City of Daphne

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ALABAMA

D'Olive Creek Watershed Study

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1. Executive Summary

The D'Olive Creek watershed analysis was performed in order to gain an understanding of the watershed by quantifying the amount of discharge associated with a given rainfall event. The information obtained can be used for future stormwater planning and management as well as restoration projects. The study was accomplished by calibrating a hydrologic model of the watershed and identifying areas where regional stormwater control measures could be beneficial. The method of analysis used for the study employed the use of the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) system, a two-dimensional overland flow model. The model was calibrated and validated by multiple rainfall events.

Results of the findings for the D'Olive Creek watershed indicate that surface runoff is highly sensitive to the degree of saturation of the soil. During drought conditions, rainfall events produce discharges that are within the range of the rural and urban regression equations. For a saturated soil condition, runoff discharges can reach upwards of 10 times that of rural regression.

The study finds that implementation of regional stormwater control measures (SCMs) are beneficial for reducing discharges along the local branch on which they are installed; however there will be minimal impact at the watershed outlet. Analysis performed using the conservative saturated conditions indicates that the regional SCMs were able to reduce local discharges upwards of 50%. While this is a significant decrease, the amount of runoff is still greater than that calculated by urban regression equations.

Recommendations for watershed improvements follow those found in the Watershed Management Plan compiled by Thompson Engineering. Regional stormwater facilities will be needed to reduce current discharges. Conservation easements, increased riparian buffers, and stronger development policies will help maintain the current conditions of the watershed. For any future developments, low impact design practices will be required in order to offset any possible detrimental effects to the hydrology. For actual future developments, the calibrated GSSHA model can be used as a dynamic management tool in which to analyze the impacts of these developments. Further studies outside of the model can also be performed on a smaller sub-basin level and then reintroduced back into the calibrated model to determine any possible impacts.

2. Introduction

2.1. Watershed Description

The D'Olive Creek Watershed is located in Baldwin County, Alabama between Spanish Fort and Daphne (see Figure 2-1). The U.S. Geological Survey (USGS) 8-digit Hydrologic Unit Code (HUC) in which the watershed is found is 03160204. The total drainage area to the outlet at D'Olive Bay is approximately 12.1 square miles.

The three main creeks that make up the watershed are D'Olive Creek, Tiawasee Creek, and Joe's Branch. Figure 2-2 indicates the sub-basins associated with each of the creeks. The Upper D'Olive Creek sub-basin and the Tiawasee Creek sub-basin flow into Lake Forest Lake. These areas drain 4.85 square miles and 4.89 square miles, respectively. Joe's Branch, which drains approximately 0.89 square miles, merges with D'Olive Creek just downstream of Lake Forest Lake. The entire watershed drains into D'Olive Bay and then into Mobile Bay.

Figure 2-1
Location Map and Watershed Boundary

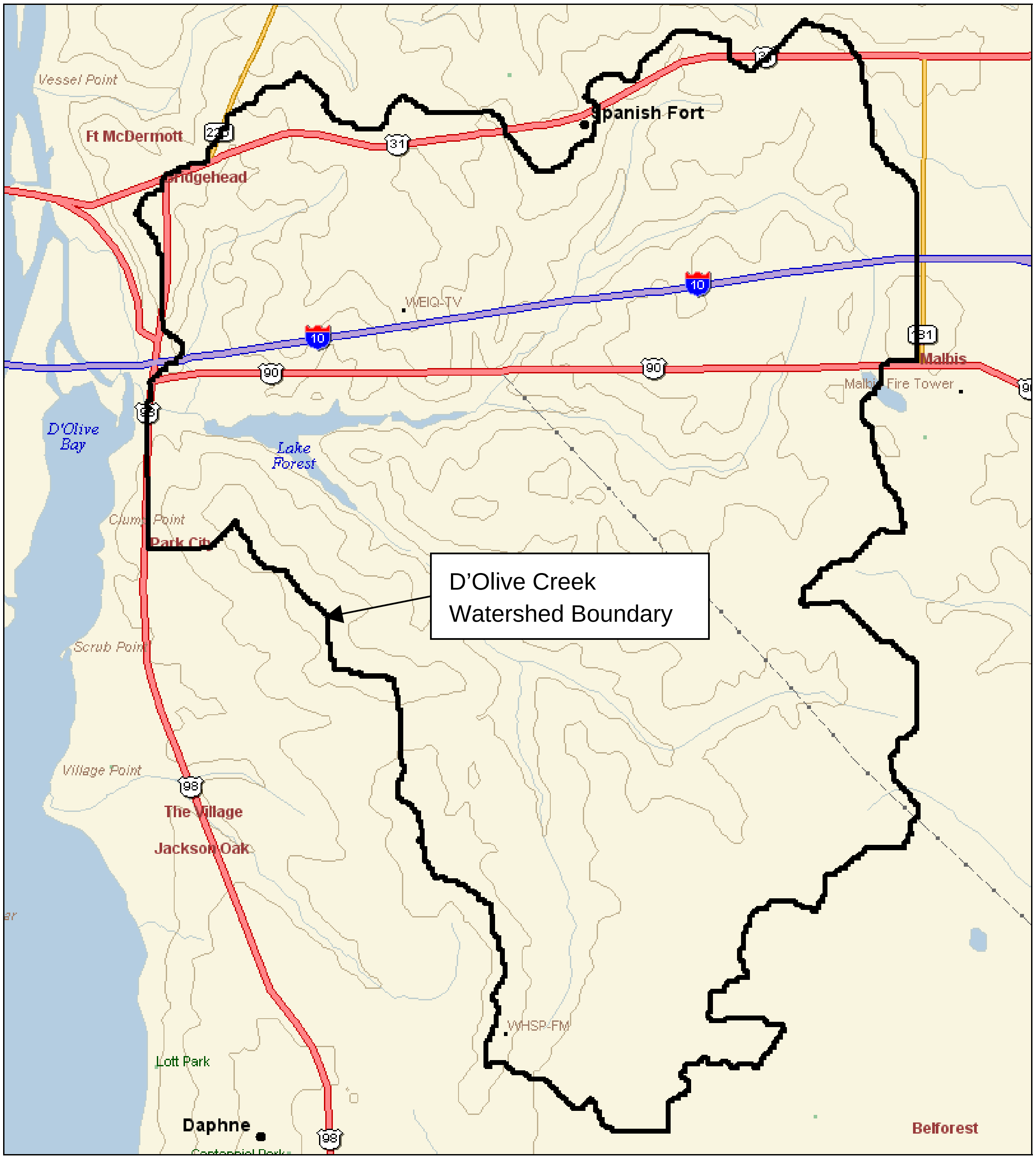
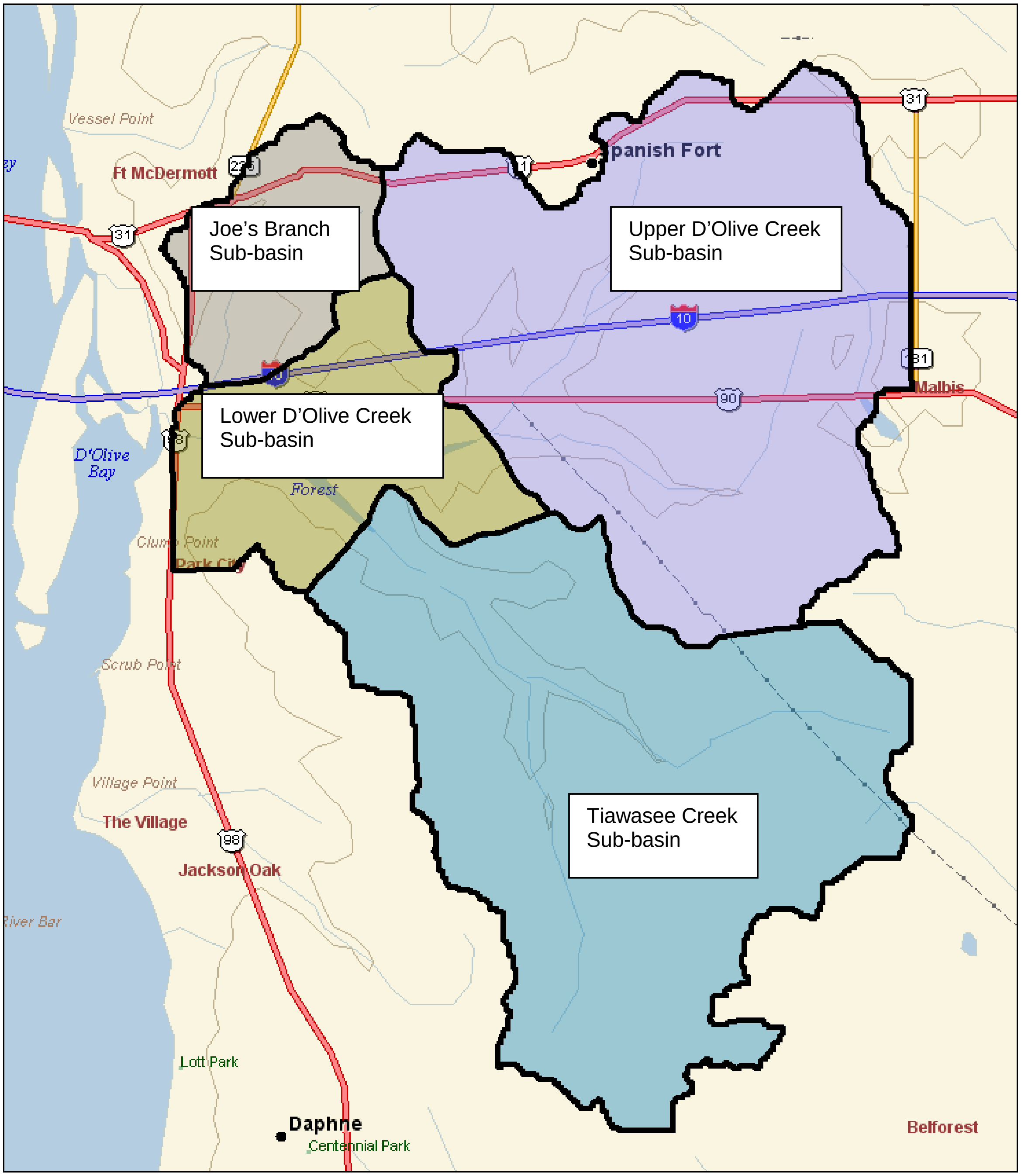


Figure 2-2
D'Olive Creek Watershed Sub-basins

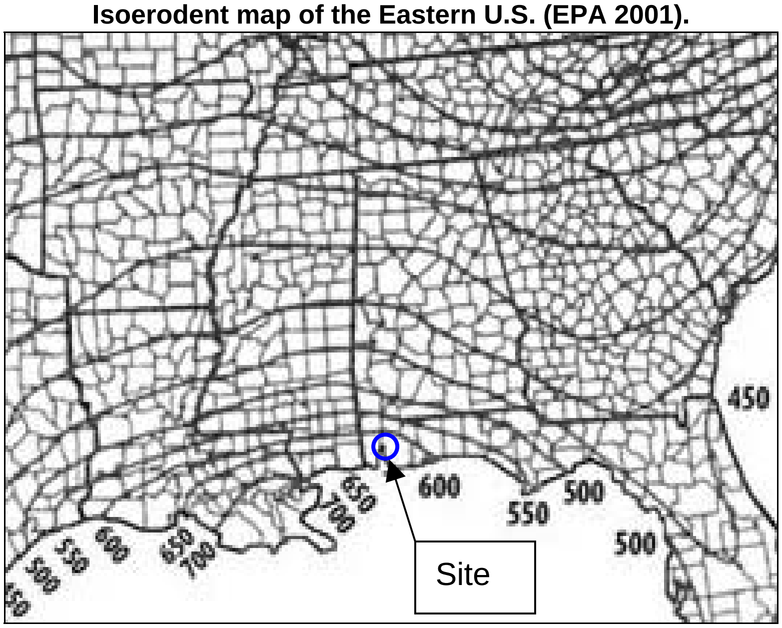


2.2. Climate

The climate for the D'Olive Creek watershed is mild but humid. Data obtained from "www.findthebest.com/category/weather" indicates that the average high and low temperatures for the area are 77 degrees and 58 degrees respectively. The hottest months are typically July and August with the coldest months being December and January. The summer months are typically the wettest averaging over 6 inches of rain per month.

The average annual rainfall for Baldwin County (Spanish Fort and Daphne area) is around 65 inches. Although the yearly rainfall is generally well distributed, significant rain events can be experienced in the watershed. A map of the Eastern U.S. indicating rainfall energy used in the RUSLE equation indicates how rainfall intensity varies per state. Based on the isoerodent map in Figure 2-3, it is evident that Baldwin County experiences some of the most intense rain in the nation. This in turn can lead to greater surface runoff and erosion.

Figure 2-3
Isoerodent map of the Eastern U.S. (EPA 2001).



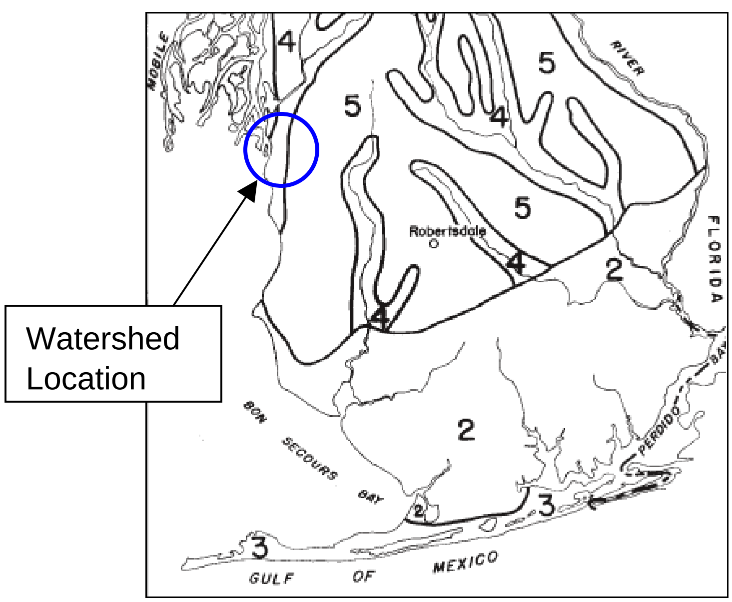
2.3. Physiography

According to the *Soil Survey of Baldwin County*, “Baldwin County is a part of the Gulf Coastal Plain physiographic region known as the Lower Coastal Plain. The county is underlain by five different kinds of deposits or geologic formations…” These formations are 1) River floodplains and terraces 2) Marine terraces 3) Areas of coastal beaches 4) Areas underlain by Hattiesburg clay and 5) Plateaus and ridgetops underlain by the Citronelle formation. The D’Olive Creek watershed falls within areas 4 and 5.

Area 4 is underlain by Hattiesburg clay, which is exposed along the streams in the county. The Hattiesburg clay consists mainly of white, pink, or purple clay and sand of Miocene age. The mostly hilly soils in the county are in this area, and the elevation in the area ranges from 50 to about 300 feet above sea level.

Area 5 is underlain by the Citronelle formation, which is of Pliocene age. It is made up of the plateaus and ridgetops of the county. The Citronelle formation underlies a large part of the county, and rests on the Hattiesburg clay and on older formations. The material in the Citronelle formation in predominately sandy, but it contains thin layers of clay. The clay is mottled gray and purple, red, or yellow, but the color varies according to the degree of weathering.

Figure 2-4
Physiographic areas of D’Olive Creek Watershed



2.4. Land Use

The land use for the D'Olive Watershed has undergone significant urbanization since the late 60s. From the table found in the Thompson Engineering WMP (p. 2-43) referenced from Isphording, 1981, urban development increased from 8% in 1967 to 27% in 1980. Forest and agriculture percentages in the watershed dropped from 91% to 67% for the same time period. Since 1980 the urban development has continued to grow.

Using the LU/LC data found in the Baldwin County GIS database, provided by the City of Daphne, a current land use coverage was developed. This data was supplemented with delineations based off of the most recent aerial photography. Table 2-1 indicates the percentages of each land use as defined in the hydrologic model used in the analysis. Using the percentages in the table, it can be seen that forest and agriculture account for about 45% of the watershed. This is a significant drop from the 67% forest and agriculture in 1980. Urban areas have increased from 27% to around 46% during the same time frame.

Table 2-1
Land Use and Percent Watershed Coverage

Land Use	% of Watershed
Agriculture	8.7
Water	1.1
Wetlands	6.2
Commercial	8.6
Grass / Brush / Shrubs	9.1
Woods	27.3
Barren	1.0
High Residential	8.1
Med Residential	24.3
Low Residential	5.6

An excerpt from Thompson p. 2-51 lists the subdivisions found within the watershed, the acreage of the subdivision, and the number of associated detention ponds. Table 2-2 indicates that the two largest subdivisions were designed without detention ponds. Undetained development exacerbates degradation of streams by increasing volume of discharge, peak discharge, and decreasing time of concentration.

Table 2-2
Excerpt from WMP indicating Subdivisions in Watershed

ID [1/]	Subdivision Name	Acreage in Watershed [2/]	Number of Detention Ponds [3/]
1	Lake Forest	1,660.8	0
2	Timber Creek	753.4	0
3	Canterbury Place	32.0	1
4	Bristol Creek	11.8	0
5	Sehoy	115.6	1
6	Sommerset Place	7.3	1
7	Estates of Tiawasee – Phase I	47.4	0
7	Estates of Tiawasee – Phase II	51.4	2
8	French Settlement	131.1	3
9	Brookhaven	57.9	0
10	Stratford Glen	52.8	0
11	Creekside	57.3	2
12	Brookside	4.9	0
13	Eagle Creek	38.8	1
14	The Park at Whispering Pines [4/]	8.0	1
15	Pecan Trace	6.3	1
16	Charleston Oaks	11.5	1
17	Caroline Woods	7.0	1
18	Timberline Court	10.0	1
19	Krystal Ridge	5.3	1
20	Oak Creek	21.0	2
21	Regency Oaks	34.3	0
22	D'Olive Estates	23.0	0
23	Wilson Heights	104.5	0
24	West Minister Gates	34.2	1
25	Spanish Village	21.3	0
26	Falls Church	4.9	0
27	Wakefield	6.3	0
28	Rolling Hills Place	6.6	1
29	Wood Forest	7.1	1
30	Oakstone	47.7	0
	Total	**3,381.5 acres**	**22**

[1/] ID numbers used to identify subdivision locations on Figure 2-24.
[2/] Acreage actually located within D'Olive Watershed. Portions of some subdivisions may extend into neighboring watersheds producing an overall total acreage larger than that listed in the table.
[3/] See Figure 6-12 which shows the locations of the individual detention ponds.
[4/] Group living facility (i.e., apartment complex).

3. Model

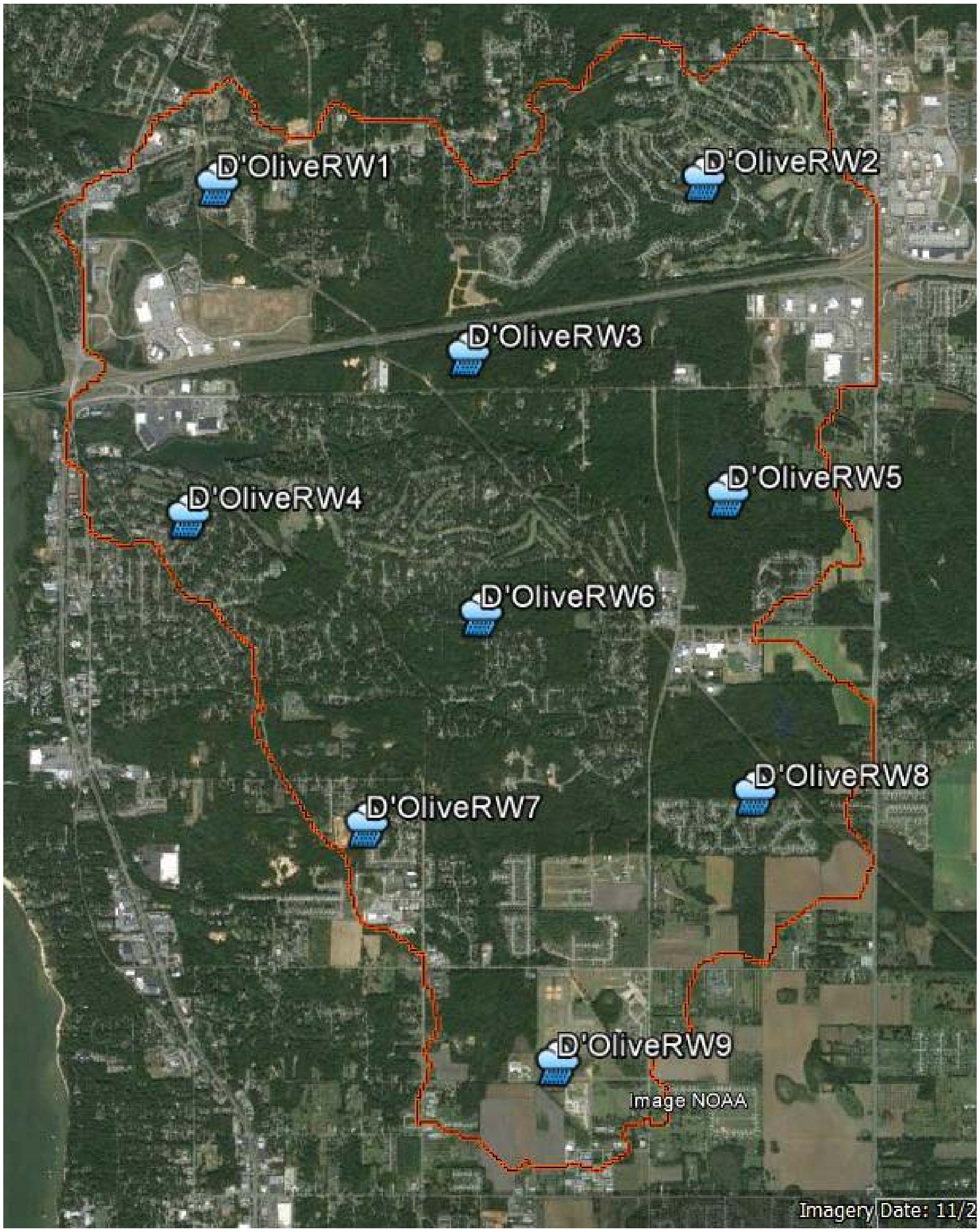
3.1. General

The hydrologic model used to evaluate the D'Olive Creek Watershed is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA is a U.S. Army Corps of Engineers (USACE) physically-based, distributed parameter hydrologic model with sediment and constituent fate and transport capabilities. Features include two dimensional (2-D) overland flow, 1-D stream flow, 1-D infiltration, 2-D groundwater, and full coupling between the groundwater, shallow soils, streams, and overland flow. Sediment and constituent fate and transport are simulated in the shallow soils, overland flow plane, and in streams and channels. GSSHA can be used as an episodic or continuous model where soil surface moisture, groundwater levels, stream interactions, and constituent fate are continuously simulated. Parameters used to generate a GSSHA simulation include rainfall data, digital terrain data, land use data, and soils data. The Watershed Modeling System (WMS v9.1) was used as the graphical user interface for entering data in the hydrologic model.

3.2. Rainfall Data

One of the strengths of the GSSHA model is the ability to perform long-term simulations. A key element in forecasting discharges for future storm occurrences depends upon good rainfall data. For the rainfall component Trimble’s RainWave precipitation monitoring service was used. The service allows a user to enter a latitude and longitude for a point of interest. Once this point is entered into the system, various rainfall data can be obtained. For the modeling simulations 10-minute rainfall intervals were utilized. This data was formatted for a GSSHA long-term simulation. Figure 3-1 indicates the RainWave point locations used for gathering rainfall distribution data.

Figure 3-1
D'Olive Creek Watershed with RainWave Point Locations



3.3. Digital Terrain Data

The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the model, one-foot Light Detection and Ranging (LiDAR) data provided by the City of Daphne was used to generate the digital elevation model (DEM). Using WMS, the 3D LiDAR contours lines were triangulated and then converted to a DEM. Once the DEM was built, it was used for basin delineation.

After the basin had been delineated, it was necessary to verify the watershed boundary limits. Ashley Campbell with the City of Daphne provided a map with field verified boundary limits that were manually incorporated in the model. The DEM data was then used to generate cell elevations for the gridded model. Figure 3-2 indicates the field verified boundary limits provided by the City. Figure 3-3 indicates the topographic data that was used in the model.

Figure 3-2
Map with field verified watershed boundary limits

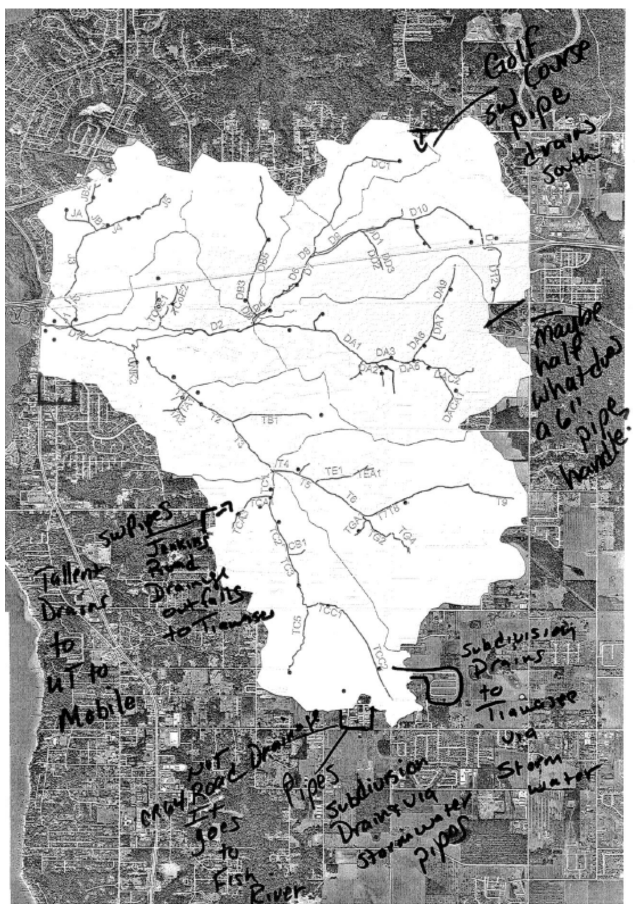
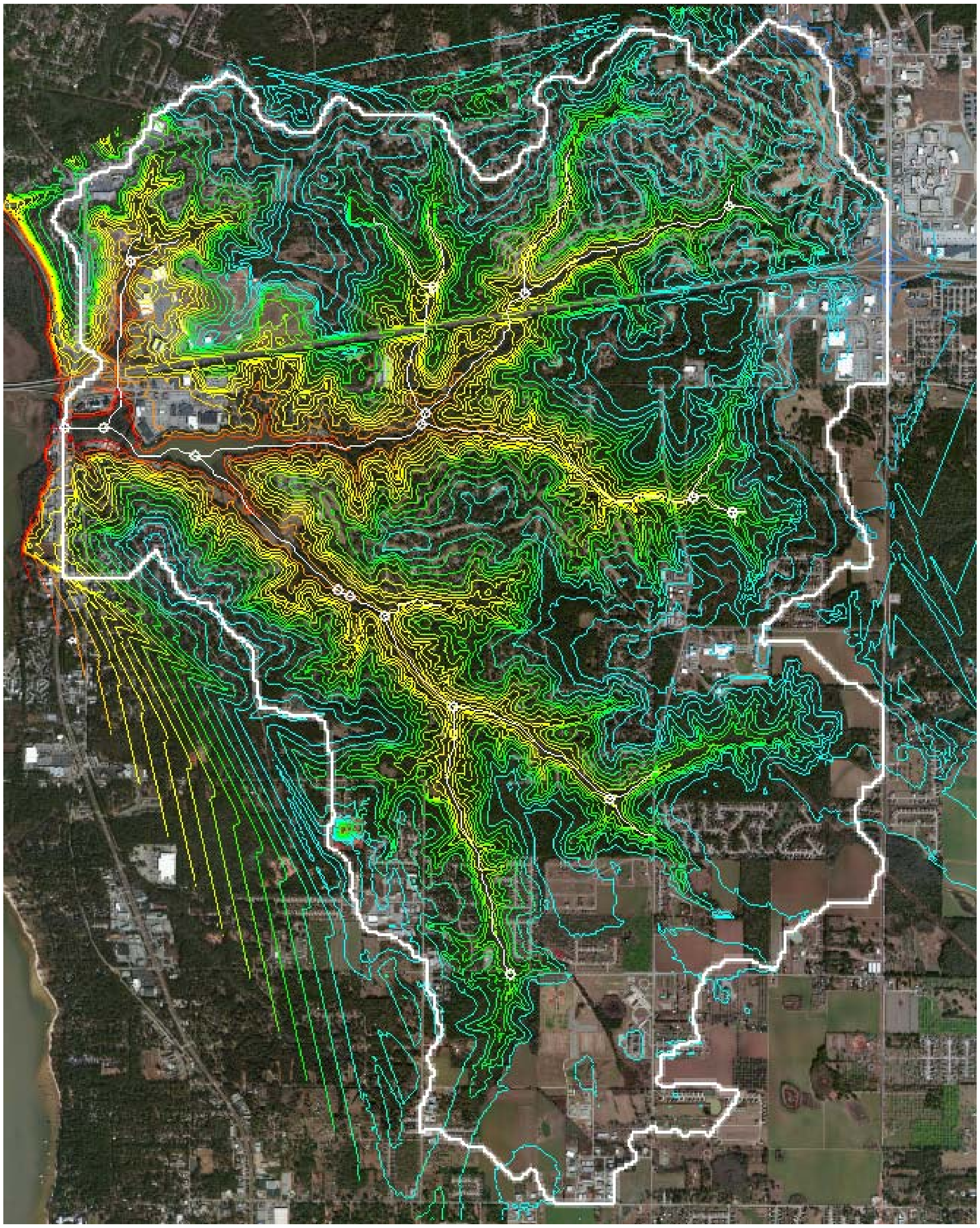


Figure 3-3
D'Olive Creek Watershed with Topographic Data



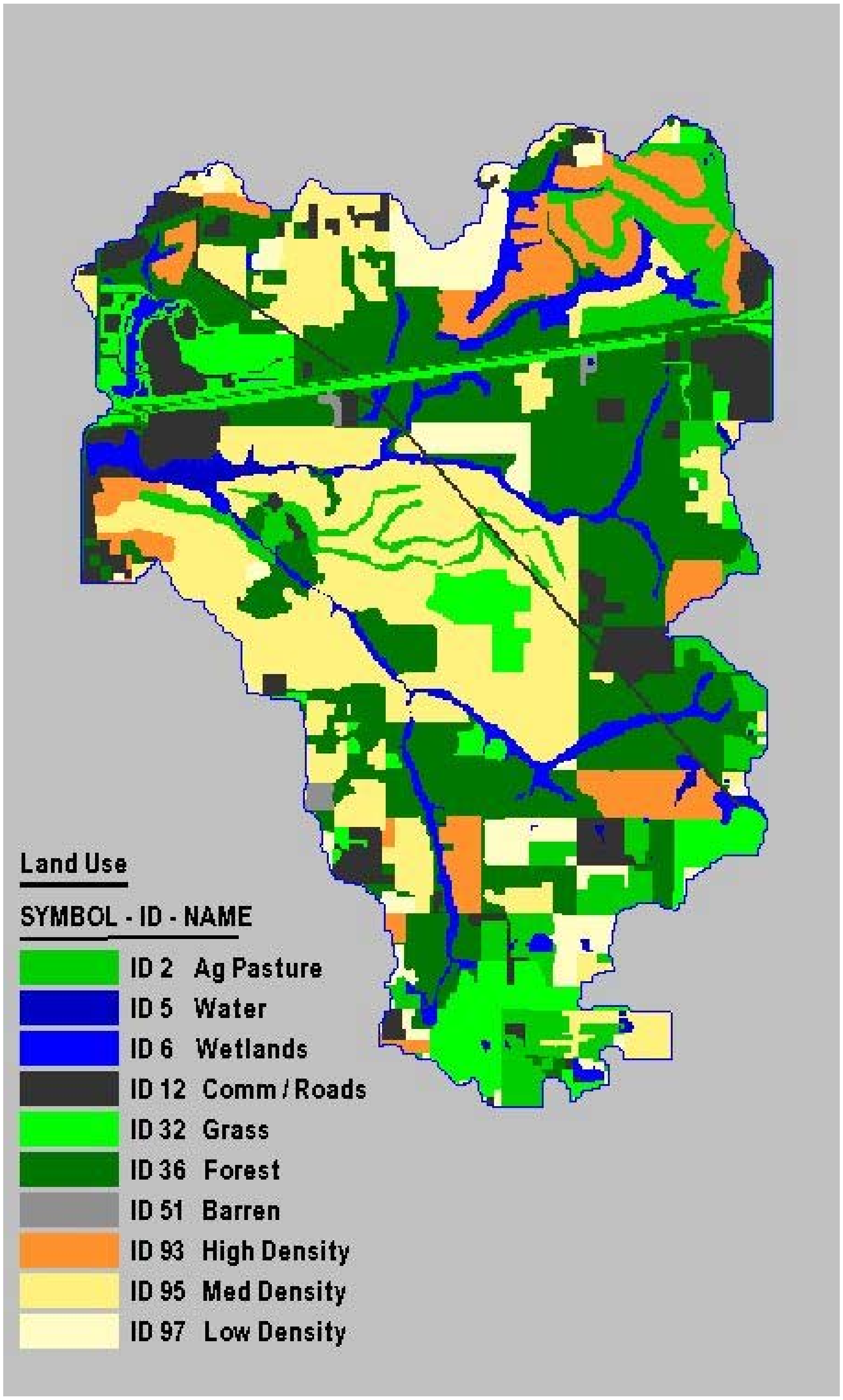
3.4. Land Use

The land use component of the model is necessary to define the various overland flow types throughout the basin. The roughness of each land use type is described by a Manning's 'n' value. A shapefile of the land use was provided by the City of Daphne. The shapefile was converted to feature objects to be used in the model. It was necessary to simplify some of the land use descriptions for calibration purposes. Using geo-referenced aerial photography also provided by the City of Daphne, land use was checked to ensure all areas were properly assigned. Table 3-1 lists the land use types and the respective calibrated 'n' values assigned to them. Figure 3-4 indicates the land use assignments.

Table 3-1
Land Use and Calibrated Manning's 'n' Values

GSSHA ID	Land Use	Calibrated Manning's n
2	Agriculture	0.144
5	Water	0.011
6	Wetlands	0.150
12	Commercial	0.011
32	Grass / Brush / Shrubs	0.166
36	Woods – Good	0.196
51	Barren	0.050
93	High Residential	0.059
95	Med Residential	0.093
97	Low Residential	0.191

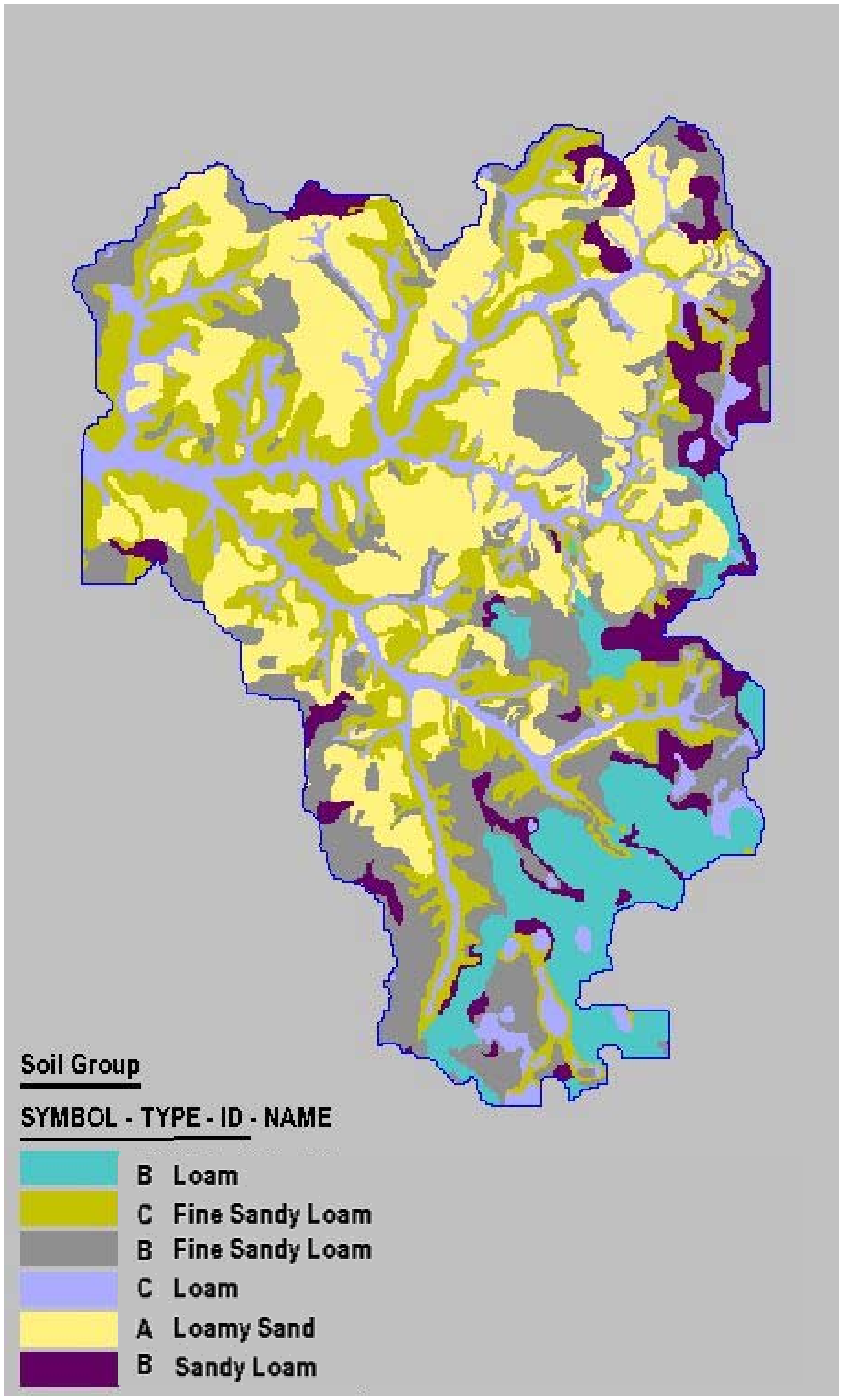
Figure 3-4
D'Olive Creek Watershed with Digitized Land Use



3.5. Soils

The GSSHA model also has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage is used for defining infiltration into the soil. The infiltration method used is Green and Ampt (G&A) with soil moisture redistribution. Soil parameters used by the G&A method include hydraulic conductivity, porosity, capillary head, pore distribution index, residual saturation, and field capacity. This allows the GSSHA model to evaluate the soil's ability to infiltrate stormwater runoff in determining the peak discharge and volume of storm events. Soils data shapefiles downloaded from United States Department of Agriculture (USDA)'s Web Soil Survey were converted to feature objects to be used in the model. Figure 3-5 indicates the soil data that has been incorporated into the model.

Figure 3-5
D'Olive Creek Watershed with Digitized Soil Type



3.6. Gridded Model

Once the topography, land use, and soil layers have been incorporated into the model, each layer is divided into individual grid cells. For the D'Olive Creek watershed model, a 20-meter x 20-meter (66 feet x 66 feet) grid size was utilized (Figure 3-6). The settings for GSSHA require the units to be in the International System of Units (SI). The total drainage area to the designated outlet is approximately 12.1 square miles. Over the entire watershed this generates approximately 79,000 grid cells. Figures 3-7 and 3-8 indicate the gridded land use and gridded soil types.

After the watershed is gridded, each grid cell contains its own unique elevation, land use type, and soil type. The model uses the elevation information to determine flow direction between adjacent cells. The land use is assigned a Manning's 'n' roughness coefficient to describe overland flow roughness. The soil type is used to determine the amount of infiltration each cell will have.

Figure 3-6
D'Olive Creek Gridded Watershed - 20 m X 20 m Grid Cell Size

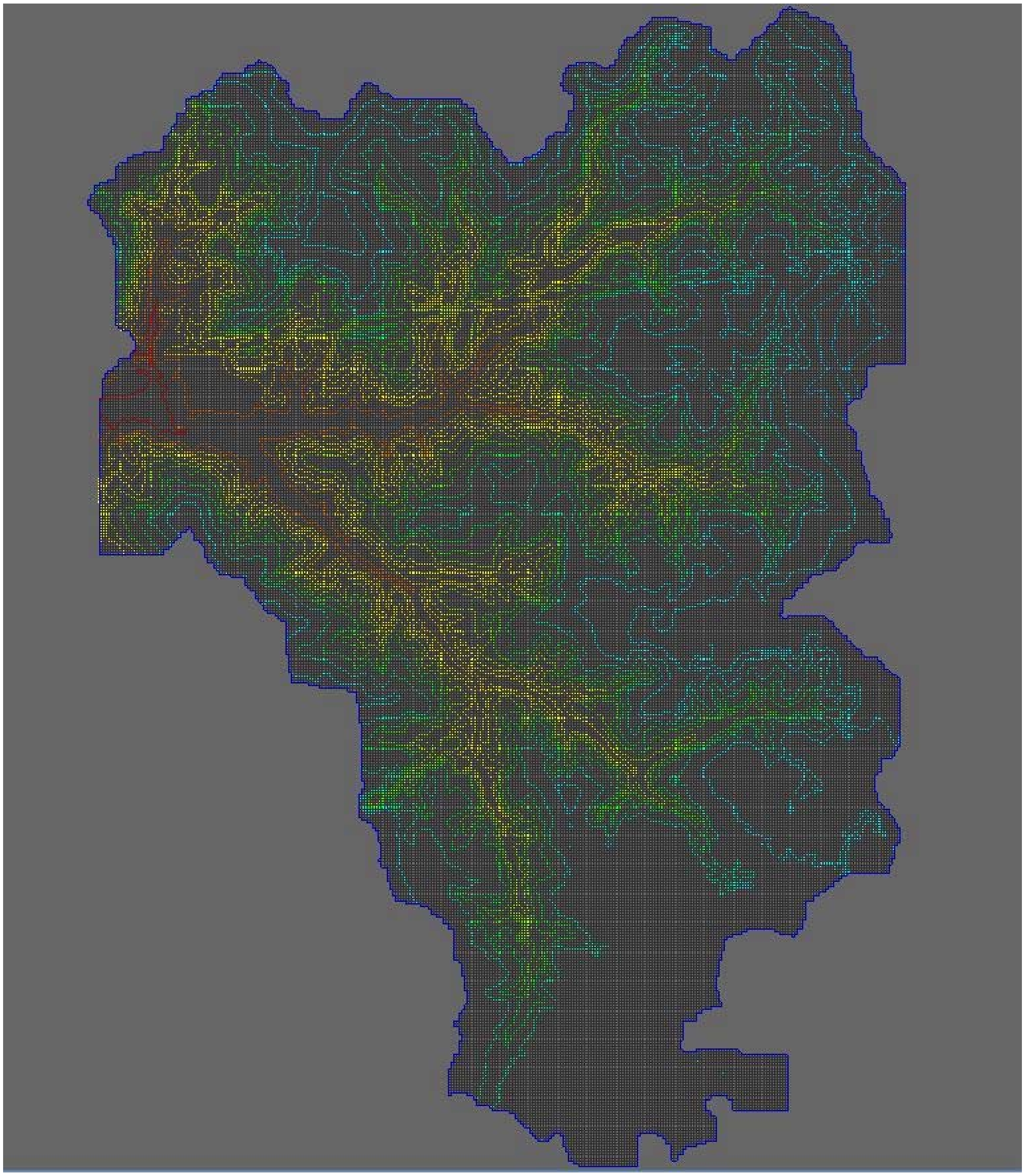


Figure 3-7
D'Olive Creek Watershed Gridded Land Use

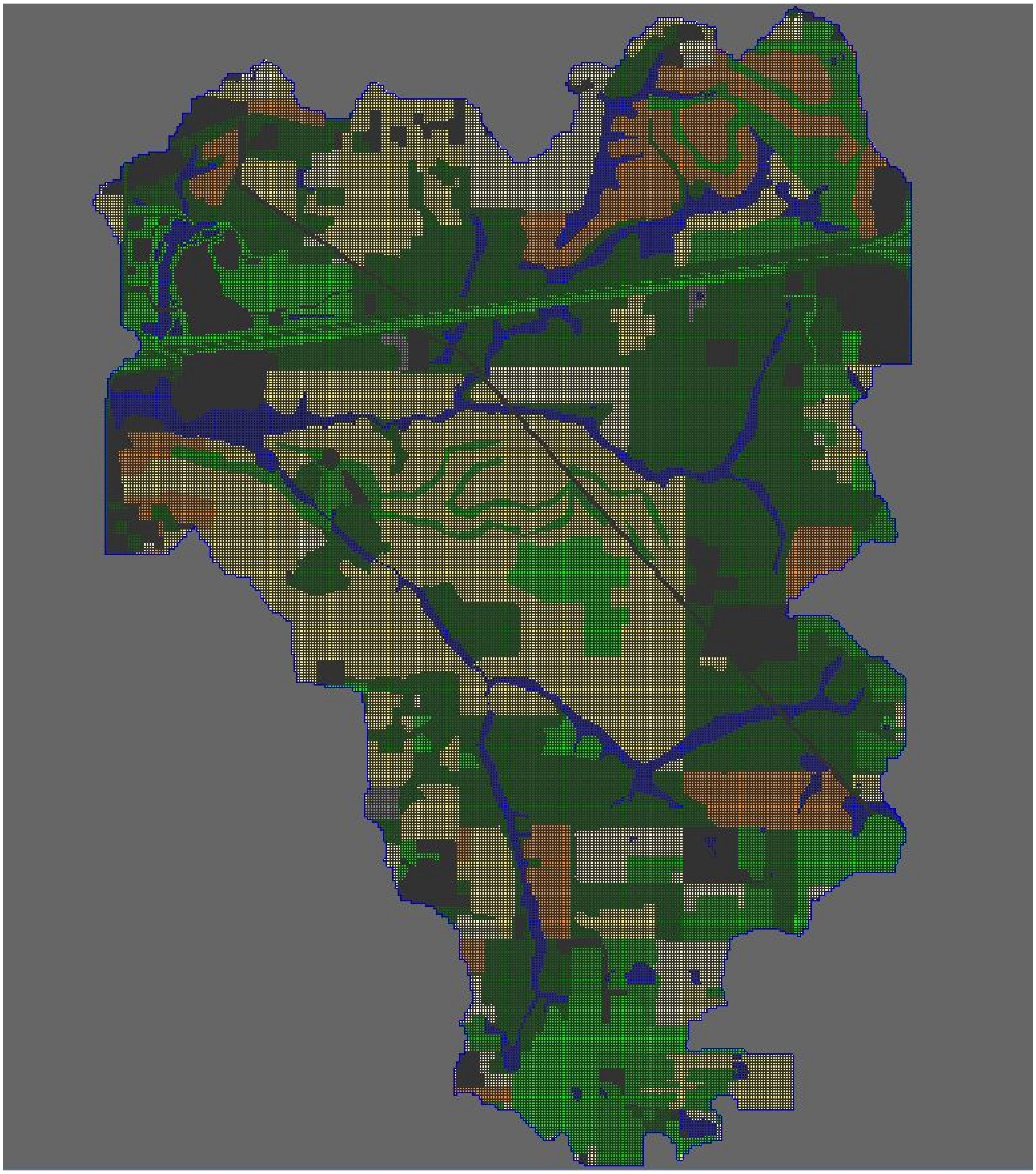
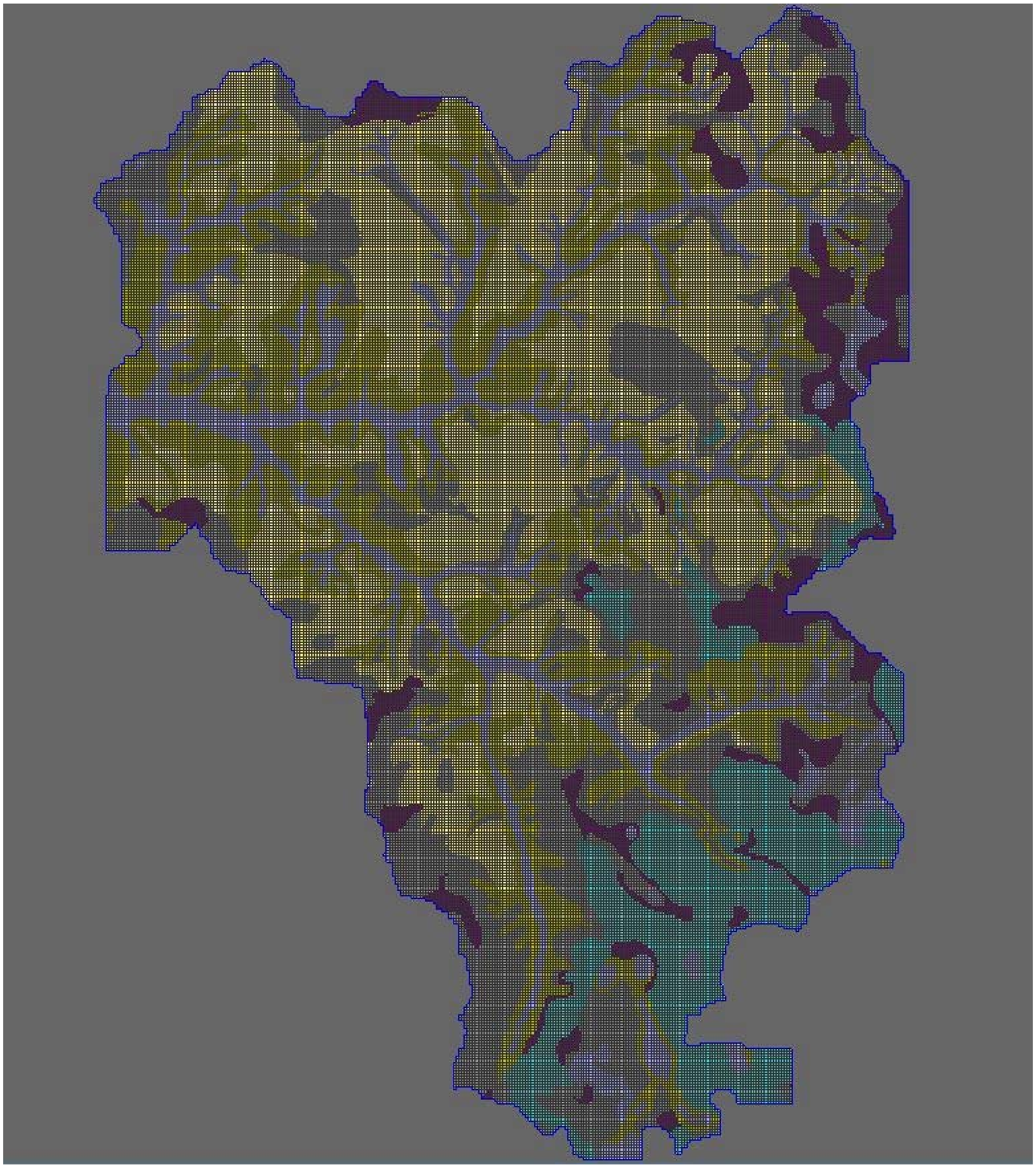


Figure 3-8
D'Olive Creek Watershed – Gridded Soil Type



3.7. Calibration

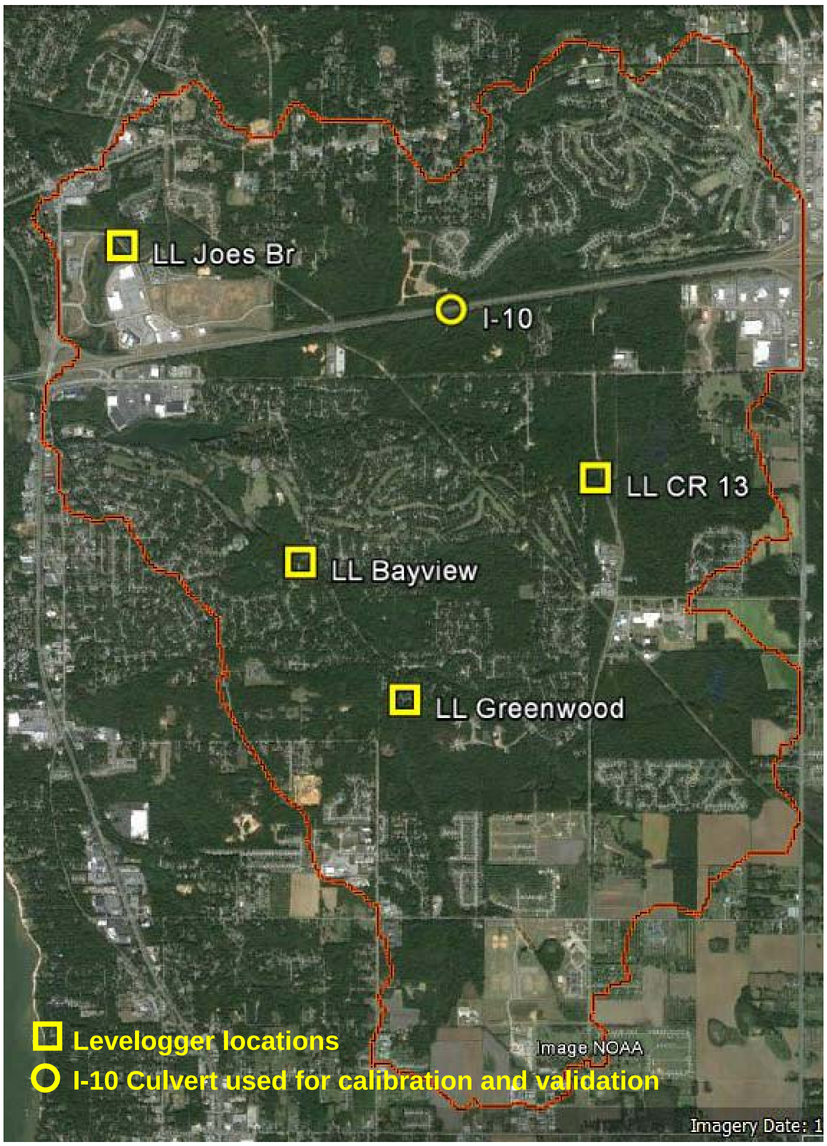
For a model to be used for forecasting it is best to calibrate to real world storm events. Calibration requires both historic rainfall data and river water surface elevations (stages) or discharges during the rain event. With the rainfall being obtained by Trimble's RainWave, it was necessary install gauges in the watershed to determine stream stages and discharges. There are currently no USGS gauges operating in the watershed. Using watershed maps and information provided by the city regarding priority areas, four locations were chosen for the watershed. Figure 3-9 indicates the locations of the four Solinst Leveloggers installed throughout the basin. The first gauge was installed on Greenwood Drive over a tributary of Tiawasee Creek. The second gauge was installed on Bayview Drive over Tiawasee Creek. The third gauge was installed just downstream of CR 13 on a tributary to D'Olive Creek. The fourth gauge was installed on Joe's Branch just above Town Centre Avenue. The gauges were installed in locations with a good control section that could be used for calculating discharges. These locations were also chosen in order to maximize the drainage area in which to calibrate, for ease of access, and for limiting the possibility of being tampered with.

Prior to installation of the gauges, a model calibration was performed using a rating curve generated at the I-10 box culvert on D'Olive Creek by Marlon Cook of the Geological Survey of Alabama, Tuscaloosa, Alabama. On July 16, 2011, the watershed draining to I-10 experienced approximately 9.2 inches in 5 hours (Figure 3-10 and Figure 3-11). A calibration to the rating curve developed by Cook was performed and a plot of the model discharges against the field-measured discharges can be found in Figure 3-12.

The leveloggers were installed on February 15, 2014. After installation, the watershed experienced a rain event on March 28, 2014. The rain occurred between 10:00 p.m. on March 28th to 5:00 a.m. on March 29th. This event produced an average of 4.6 inches (Figure 3-13 and 3-14). The calibrated model variables used for the July 16, 2011 event were then applied to the March 28, 2014 event. Using the 2011 calibrated variables, the model resulted in discharges much lower than that indicated by the levelogger data. The infiltration variables were adjusted in order to better match the discharges from the March 2014 event. A plot of the GSSHA output against the levelogger output can be found in Figures 3-15 to 3-18. The GSSHA output in these figures used the updated calibration parameters.

A second rainfall event fell on April 14th. This rainfall produced a much more intense rainfall with around 4 inches of rain falling in approximately 4 hours (Figures 3-19 and 3-20). The gauge at the southern portion of the watershed (RW9) experienced 5 inches in the four-hour period (Figure 3-20). The updated model variables used for the March 28th event were also used for the April 14th event. Since there were no changes in model parameters, the April 14th event became the first validation event. A plot of model output and levelogger output can be found in Figures 3-21 to 3-24.

Figure 3-9
D'Olive Creek Watershed with Levelogger Locations



On April 29, 2014 the watershed experienced a 100-year storm event. Just over a 24-hour period, approximately 13.3 inches of rain fell on the watershed (Figures 3-25 and 3-26). A site inspection was performed on May 2, 2014 to assess the watershed. During the site inspection it was noted that the levelogger attached to a tree downstream of CR 13 had been displaced due to erosion of the bank (Figure 3-27). Due to the amount of rainfall, calibration/validation was enhanced by using high water marks at the culvert under CR 13 (Figure 3-28) and at the I-10 culvert on D'Olive Creek (Figure 3-29). A hydraulic model using the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) was built implementing each of the structures. Discharges were entered into the model until the water surface elevations matched the high water marks determined in the field. These discharges were then compared to those calculated in the GSSHA hydrologic model. Table 3-2 compares the discharges calculated from HEC-RAS and GSSHA.

Table 3-2
Discharge Calibration using CR13 and I-10 Culverts

	High Water Mark from Upstream Invert	HEC-RAS Q (cfs)	GSSHA Q (cfs)
CR 13	14.8'	1350	1400*
I-10	8'	3150	3750

* Storage routing occurred behind the CR 13 culvert

These two culverts help supplement the levelogger data. The original calibrated variables from the March 28th event were kept the same making this event the second validation event. A plot of model output and levelogger output for the April 29-30 event can be found in Figures 3-30 to 3-33.

On May 14th a two-inch rain event was analyzed to see if the calibrated/validated variables would be representative of a smaller rainfall. The average rainfall was 1.7 inches in 6 hours with a maximum rainfall of 2.4 inches at gauge RW9 (Figures 3-34 and 3-35). Figure 3-36 and Figure 3-37 indicate the GSSHA output versus the levelogger output for the May 14th event. Output indicates the model provides fairly accurate results for both small and large rains.

Figure 3-10
Rainfall Distribution – July 15-16, 2011

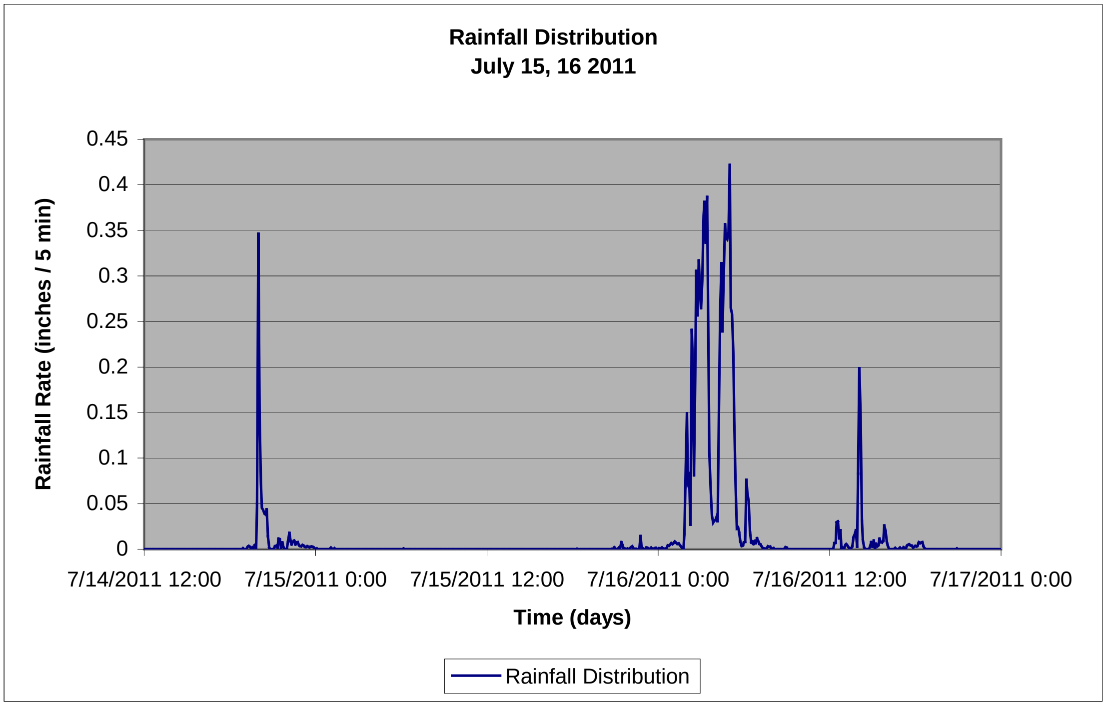


Figure 3-11
Cumulative Rainfall – July 15-16, 2011

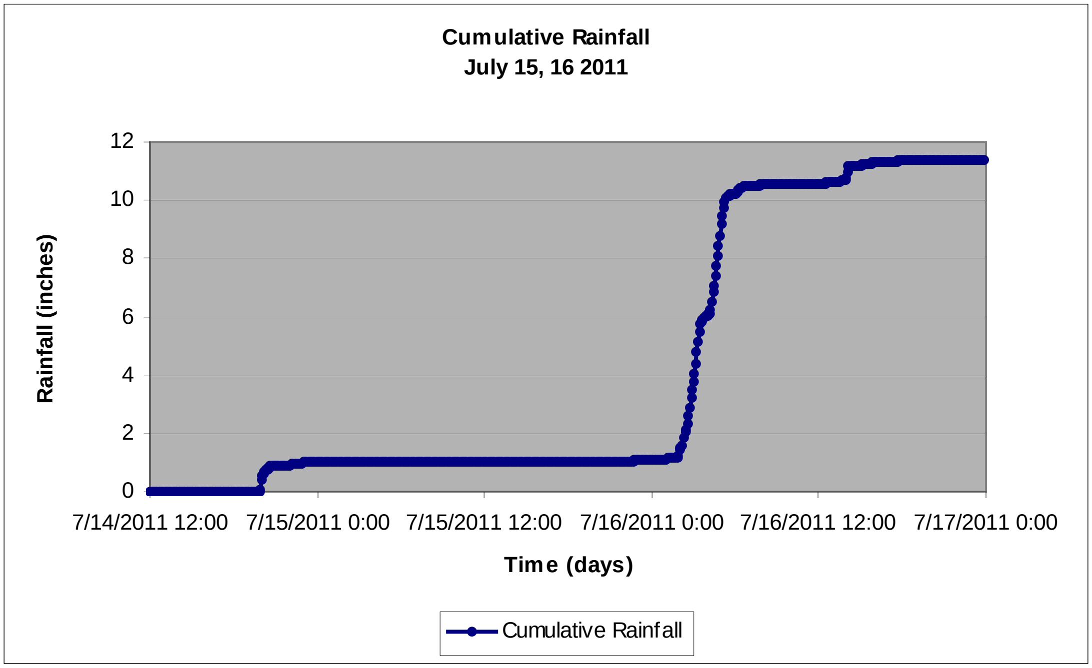


Figure 3-12
Calibration at I-10 Culvert – July 15-16 2011

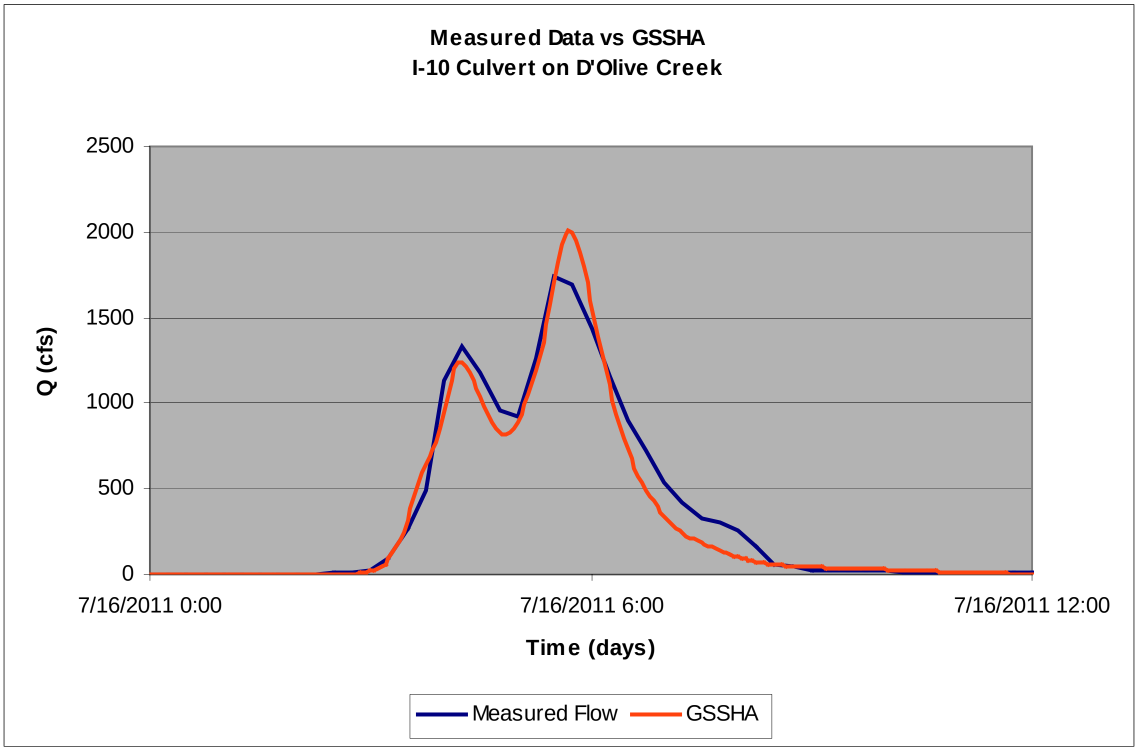


Figure 3-13
Rainfall Distribution – March 28-29, 2014

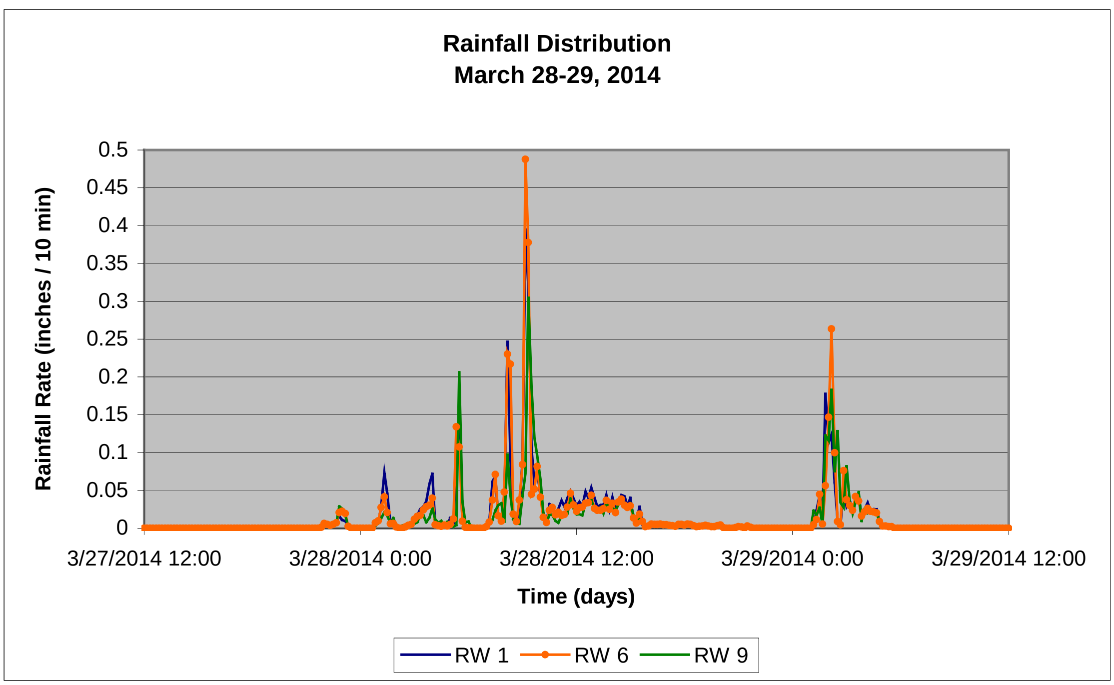


Figure 3-14
Cumulative Rainfall – March 28-29, 2014

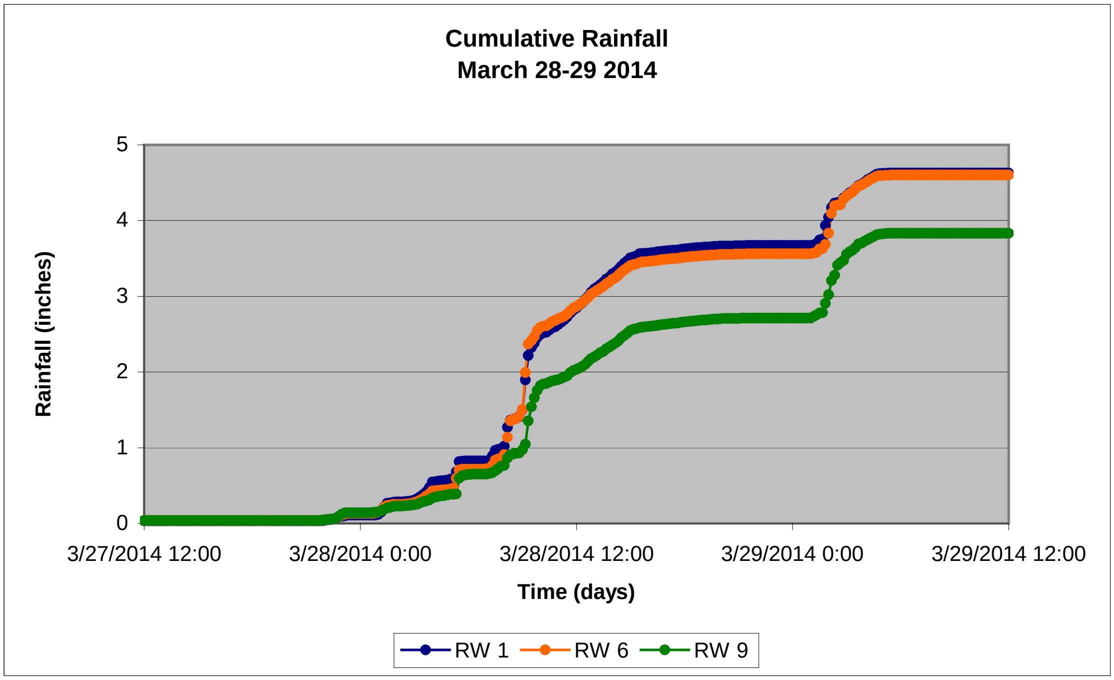


Figure 3-15
Calibration at Joe's Branch - March 28-29, 2014

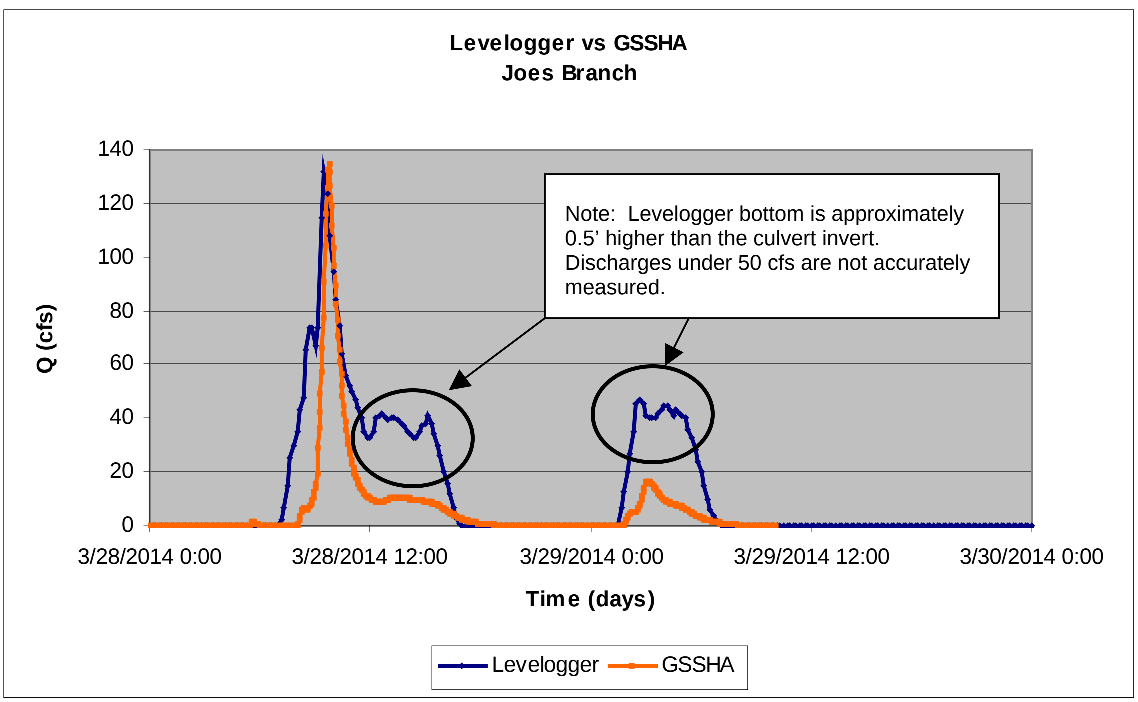


Figure 3-16
Calibration at CR 13 - March 28-29, 2014

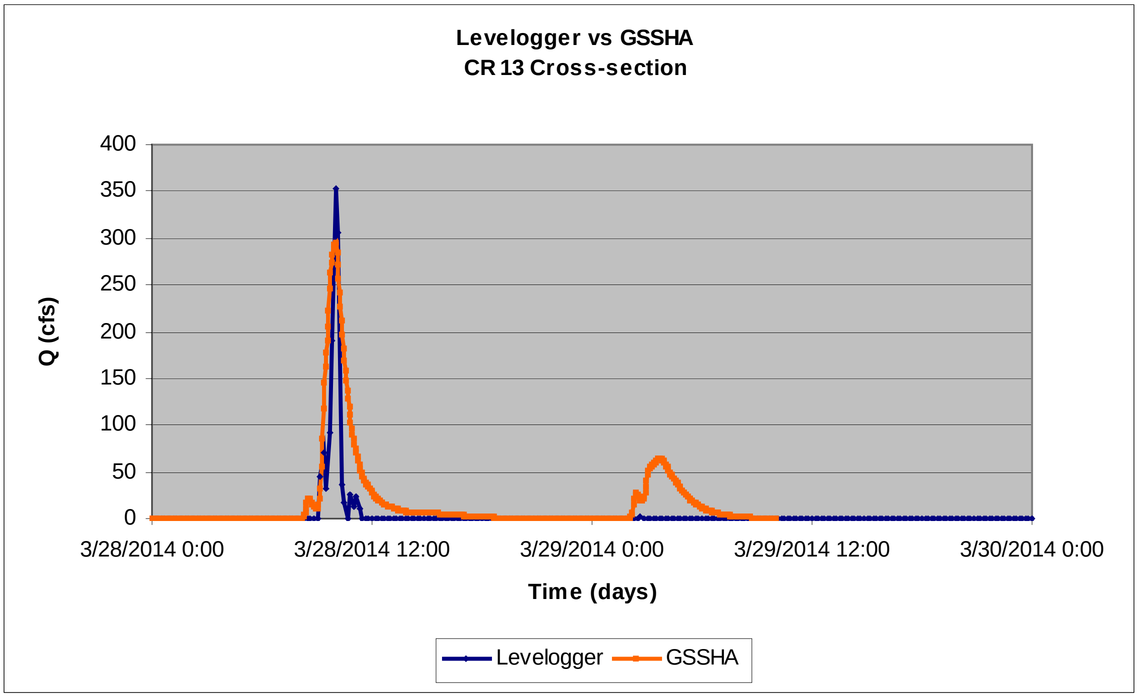


Figure 3-17
Calibration at Greenwood Drive - March 28-29, 2014

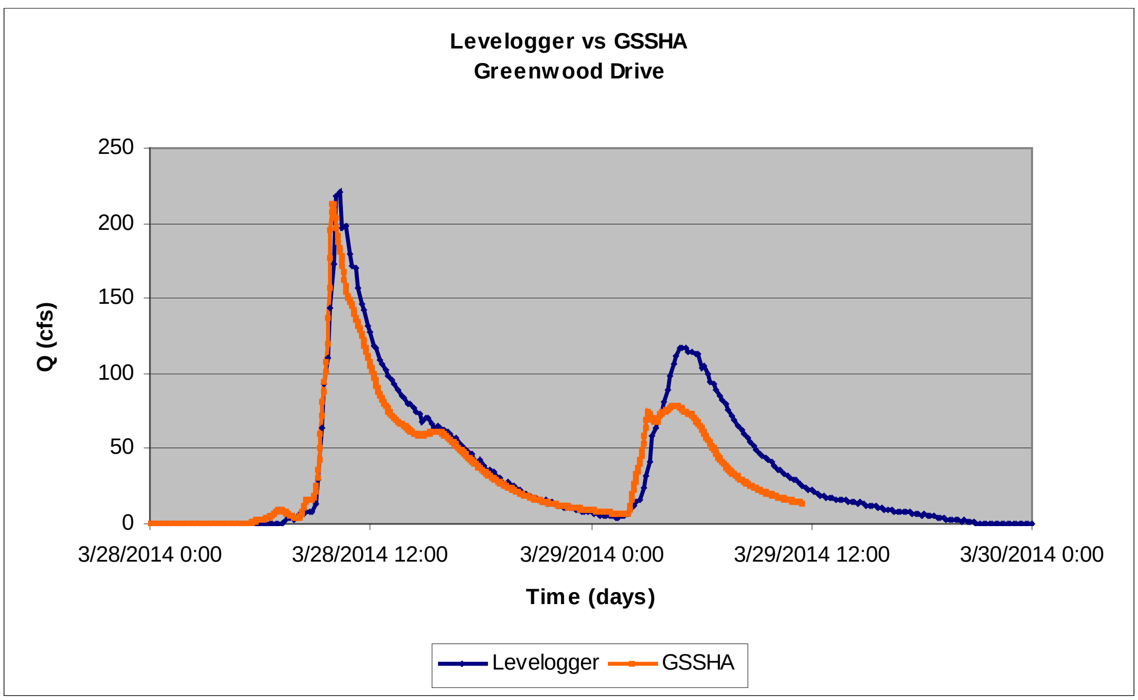


Figure 3-18
Calibration at Bayview Drive - March 28-29, 2014

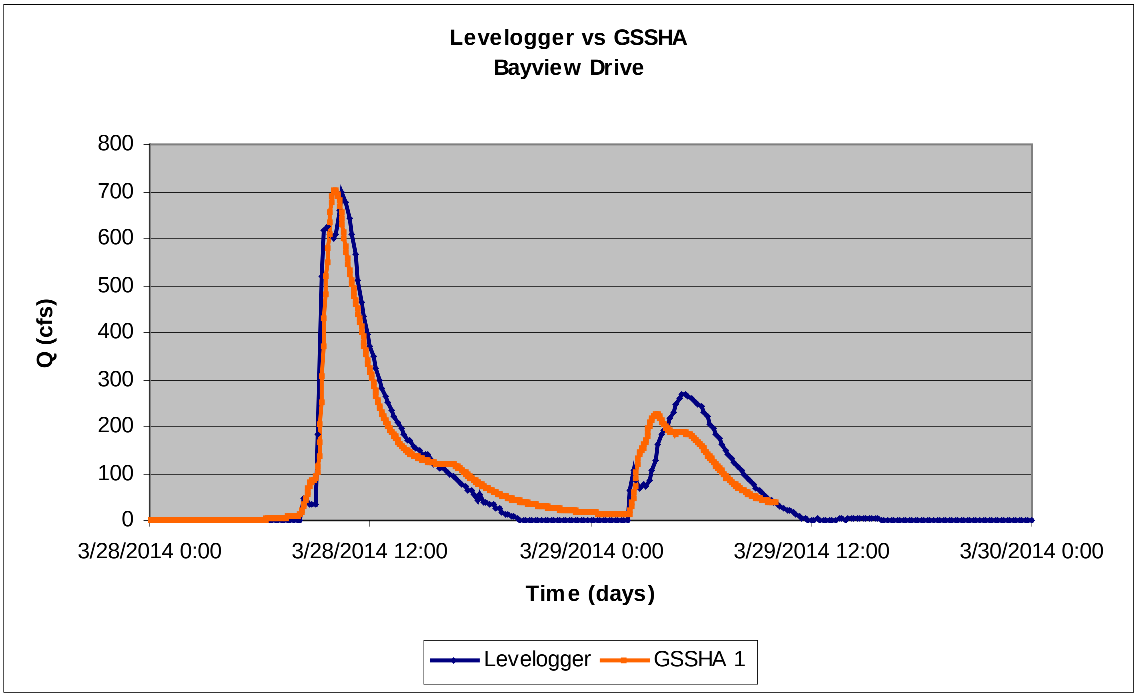


Figure 3-19
Rainfall Distribution – April 14, 2014

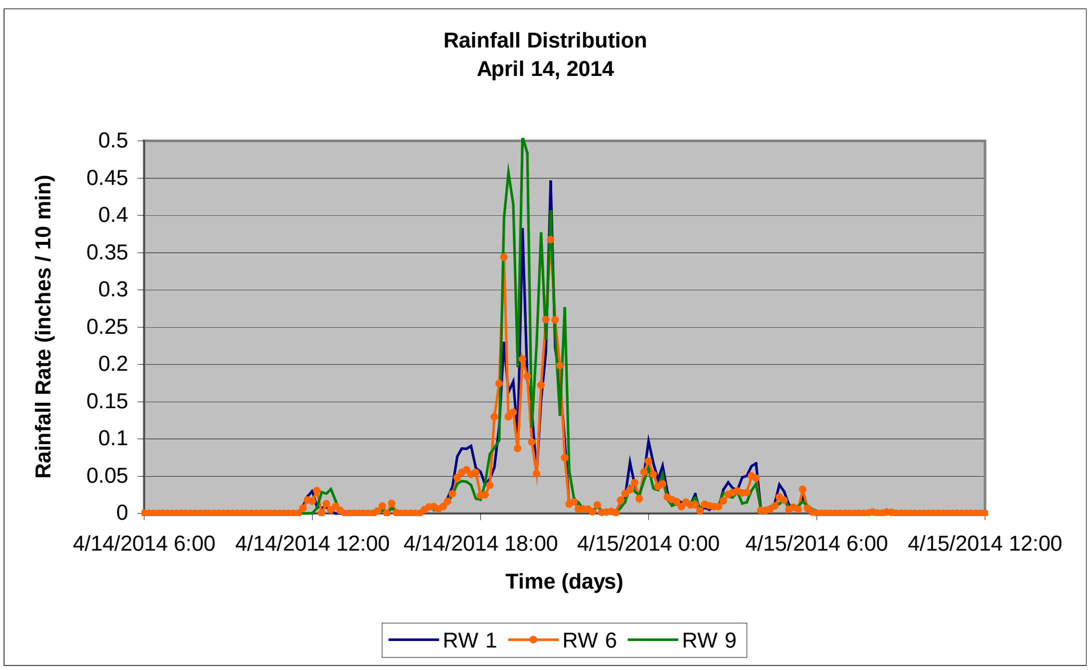


Figure 3-20
Cumulative Rainfall – April 14, 2014

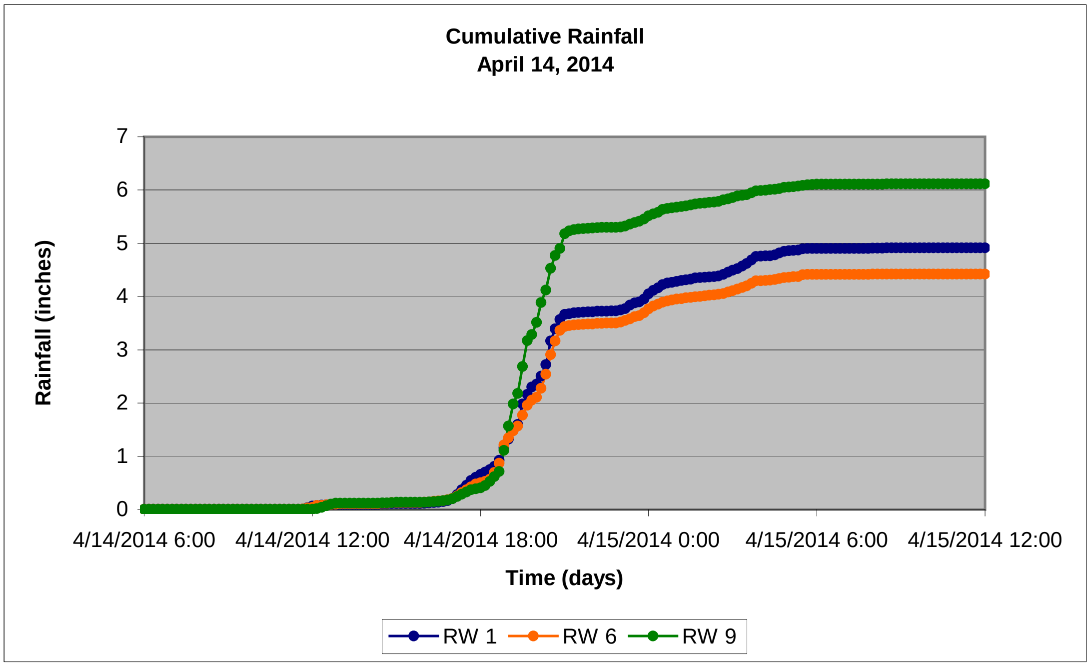


Figure 3-21
Validation at Joe's Branch – April 14, 2014

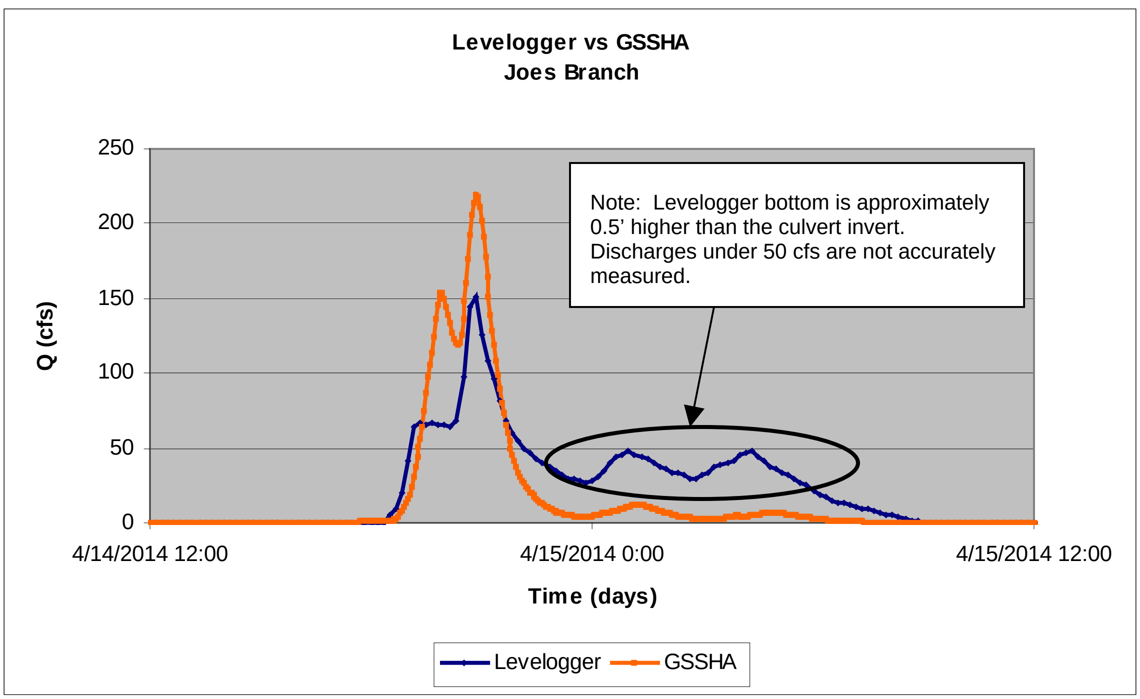


Figure 3-22
Validation at CR 13 – April 14, 2014

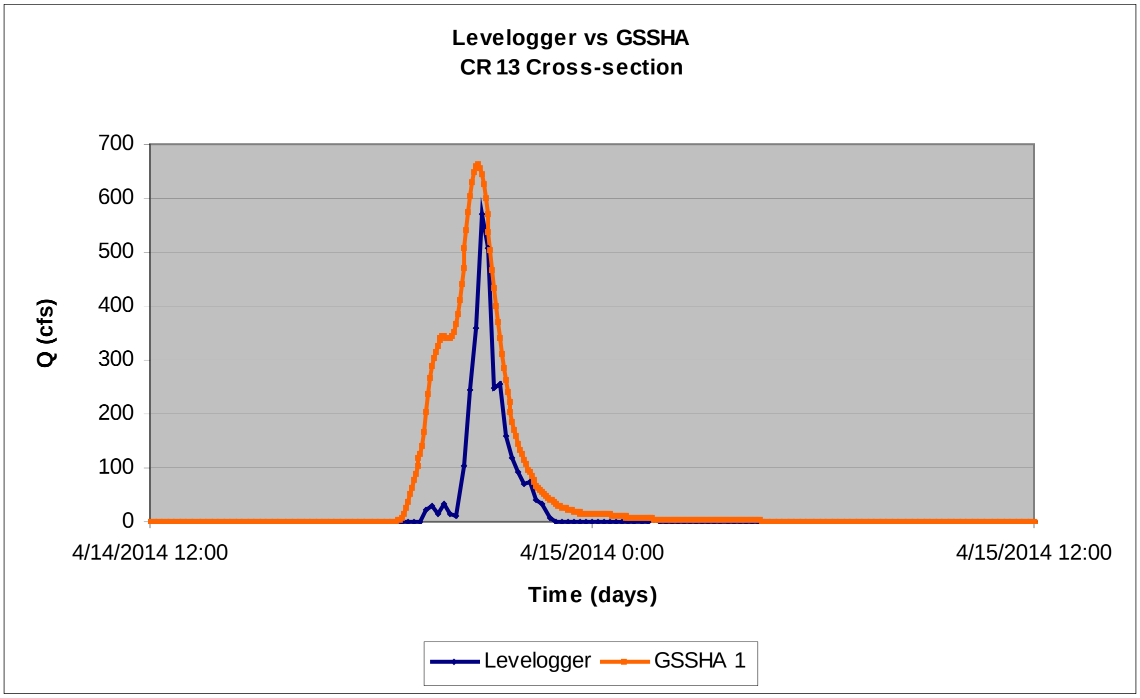


Figure 3-23
Validation at Greenwood Drive – April 14, 2014

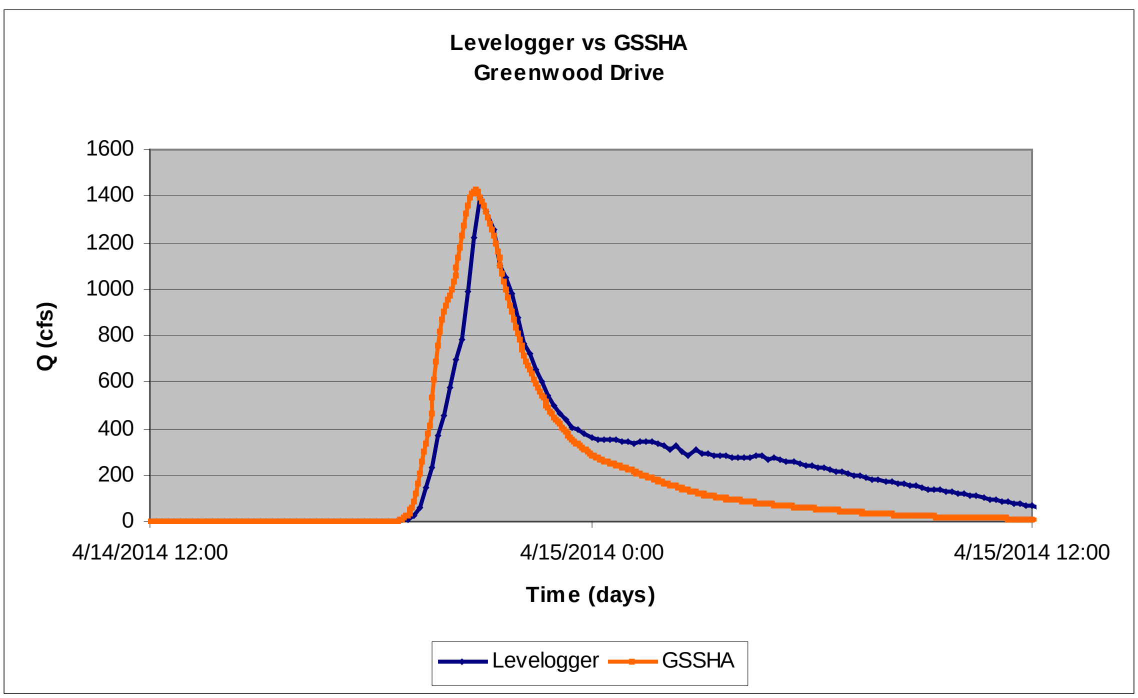


Figure 3-24
Validation at Bayview Drive – April 14, 2014

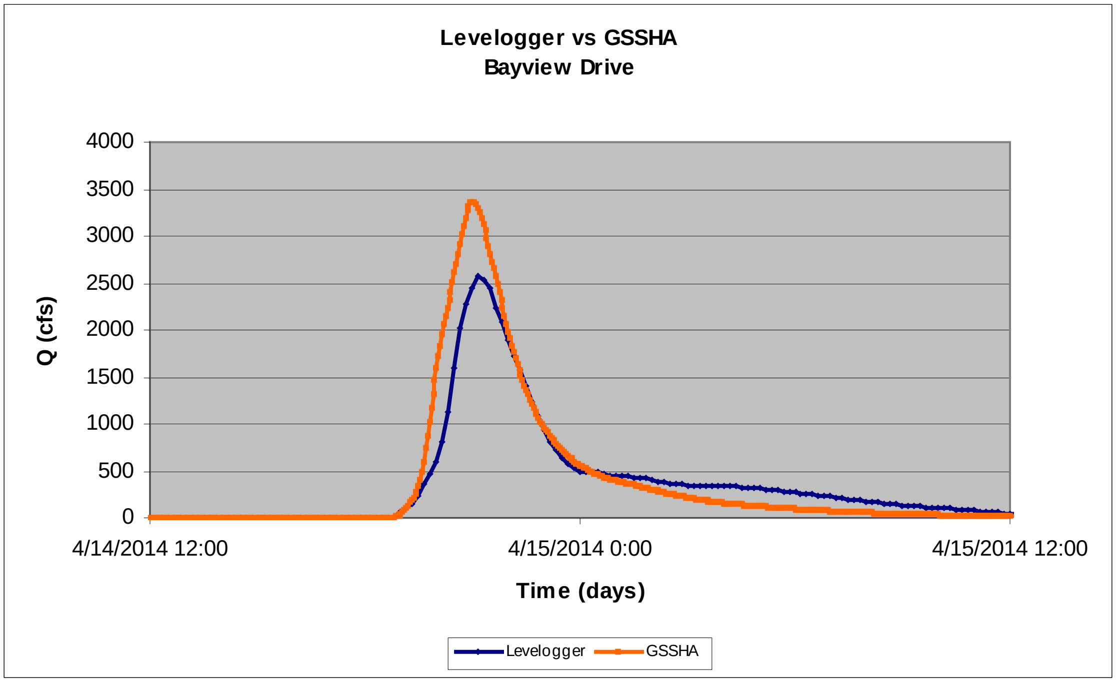


Figure 3-25
Rainfall Distribution – April 29-30, 2014

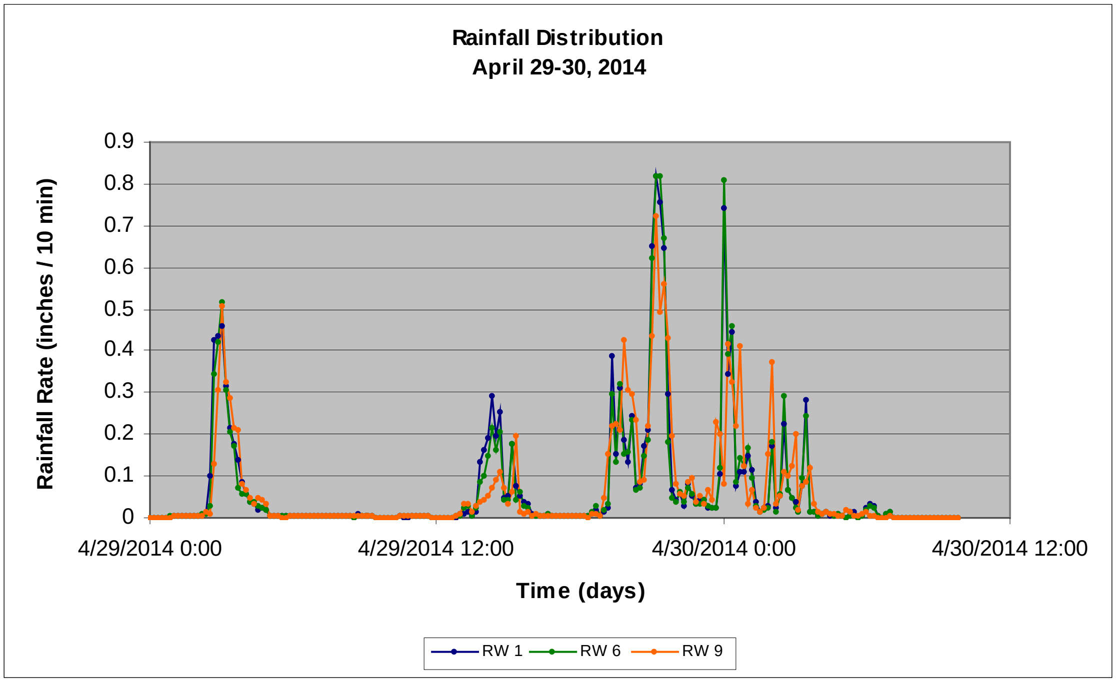


Figure 3-26
Cumulative Rainfall – April 29-30, 2014

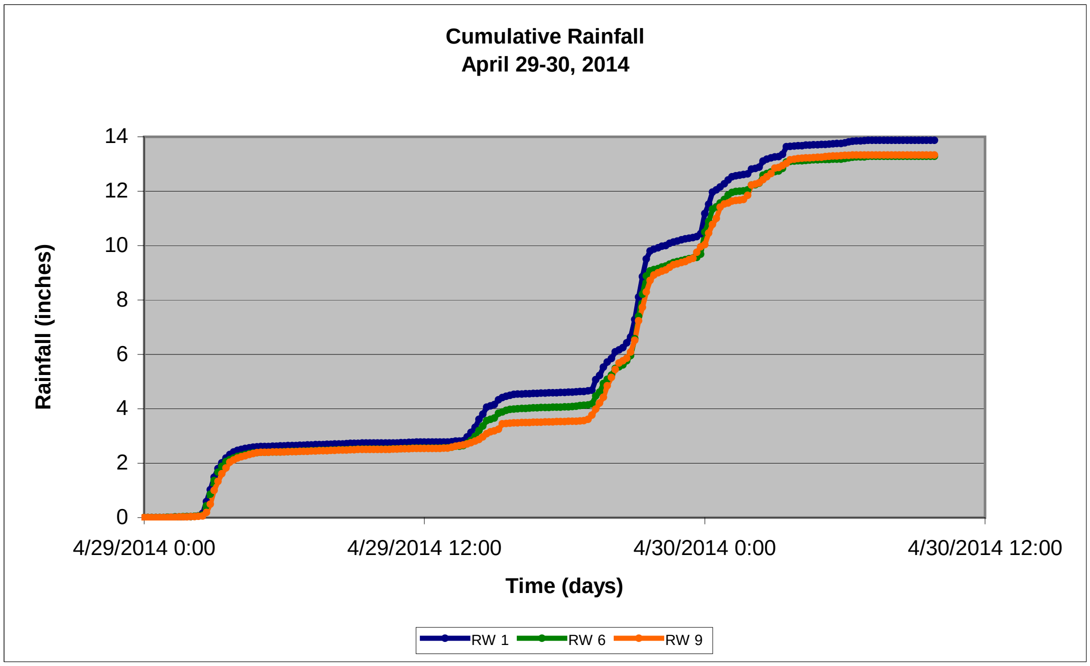


Figure 3-27
Moved Levelogger at CR 13 – April 29-30, 2014

Figure 3-28
High Water Mark CR 13 Culvert – April 29-30, 2014

Figure 3-29
Downstream Scour I-10 Culvert – April 29-30, 2014

Figure 3-30
Validation Joe's Branch – April 29-30, 2014

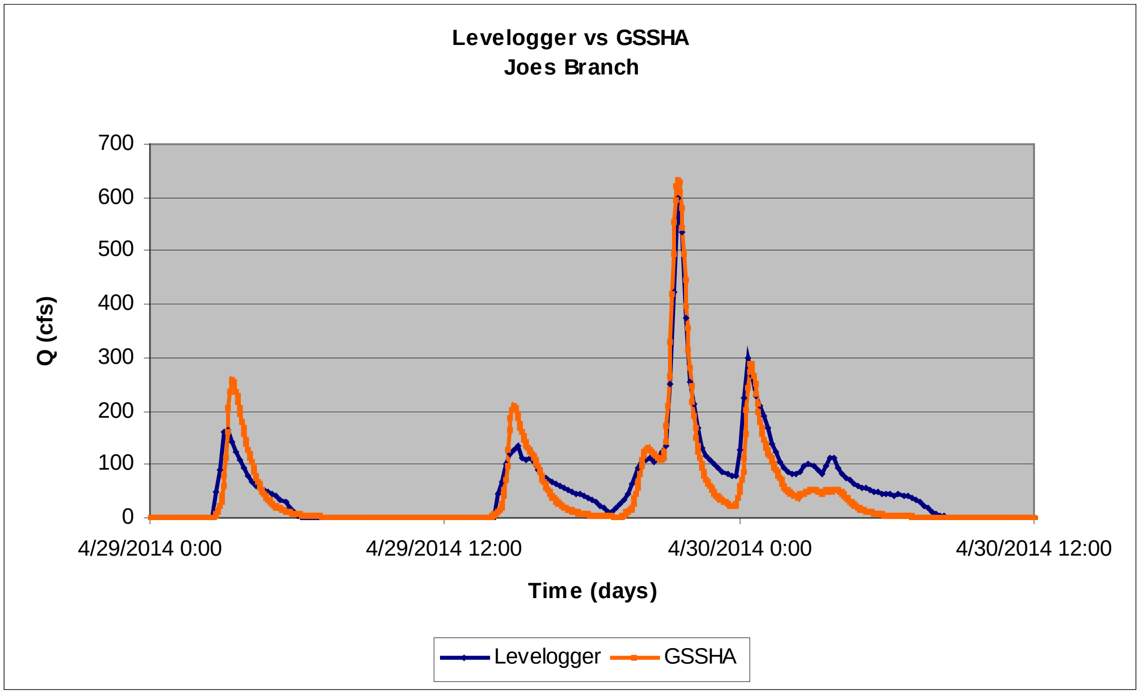


Figure 3-31
Validation CR 13 – April 29-30, 2014

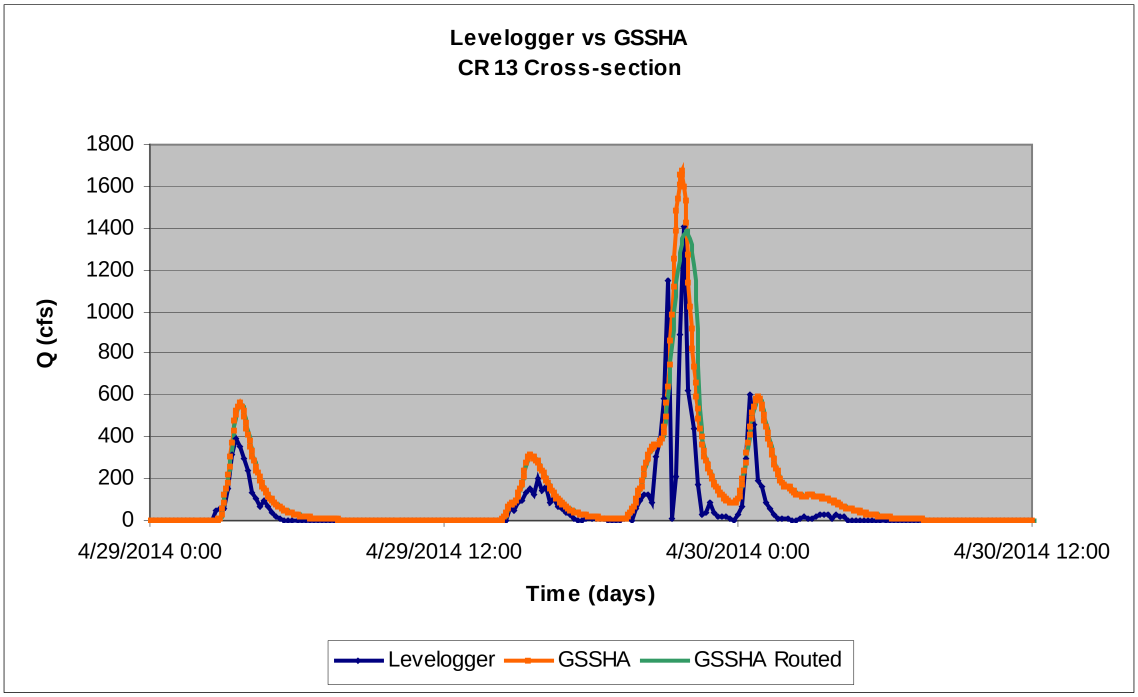


Figure 3-32
Validation Greenwood Drive – April 29-30, 2014

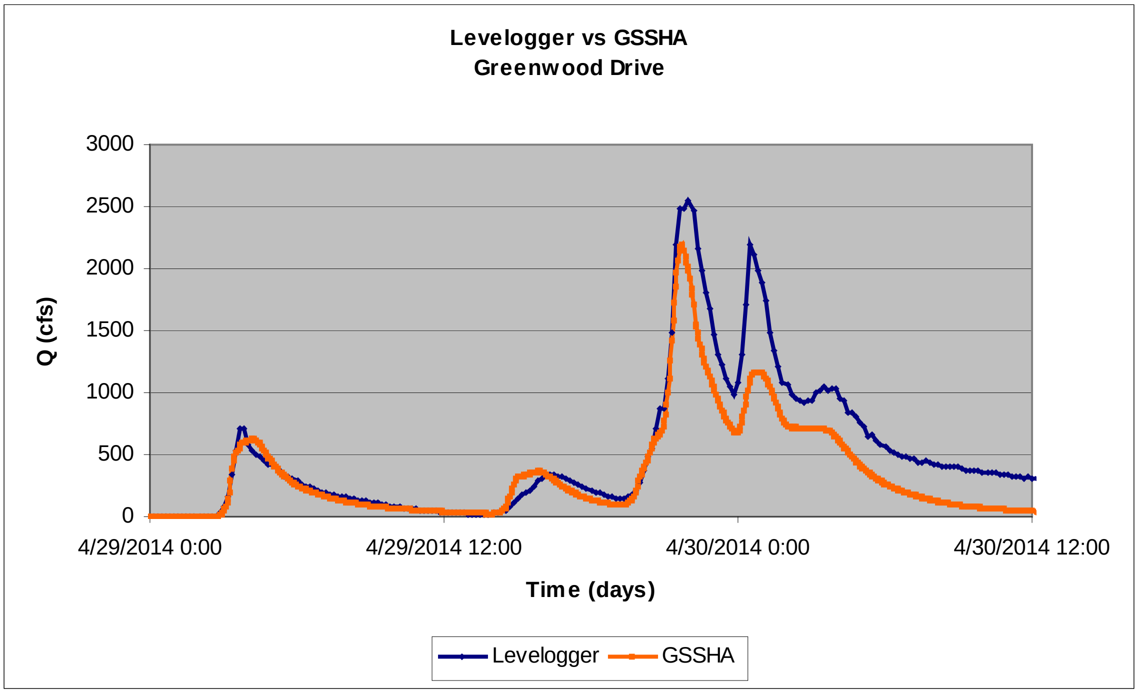


Figure 3-33
Validation Bayview Drive – April 29-30, 2014

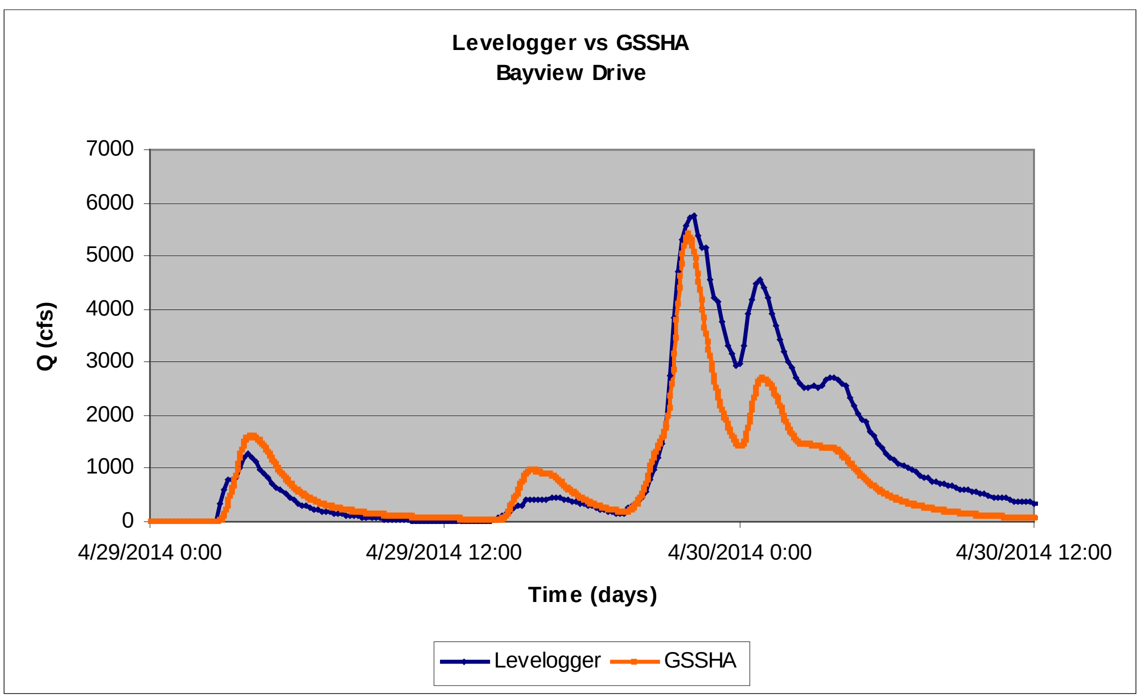


Figure 3-34
Rainfall Distribution – May 14, 2014

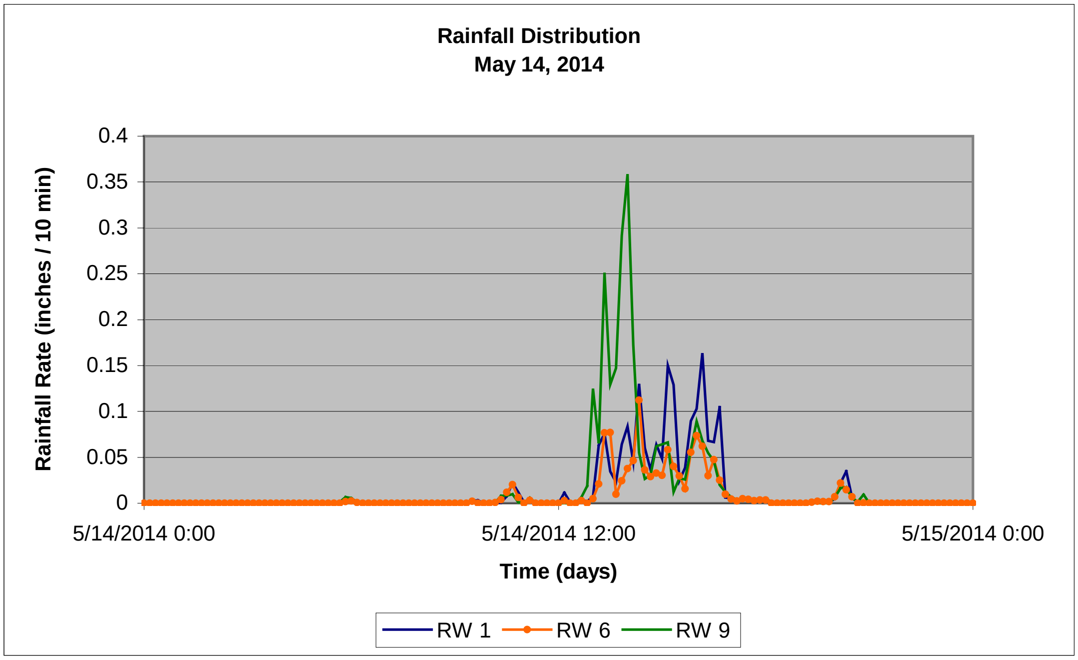


Figure 3-35
Cumulative Rainfall – May 14, 2014

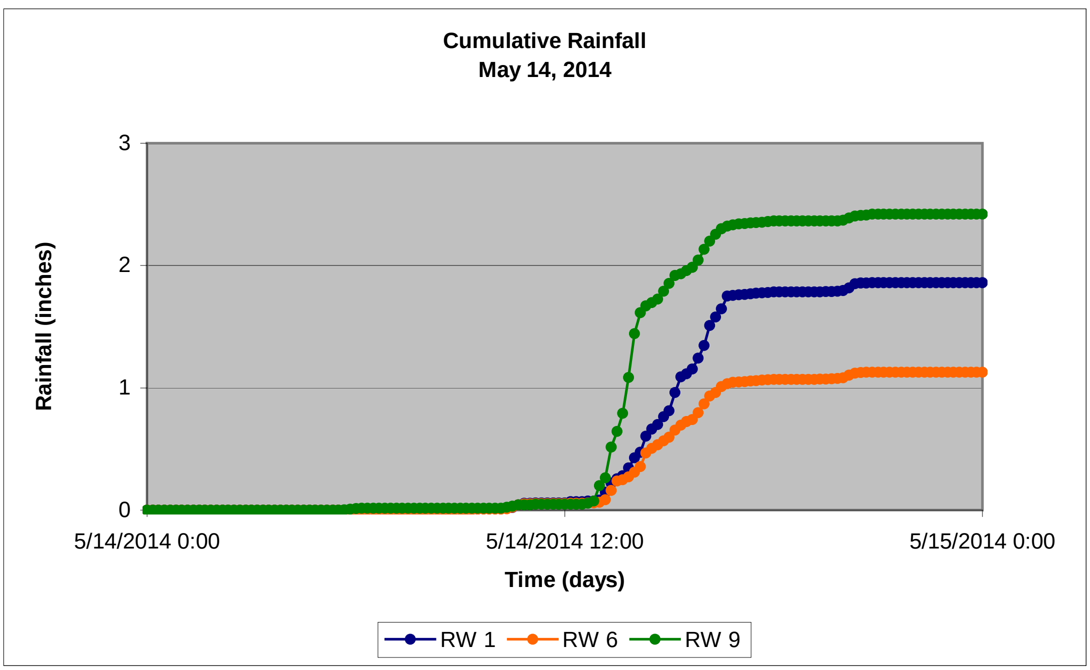


Figure 3-36
Validation Greenwood Drive - May 14, 2014

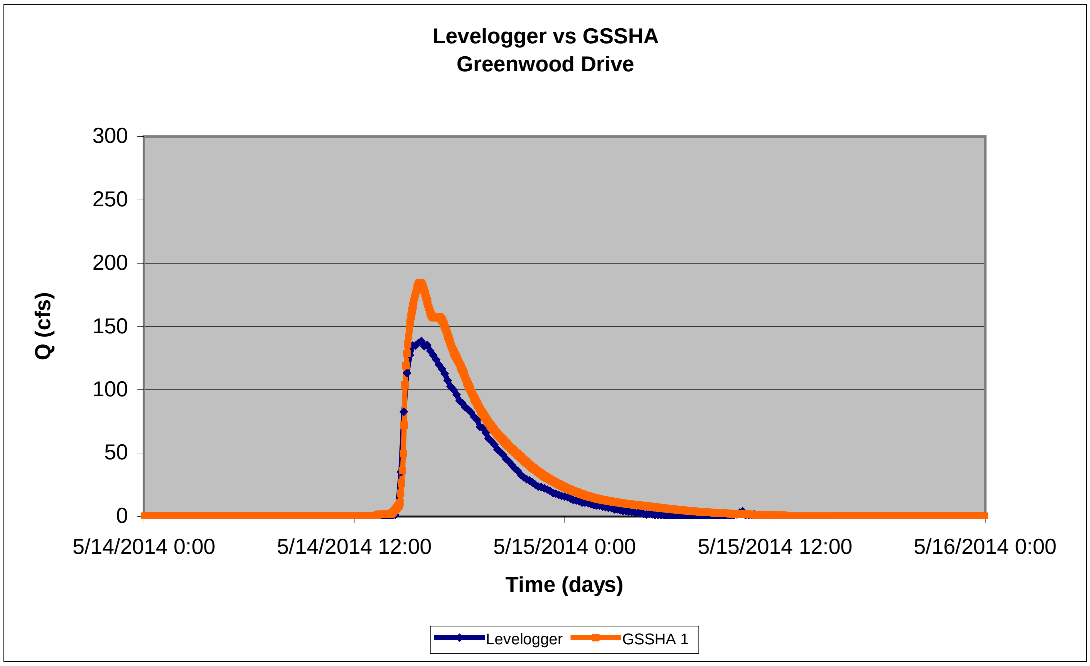
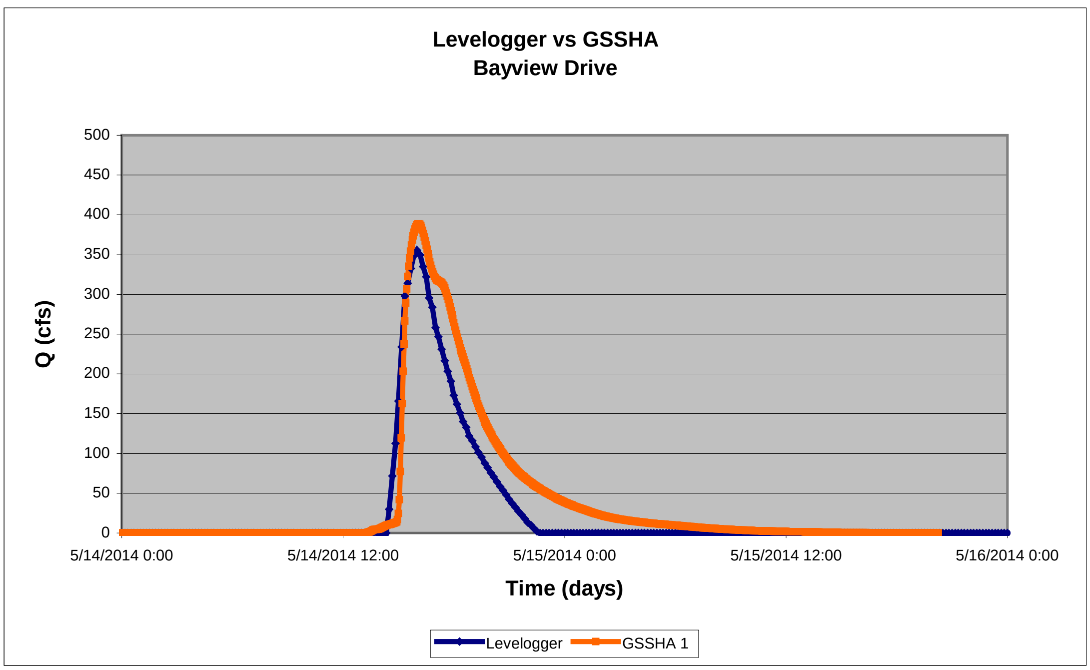


Figure 3-37
Validation Bayview Drive - May 14, 2014



4.1. Watershed Analysis

After the model was calibrated to the 2014 rain events, the precipitation and rainfall distribution were changed in order to analyze a 1-yr 24-hour storm event. The 1-year 24-hour rainfall amount for the drainage basin was taken from *NOAA Atlas 14 – Precipitation-Frequency Atlas of the United States - Volume 9 Version 2.0*. It was determined the average rainfall amount over the watershed is 5.0 inches or 127 millimeters. The rainfall distribution employed was the SCS Type III distribution. The model was rerun with the previously calibrated parameters and the discharges were examined at the outlet, and other areas of interest throughout the watershed (Figure 4-1). To get an understanding of the magnitude of the discharges, comparisons were made to both the rural and urban regression equations. The publication *Magnitude and Frequency of Floods in Alabama, 2003 USGS Scientific Investigations Report 2007–5204* was used to calculate discharges using the rural regression equations. The publication *Magnitude and Frequency of Floods for Urban Streams in Alabama, 2007 USGS Scientific Investigations Report 2010–5012* was used to determine the urban regression discharges.

Analysis indicates that discharges throughout the watershed are higher than those calculated by the regression equations. After comparing the calibrated models with the regression discharges, different stormwater control measures (SCMs) were analyzed throughout the watershed in order to determine what discharge reductions could be made. These SCMs consisted of detention storage as well as floodplain storage via increasing floodplain connectivity and roughness. Analysis was performed using the calibrated GSSHA model for saturated conditions in order to simulate a worst-case scenario. Due to the magnitude of the discharges, it was determined that regional SCMs would be required for significant flow reduction. Figure 4-1 indicates the locations of the regional SCMs that were analyzed for the 5” rain event under saturated conditions. The SCMs were conceptually designed to try to reach a target peak discharge reduction near 50%. This generally produced a peak stage at the SCM of approximately 10 feet. Table 4.1 indicates outlet structure size, stage, and storage volume for each of the proposed SCMs.

The conceptual design of the SCMs presented in this report will need to be modified based on specific site criteria during the design. Environmental factors also will need to be examined during the final design phase to ensure that any impacts are minimized. Possible changes may include different outlet structures than those listed in Table 4-1, e.g. open bottom structure. Initial water surface elevations (stages) may need to be adjusted to avoid impacting nearby property structures. SCM locations may also need to be adjusted if there are endangered species or habitat concerns. Finally, mitigation and construction costs will influence the final design and location of the stormwater control measures in order to provide the best cost-benefit ratio.

Table 4-1
Stage and Storage Volumes for Proposed SCMs

SCM	Outlet Structure	Stage (ft)	Storage (ft^3)
1	60” Pipe	9.9	628,572
2	(2) 60” Pipes	12.6	2,040,211
3	60” Pipe	11.4	461,556
4	60” Pipe	11.5	280,424
5	60” Pipe	9.4	412,499
6	60” Pipe	9.5	1,125,538
7	(2) 48” Pipes	18.4	2,273,886

Figure 4-1
Watershed Analysis and Regional Stormwater Control Measure Locations

5. Results and Conclusions

5.1. Results

Results from the calibrated models indicate that the discharges are approximately 3 to 6 times higher than urban regression equations. Due to the excessive amount of discharge further investigation was performed using the model calibrated to the July 2011 event. It was determined that these discharges are very comparable to the urban regression equations. The suspected reason for the discrepancy in discharges is due to soil moisture conditions. Using the Palmer Drought Severity Index Maps found under the Climate Prediction Center section of the National Oceanic and Atmospheric Administration (NOAA) website, it was determined that during the period around July 16, 2011 the area was in a “severe drought” (Figure 5-1). Prior to the first calibration on March 28, 2014 the area was in a “near normal” condition (Figure 5-2). The April 2014 calibration events, however, occurred during periods of an “unusual moist spell” (Figures 5-3 and 5-4). The May event occurred during “extremely moist” periods (Figure 5-5). A comparison of the rural, urban, GSSHA drought, and GSSHA saturated discharges at various discharge points within the watershed are listed in Table 5-1.

From Table 5-1 it can be seen that during the drought conditions for a 1-yr 24-hour storm, the discharges are typically greater than the rural regression discharges and less than the urban regression. During saturated soil conditions the discharges in some areas can reach up to 10 times that of the rural regression equations and 5 times that of the urban equation. With the implementation of the detention storage SCMs, local flow reductions can be upwards of 50% (Tables 5-2 to 5-5). Discharges at the outlet can see a 13% with the implementation of multiple SCMs working in conjunction. The analysis was performed under the assumptions that the property has been acquired, permitting has been allowed, and water surface elevations do not impact houses. The discharge reductions based on floodplain storage can be found in Table 5-6.

Figure 5-1
Drought Severity Index – July 9, 2011

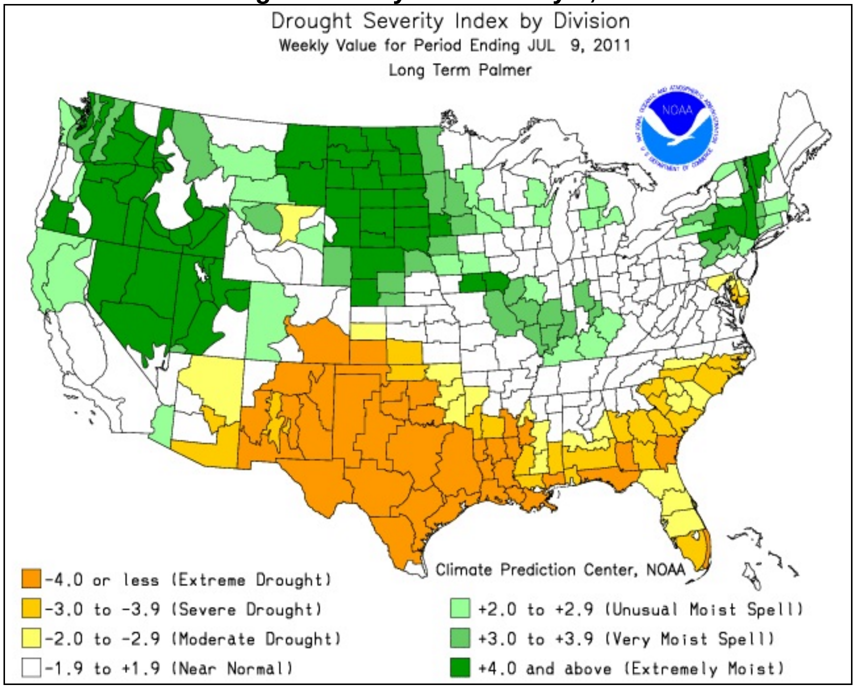


Figure 5-2
Drought Severity Index – March 22, 2014

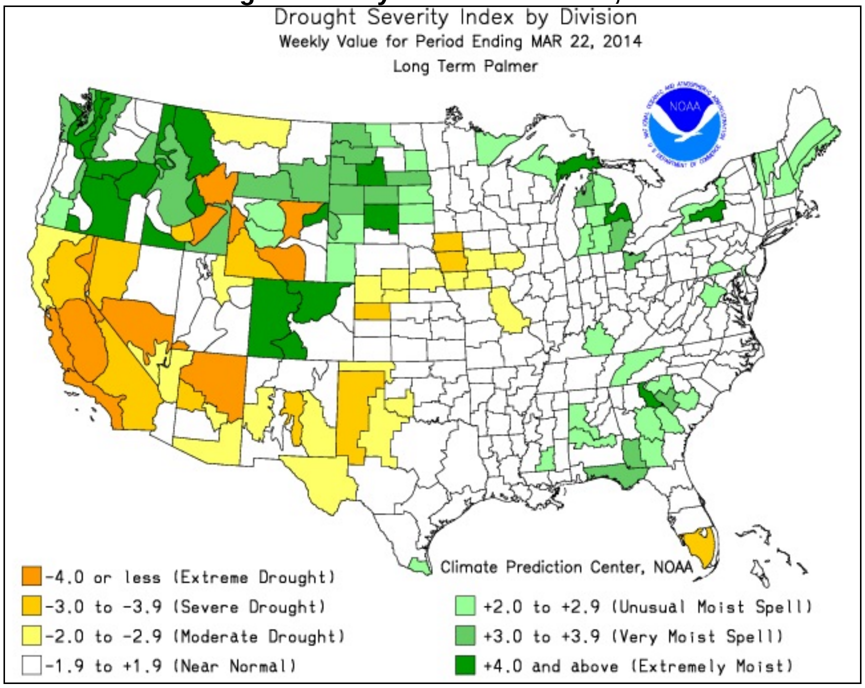


Figure 5-3

Drought Severity Index – April 12, 2014

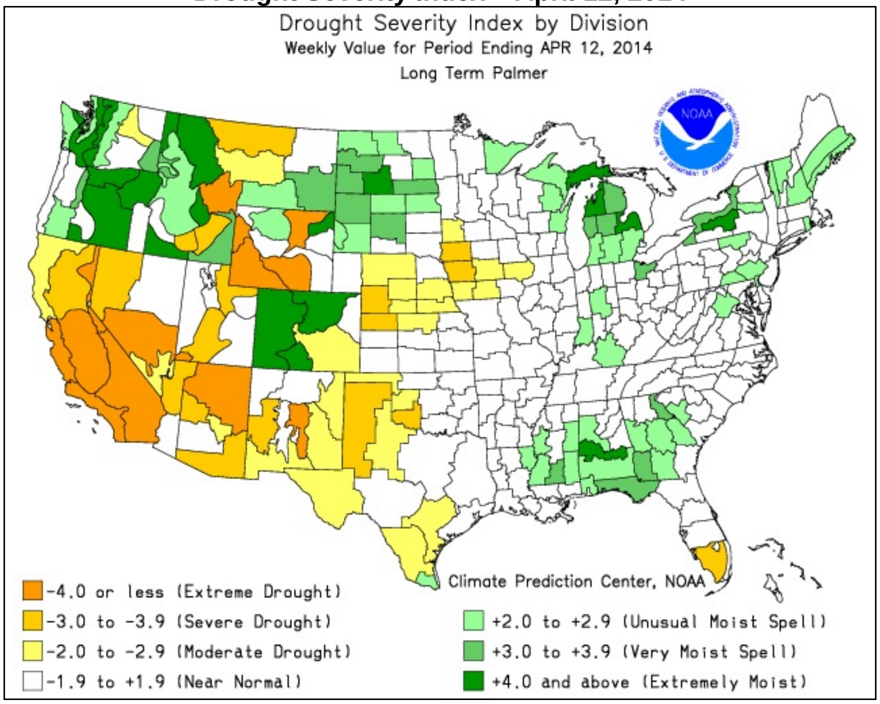


Figure 5-4

Drought Severity Index – April 26, 2014

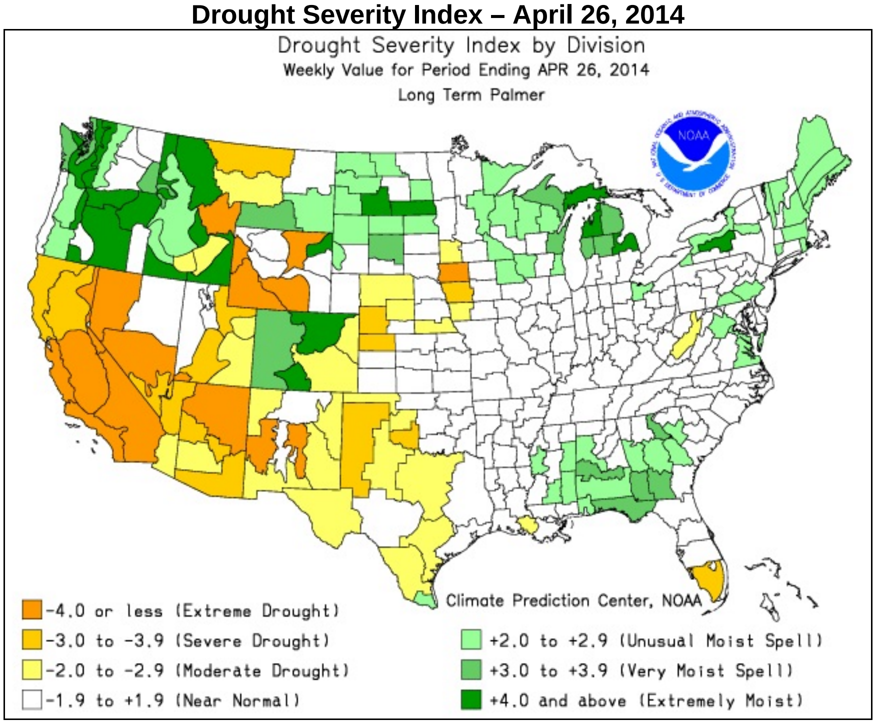


Figure 5-5
Drought Severity Index – May 10, 2014

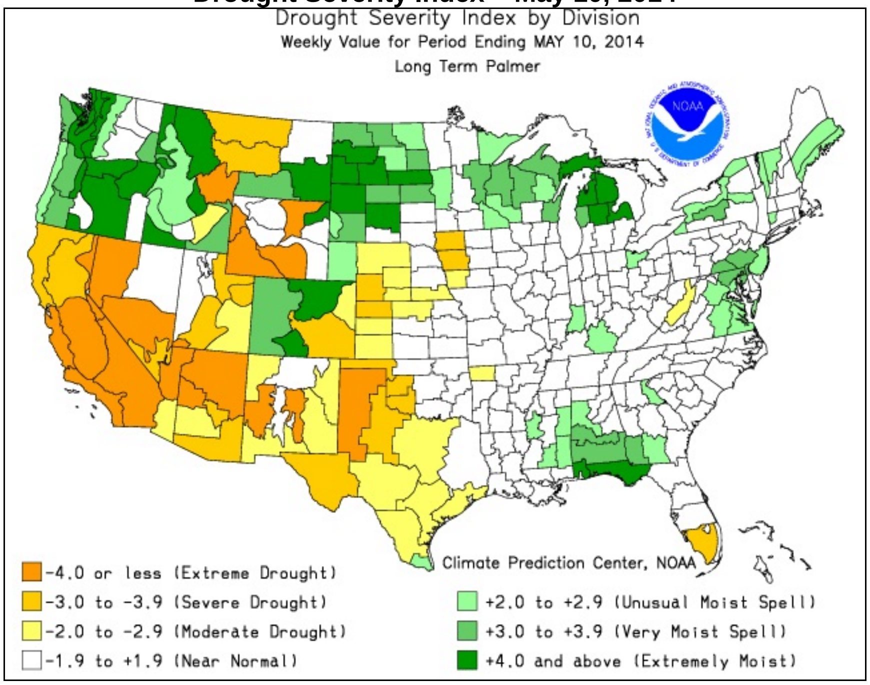


Table 5-1
D'Olive Creek Watershed Summary of Discharges

Event	Joes Branch				CR 13			
1yr –24hr Type III	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)
5" Rain	36	110	108	384	75	140	195	872
Event	**I-10**				**Greenwood Drive**			
1yr –24hr Type III	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)
5" Rain	150	430	360	1683	152	430	168	957
Event	**Bayview Drive**				**Outlet**			
1yr –24hr Type III	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)	Rural (cfs)	Urban (cfs)	GSSHA (Drought) (cfs)	GSSHA (Saturated) (cfs)
5" Rain	270	700	362	2539	520	1330	1206	6976

Table 5-2
D'Olive Creek Watershed Summary of Discharges

	SCM 1			SCM 2			SCM 3		
Location	Ex. Q (cfs)	Atten. Q (cfs)	% Red.	Ex. Q (cfs)	Atten. Q (cfs)	% Red.	Ex. Q (cfs)	Atten. Q (cfs)	% Red.
SCM Outlet	562	258	54.1%	1271	600	52.8%	396	283	28.5%
A	1654	1412	14.6%	1686	952	43.5%	1683	1541	8.4%
B	3616	3605	0.3%	3555	3343	6.0%	3613	3539	2.0%
Outlet	6966	6940	0.4%	6919	6674	3.5%	6965	6882	1.2%

Note: Reductions in table are based on detention storage

Ex. Q = Existing Discharge, Atten. Q = Attenuated Discharge, % Red. = Percent Reduction

Table 5-3
D'Olive Creek Watershed Summary of Discharges

	SCM 4			**SCM 5**		
Location	Ex. Q (cfs)	Atten. Q (cfs)	% Red.	Ex. Q (cfs)	Atten. Q (cfs)	% Red.
SCM Outlet	416	283	32.0%	410	249	39.3%
C	830	669	19.4%	877	687	21.7%
B	3603	3487	3.2%	3629	3468	4.4%
Outlet	6961	6866	1.4%	6981	6846	1.9%

Note: Reductions in table are based on detention storage
Ex. Q = Existing Discharge, Atten. Q = Attenuated Discharge, % Red. = Percent Reduction

Table 5-4
D'Olive Creek Watershed Summary of Discharges

	SCM 6			**SCM 7**		
Location	Ex. Q (cfs)	Atten. Q (cfs)	% Red.	Ex. Q (cfs)	Atten. Q (cfs)	% Red.
SCM Outlet	521	250	52.0%	947	490	48.3%
D	912	666	27.0%	---	---	---
E	2141	2005	6.4%	2166	1644	24.1%
Outlet	6960	6869	1.3%	6951	6568	5.5%

Note: Reductions in table are based on detention storage
Ex. Q = Existing Discharge, Atten. Q = Attenuated Discharge, % Red. = Percent Reduction

Table 5-5
D'Olive Creek Watershed Summary of Discharges

	SCM 2 & 3			SCM 2,3,4,5,6,7		
Location	Ex. Q (cfs)	Atten. Q (cfs)	% Red.	Ex. Q (cfs)	Atten. Q (cfs)	% Red.
A	1679	891	46.9%	1679	891	46.9%
B	3535	3248	8.1%	3535	3248	8.1%
C				848	545	35.7%
D				912	668	26.8%
E				2137	1484	30.6%
Outlet	6898	6571	4.7%	6845	5932	13.3%

Note: Reductions in table are based on detention storage
Ex. Q = Existing Discharge, Atten. Q = Attenuated Discharge, % Red. = Percent Reduction

Table 5-6
D'Olive Creek Watershed Summary of Discharges

	Floodplain Storage		
Location (FP#)	Ex. Q (cfs)	Atten. Q (cfs)	% Red.
A (FP 1,2)	1686	1630	3.3%
B (FP 1,2,3,4,5)	3622	3309	8.6%
C (FP 4,5)	877	864	1.5%
D (FP 6,7)	934	920	1.5%
E (FP 6,7,8)	2170	2096	3.4%
Outlet (FP ALL)	6975	6633	6.3%

Note: Reductions in table are based on floodplain storage
FP# indicates the floodplain storage areas associated with the comparison location
Ex. Q = Existing Discharge, Atten. Q = Attenuated Discharge, % Red. = Percent Reduction

5.2. Conclusions

The D'Olive Creek has undergone a significant increase in urbanization over the past 40 years. As of now, residential and commercial developments comprise approximately 46% of the watershed. As previously indicated in Table 2-2, a majority of this development was constructed without any detention ponds that could help manage stormwater quantity and/or quality. The two largest subdivisions, Lake Forest and Timber Creek, account for about 70% of the residential area in the watershed. Without detention ponds in place, there is little to no attenuation of increased peak discharges. These increased discharges from the undetained developments have caused streams to react. Active erosion and degradation are evident at many of the streams and tributaries within the watershed.

In addition to the land use changes, the watershed experiences relatively steep topography and areas of narrow or little floodplain. Steeper slopes generate higher velocities that can result in increased stream erosion. The lack of floodplain also lends itself to higher velocities because the flow cannot expand and utilize the floodplain. The condition of the soil is also a large factor when it comes to surface runoff. During dry drought conditions, discharges are comparable to urban regression equations. During saturated conditions, discharges are significantly increased. As evident from the calibrated models, discharges are many times higher than that of urban regression equations. All of the above factors make it difficult to restore the hydrology of the watershed without incurring extremely high costs.

As mentioned in the Thompson WMP p 2-58, "... it is believed the actual Percent Impervious Cover within the D'Olive Watershed likely ranges somewhere between 20% and 25%. If this is the case, this level of imperviousness would place the D'Olive Watershed near the upper threshold of 25% for the Impacted Stream category which may make complete restoration of the Watershed's streams and reduction in stormwater runoff from the contiguous watershed areas problematic to achieve."

The recommendations found in Thompson's WMP are necessary for trying to maintain the current status of the watershed. Some of these include stabilization of headcuts to prevent further degradation from moving upstream, low impact development and increased riparian buffer requirements for future developments, creating conservation easements to protect natural areas, and additional regulatory requirements. In order to try to restore the watershed back to a feasible point, subdivisions must be retrofit with appropriate SCMs. Since the undetained residential development makes up approximately 37% of the watershed, installing the amount of retrofits needed to provide a significant reduction may not be feasible.

Due to the amount of development, regional reference curve data would not be appropriate for stream restoration design. A calibrated watershed model has been developed for the D'Olive Creek watershed. This model can be used to determine discharges within the watershed based on any rain event. Restoration projects can use the model in order to come up with more representative discharges along a stream reach. The calibrated GSSHA model can be also used as a dynamic management tool in which to analyze future developments. Outside analysis at a smaller sub-basin level can also be performed and reintroduced into the model to determine possible impacts.

6. **References**

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