Urban Flooding

Memorial Day flood in Austin, TX

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GIS in Water Resources

Final Project

Introduction

The Memorial Day flood event that took place in Central Texas this past year has been called the "highest flood in the history of the State of Texas" [1]. Record levels of precipitation fell over the region, resulting in flash flooding of several rivers in the area, including Shoal Creek in Austin and the Blanco River, located near San Marcos. The amount of water that overtook the area was unprecedented and unpredictable. In fact, the first indication of the impending flood in Hays County came from a rancher on the upper Blanco River. In Austin, about thirty miles away, the urban landscape was flooded with water, with some parts of the city getting over eighteen inches of rain. City streets, retail stores, and even football stadiums were subject to flash flooding of the nearby creeks.

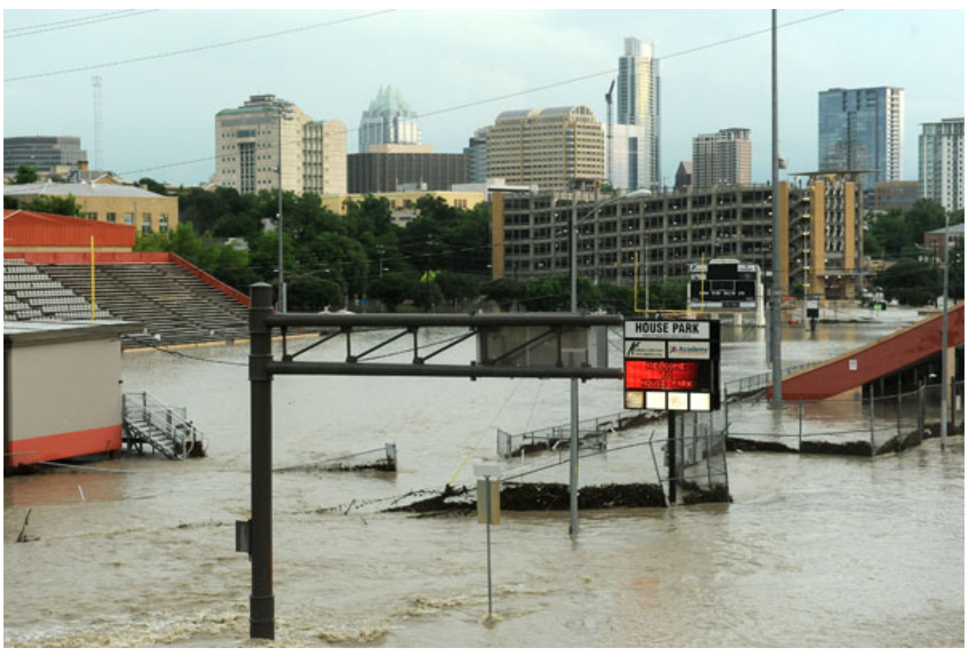


Figure 1: May 2015 flooding in Austin, TX.
http://www.austinchronicle.com/news/2015-08-14/after-the-flood-before-the-flood/

Austin is located in what is known as "flash flood alley," meaning that the area is prone to these types of events. When dealing with large storm events, it is important to have some insight into how a system is going to respond to tremendous amounts of water over short amounts of time, such as with the

Figure 2: May 2105 flooding in Austin, TX. www. http://knue.com/texas-floods-photos-2015/

Memorial Day flood. In this case, professionals were not able to foresee how the system would react, which is an indication that the current method of flood modeling has its downfalls.

Background

Global warming effects have led to the existence of new, extreme rainfall events. In this day and age, it is not unheard of to have two 100-year storm events only a few months apart. Being able to accurately model how urban systems will respond to large storm events is of particular importance due to the sheer amount of urban dwellers worldwide. Currently, more than 54% of the world's population resides in urban areas, and this number is only expected to increase [2]. Managing urban environments and their infrastructure will be a great challenge in the coming years.

Despite the rapid urbanization occurring globally, classic feature extraction methods are still being used and drainage systems are being conceived for antiquated "design storms." The greatest challenge for hydrodynamic modeling of urban landscapes lies with the fact that feature extraction tools for urban environments are not completely developed. Sharp features like streets, buildings and gutters that are found in urban landscapes can make flood modeling very difficult.

The primary objective of this report is to determine how urban systems respond to tremendous amounts of water. This report will examine the effects of the Memorial Day flood event in Austin by evaluating land cover, runoff and stream flow data. Further, the land cover distribution for Austin, an urban city, will be compared with that of San Marcos, a rural town, to identify how large areas of development effect the runoff for a large storm event.

Characterizing the Austin Basin

Analysis of the general characteristics of the San Marcos River basin was performed previously in a class exercise. The characteristics of the Austin area were determined utilizing the same procedure. Using the NFIE Geodatabase in ArcGIS, the sub-watersheds for the Austin area basin were isolated in order to specify the area of study. As can be seen on the map below, the Austin area basin is comprised of four HUC_10 watersheds and thirty-one HUC_12 watersheds.

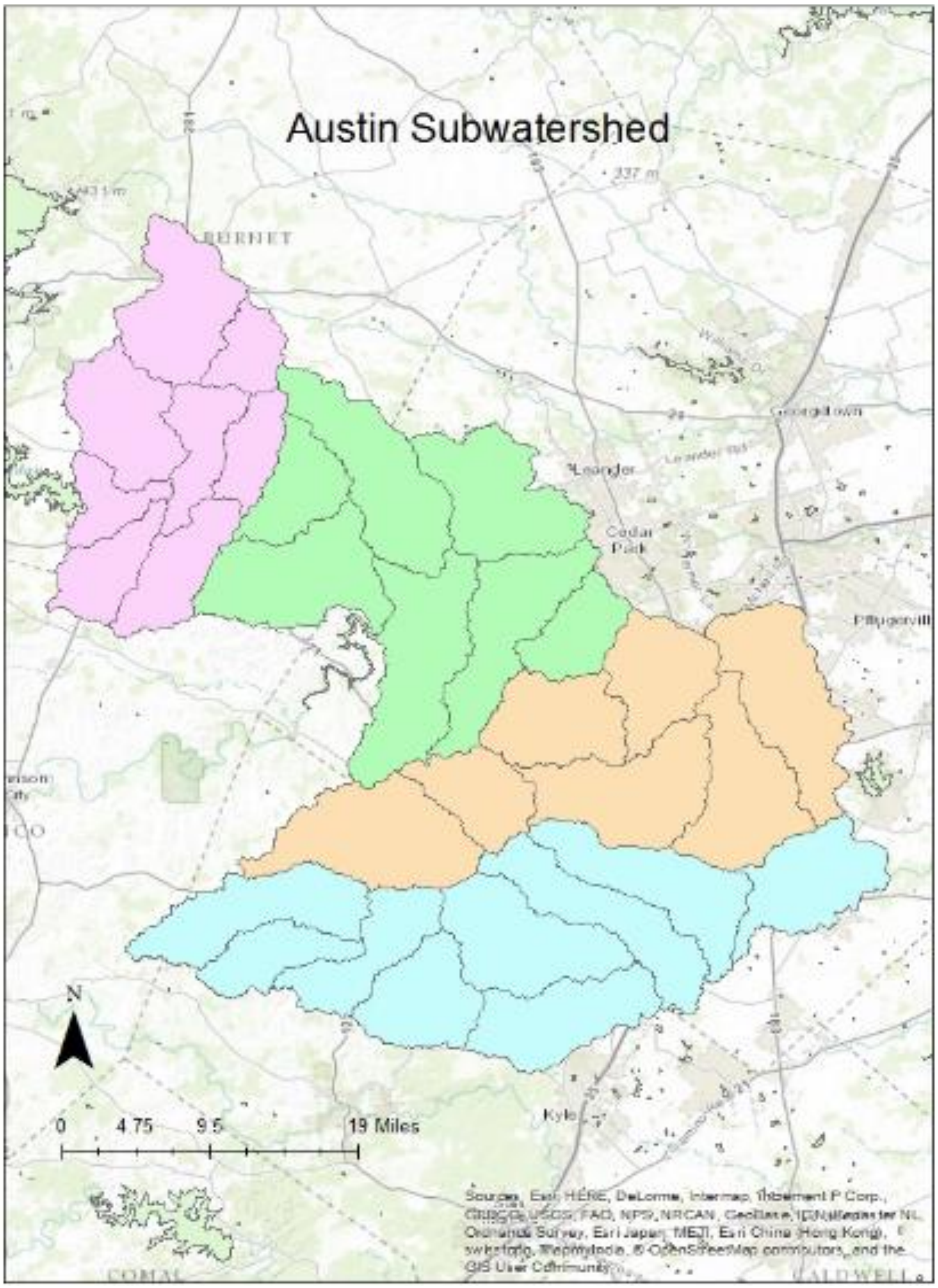


Figure 3: Map of the Austin area basin

The NFIE Geodatabase was further utilized to examine the hydraulic landscape of the Austin basin. A map showing the flow lines and catchments for all creeks and rivers in the Austin basin can be seen below. It was determined that the Austin basin has a total catchment area of 3199.3 km^2, with all flow paths adding up to a total length of 1824.2 km.

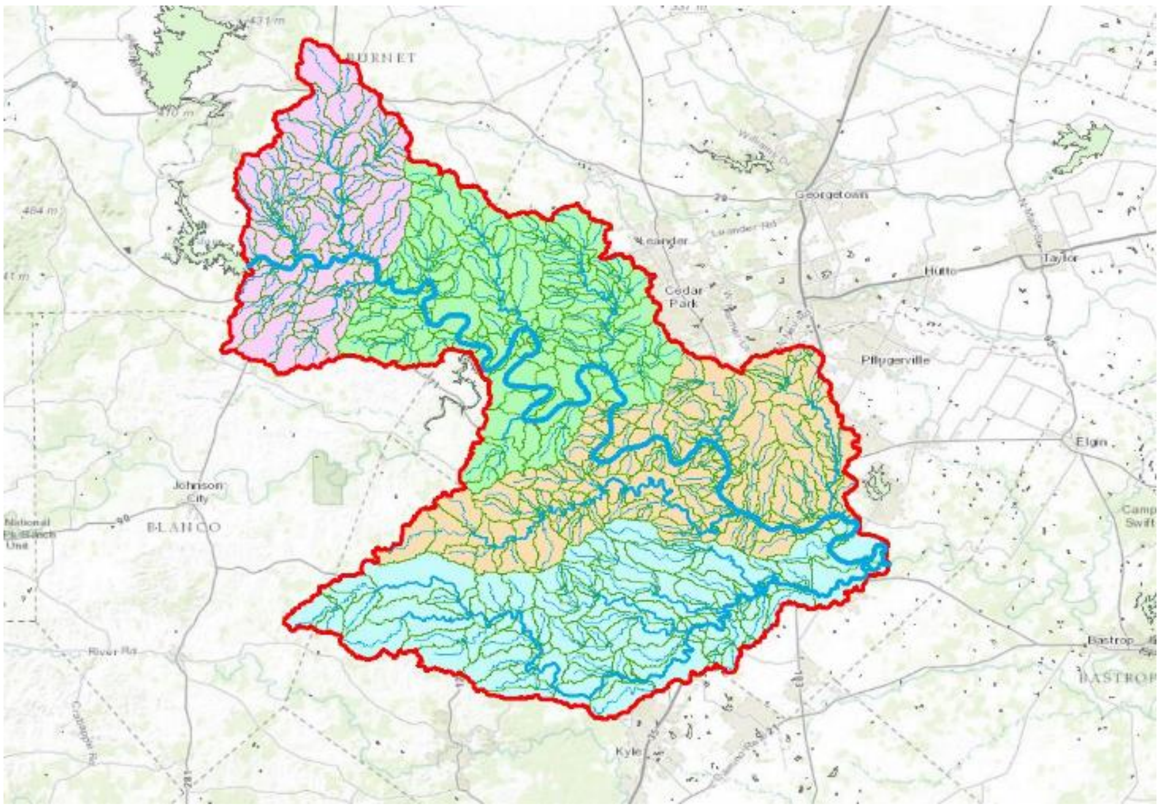


Figure 4: Map showing the catchments and flow lines in the Austin basin

Stream Flow

After determining the location of the flow lines and catchments in the Austin basin, the next step was to set up stream gages on creeks that were known to have flooded during the Memorial Day flood event. Six gage locations were set up in the

Austin basin with two gages on Shoal Creek, two gages on Waller Creek and two gages on Barton Creek. The map below shows the locations of the gages.

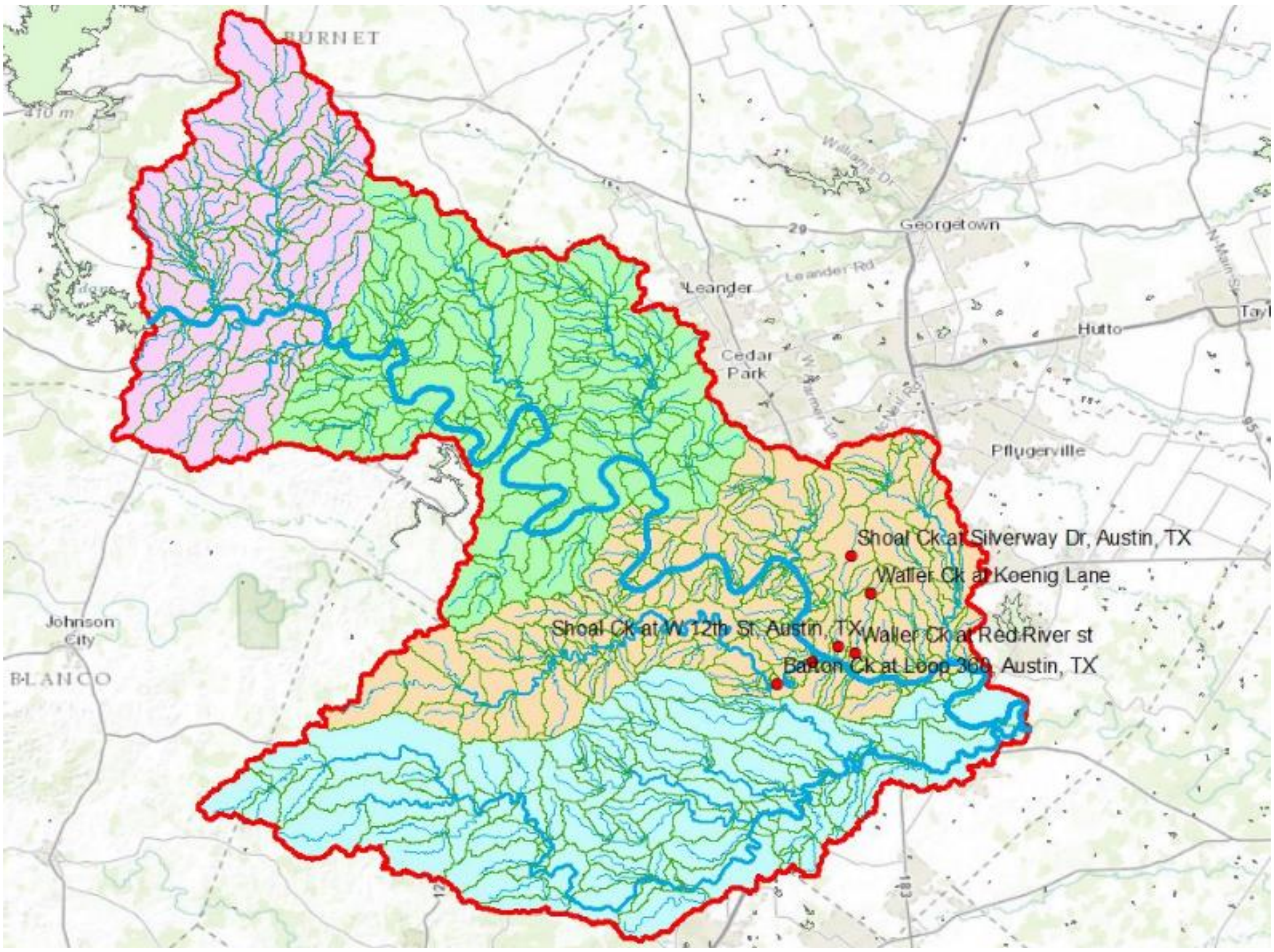


Figure 5: Map showing gage locations in Austin basin

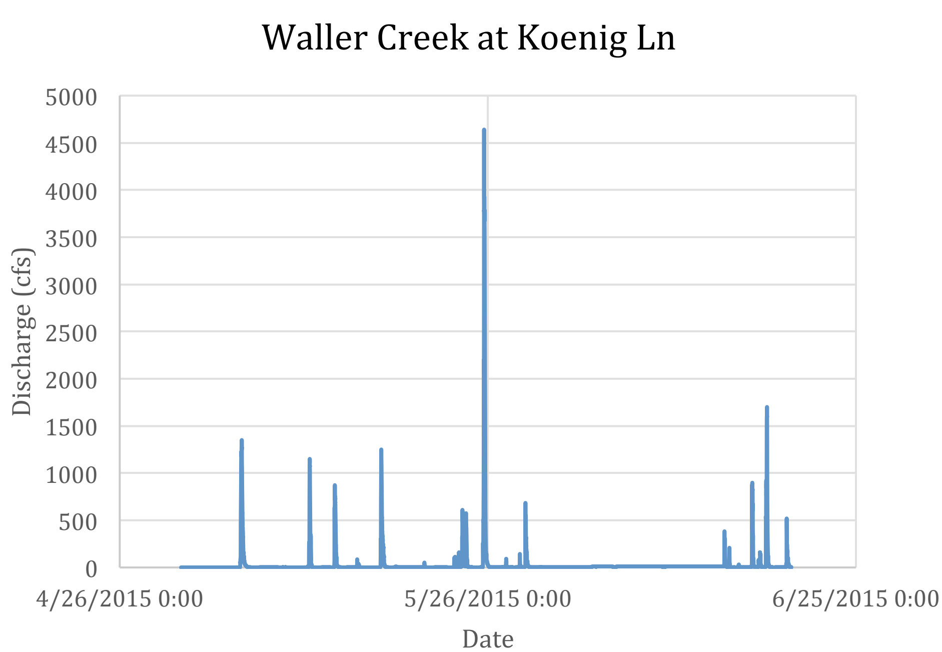
These gage locations were chosen because they are well known creeks in Austin with good data from the Memorial Day flood event and because with two gages on each stream, the upstream and downstream flows could be compared.

Below is a summary table containing the coordinates, mean annual flow and drainage area of each of the gages.

Table 1: Summary of attributes for gages

SiteName	Lat DD	Long DD	DA sqMile	MA Flow (cfs)
Waller Ck at Red River st	30.272	-97.736	4.13	13.5
Waller Ck at Koenig Lane	30.323	-97.723	1.09	3.08
Barton Ck abv Barton Spgs at Austin,TX	30.264	-97.772	125	68
Barton Ck at Loop 360, Austin, TX	30.245	-97.802	116	175.1
Shoal Ck at W 12th St, Austin, TX	30.277	-97.750	12.3	13.6
Shoal Ck at Silverway Dr, Austin, TX	30.354	-97.739	5.59	3.46

Using CUAHSI and USGS, the stream flow data from the May flood was obtained for each of the gage locations. The stream flow data for the six gages is summarized and plotted below. It is clear from the plots that the creeks in Austin had a huge surge of stream flow as a result of the extreme rainfall event. This trend implies that the majority of the precipitation became runoff, with very little rainfall being absorbed into the ground.



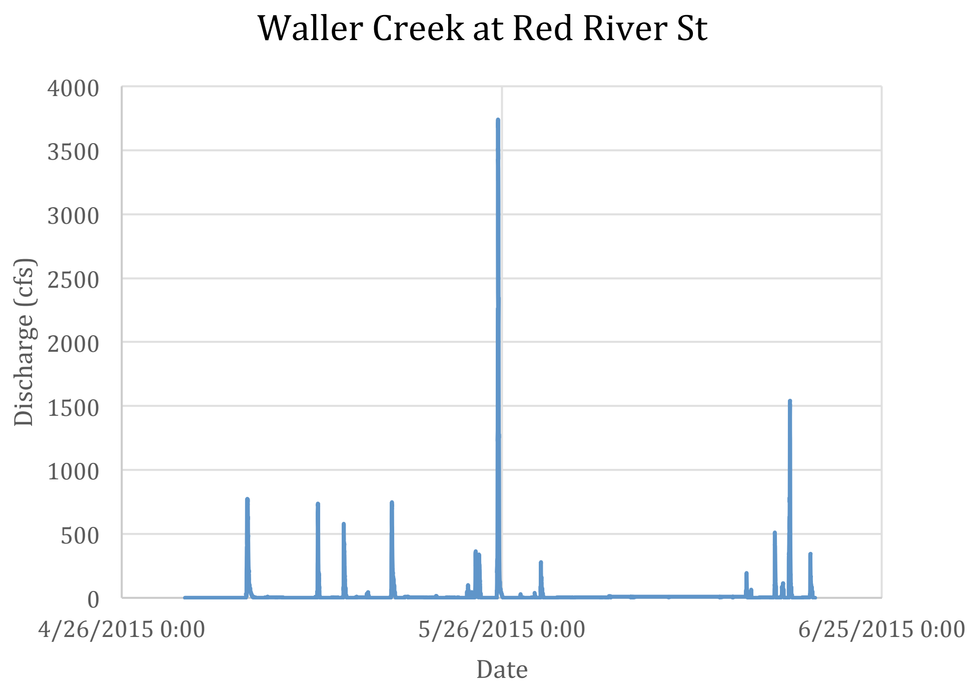


Figure 7: Stream flow data for gage on Waller Creek at Red River Street

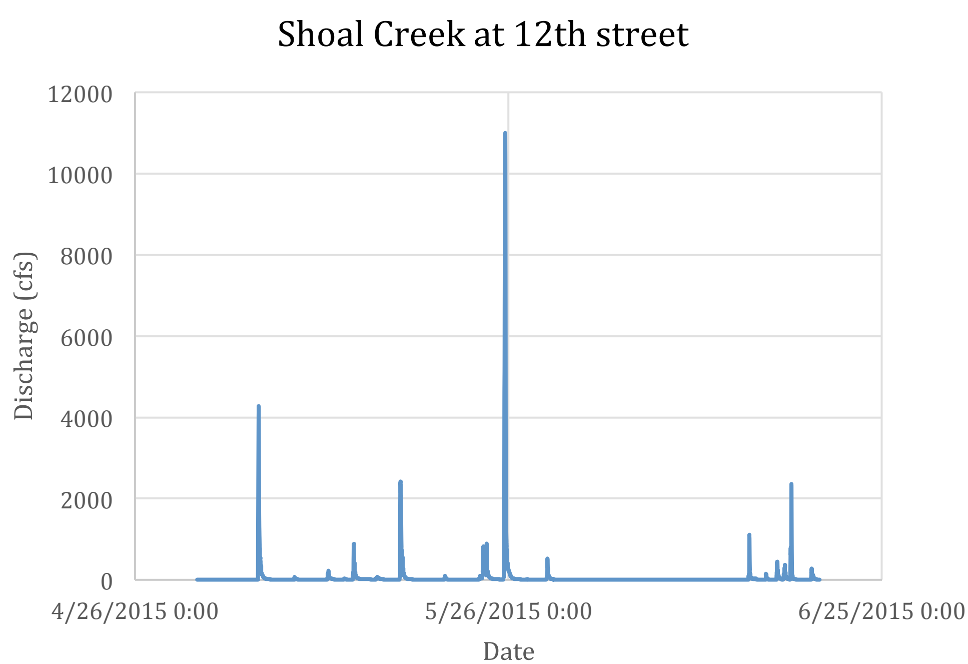


Figure 8: Stream flow data for gage on Shoal Creek at West 12th Street

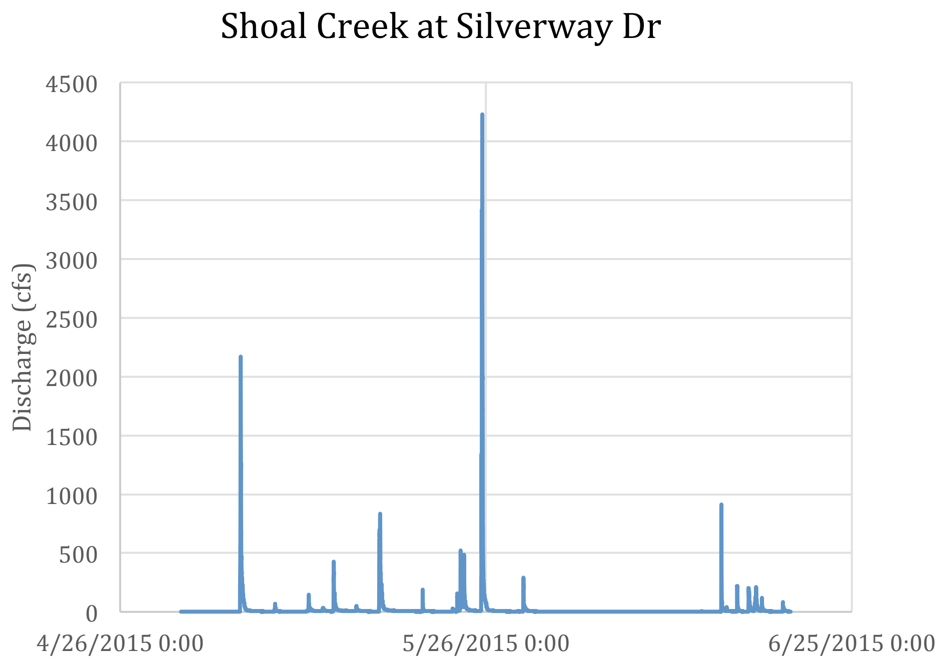


Figure 9: Stream flow data for gage on Shoal Creek at Silverway Drive

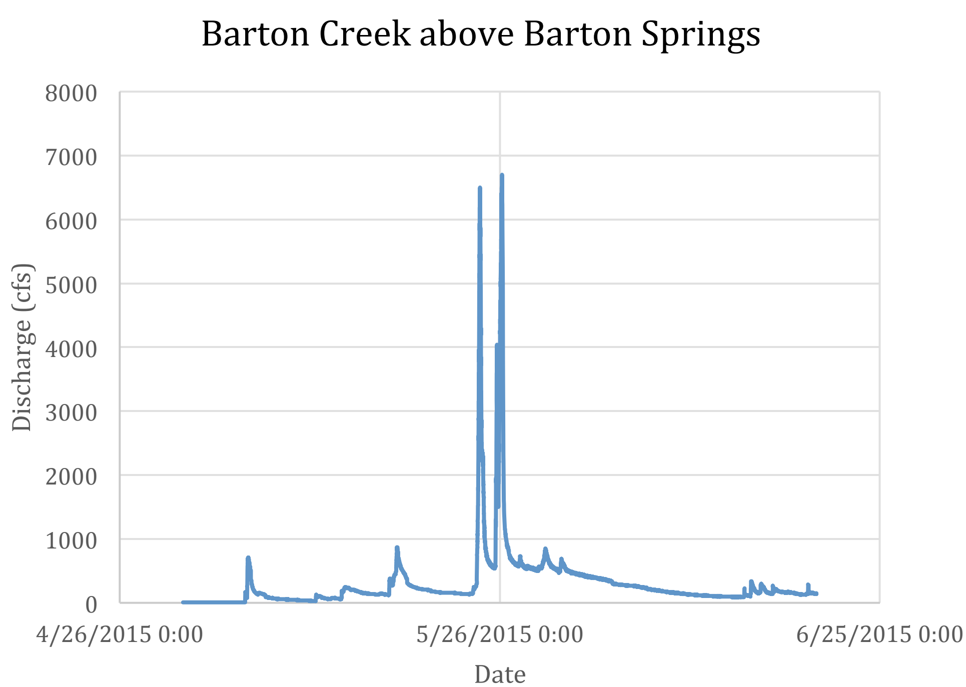


Figure 10: Stream flow data for gage on Barton Creek above Barton Springs

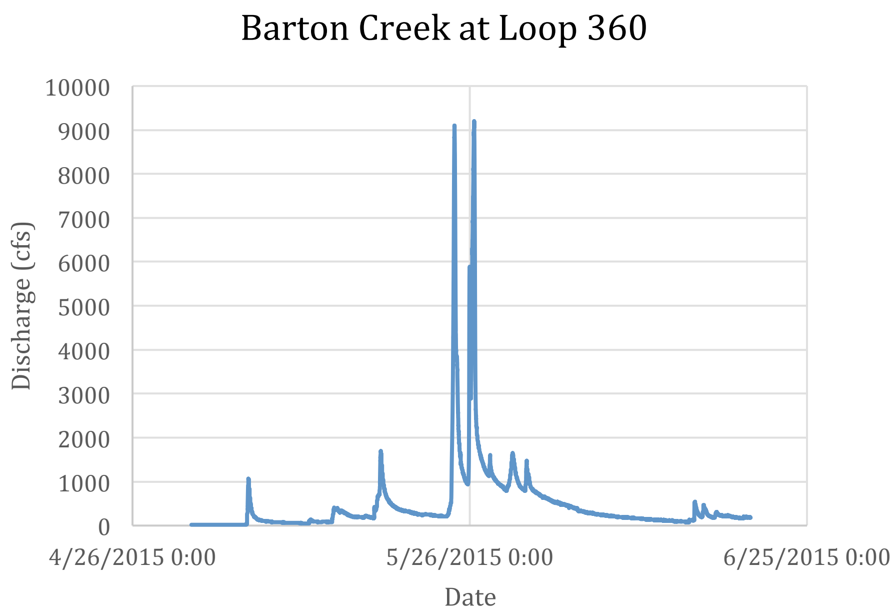


Figure 11: Stream flow data for gage on Barton Creek at Loop 360

Land Cover Comparison

The land cover distribution for the San Marcos River basin was determined in a previous class exercise (see summary Table 2 below for results). Using the same source from the National Land Cover Database, the land cover distribution for the Austin basin was obtained in order to see how land cover changed between rural to urban environments. The land cover percentages are summarized in Table 3 below.

Impervious surfaces result in greater runoff because water is unable to permeate into the ground during extreme rainfall events, causing the water to pool on the surface or enter nearby creeks. A highly developed area, like any modern city, is in particular danger during large rainfall events because oftentimes the water has nowhere to go. It can be seen on the map below that Austin has a fairly high percentage of impervious/developed cover at around 21.5% compared to the San Marcos basin that only has about 9.2% developed.

Table 2: Land cover distribution for the San Marcos River basin

Land Cover	Area (%)	Area (km^2)
Agriculture	19.2	902
Development	9.2	434
Forest	25.9	1215
OpenWater	0.4	20
ShrubScrubGrass	43.0	2020
SnowIceBarren	0.2	8
Wetland	2.1	99

Table 3: Land cover distribution for Austin basin

Land Cover	Area (%)	Area (km^2)
Agriculture	1.17	50.7
Development	21.47	930.1
Forest	40.91	1772.0
OpenWater	2.74	118.6
ShrubScrubGrass	32.34	1400.8
SnowIceBarren	0.36	15.5
Wetland	1.01	43.9
Total	100.00	4331.62

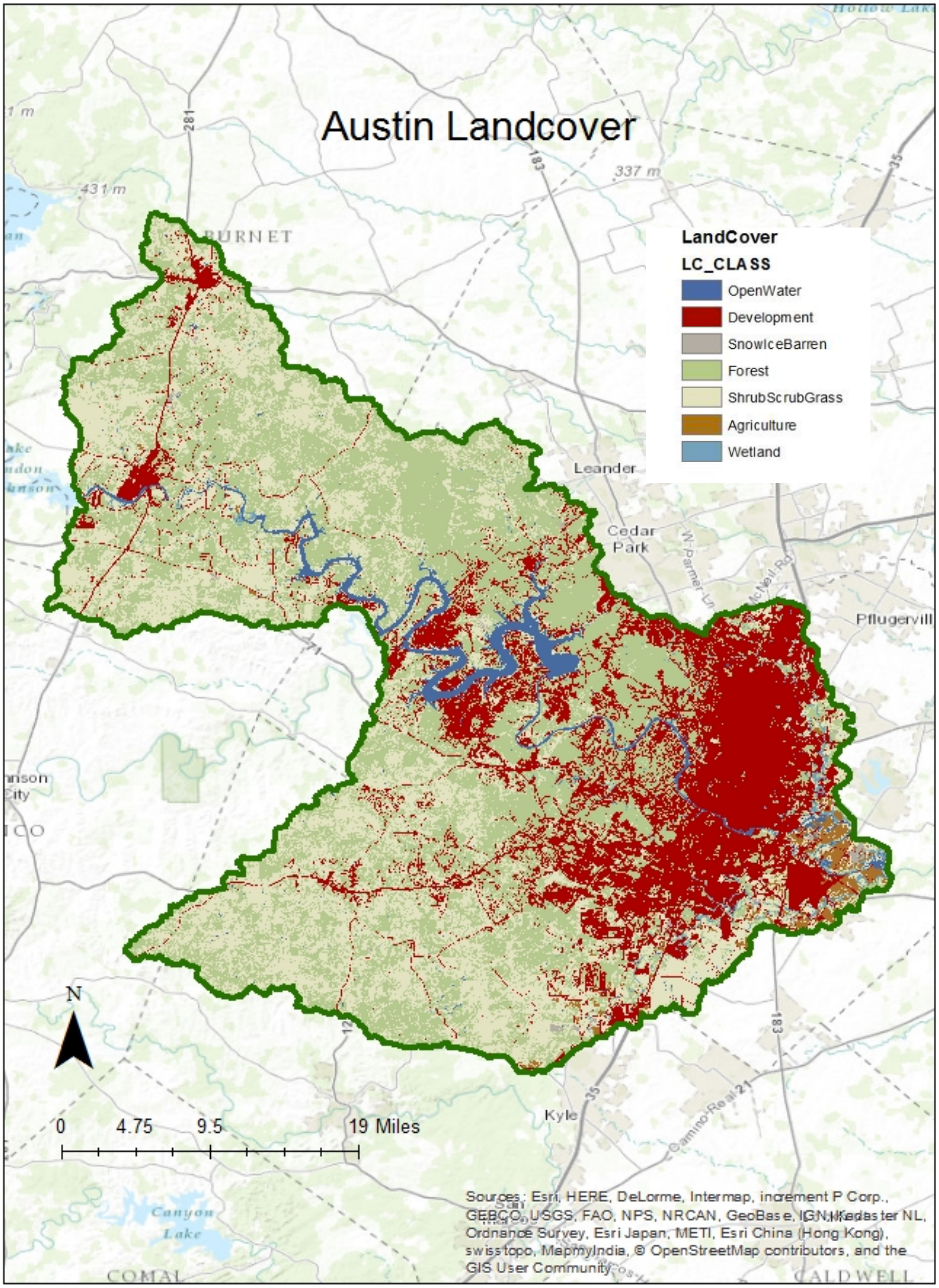


Figure 12: Map of Austin basin land cover

Runoff Comparison

To see how land cover affects runoff, curve numbers were calculated for the San Marcos and Austin basins using the soil conservation service method. The calculations and results are highlighted below. Table 4 contains the runoff curve numbers for urban areas, obtained from the United States Department of Agriculture (USDA) manual, *Urban Hydrology for Small Watersheds*. Table 5 contains the runoff curve numbers for agricultural areas. The curve number for impervious areas is 98. Wetlands and open water were assumed to have a curve number of 0 and grass and agricultural lands were assumed to be in good condition. Assuming a hydrologic soil group of C for both San Marcos and Austin, which is common for the central Texas region, estimates of the composite curve numbers for both environments were calculated. The composite curve number for Austin was found to be approximately 74 and the composite curve number for San Marcos was found to be approximately 70. Austin has a higher runoff curve number than San Marcos, meaning that water does not as easily permeate into ground surfaces and a large amount of the rainfall becomes runoff. Although the curve numbers are fairly close in magnitude, the difference can be huge when dealing with a large storm event such as the Memorial Day flood. Figures 6-11 provide further evidence for this conclusion. The Memorial Day extreme rain event occurred in both cities, however, it is clear that land cover was a contributing factor as to why Austin incurred so much runoff.

Table 4: Runoff curve numbers for fully developed areas

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area 2/	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98

Table 5: Runoff curve numbers for agricultural areas

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[A]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[B]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[C]	48	65	73
Woods—grass combination (orchard or tree farm).[D]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[E]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

Conclusions

The composite curve number calculated for the Austin area was not very different from that of San Marcos, however, this is because the curve number was a function of the entire area not just the urban downtown. If the composite curve number were calculated for just the downtown area, it would have been a lot closer to the fully developed impervious curve number of 98. The Memorial Day flood event most obviously affected the downtown area, with the excess runoff having nowhere to go but to pool on the surface. The more suburban or rural parts of Austin did not see this caliber of flooding. In order to help mitigate flood risks, Austin and other urban cities can utilize permeable pavements, rain gardens, or other kinds of pervious cover to decrease the runoff curve number and allow more water to infiltrate into the ground and not collect on the surface.

References

[1] Price, A., & Tilove, J. (2015, May 25). Gov. Abbott: 'This is the highest flood recorded in state of Texas'. Retrieved October 12, 2015.
[2] World's population increasingly urban with more than half living in urban areas | UN DESA | United Nations Department of Economic and Social Affairs. (2014, July 10). Retrieved October 1, 2015.