Determination of Upper Dry Comal Creek Watershed Runoff Potential

Douglas P. Schoenenberger

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Prepared for Dr. Mark Helper

Abstract:

Three low water road crossings in Comal County were analyzed due to their flash flooding potential. These particular flooded roadways create a temporary barrier for residents which may be stranded for hours while floodwaters make these roads impassable. For hours emergency services cannot reach the residents should the need occur. A useful tool would be to predict for residents and county emergency personnel when the low water crossing (LWC) would become impassable. The specific low water crossings are; FM 1863 east of FM 3009 and Schoenthal Road North and South. All three LWC lie along separate forks that form the upper Dry Comal Creek watershed. In (Appendix A) there is a detailed map of the project area and watershed areas. Located on Schoenthal road north and south are Comal County precipitation gauge stations as well as LWC height monitors. These LWC monitors are useful but are reactive, and only alert residents and emergency personnel once the roadway surface begins to flood. The primary goal of the modeling analysis is to determine the effects of varying antecedent soil moisture levels and how the runoff from these tributaries will be effected. By knowing the past weeks rainfall volumes, the soil saturation levels can be estimated, and a future predicted event could theoretically be translated into a future flow rate or volume of water expected to cross the LWCs.

Introduction:

The upper Dry Comal Creek watershed was analyzed to determine the potential precipitation runoff characteristics. The Upper portion of the Dry Comal Creek watershed originates from three smaller tributaries that all eventually combine into a single channel creek bed that is considered only to flow after a sufficient precipitation event occurred. Due to the watersheds relatively high natural impervious limestone out crops along with thin soil depths, flash flooding is a large concern. The three areas of the watershed can be subdivided into the Southern, Upper and East Forks of the Upper Dry Comal Creek. This division is based on the three smaller tributaries all before combining into the single Dry Comal Creek (Figure 1).

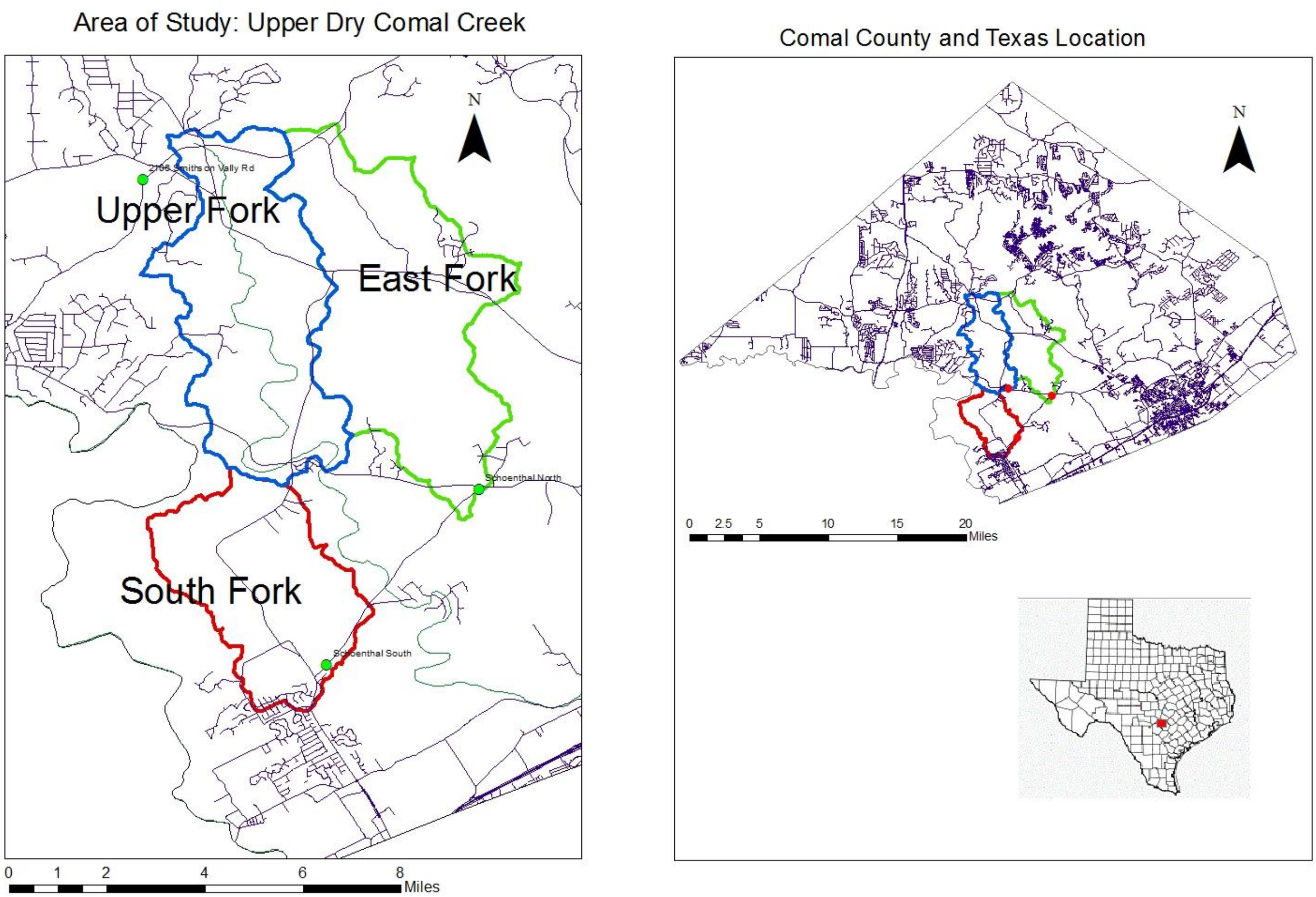


Figure 1: Screen shot, area of study Dry Comal Creek upper three tributaries.

All three watersheds cross several TxDOT roadways, and per our study area creates a triangular road closure pattern that land locks several Comal county neighborhoods. The Southern watershed crosses Schoenthal Rd South, while the Eastern watershed crosses Schoenthal North and FM 1863, with Schoenthal North and South low water crossing monitored by Comal County Engineering Office (at https://cceo.org Low Water Crossings). These two low water crossing stations are conveniently called Schoenthal South and North. Both of these two monitoring stations report real time precipitation, and low water crossing heights. The upper section of the Dry Comal creek crosses FM1863 where there is an impassable low water crossing that is unmonitored by Comal during times of flood. The upper portion of the Dry Comal creek then flows to cross the mid portion of Schoenthal rd, but after being contained by a soil preservation dam called Krause Dam. This dam acts as a flood control measure, and as a result Comal does not monitor the crossing at Schoenthal at this point.

For our watershed delineation the North and South Schoenthal Monitoring stations, along with the FM 1863 crossing points were chosen as the pour points for our analysis. Several factors affect the Dry Comal Creek flow of the South, Upper, and East tributaries. Watershed areas were analyzed for, soil conditions, vegetation, realistic rainfall patterns from actual events, and an attempt to adjust antecedent moisture conditions to vary potential runoff estimations. Additional development in Comal County has increased the amount of manmade impervious cover, reducing the area of soil available to absorbed runoff and increasing runoff potential.

The analysis focused on a starting point, and an estimated of what was reasonable. The rational was based on soil conditions in the area being of a very thin covering of relatively impervious layer of limestone. The runoff once soil saturation had occurred would be quick and not exhibit residual runoff for days or weeks following a precipitation event. This seems to be the case as the data from the LWC once the roads are overtopped, only are impassable for several hours. The Dry Comal creek is very flood prone and only flows for a short time after the precipitation events.

Large amounts of runoff can be generated when the ground is saturated. The next step in further analyzing the watershed runoff characteristics was to develop a method to factor in the unique soil types in the watershed area, along with antecedent moisture then modifying the equations for calculations. The results from recent precipitation events produced large changes in the runoff volumes of water, when the ground was considered dry at 20% and very saturated at 90%.

An unscientific observation due to living in the study area seems that flooding would occur after a four to five inch precipitation event, but sometimes due to perceived area saturation, flooding would occur with a much smaller event. The inverse also true, after several inches of precipitation while the ground antecedent moisture was low, no flooding, nor even light flow would occur in the upper portion of the Dry Comal Creek watershed.

It is clear that multiple variables are at work when determining the flow characteristics of these watersheds. The variables include: area, precipitation coverage, soil type, soil depth, vegetation cover, and antecedent moisture content. Utilizing curve number calculations as defined in the Natural Resource Conservation Service “Urban Small Stream Guide”, area runoff can be determined utilizing the different variables discussed. The curve number approach utilizes a set estimated ascendant moisture content that

A final goal of the analysis was to create an estimator of runoff conditions that could be modified to input 24 hour conditions based on predicted rainfall, along with the changing area saturation levels to determine if the roadways would be expected to flood.

Methodology/Results:

The first step in the process was to identify the areas of the study, and to where the watersheds existed. The watershed delineation process utilizes a DEM of the area, and for this study 10m resolution was utilized and downloaded from the Texas Natural Resources Commission website. Utilizing the hydrology toolset in ArcGIS we were able to delineate the three watersheds that correspond to our selected pour points. In (Figure 2) below the general DEM for our area is shown with the watersheds outlined as Southern, Upper and Eastern Forks of the Dry Comal Creek.

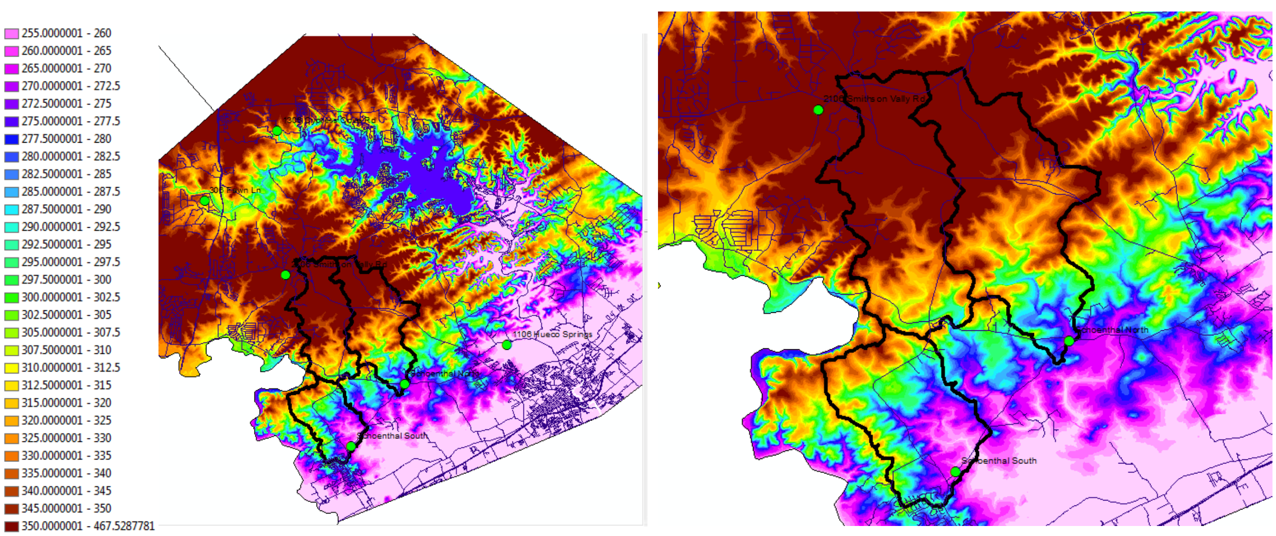


Figure 2: Elevation DEM of study area (Meters MSL). Dark red higher elevation with white representing lower.

We next process the DEM with the fill tool, where any cells that would not process the flow directions are were modified. In (Figure 3) the direction of flow values assigned to different directions illustrates the process to create the watershed areas that flows to our pour point. Each pixel is assigned a value that describes the flow direction.

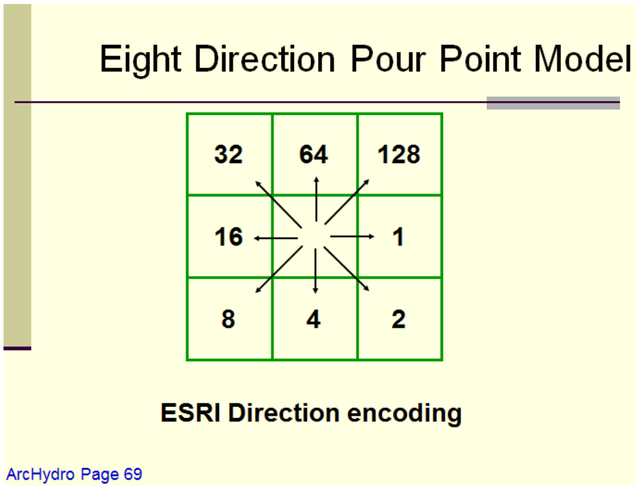


Figure 3: ERSI directional encoding scheme

The next step in the delineation process was to process the flow directions by running the flow direction tool ArcGIS. Each unique color represents as from (Figure 3) the flow directions as shown in (Figure 4) with the color coded legend.

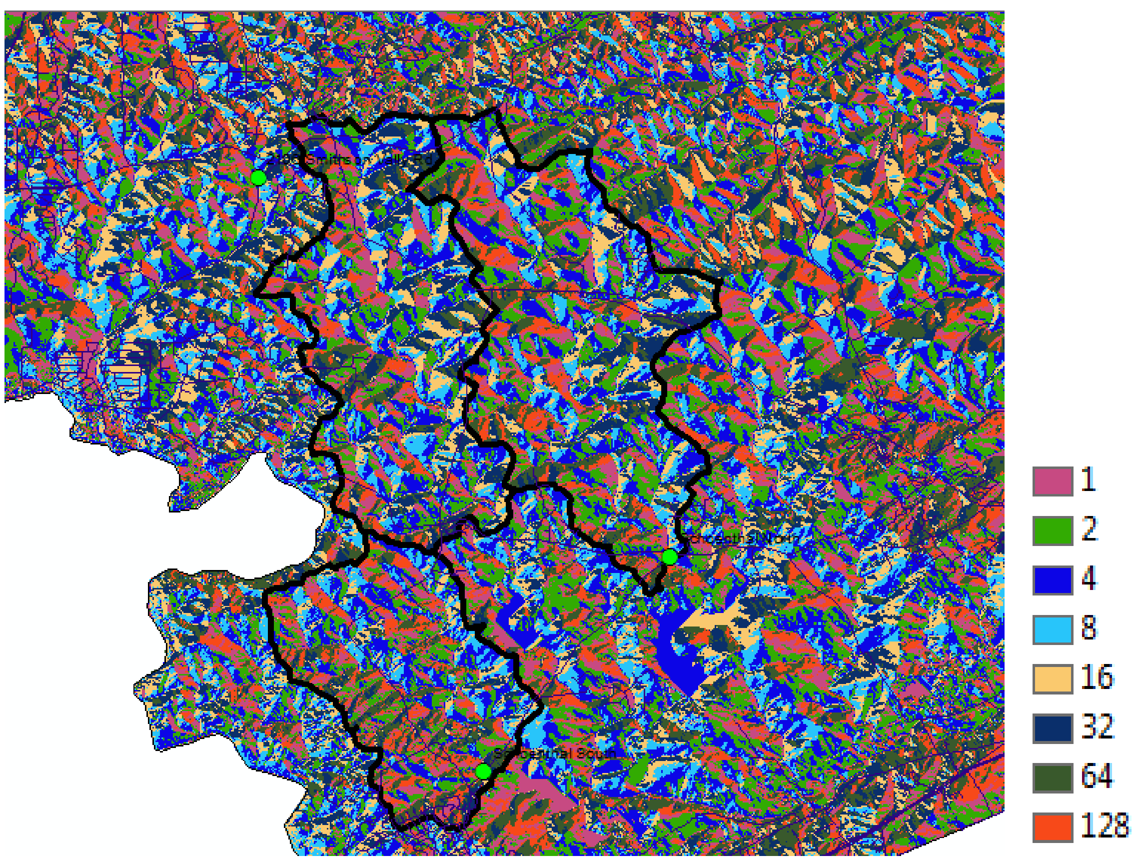


Figure 4: Flow direction raster of study area.

The next step was to produce the flow accumulation raster, by running the Watershed tool. The first step in the process was to create a shape file that contained a point that was on the final pixel of the flow path of the accumulation of the different flow paths. Placement of this pixel was important, as if the pixel was off then the wrong watershed would be calculated, and or only a few pixels would be summed to calculate the flows if an off major flow path was selected. In (Figure 5) the Watershed tool product and legend to pixel accumulations in the flow paths are shown.

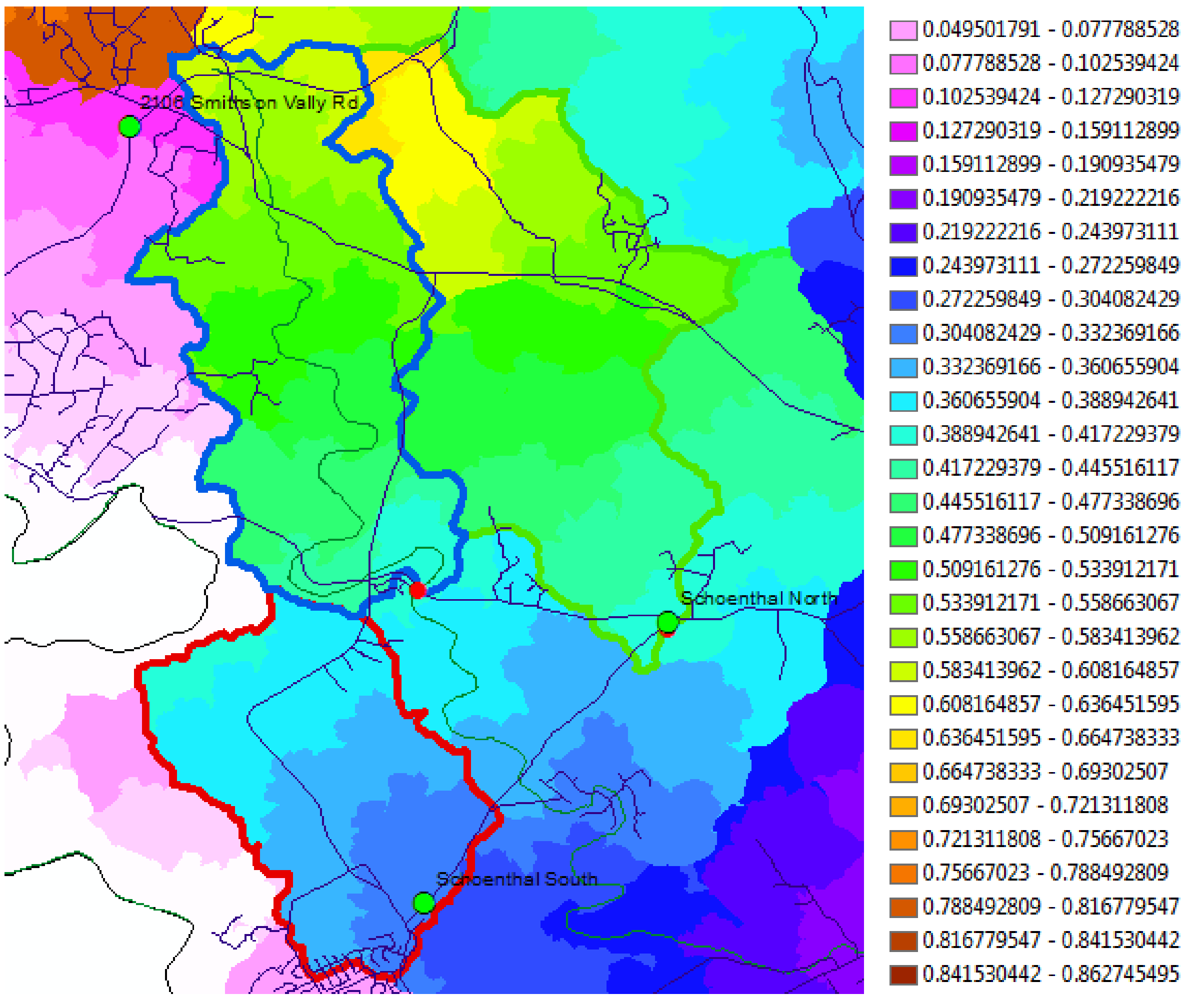


Figure 5: Flow direction of watershed, legend shows low to high trend of colors.

Once the flow paths were determined the Watershed tool was run based on the 1863 and Schoenthal road low water crossing areas as our pour points. The polygons in (Figure 6) below were then made into outlines and areas calculated.

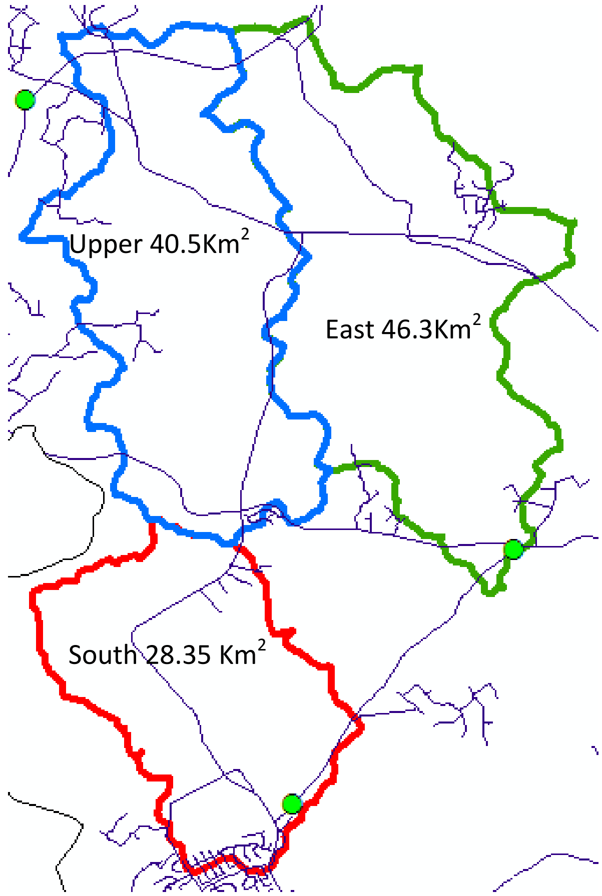


Figure 6: Polygons of South, Upper and East Forks of the Dry Comal Creek.

The area calculated for each watershed forks were South – 309,735 pixels, Upper 442,643 pixels, East 505,897 pixels with a pixel width and height of 10.25x8.93 meters for an area of respectively, 28.35, 40.51, 46.3 Km^2 .

The next major step to understanding the composition of the area is to calculate the curve number based on the soil types and composition. The soil composition was downloaded for this section of the state from the Natural Resource Conservation Service (NRCS) and clipped to the three watersheds.

The NRCS curve number is related to soil type, soil infiltration capability, and land use. To account for different soils' ability to infiltrate, NRCS has divided soils into four hydrologic soil groups (HSGs), A to D. With A being more pervious and D being the most impervious. (Figure 7), shows the results of aligning the impervious cover classification schemes A to D.

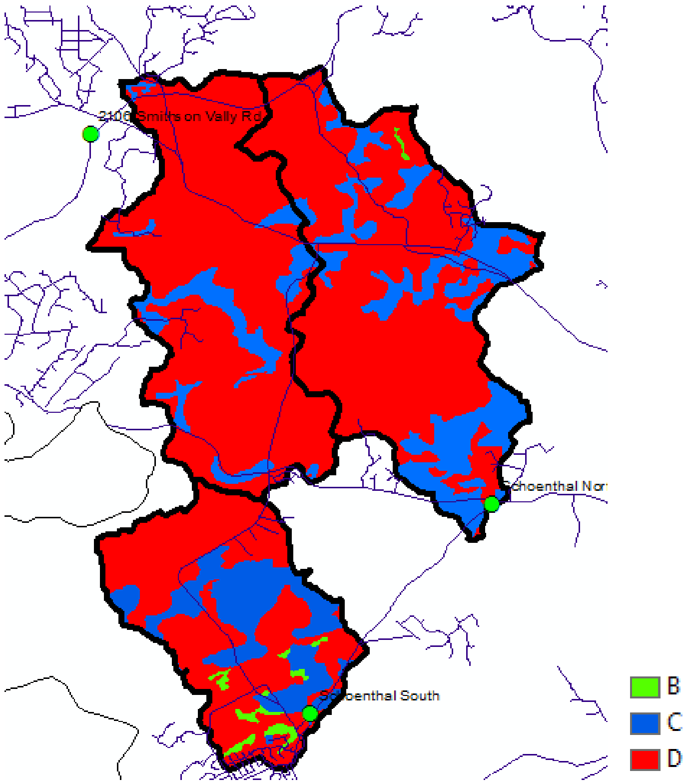
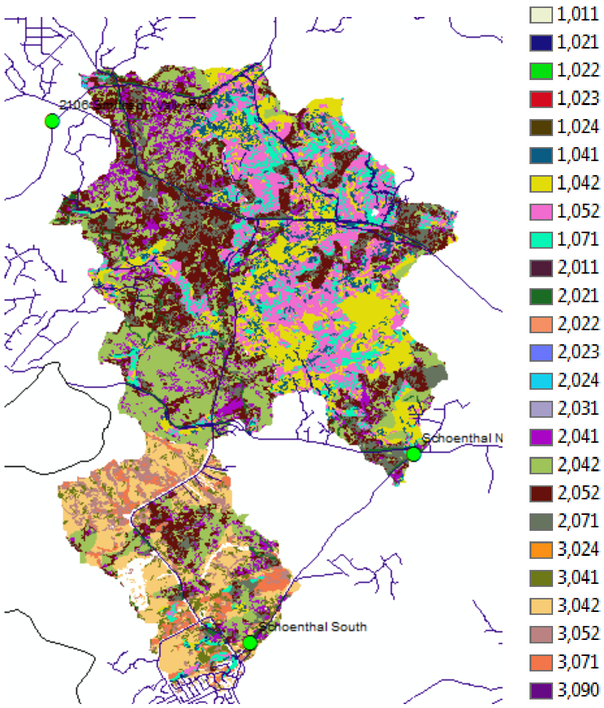


Figure 7: Hydrologic soil groups for South, Upper, and East Dry Comal Creek

From (Grove et al., 1998), and NRCS the combination of impervious cover, hence land use, along with soil type must be derived to determine the CN. The National Land Cover Data (NLCD) imagery (https://www.mrlc.gov/nlcd06_leg.php) is the current use of the land. A NLCD image raster combined with the HSGs soil types A thru D produces a combined raster is created to allocated CNs, (Figure 8a). The legend corresponding to (Figure 8a) is the coding classification of the combined raster that the look up tables to find the corresponding CN numbers are utilized. The HSG assignment of B-D (for our area there was no A soil types) were reclassified a value of 1000 for a B value, 2000 for a C value, and 3000 for a D value. The NLCD standard coding (Located in Appendix A) which range from 0-99 were added to the reclassified HSG raster's to form the coded values. For Example a value from the attribute table of the combined raster of 1052 means 1000+52 which is a "B" and a scrubland class. Using the HSG-NLCD looks up tables allocated the CN in this combined coding scheme. Once all the CN's are calculated from the look up tables as a weighted average across the area of interest can be determined quite easily. Figure 8b, shows the CN's as allocated from the HSG – NLCD combination of soil types and absorption criteria.



CN	HSG-NLCD Combination
0	11DCB, 90DCB,95B
93	23D
92	21D,22D,23D
91	23C,24C
90	22C
88	23B,24B
85	82D
84	31D
82	82C
80	52D,71D,81D,82D,21C
79	31C
77	41D,42D,43D
75	82B
74	52C,71C,81C
70	42C,43C
69	31B
61	52B,71B
55	41B,42B,43B

Figure 8a: Unique coding for watershed area. Figure 8b: Combination of HSG and NLCD and their respective Curve Numbers as derived from Grove et al., 1998, and NRCS.

In (Appendix A) the calculations for each of the three tributary areas and corresponding weighted CN are listed.

The CN is formulated using lookup tables, based on the watershed composition in question. Once the composition is known the area weighted or mean CN can be determined. The CN is then used in determining the Uniform Depth of Runoff "Q". Below are the CN and S formulas used for the calculations. With Q being flow per unit area, P being precipitation, and CN being curve number.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad I_a = 0.2S \qquad Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad S = \frac{1000}{CN} - 10 \quad for \quad Q, P, S \; in \; inches$$

I_a is Initial abstraction, with the 0.2 factor has been estimated from previous studies and if modified will change the absorption rates. This could increase the accuracy of a specific regions flow rate calculations based on a lesser or greater soil absorption rate.

Utilizing the Comal County rain gauge stations; the four in close proximity to the tributaries of the Dry Comal Creek were selected to create interpolations of actual recorded precipitation events. These interpolations will produce precipitation events across our watershed areas where the mean precipitation values can be calculated, and hence stream flow quantities. This relationship becomes complex as the soil saturation levels, delay for the runoff to accumulate and time to flow downstream.

The rain event of April 15-21, 2016 was chosen to be analyzed because an approximate 4 hour runoff event closing the low water crossings. The runoff even occurred on April 21st after several previous days of precipitation fully saturating the surrounding soils. The separate precipitation events of April 15-21, 2016 were modeled to create realistic precipitation coverage that can be used to produce the predictive algorithm for runoff prediction and estimation. In (Figures 9a – 9e) below show the interpolated results utilizing the spline interpolation in Arc Map. In (Figure 10) the combined total for the week of precipitation is was calculated and will be used in computation for predictive flow. In (Table 1) the location and names of the Comal County precipitation gauges are listed; the data is maintained by the Comal County Engineers Office.

Table 1: Location of four closest gauges to Dry Comal Creek watershed

Name	LAT	LONG	UTM_E	UTM_N
1106 Hueco Springs	29.74232	-98.16839	580414.7	3290523
2106 Smithson Vally Rd	29.80035	-98.35384	562445.5	3296838
Schoenthal North	29.70898	-98.25451	572110.9	3286772
Schoenthal South	29.65719	-98.29944	567799.6	3281006

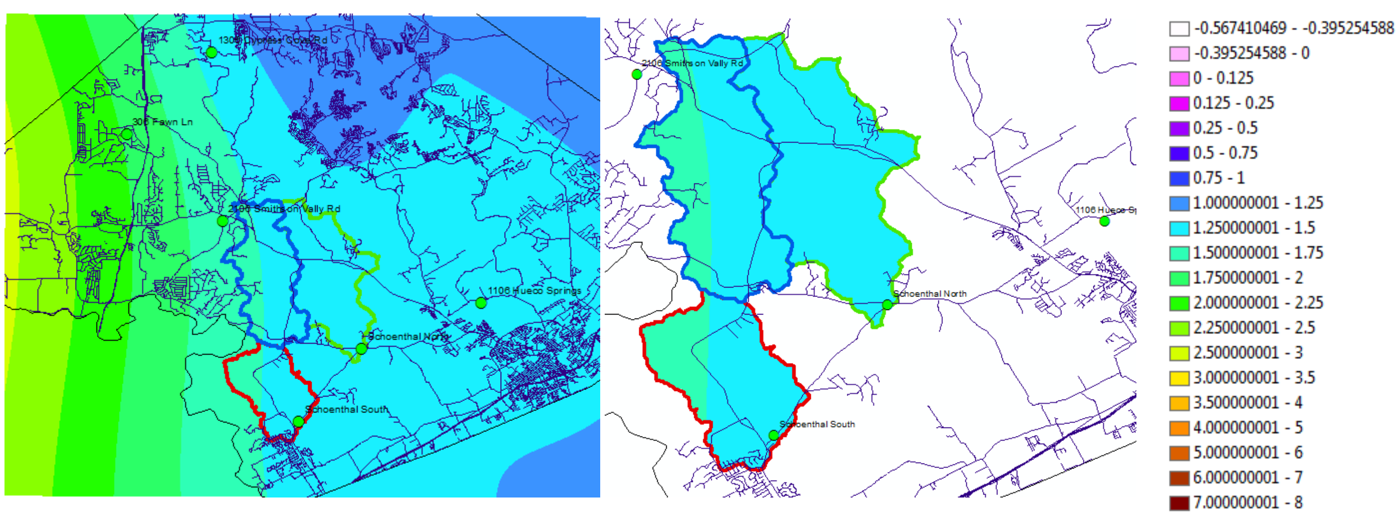


Figure 9a: April 15, 2016 precipitation total (In)

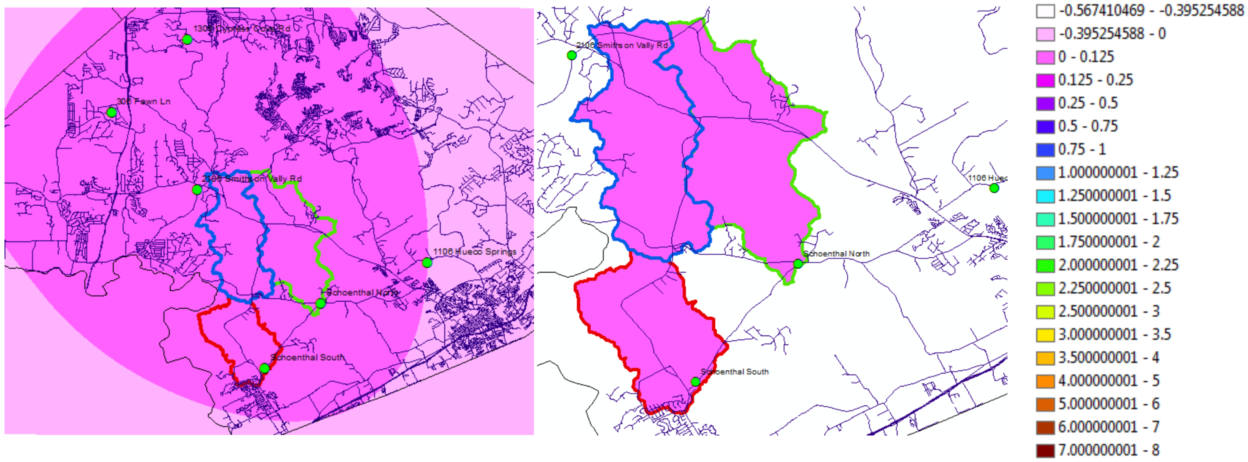


Figure 9b: April 17, 2016 precipitation total (In)

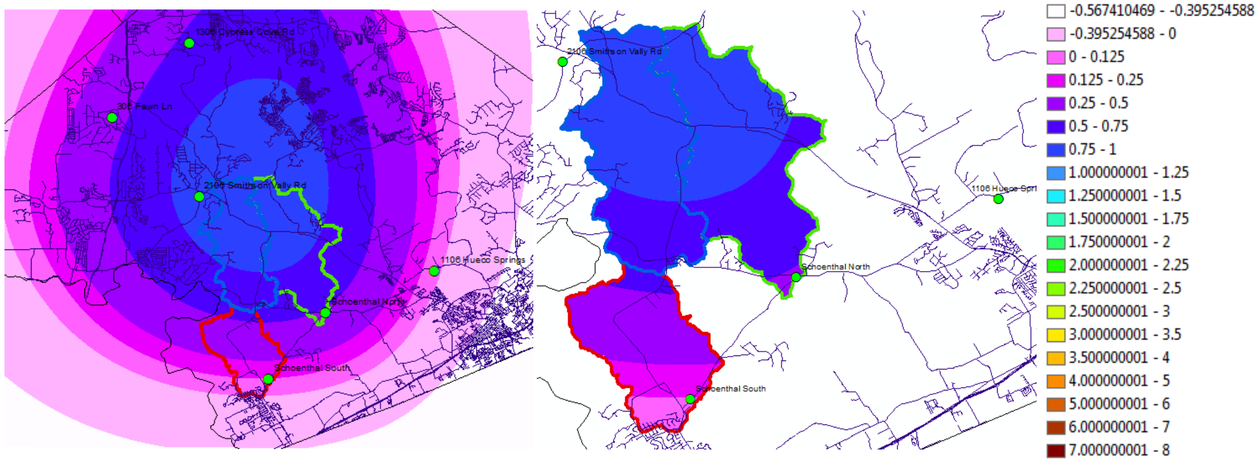


Figure 9c: April 18, 2016 precipitation total (In)

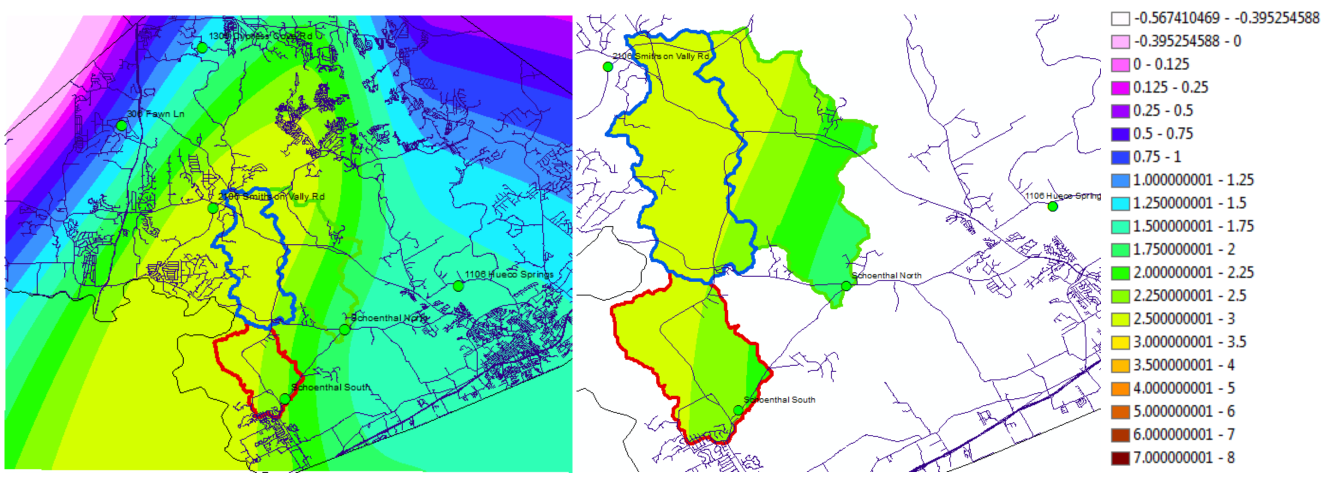


Figure 9d: April 19, 2016 precipitation total (In)

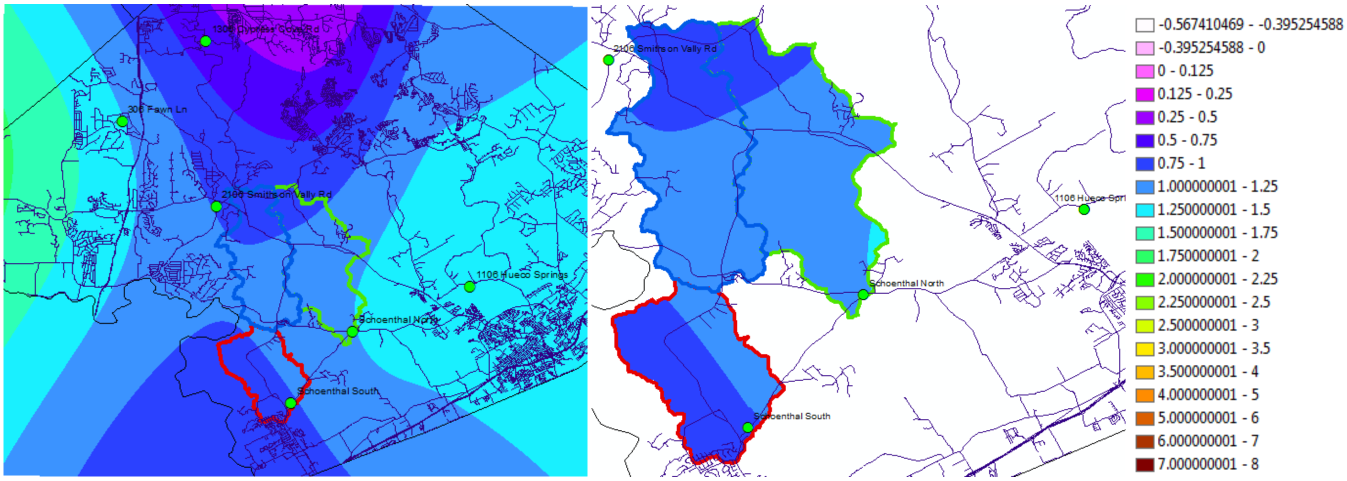


Figure 9e: April 21, 2016 precipitation total (In)

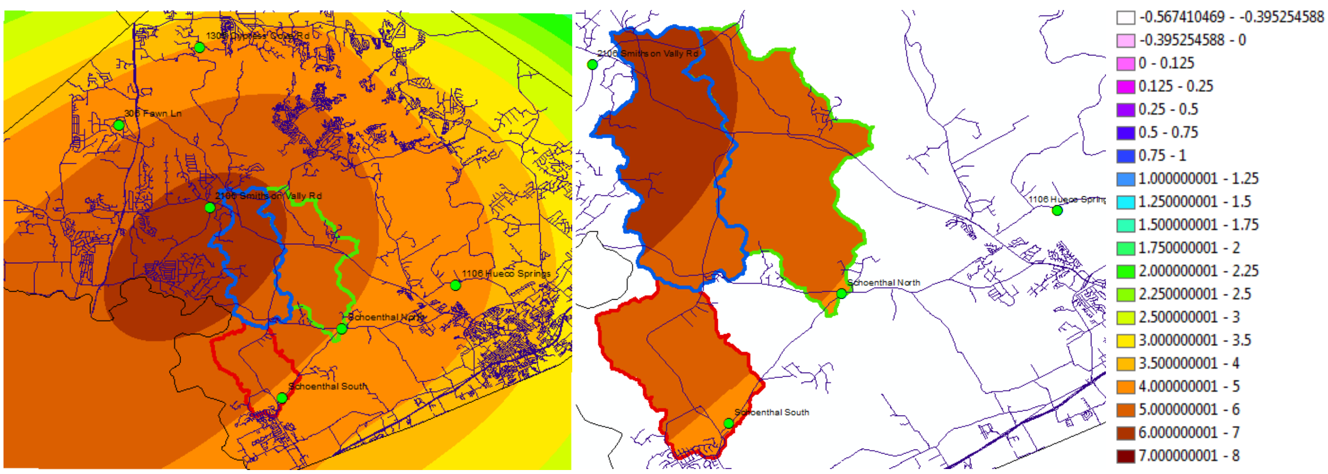


Figure 10: April 15-21 2016 combined, precipitation total (In)

This precipitation event produced very saturated conditions over a weeks' time, and created a hypothetical combined event where a single rain event could be created and utilized for modeling.

Results/Discussion:

Using the Spline interpolations method of the precipitation event of April 21 the delineated runoff areas average precipitation event over the areas were calculated. The mean precipitation over the Upper tributary – 1.009 in, East tributary – 1.10 in and the South tributary was 0.981 in. Using the standard equations for calculating CN, S and finally the estimated Q runoff potential for the three Dry Comal Creek tributaries were produced. In (Table 2) below the flow rates for runoff are shown.

Table 2: April 21, 2016 single day precipitation event calculated from spline interpolated precipitation gauge data, and using an antecedent moisture of 0.2S.

Year	S	CN Ave	Precip(in)	Q Upper	Q East	Q South	Upper Acre/Ft	East Acre/Ft	South Acre/Ft
2011									
Upper	3.68	73.09	1.009	0.018854			15.73		
East	2.91	77.44	1.1027		0.07903			75.35	
South	5.49	64.54	0.98155			0.002524			1.47

Using the same CN, S and areas calculated from the delineated Dry Comal creek tributaries, (Table 3) below shows the Q flow rate for hypothetical precipitation events of 1,2,5,10,15, and 20 inches of precipitation over our areas.

Table 3: The hypothetical precipitation event using an antecedent moisture of 0.2S using various levels off precipitation.

Year	S	CN Ave	Precip(in)	Q Upper	Q East	Q South	Upper Acre/Ft	East Acre/Ft	South Acre/Ft
2011			1	0.017671	0.052501	0.001781	14.74	50.05	1.04
Upper	3.68	73.09	2	0.323159	0.464585	0.127285	269.57	442.93	74.31
East	2.91	77.44	5	2.288733	2.663581	1.621125	1909.19	2539.44	946.37
South	5.49	64.54	10	6.63023	7.1949	5.506226	5530.73	6859.58	3214.39
			15	11.3387	11.99669	9.966254	9458.39	11437.58	5818.04
			20	16.17424	16.88726	14.64766	13492.04	16100.21	8550.92

Utilizing the modeled precipitation data over our calculated watershed area as our guide, we created a simple flow estimator based on only the individual Comal county precipitation gauges as the precipitations amounts and not the spline interpolations. The inverse distance weighted method (IDW) was used to interpolate the effects of each precipitation gauge and its distance from the center of each of our South, Upper and East Dry Comal creek watersheds. The IDW from each gauge location and its weighted percentage is shown as Effected Area % for each individual gauge location to center of each watershed. Below (Figure 11) is a snap shot of the estimator showing the April 21st event derived from only recorded Comal precipitation gauges.

			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	4.48	4.49	4.27	6.27
			South Fork				
Dry Comal South Fork		Area KM2	Effected Area %	0.525	0.249	0.105	0.121
S=	5.49	28.35	**South Fork**	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
Dry Comal Upper Fork			24hr (in) Precip	0.98	1.24	1.36	0.99
S=	3.68	40.51	168hr (in) Precip	4.48	4.49	4.27	6.27
Dry Comal East Fork			**Q (in)per unit Area**	**0.098226691**	57.34	Acre-ft	
S=	2.91	46.3	**Upper Fork**				
			Effected Area %	0.183	0.253	0.149	0.415
			Upper Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	4.48	4.49	4.27	6.27
			Q (in)per unit Area	**0.261010904**	217.73	Acre-ft	
			East Fork				
			Effected Area %	0.188	0.359	0.205	0.247
			East Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	4.48	4.49	4.27	6.27
			Q (in)per unit Area	**0.351400739**	335.02	Acre-ft	

Figure 11: April 21st 2016, “Q” flow estimator for the three watersheds derived from precipitation gauges.

The variables in calculating Q are the precipitation, S derived from the Curve Number, and an approximation of the antecedent moisture a 0.2 multiplier in the numerator, and a 0.8 multiplier in the denominator. These multipliers are a representation of a collection of average small stream moisture conditions on an average day over many different soil and impervious conditions (NRCS, 1986). Our attempt is to create a variable rate antecedent moisture influence based on previous precipitation events. Note this is a starting point approach and many iterations from actual data, correlating to actual creek flow conditions would be warranted to fine tune this estimator. Our a assumption to start with is over a 7 day period or 168 Hrs, should 10 inches of precipitation fall then the ground will be 90 percent or more saturated. Conversely over the same period of time should the recorded precipitation be zero, then the standard antecedent moisture of 20% should be more accurate. A linear equation was produced to represent these conditions, where the 0.2, and 0.8 multipliers would be eliminated at 10 inches of precipitation over 168 hours, and hence be in full effect at zero precipitation. The equation produced is shown below in (Figure 12).

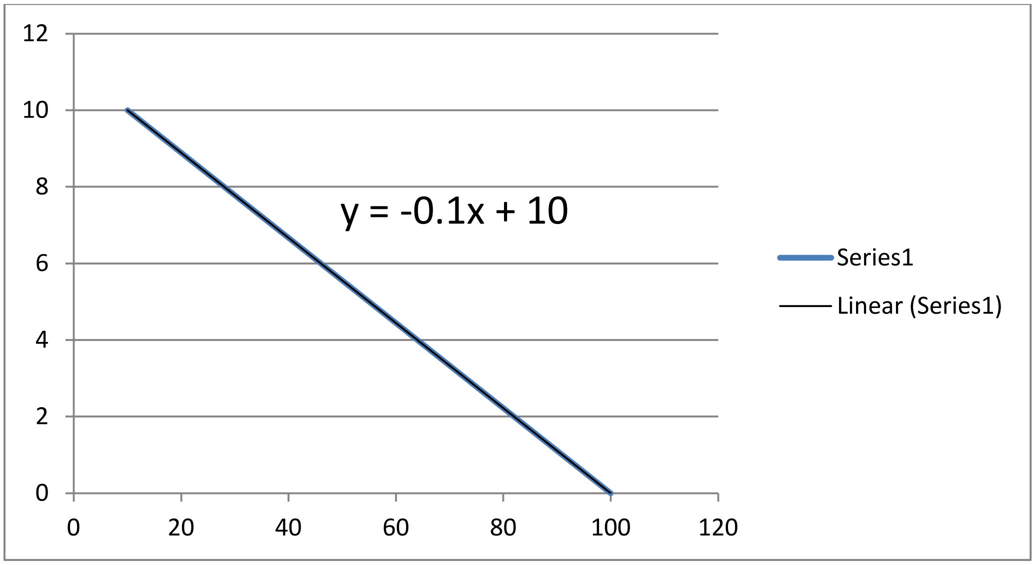


Figure 12: Formulation of linear equation for antecedent moisture assumptions

The calculator with this linear assumption of starting antecedent moisture can from prior precipitation data estimate the runoff more accurately. Two examples are below for the April 21st precipitation event, one with a hypothetical 10 inches of rain, and one with zero inches of rain. As expected when the total precipitation was 10 inches there was estimated 90 percent runoff, and for zero weekly precipitation there was 20 percent. Of course the estimated precipitation was weighted using the IDW method of the precipitation gauges distance from the center of the watersheds. Below (Figures 13 and 14) demonstrate these conditions.

			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	10	10	10	10
			South Fork				
Dry Comal South Fork		Area KM2	Effected Area %	0.525	0.249	0.105	0.121
S=	5.49	28.35	**South Fork**	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
Dry Comal Upper Fork			24hr (in) Precip	0.98	1.24	1.36	0.99
S=	3.68	40.51	168hr (in) Precip	10	10	10	10
Dry Comal East Fork			**Q (in)per unit Area**	**1.08585**	633.89	Acre-ft	
S=	2.91	46.3	**Upper Fork**				
			Effected Area %	0.183	0.253	0.149	0.415
			Upper Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	10	10	10	10
			Q (in)per unit Area	**1.10655**	923.05	Acre-ft	
			East Fork				
			Effected Area %	0.188	0.359	0.205	0.247
			East Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	10	10	10	10
			Q (in)per unit Area	**1.149592826**	1096.02	Acre-ft	

Figure 13: Maximum runoff based on 90% antecedent moisture with 10 inches of precipitation over a 168hr period.

			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	0	0	0	0
			South Fork				
Dry Comal South Fork		Area KM2	Effected Area %	0.525	0.249	0.105	0.121
S=	5.49	28.35	**South Fork**	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
Dry Comal Upper Fork			24hr (in) Precip	0.98	1.24	1.36	0.99
S=	3.68	40.51	168hr (in) Precip	0	0	0	0
Dry Comal East Fork			**Q (in)per unit Area**	**0.001888499**	1.10	Acre-ft	
S=	2.91	46.3	**Upper Fork**				
			Effected Area %	0.183	0.253	0.149	0.415
			Upper Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	0	0	0	0
			Q (in)per unit Area	**0.052499625**	43.79	Acre-ft	
			East Fork				
			Effected Area %	0.188	0.359	0.205	0.247
			East Fork	Schoenthal S	Schoenthal N	Hueco Rd	Smithson Valley
			24hr (in) Precip	0.98	1.24	1.36	0.99
			168hr (in) Precip	0	0	0	0
			Q (in)per unit Area	**0.121758025**	116.08	Acre-ft	

Figure 14: Minimum runoff based on 20% antecedent moisture with zero inches of precipitation in 168hr period.

Comparing the two runoff rates, as calculated by total watershed volumes in Acre feet, the difference from 20 to 90 percent antecedent moisture is quite amazing. For example the Dry Comal creek South with 10 inches of rain is 633 Acre/ft to 1.1 Acre/ft with no precipitation in the last 168 hours. The other 2 watersheds are similar with vastly different volumes of runoff based on the antecedent moisture levels.

The runoffs calculated from the spline interpolations of the April 21st 2016 event with an Antecedent moisture level of 0.2S as compared to the IDW precipitation gauge event on the same day with 168th hour precipitation taken into account is quite starkly different! The spline 0.2S antecedent moisture Q runoff flow rates were calculated to be Upper tributary – 15.73 Acre/Ft, East tributary – 75.3 Acre/Ft and the South tributary - 1.47 Acre/Ft. As compared to the 168th hour variable precipitation antecedent moisture conditions concluding with the Upper tributary – 217.73 Acre/Ft, East tributary – 335.02 Acre/Ft and the South tributary - 57.34 Acre/Ft. Assuming that the initial conditions of estimated saturation levels and antecedent moisture approximations are accurate, the stark difference between the two methods is amazing. An order of magnitude or more would be observed, this demonstrates the importance of knowledge of the soils existing saturation level for determining Q the run off potential.

Conclusion:

The modeling attempt was to create runoff levels consistent with known precipitation events and to determine the effects of varying antecedent soil moisture levels effects on the flow. Several factors affect the Dry Comal Creek flow of the South, Upper, and East tributaries. We analyzed the watershed areas, the soil conditions, vegetation, created realistic rainfall patterns, and attempted to adjust antecedent moisture conditions. Analyzing the historical data events where the LWC was measured is a very good determination to calculate the total volume of water that was runoff. The Dry Comal creek is a good test subject, as its name suggests the creek is only flowing after periods of very heavy precipitation.

The three road crossings that were analyzed were FM 1863 and Schoenthal Road North and South. These three LWC represent our pour points for watershed delineation and two points Schoenthal North and South are also Comal County Precipitation gauge stations as well as LWC height monitors. These gauge stations are self reporting daily or whenever there is a change in status, such as a change in precipitation heights, or LWC water level heights.

The analysis focused on a starting point, and an estimated of what was reasonable. Our rational was due to soil conditions in the area being very thin covering a relatively impervious layer of limestone, runoff once soil saturation had occurred would be quick and not have residual runoff for days or weeks following a precipitation event. This does seem to be the case as the data from the LWC once the roads are over topped, only are impassable for several hours. The Dry Comal creek is very flood prone and only flows shortly after the precipitation events. One factor yet to be studied is the time it takes for the precipitation to accumulate, and then flow down the kilometers of creek bed prior to reaching the road way LWC.

It was found that good correlation of the IDW method of calculating the precipitation coverage area was well suited to the interpolated results from actual rain events. Large amounts of runoff can be generated when the ground is saturated prior to the next precipitation event. The method of assigning an antecedent moisture percentage which then correlates to a certain flow rate was a good starting point. The next step in further determine the watershed runoff characteristics is to work backwards. Assuming that the curve numbers are accurate, the flow rates from several different flood events could help determined the runoff based on previous saturation levels. The result could then be averaged and inserted into the flow rate equation to serve as an estimator of future events several hours prior to the road ways flooding.

References:

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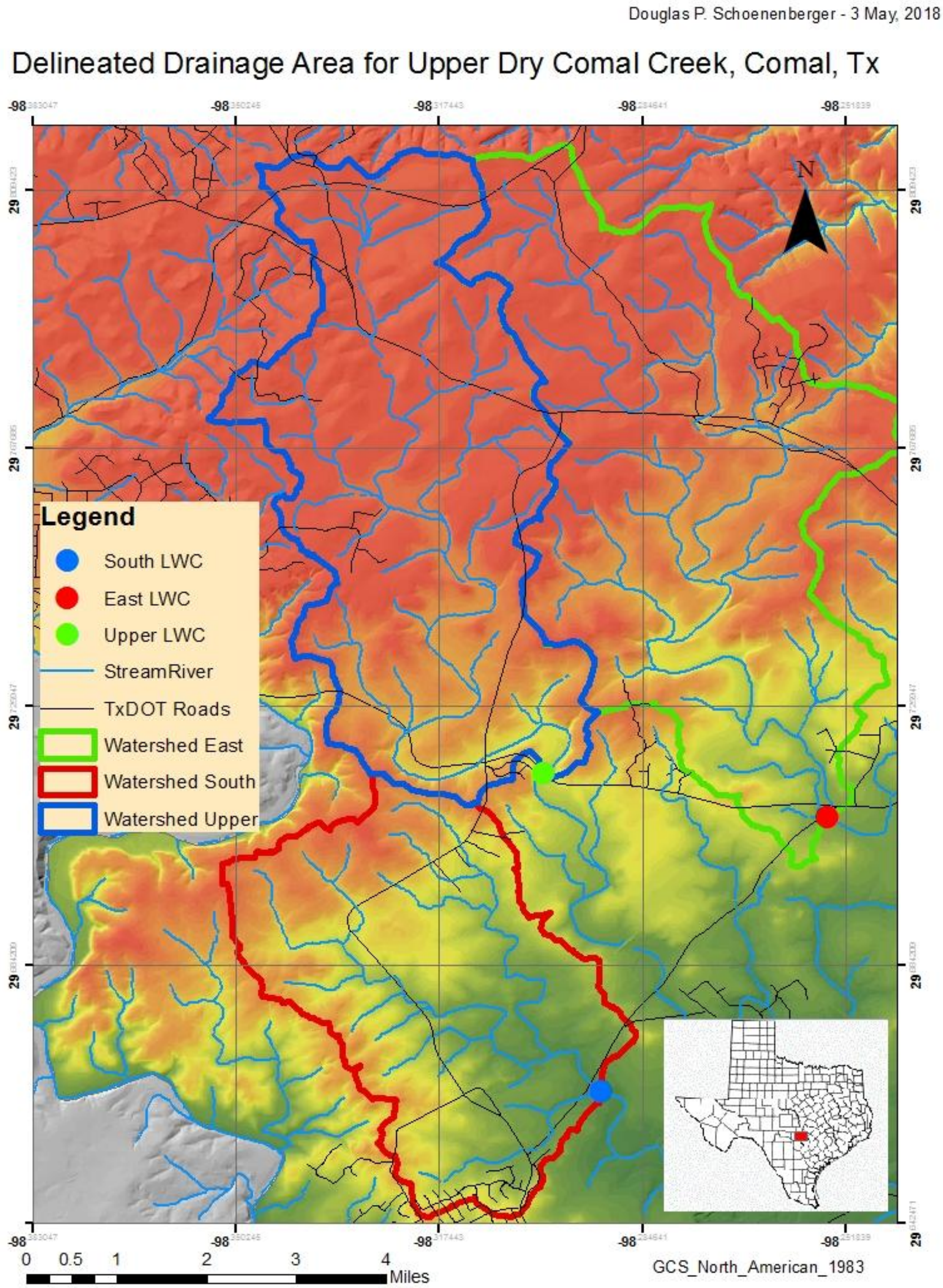
Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

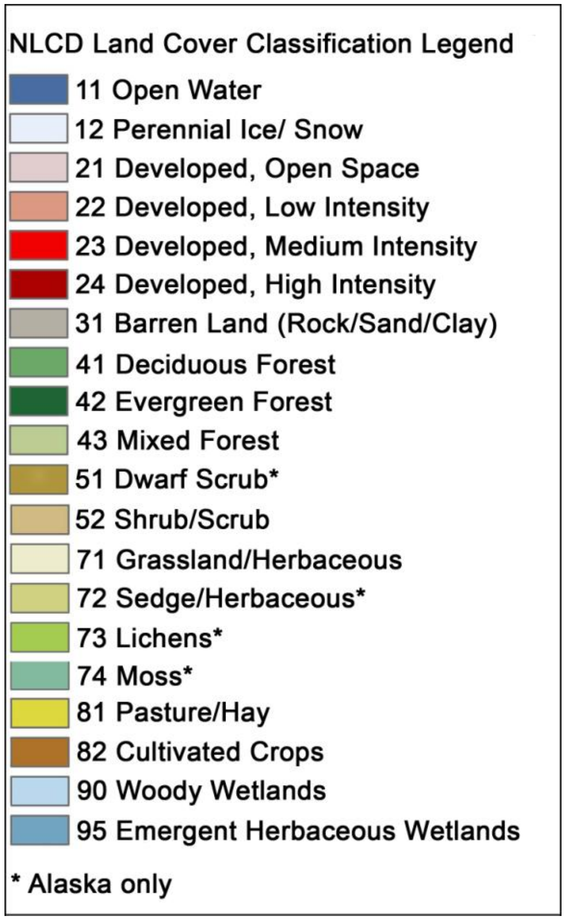
Urban Hydrology for Small Streams T-55, June 1986. Natural Resources Conservation Service. U.S. Department of Agriculture,

Appendix A:



Project Map of Dry Comal Creek Upper Tributaries Delineated Watershed Areas

NLCD Usage Codes for various land use types.



2011	East						
OBJECTID	Value	Count	Area (m2)	NCLD code	HSG	CN	CN x Area
1	1021	929	916620.9	21	D	92	84329126.9
2	1022	132	130241.1	22	D	92	11982179.5
3	1023	17	16773.47	23	D	93	1559932.95
4	1031	43	42427.02	31	D	84	3563869.59
5	1041	4075	4020700	41	D	77	309593904
6	1042	11433	11280654	42	D	77	868610333
7	1052	12957	12784346	52	D	80	1022747693
8	1071	5078	5010335	71	D	80	400826795
9	2021	557	549577.9	21	C	80	43966231.8
10	2022	44	43413.69	22	C	80	3473095.51
11	2023	4	3946.699	23	C	91	359149.649
12	2041	990	976808.1	41	C	70	68376567.8
13	2042	2657	2621595	42	C	70	183511657
14	2052	4951	4885027	52	C	74	361492015
15	2071	3194	3151440	71	C	74	233206523
16	3041	8	7893.399	41	B	55	434136.938
17	3052	62	61173.84	52	B	61	3731604.32
18	3071	23	22693.52	71	B	61	1384304.83
Totals			46525666		AVE CN	77.4	3603149120
					S	2.91	

Calculations on the East Tributary of the Dry Comal Creek of CN, and S

2011	South						
OBJECTID	Value	Count	Area (m2)	NCLD code	HSG	CN	CN x Area
1	1021	55	49060.2	21	D	92	4513538.22
2	1022	5	4460.018	22	D	92	410321.656
3	1023	1	892.0036	23	D	92	82064.3312
4	1041	145	129340.5	41	D	77	9959220.19
5	1042	157	140044.6	42	D	77	10783431.5
6	1052	159	141828.6	52	D	80	11346285.8
7	1071	472	421025.7	71	D	80	33682055.9
8	2021	417	371965.5	21	C	80	29757240.1
9	2022	69	61548.25	22	C	80	4923859.87
10	2023	7	6244.025	23	C	91	568206.293
11	2024	2	1784.007	24	C	91	162344.655
12	2041	1459	1301433	41	C	70	91100327.7
13	2042	3928	3503790	42	C	70	245265310
14	2052	2330	2078368	52	C	74	153799261
15	2071	1122	1000828	71	C	74	74061274.9
16	2090	7	6244.025	90	C	0	0
17	3021	1909	1702835	21	B	88	149849469
18	3022	596	531634.1	22	B	88	46783804.8
19	3023	75	66900.27	23	B	88	5887223.76
20	3024	4	3568.014	24	B	88	313985.267
21	3041	2664	2376298	41	B	55	130696367
22	3042	9911	8840648	42	B	55	486235622
23	3052	3964	3535902	52	B	61	215690038
24	3071	2515	2243389	71	B	61	136846732
25	3090	34	30328.12	90	B	0	0
Totals			28550359		AVE CN	64.5	1842717985
					S	5.49	
2011	East						
OBJECTID	Value	Count	Area (m2)	NCLD code	HSG	CN	CN x Area

Calculations on the South Tributary of the Dry Comal Creek of CN, and S

2011	Upper						
OBJECTID	Value	Count	Area (m2)	NCLD code	HSG	CN	CN x Area
1	1011	2	1780.847	11	D	0	0
2	1021	390	347265.2	21	D	92	31948400.2
3	1022	13	11575.51	22	D	92	1064946.67
4	1023	8	7123.389	23	D	92	655351.799
5	1024	1	890.4236	24	D	92	81918.9749
6	1041	502	446992.7	41	D	77	34418435.4
7	1042	1390	1237689	42	D	77	95302042.2
8	1052	1921	1710504	52	D	80	136840305
9	1071	1256	1118372	71	D	80	89469767.3
10	2011	16	14246.78	11	C	0	0
11	2021	1835	1633927	21	C	80	130714190
12	2022	255	227058	22	C	80	18164642.3
13	2023	37	32945.67	23	C	91	2998056.4
14	2024	17	15137.2	24	C	91	1377485.37
15	2031	42	37397.79	31	C	69	2580447.71
16	2041	5704	5078976	41	C	70	355528351
17	2042	15679	13960952	42	C	70	977266658
18	2052	11965	10653919	52	C	74	788389995
19	2071	4712	4195676	71	C	74	310480038
Totals			40732429		AVE CN	73.1	2977281032
					S	3.68	

Calculations on the Upper Tributary of the Dry Comal Creek of CN, and S