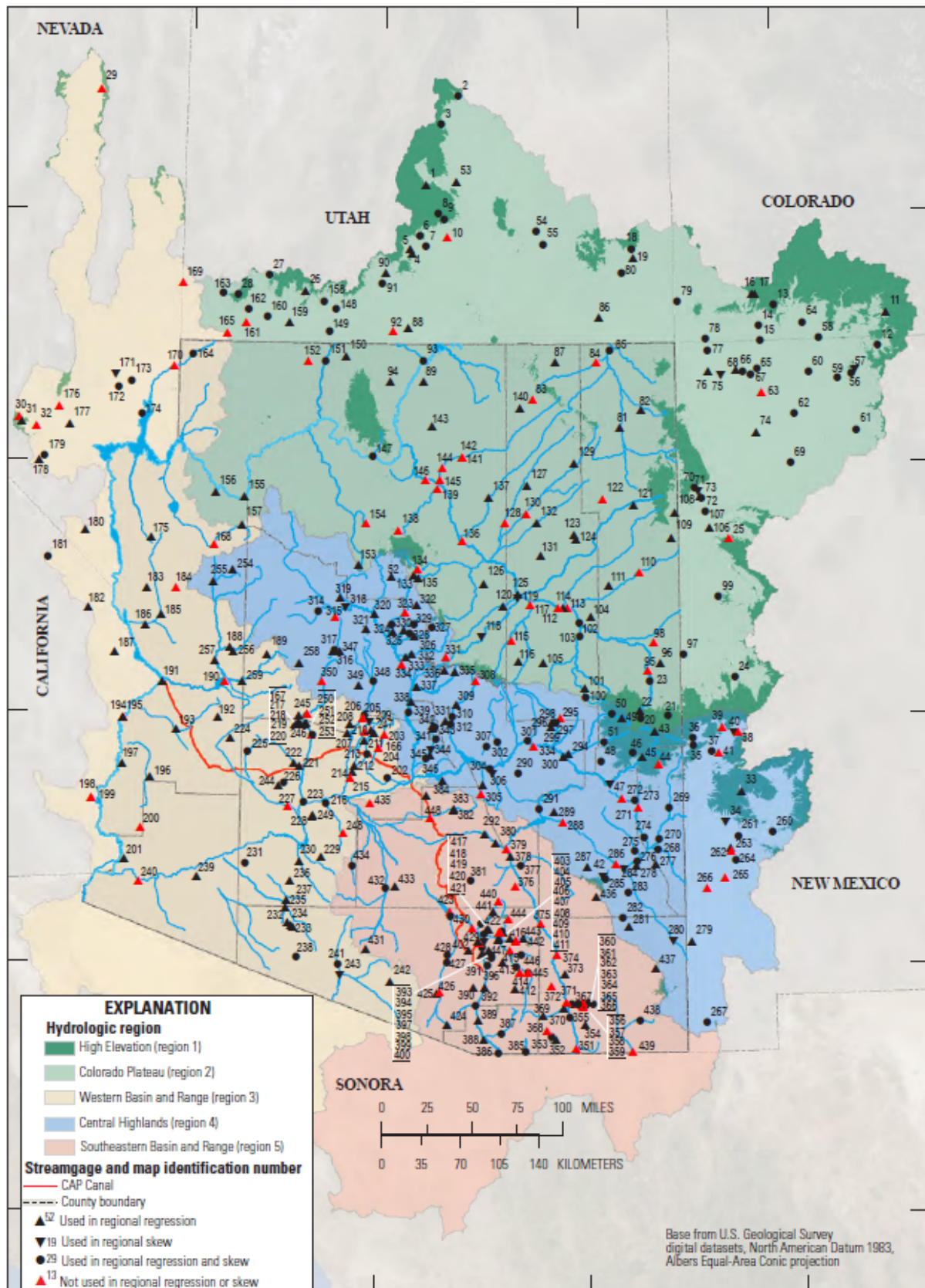


Figure 1. Map of regions and stream gages used in SIR 2014-5211 regression equations (Figure 4 in SIR 2014-5211)

Table 1. Flood region 5 regression equations from SIR 2014-5211, DRNAREA in square miles

AEP (percent)	Regression Equation (peak discharge, cubic feet per second)	Standard Error of Prediction (SEP) in percent
50	$10^{(6.363-4.386*DRNAREA^{-0.06})}$	86.6
20	$10^{(5.868-3.506*DRNAREA^{-0.08})}$	61.5
10	$10^{(5.778-3.218*DRNAREA^{-0.09})}$	52.4
4	$10^{(5.757-2.988*DRNAREA^{-0.10})}$	45.8
2	$10^{(5.696-2.795*DRNAREA^{-0.11})}$	43.5
1	$10^{(5.651-2.634*DRNAREA^{-0.12})}$	42.6
0.5	$10^{(5.761-2.638*DRNAREA^{-0.12})}$	42.4
0.2	$10^{(5.750-2.502*DRNAREA^{-0.13})}$	43.2

Watersheds to seven (7) key locations on Queen Creek and Devil's Canyon were identified upstream and downstream of the proposed mining impact areas. Drainage basins were delineated to each from USGS 7.5 minute topographic quadrangles. The drainage area for each location was then computed using GIS.

Impacts from the proposed mining operations were assessed by subtracting the impacted areas from the drainage areas for each watershed. This approach reflects the assumption that surface water drainage will not be allowed to exit the proposed mining impact areas or will be diverted around any impacted areas. The seven key locations, watershed boundaries, and proposed mining impact areas area shown in Figure 2.

The results of the peak-flow magnitude and frequency calculations from the SIR 2014-5211 regression equations are shown in Table 2. In general, the results show that the peak discharge for each frequency (AEP) is reduced by about half the percentage difference in the reduction in drainage area. The reduction in peak discharges is less than the reduction in drainage area because smaller drainage areas tend to have higher unit peak discharges (cfs/sq.mi.) for a given AEP than watersheds with more drainage area (FCDMC, 2013). One cause for this pattern is that storm intensities tend to be less over larger areas. In other words, spatially large intense storms are less likely (probable) than smaller storms. Or, intense smaller storms occur more frequently than spatially larger, similarly intense storms.

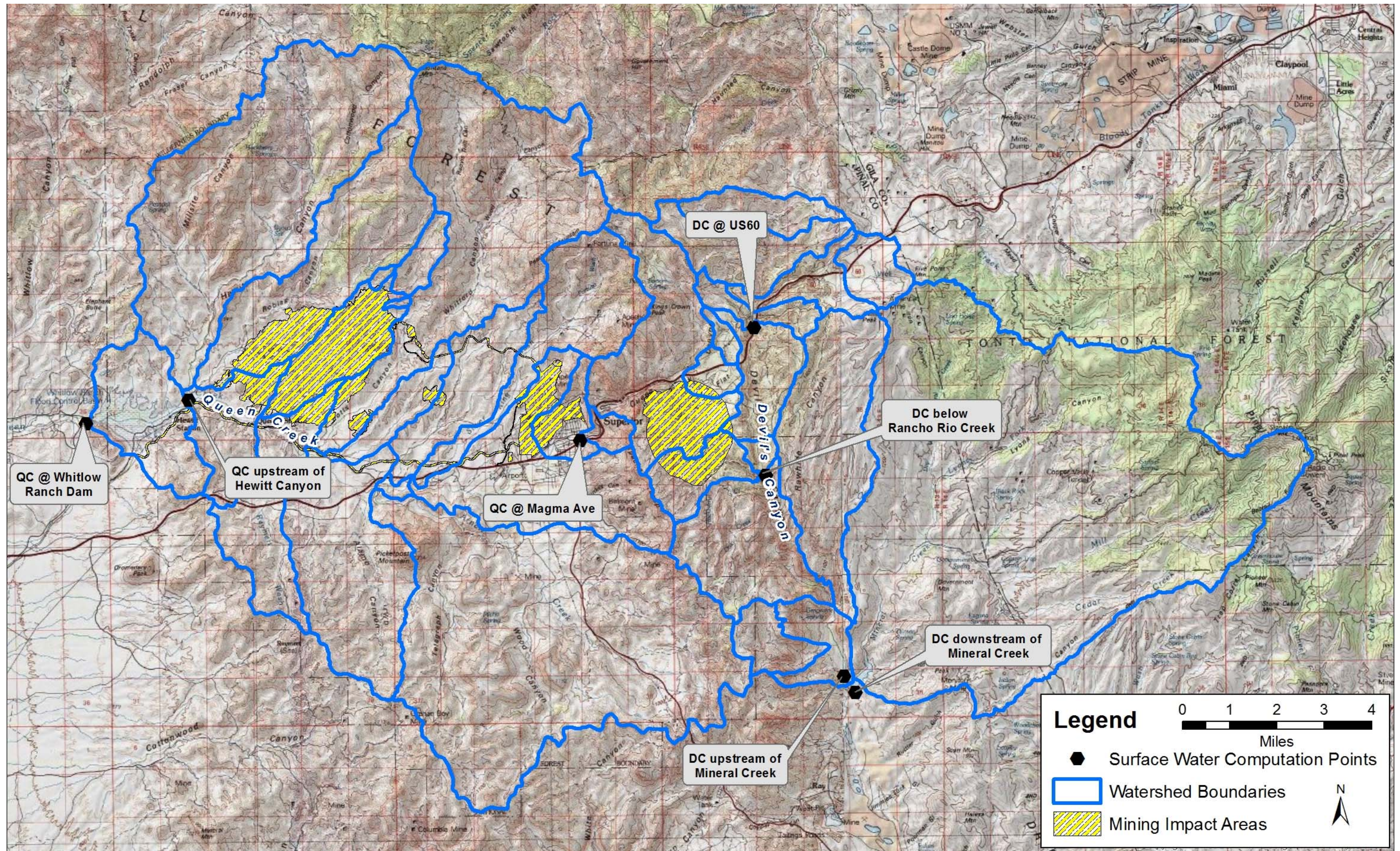


Figure 2. Watershed boundaries and regression equation computation locations

Table 2. Peak-flow frequency computations for selected locations on Queen Creek and Devil's Canyon

Existing Condition

Location	D.A. (sq.mi.)	Flood Peak Flows, in cfs, for Annual Exceedance Probability (%)							
		50	20	10	4	2	1	0.5	0.2
QC at WRD	143.401	1,280	3,246	5,245	8,679	11,949	15,829	20,289	27,415
QC u/s Hewitt Canyon	117.49	1,169	2,975	4,814	7,977	11,001	14,599	18,710	25,326
QC at Magma Ave	10.4	356	914	1,484	2,471	3,433	4,595	5,879	8,029
DC @ US60	10.95	366	940	1,526	2,541	3,531	4,727	6,047	8,260
DC blw Rancho Rio	16.55	454	1,167	1,898	3,163	4,399	5,890	7,538	10,300
DC u/s Mineral Creek	35.63	666	1,713	2,786	4,642	6,447	8,619	11,037	15,054
DC d/s Mineral Creek	90.4	1,037	2,647	4,290	7,122	9,841	13,086	16,768	22,745

Proposed Condition

Location	D.A. (sq.mi.)	Flood Peak Flows, in cfs, for Annual Exceedance Probability (%)							
		50	20	10	4	2	1	0.5	0.2
QC at WRD	132.685	1,236	3,138	5,074	8,400	11,573	15,341	19,663	26,588
QC u/s Hewitt Canyon	106.84	1,120	2,853	4,619	7,658	10,570	14,037	17,988	24,368
QC at Magma Ave	8.27	316	808	1,310	2,178	3,024	4,044	5,173	7,061
DC @ US60	10.95	366	940	1,526	2,541	3,531	4,727	6,047	8,260
DC blw Rancho Rio	15.59	440	1,131	1,840	3,066	4,264	5,709	7,307	9,983
DC u/s Mineral Creek	34.67	657	1,690	2,749	4,582	6,364	8,508	10,895	14,861
DC d/s Mineral Creek	89.45	1,032	2,635	4,270	7,089	9,796	13,028	16,693	22,645

Difference (Proposed – Existing)/Existing

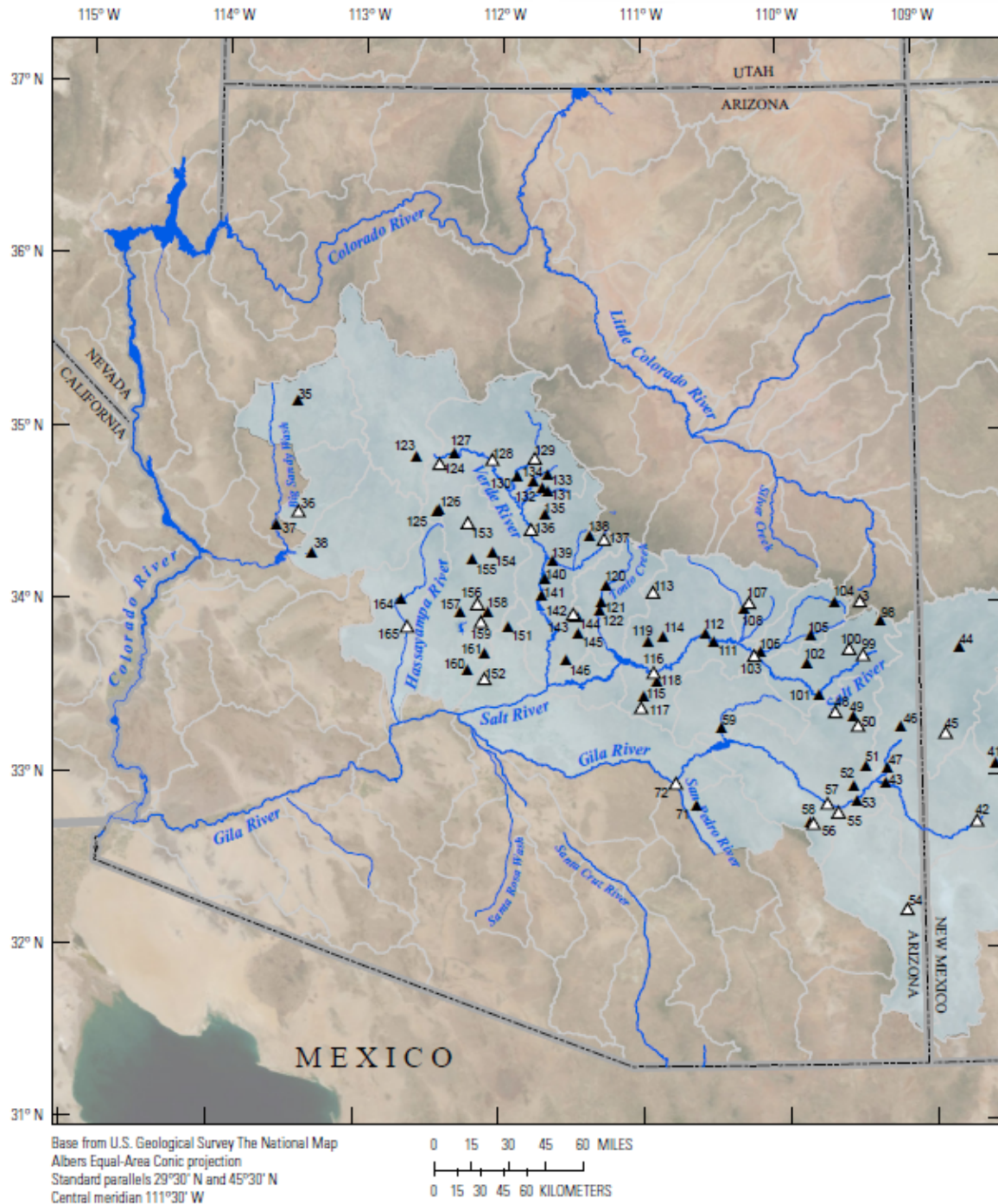
Location	D.A. (sq.mi.)	Flood Peak Flows, in cfs, for Annual Exceedance Probability (%)							
		50	20	10	4	2	1	0.5	0.2
QC at WRD	-7.5%	-3.4%	-3.3%	-3.3%	-3.2%	-3.1%	-3.1%	-3.1%	-3.0%
QC u/s Hewitt Canyon	-9.1%	-4.2%	-4.1%	-4.1%	-4.0%	-3.9%	-3.8%	-3.9%	-3.8%
QC at Magma Ave	-20.5%	11.4%	-11.6%	11.8%	11.9%	-11.9%	12.0%	-12.0%	-12.1%
DC @ US60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DC blw Rancho Rio	-5.8%	-3.0%	-3.0%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%
DC u/s Mineral Creek	-2.7%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%
DC d/s Mineral Creek	-1.1%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.4%	-0.4%	-0.4%

Volume-Duration-Frequency (SIR 2014-5109, v1.1)

The USGS also developed regression equations from streamflow gaging stations to compute magnitude and frequency of flow volumes for five (5) durations – the 1-, 3-, 7-, 15-, and 30-day durations for the same eight (8) annual exceedance probabilities (AEP) as for the peak-flow frequency equations (50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent) yielding 40 separate regression equations. Only one region of the state was found to have statistically significant relationships for the volume-duration estimates – the central highland region, which includes the Queen Creek and Devil’s Canyon watersheds. Figure 3 shows the location of the central highland region and the stream gaging station locations used in the development of the volume-duration-frequency regression equations.

Three variables were found to explain the volume-duration-frequency relationships – drainage area (DRNAREA), mean annual precipitation (PRECIP), and mean basin elevation (ELEV). The resulting equations are shown in Figure 3 (Table 9 from SIR 2014-5109, v1.1). The standard error of prediction for these equations ranges from a little more than 50 percent for the 50-percent AEP equations to a little less than 30 percent for the 15- and 30-day 0.2-percent AEP equations. Drainage areas were computed using GIS from watersheds delineated using USGS 7.5 minute topographic quadrangles. Mean annual precipitation was computed for each watershed area in GIS from the NOAA US PRISM climate data for the 1990-2010 period. Mean basin elevation was computed in GIS from the USGS 10-meter digital elevation models (DEM).

Tables 3, 4, and 5 present the volume-duration-frequency results for the existing and proposed conditions and the differences between the two. The results show that the differences are nearly directly proportional to the reduction in drainage area at each location.



EXPLANATION

- ▲ Streamgaging stations used in the regional regression analysis
- △ Streamgaging stations with regression-weighted flood-duration flow estimates
- Region over which volume regression equations apply
- Eight-digit Hydrologic Unit Code (HUC) boundaries

Figure 3. Map showing central highland region and stream gage locations used in SIR 2014-5109

[Pct. AEP, percent annual exceedance probability; DRNAREA, drainage area in square miles; PRECIP, mean annual precipitation in inches. ELEV, mean basin elevation in feet]

Pct. AEP	Regression equation
1 day	
50	$0.00759 (DRNAREA)^{0.882} (PRECIP)^{2.454} 10^{(-0.095 * ELEV/1,000)}$
20	$0.0692 (DRNAREA)^{0.836} (PRECIP)^{2.310} 10^{(-0.128 * ELEV/1,000)}$
10	$0.189 (DRNAREA)^{0.808} (PRECIP)^{2.233} 10^{(-0.131 * ELEV/1,000)}$
4	$0.240 (DRNAREA)^{0.781} (PRECIP)^{2.422} 10^{(-0.136 * ELEV/1,000)}$
2	$0.619 (DRNAREA)^{0.765} (PRECIP)^{2.278} 10^{(-0.138 * ELEV/1,000)}$
1	$1.50 (DRNAREA)^{0.751} (PRECIP)^{2.132} 10^{(-0.139 * ELEV/1,000)}$
0.5	$3.44 (DRNAREA)^{0.739} (PRECIP)^{1.988} 10^{(-0.140 * ELEV/1,000)}$
0.2	$30.1 (DRNAREA)^{0.700} (PRECIP)^{1.503} 10^{(-0.144 * ELEV/1,000)}$
3 day	
50	$0.00597 (DRNAREA)^{0.875} (PRECIP)^{1.978}$
20	$0.0127 (DRNAREA)^{0.868} (PRECIP)^{2.516} 10^{(-0.101 * ELEV/1,000)}$
10	$0.0524 (DRNAREA)^{0.847} (PRECIP)^{2.360} 10^{(-0.121 * ELEV/1,000)}$
4	$0.173 (DRNAREA)^{0.826} (PRECIP)^{2.285} 10^{(-0.144 * ELEV/1,000)}$
2	$0.568 (DRNAREA)^{0.812} (PRECIP)^{2.081} 10^{(-0.152 * ELEV/1,000)}$
1	$1.68 (DRNAREA)^{0.800} (PRECIP)^{1.882} 10^{(-0.158 * ELEV/1,000)}$
0.5	$4.61 (DRNAREA)^{0.790} (PRECIP)^{1.688} 10^{(-0.163 * ELEV/1,000)}$
0.2	$23.6 (DRNAREA)^{0.755} (PRECIP)^{1.365} 10^{(-0.165 * ELEV/1,000)}$
7 day	
50	$0.000538 (DRNAREA)^{0.916} (PRECIP)^{2.527}$
20	$0.00314 (DRNAREA)^{0.877} (PRECIP)^{2.669} 10^{(-0.074 * ELEV/1,000)}$
10	$0.00820 (DRNAREA)^{0.871} (PRECIP)^{2.719} 10^{(-0.118 * ELEV/1,000)}$
4	$0.0267 (DRNAREA)^{0.847} (PRECIP)^{2.672} 10^{(-0.147 * ELEV/1,000)}$
2	$0.180 (DRNAREA)^{0.816} (PRECIP)^{2.288} 10^{(-0.161 * ELEV/1,000)}$
1	$0.298 (DRNAREA)^{0.816} (PRECIP)^{2.246} 10^{(-0.168 * ELEV/1,000)}$
0.5	$0.877 (DRNAREA)^{0.803} (PRECIP)^{2.041} 10^{(-0.175 * ELEV/1,000)}$
0.2	$3.24 (DRNAREA)^{0.788} (PRECIP)^{1.787} 10^{(-0.183 * ELEV/1,000)}$
15 day	
50	$0.0000440 (DRNAREA)^{0.958} (PRECIP)^{3.121}$
20	$0.000508 (DRNAREA)^{0.908} (PRECIP)^{3.006} 10^{(-0.065 * ELEV/1,000)}$
10	$0.00209 (DRNAREA)^{0.884} (PRECIP)^{2.880} 10^{(-0.094 * ELEV/1,000)}$
4	$0.00652 (DRNAREA)^{0.860} (PRECIP)^{2.865} 10^{(-0.129 * ELEV/1,000)}$
2	$0.0217 (DRNAREA)^{0.844} (PRECIP)^{2.678} 10^{(-0.144 * ELEV/1,000)}$
1	$0.0668 (DRNAREA)^{0.829} (PRECIP)^{2.490} 10^{(-0.157 * ELEV/1,000)}$
0.5	$0.192 (DRNAREA)^{0.816} (PRECIP)^{2.305} 10^{(-0.168 * ELEV/1,000)}$
0.2	$1.20 (DRNAREA)^{0.808} (PRECIP)^{1.857} 10^{(-0.172 * ELEV/1,000)}$
30 day	
50	$0.00000789 (DRNAREA)^{0.978} (PRECIP)^{3.519}$
20	$0.000512 (DRNAREA)^{0.889} (PRECIP)^{2.637}$
10	$0.000361 (DRNAREA)^{0.903} (PRECIP)^{3.208} 10^{(-0.078 * ELEV/1,000)}$
4	$0.000897 (DRNAREA)^{0.882} (PRECIP)^{3.255} 10^{(-0.113 * ELEV/1,000)}$
2	$0.00261 (DRNAREA)^{0.868} (PRECIP)^{3.103} 10^{(-0.129 * ELEV/1,000)}$
1	$0.00716 (DRNAREA)^{0.855} (PRECIP)^{2.942} 10^{(-0.141 * ELEV/1,000)}$
0.5	$0.0187 (DRNAREA)^{0.843} (PRECIP)^{2.778} 10^{(-0.152 * ELEV/1,000)}$
0.2	$0.111 (DRNAREA)^{0.837} (PRECIP)^{2.327} 10^{(-0.154 * ELEV/1,000)}$

Figure 4. Volume-duration-frequency regression equations for Arizona central highland region (SIR 2014-5109, v1.1)

Table 3. Volume-duration-frequency results for select locations - Existing conditions

Queen Creek at Whitlow Ranch Dam								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	143.401	19.44	3435					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	415	1,514	2,797	5,230	8,000	11,633	16,266	26,942
3 day	163	743	1,485	2,947	4,625	6,810	9,612	15,456
7 day	91.8	375	778	1,554	2,573	3,559	5,056	7,660
15 day	53.9	206	412	828	1,297	1,915	2,732	4,207
30 day	34.8	105.9	235	459	699	1,013	1,405	2,090
Queen Creek upstream of Hewitt Canyon								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	117.49	19.54	3484					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	349	1,279	2,373	4,464	6,842	9,969	13,960	23,234
3 day	138.3	626	1,252	2,488	3,909	5,759	8,132	13,148
7 day	77.5	316	654	1,309	2,173	3,002	4,269	6,472
15 day	45.2	173.6	347	697	1,094	1,615	2,305	3,546
30 day	29.1	89.9	197.8	386	588	854	1,184	1,759
Queen Creek at Magma Ave								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	10.4	23.09	4289					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	52	195	381	782	1,213	1,780	2,501	4,189
3 day	23	96	190	377	583	846	1,174	1,959
7 day	12.8	51	100	200	327	442	619	919
15 day	7.5	28	55	110	169	245	343	496
30 day	4.9	16	33	64	95	135	184	256
Devil's Canyon at US60								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	10.95	24.37	4773					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	56	200	387	798	1,223	1,778	2,475	4,011
3 day	27	103	197	379	574	818	1,116	1,824
7 day	15.4	57	106	205	322	432	593	860
15 day	9.3	32	61	116	174	246	336	471
30 day	6.2	19.5	37	70	102	141	188	256

Table 3. Volume-duration-frequency results for select locations - Existing conditions - continued

Devil's Canyon below Rancho Rio Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	16.55	24.07	4587					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	81	290	556	1,133	1,730	2,507	3,479	5,592
3 day	38	149	286	551	835	1,190	1,625	2,627
7 day	22	82	155	299	470	632	868	1,260
15 day	13.3	46	88	169	254	359	492	692
30 day	8.9	27	54	101	148	206	275	375
Devil's Canyon upstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	35.63	22.07	4190					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	141	507	960	1,892	2,896	4,208	5,864	9,577
3 day	62	256	499	971	1,493	2,157	2,985	4,835
7 day	35.3	136	266	520	835	1,134	1,580	2,333
15 day	21.1	76.2	147	287	438	630	877	1,282
30 day	13.9	42.9	87.7	167	247	350	474	670
Devil's Canyon downstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	90.4	22.84	4171					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	350	1,203	2,211	4,280	6,422	9,165	12,569	19,471
3 day	149.7	629	1,197	2,279	3,437	4,879	6,648	10,288
7 day	90.4	339	660	1,261	1,944	2,638	3,606	5,208
15 day	57.3	197.3	372	710	1,060	1,495	2,045	2,920
30 day	39.0	107.4	227.7	426	620	864	1,152	1,592

Table 4. Volume-duration-frequency results for select locations - Proposed conditions

Queen Creek at Whitlow Ranch Dam								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	132.685	19.44	3435					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	388	1,419	2,626	4,923	7,538	10,974	15,359	25,516
3 day	152	695	1,390	2,764	4,342	6,400	9,040	14,578
7 day	85.5	350	727	1,455	2,415	3,340	4,750	7,205
15 day	50.0	192	385	774	1,215	1,795	2,564	3,951
30 day	32.2	98.8	219	428	653	948	1,316	1,959
Queen Creek upstream of Hewitt Canyon								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	106.84	19.54	3484					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	321	1,181	2,197	4,144	6,362	9,282	13,013	21,739
3 day	127.2	577	1,155	2,301	3,618	5,338	7,544	12,241
7 day	71.0	291	602	1,208	2,011	2,778	3,955	6,005
15 day	41.3	159.2	319	643	1,010	1,493	2,133	3,284
30 day	26.5	82.6	181.5	355	542	787	1,093	1,625
Queen Creek at Magma Ave								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	8.27	23.09	4289					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	42	161	317	654	1,018	1,499	2,112	3,568
3 day	19	79	157	312	484	704	979	1,649
7 day	10.4	42	82	165	271	367	515	768
15 day	6.0	23	45	90	139	203	285	412
30 day	3.9	13	27	52	78	111	152	212
Devil's Canyon at US60								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	10.95	24.37	4773					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	56	200	387	798	1,223	1,778	2,475	4,011
3 day	27	103	197	379	574	818	1,116	1,824
7 day	15.4	57	106	205	322	432	593	860
15 day	9.3	32	61	116	174	246	336	471
30 day	6.2	19.5	37	70	102	141	188	256

Table 4. Volume-duration-frequency results for select locations - Proposed conditions - continued

Devil's Canyon below Rancho Rio Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	15.59	24.07	4587					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	77	276	530	1,081	1,653	2,397	3,329	5,363
3 day	36	142	272	524	795	1,134	1,550	2,512
7 day	21	78	147	284	448	602	827	1,202
15 day	12.5	44	84	161	241	341	468	660
30 day	8.4	26	51	96	140	196	262	356
Devil's Canyon upstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	34.67	22.07	4190					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	137	496	939	1,853	2,836	4,123	5,747	9,395
3 day	60	250	488	949	1,460	2,110	2,922	4,736
7 day	34.4	133	260	508	816	1,109	1,545	2,284
15 day	20.5	74.3	144	281	428	616	858	1,254
30 day	13.6	41.9	85.5	163	241	342	464	655
Devil's Canyon downstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	89.45	22.84	4171					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	346	1,192	2,192	4,245	6,370	9,093	12,472	19,327
3 day	148.3	624	1,186	2,260	3,408	4,838	6,593	10,206
7 day	89.5	336	654	1,250	1,927	2,616	3,575	5,165
15 day	56.7	195.4	368	703	1,051	1,482	2,027	2,896
30 day	38.6	106.4	225.5	422	615	856	1,142	1,578

Table 5. Volume-duration-frequency results for select locations – Difference (Existing – Proposed)/Existing

Queen Creek at Whitlow Ranch Dam								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-7.5%	19.44	3435					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-6.6%	-6.3%	-6.1%	-5.9%	-5.8%	-5.7%	-5.6%	-5.3%
3 day	-6.6%	-6.5%	-6.4%	-6.2%	-6.1%	-6.0%	-6.0%	-5.7%
7 day	-6.9%	-6.6%	-6.5%	-6.4%	-6.1%	-6.1%	-6.0%	-5.9%
15 day	-7.2%	-6.8%	-6.6%	-6.5%	-6.3%	-6.2%	-6.1%	-6.1%
30 day	-7.3%	-6.7%	-6.8%	-6.6%	-6.5%	-6.4%	-6.3%	-6.3%
Queen Creek upstream of Hewitt Canyon								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-9.1%	19.54	3484					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-8.0%	-7.6%	-7.4%	-7.2%	-7.0%	-6.9%	-6.8%	-6.4%
3 day	-8.0%	-7.9%	-7.7%	-7.5%	-7.4%	-7.3%	-7.2%	-6.9%
7 day	-8.3%	-8.0%	-7.9%	-7.7%	-7.5%	-7.5%	-7.3%	-7.2%
15 day	-8.7%	-8.3%	-8.1%	-7.8%	-7.7%	-7.6%	-7.5%	-7.4%
30 day	-8.9%	-8.1%	-8.2%	-8.0%	-7.9%	-7.8%	-7.7%	-7.6%
Queen Creek at Magma Ave								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-20.5%	23.09	4289					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-18.3%	-17.4%	-16.9%	-16.4%	-16.1%	-15.8%	-15.6%	-14.8%
3 day	-18.2%	-18.0%	-17.6%	-17.2%	-17.0%	-16.8%	-16.6%	-15.8%
7 day	-18.9%	-18.2%	-18.1%	-17.6%	-17.1%	-17.1%	-16.8%	-16.5%
15 day	-19.7%	-18.8%	-18.3%	-17.9%	-17.6%	-17.3%	-17.1%	-16.9%
30 day	-20.1%	-18.4%	-18.7%	-18.3%	-18.0%	-17.8%	-17.6%	-17.5%
Devil's Canyon at US60								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	0.0%	24.37	4773					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3 day	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7 day	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15 day	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30 day	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5. Volume-duration-frequency results for select locations - Difference - continued

Devil's Canyon below Rancho Rio Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-5.8%	24.07	4587					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-5.1%	-4.9%	-4.7%	-4.6%	-4.5%	-4.4%	-4.3%	-4.1%
3 day	-5.1%	-5.1%	-4.9%	-4.8%	-4.7%	-4.7%	-4.6%	-4.4%
7 day	-5.3%	-5.1%	-5.1%	-4.9%	-4.8%	-4.8%	-4.7%	-4.6%
15 day	-5.6%	-5.3%	-5.1%	-5.0%	-4.9%	-4.8%	-4.8%	-4.7%
30 day	-5.7%	-5.2%	-5.3%	-5.1%	-5.1%	-5.0%	-4.9%	-4.9%
Devil's Canyon upstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-2.7%	22.07	4190					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-2.4%	-2.3%	-2.2%	-2.1%	-2.1%	-2.0%	-2.0%	-1.9%
3 day	-2.4%	-2.3%	-2.3%	-2.2%	-2.2%	-2.2%	-2.1%	-2.0%
7 day	-2.5%	-2.4%	-2.4%	-2.3%	-2.2%	-2.2%	-2.2%	-2.1%
15 day	-2.6%	-2.4%	-2.4%	-2.3%	-2.3%	-2.2%	-2.2%	-2.2%
30 day	-2.6%	-2.4%	-2.4%	-2.4%	-2.3%	-2.3%	-2.3%	-2.3%
Devil's Canyon downstream of Mineral Creek								
	DRNAREA (sq.mi.)	PRECIP (in)	ELEV (ft)					
	-1.1%	22.84	4171					
	Flood Duration Flows, in cfs, for Annual Exceedance Probability (%)							
Duration	50	20	10	4	2	1	0.5	0.2
1 day	-0.9%	-0.9%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.7%
3 day	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.8%	-0.8%	-0.8%
7 day	-1.0%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.8%	-0.8%
15 day	-1.0%	-1.0%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.8%
30 day	-1.0%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%

References

FCDMC, 2013, Drainage Design Manual for Maricopa County, Arizona, Hydrology, 4th Edition, August 15, 2013.

Kennedy, J. R., Paretti, N.V., and Veilleux, A.G., 2015, Methods for Estimating Magnitude and Frequency of 1-, 3-, 7-, 15-, and 30-day flood-duration flows in Arizona, USGS Scientific Investigations Report (SIR) 2014-5109, Version 1.1, 35 pp.

Paretti, N. V., Kennedy, J. R., Turney, L. A., and Veilleux, A. G., 2014, Methods for Estimating Magnitude and Frequency of Floods in Arizona, Developed with Unregulated and Rural Peak-Flow Data through Water Year 2010. USGS Scientific Investigations Report (SIR) 2014-5211, 61 pp.

October 3, 2017

Ms. Mary Rasmussen
US Forest Service
Supervisor's Office
2324 East McDowell Road
Phoenix, AZ 85006-2496

Subject: Resolution Copper Mining, LLC – Mine Plan of Operations and Land Exchange – August 14, 2017 Surface Water Kick Off Meeting Verbal Request for Surface Water Analysis Information and Baseline Springs and Seeps Information

Dear Ms. Rasmussen,

In response to a verbal request received from SWCA on the August 14, 2017 Surface Water Kick Off Meeting, enclosed with this letter please find 2 DVD's containing the following documents listed below:

Document Title	Document Date	Author (Organization)	File Key
<i>Spring and Seep Catalog Resolution Copper Project Area Upper Queen Creek and Devils Canyon Watersheds</i>	OCT 2017	M&A	RC_Spring Catalog V 1.0.pdf
<i>USGS Regression Equation Computations for Queen Creek & Devil's Canyon</i>	OCT 2017	JE Fuller	Memorandum_usgs_regressions_rev02.pdf
<i>Methods for Estimating Magnitude and Frequency of 1-,3-,7-,15- and 30-day flood-duration flows in Arizona</i>	APR 2015	USGS	sir2014-5109v1.1.pdf
<i>Methods for Estimating Magnitude and Frequency of Floods in Arizona, Developed with Unregulated and Rural Peak-Flow Data through Water Year 2010</i>	OCT 2014	USGS	sir2014-5211.pdf

Should you have any questions or require further information please do not hesitate to contact me.

Sincerely,



Vicky Peacey,

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Senior Manager, Permitting and Approvals; Resolution Copper Company, as Manager of Resolution Copper Mining, LLC

Cc: Ms. Mary Morissette; Senior Environmental Specialist; Resolution Copper Company

Enclosure(s): Resolution Copper Mining, LLC – Mine Plan of Operations and Land Exchange – Surface Water Analysis and Springs/Seeps Catalogue – October 3, 2017 (2)