MBNEP

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Dog River Watershed Study

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1. Executive Summary

The study on the Dog River watershed was performed to gain an understanding of the watershed's response during rain events. It was also performed to generate a baseline hydrologic model that can be used for determining discharges for the design of future restoration projects and their impact on the watershed, as well as information that can be used for future stormwater planning and management. The method of analysis used for the study employed the use of the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. This two-dimensional overland flow model was calibrated to available rain events from September 2018 to June 2020 for use in predicting watershed reaction to various land use changes.

During the evaluation period, the Dog River watershed experienced a number of small rain events. The majority of the events used for calibration of the hydrologic model were around a 1-year event. These events occurred on September 4, 2018, December 8, 2018, and August 26, 2019. The first two events were classified as being less than a 1-year event, 2" in 5 hours and 2.8" in 12 hours respectively. The August event produced 3.7" in 6 hours which equates to a 1-year storm with some local areas experiencing a 2-year event (4.1" in 6 hours). The largest event occurred on September 19, 2019 where the entire watershed experienced, on average, between a 10-year and 25-year storm event. In the northeastern part of the watershed, an average of 8.0 inches of rain fell in a 3 hour period. Using NOAA Atlas 14, it was determined that this amount of rainfall in this time period is equal to a 200-year event. The June 6-8, 2020 rainfall from Tropical Storm Cristobal produced the highest stages in the Halls Mill Creek sub-watershed.

During the evaluation period the watershed experienced both low 1-year rainfall events, as well as, one large flooding event. Hydrologic models calibrated to the smaller events usually do not translate to higher flooding events; therefore two calibrated models were necessary. For 2-year rain events or less, the first calibrated GSSHA model can be used as a management tool for determining bank forming discharges throughout the watershed. Future restoration projects may be able to utilize these discharges for bankfull analysis. For larger flood events (10-yr+), the second calibrated model can be used to analyze the impacts of future developments on stormwater runoff.

2. Introduction

2.1. Description

Dog River Watershed is a coastal river located in southwest Mobile County, AL (Figure 2-1). The Dog River Watershed Management Plan (WMP) prepared by Goodwyn Mills & Cawood (2014) states, "The greater Dog River Watershed's reach is approximately 12 miles inland from the western shore of Mobile Bay, spans 10.8 miles from north to south…. and has approximately 174 miles of streams and waterway networks (USGS,2017)." Its headwater begins at the lower tip of the city of Mobile. The drainage area of Dog River is approximately 93.3 square miles.

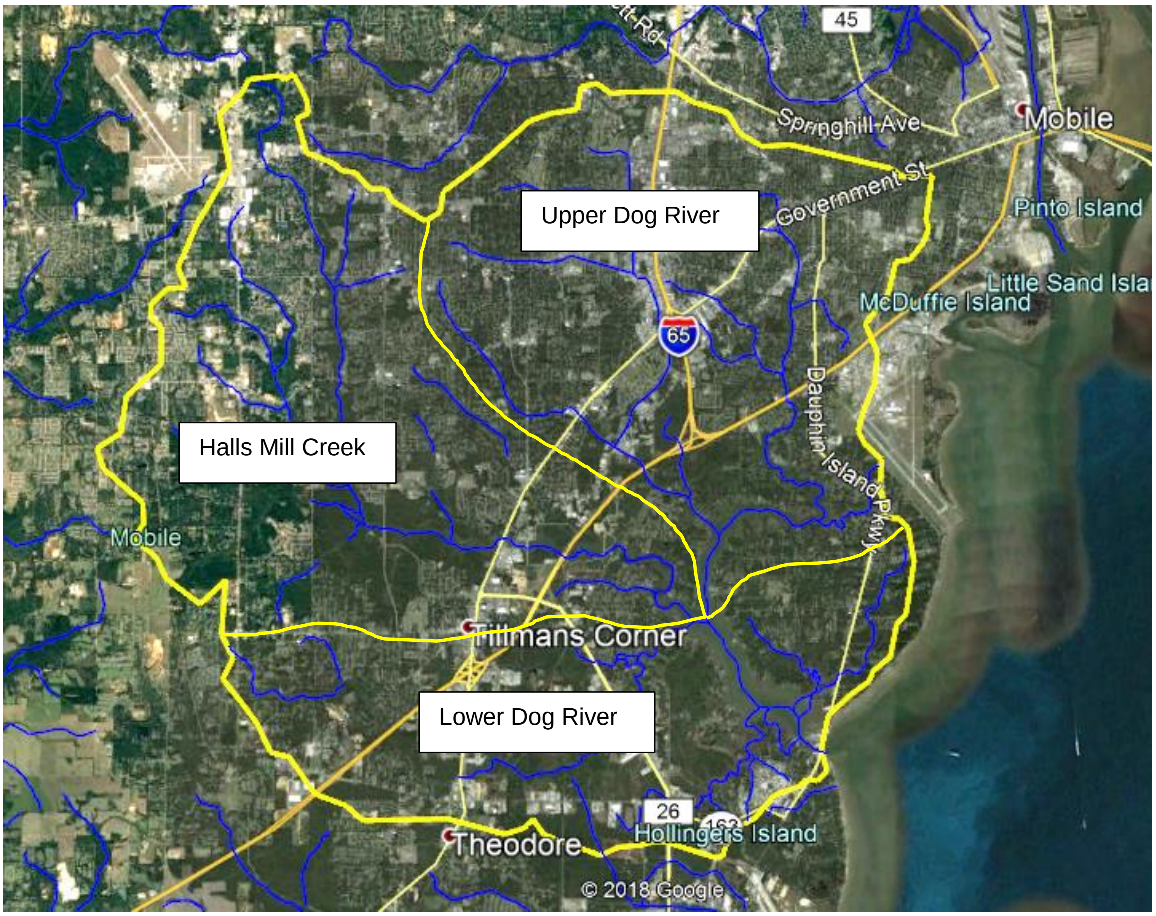
The Dog River Watershed is comprised of three main sub-watersheds: Upper Dog River, Halls Mill Creek, and Lower Dog River (Figure 2-1). The three U.S. Geological Survey (USGS) 12-digit hydrological unit codes (HUCs) are: HUC 031602050101 (Upper Dog River), HUC 031602050102 (Halls Mill Creek), and HUC 031602050103 (Lower Dog River) (GMC, 2014). The watershed boundary of Dog River generally extends north from the confluence with Mobile Bay to Mobile, extends west from Mobile to the Mobile Regional Airport, continues south just below Theodore, and extends east back to the confluence with Mobile Bay.

2.2. Climate

According to the 2014 Dog River WMP, "Mobile County has a hot, humid, subtropical climate with abundant rainfall. Rainfall and climate data from March 1900 through April 2012 are available from the Southeast Regional Climate Center database for the Weather Forecast Office (WFO) located at the Mobile Regional Airport, Weather Station 015478. Precipitation is usually in the form of showers with long periods of continuous rain being rare. Exceptions occur during tropical storms and hurricanes, when rainfall may be long and intense. Thunderstorms may occur at any time of the year."

Goodwyn Mills & Cawood (2016) states, "Average annual precipitation at the Mobile Airport is 65.3 inches. Average monthly precipitation ranges from 2.93 inches in October to 7.53 inches in July. Rainfall is only slightly seasonally distributed. October and November are the only months when rainfall averages less than 5 inches. The months of March and July through September all average greater than 6 inches of rainfall per month. Monthly mean maximum temperatures range from 91 degrees Fahrenheit (°F) in July to 60.9 °F in January. Monthly mean minimum temperatures range from 72.9 °F in July to 40.8 °F in January. The lowest temperature recorded was 3 °F on January 21, 1985. The highest temperature recorded was 104 °F on July 25, 1952."

Figure 2-1
Location Map and Dog River Watershed Boundary



2.3. Physiography

The 2014 Dog River WMP states, "The greater Dog River Watershed is located within the East Gulf Coastal Plain physiographic section, and lies within two physiographic districts: the Coastal Lowlands and the Southern Pine Hills (Sapp and Emplaincourt, 1975). The Coastal Lowlands is a flat to gently undulating plain with localized swamps. It is underlain by sediments of Holocene and late

Pleistocene age. Streams are tidally influenced and fringed by tidal marshes with significant saltwater influence. The landward boundary between the Coastal Lowlands district and the Southern Pine Hills is defined by the Pamlico marine scarp at an elevation of 25 to 30 feet above sea level…"

According to the Dog River WMP there are four major soil associations present in the Dog River Watershed: Urban Land-Smithton-Benndale, Bayou-Escambia-Harleston, Notcher-Saucier-Malbis, and the Troup-Heidel-Bama. The majority of the watershed consists of the Urban Land-Smithton-Benndale and Troup-Heidel-Bama soils. The Urban Land-Smithton-Benndale soil association consists of nearly level to gently rolling urban land areas that are intermingled with poorly and well-drained soils that have loamy subsoils, and are formed in loamy marine and fluvial sediments on uplands. The Bayou-Escambia-Harleston soil association consists of nearly-level to gently-undulating, poorly to moderately well-drained soils with loamy subsoils formed in marine and fluvial sediments located on uplands and terraces. The Notcher-Saucier-Malbis soils are present in the eastern and western portion of the Watershed in a relatively narrow area along Dawes Road. Troup-Heidel-Bama soils are present in most of the Halls Mill Creek Watershed, except for an area east of Interstate 10, where Bayou-Escambia-Harleston soils are present near Dog River.

2.4. Land Use

The majority of the Dog River watershed is urban covering approximately 68% of the total watershed area. Most of the urban areas consist of residential development which can be found throughout the entire watershed. The urban land use is most concentrated in the northeast portion of the watershed along I-65 in the Upper Dog River sub-watershed. Higher density development can also be found along Government Boulevard, especially near Tillmans Corner. Upland forest, the second largest land use coverage, makes up about 16% of the total watershed area. The upland forest areas are generally located to the northwest and southeast of Tillmans Corner. The woody wetlands cover approximately 9% of the watershed and are generally located south of I-10 and in the Halls Mill Creek sub-watershed. The remainder of the watershed consists of upland herbaceous areas, non woody wetlands, and open water.

3. Hydrologic Model

3.1. General

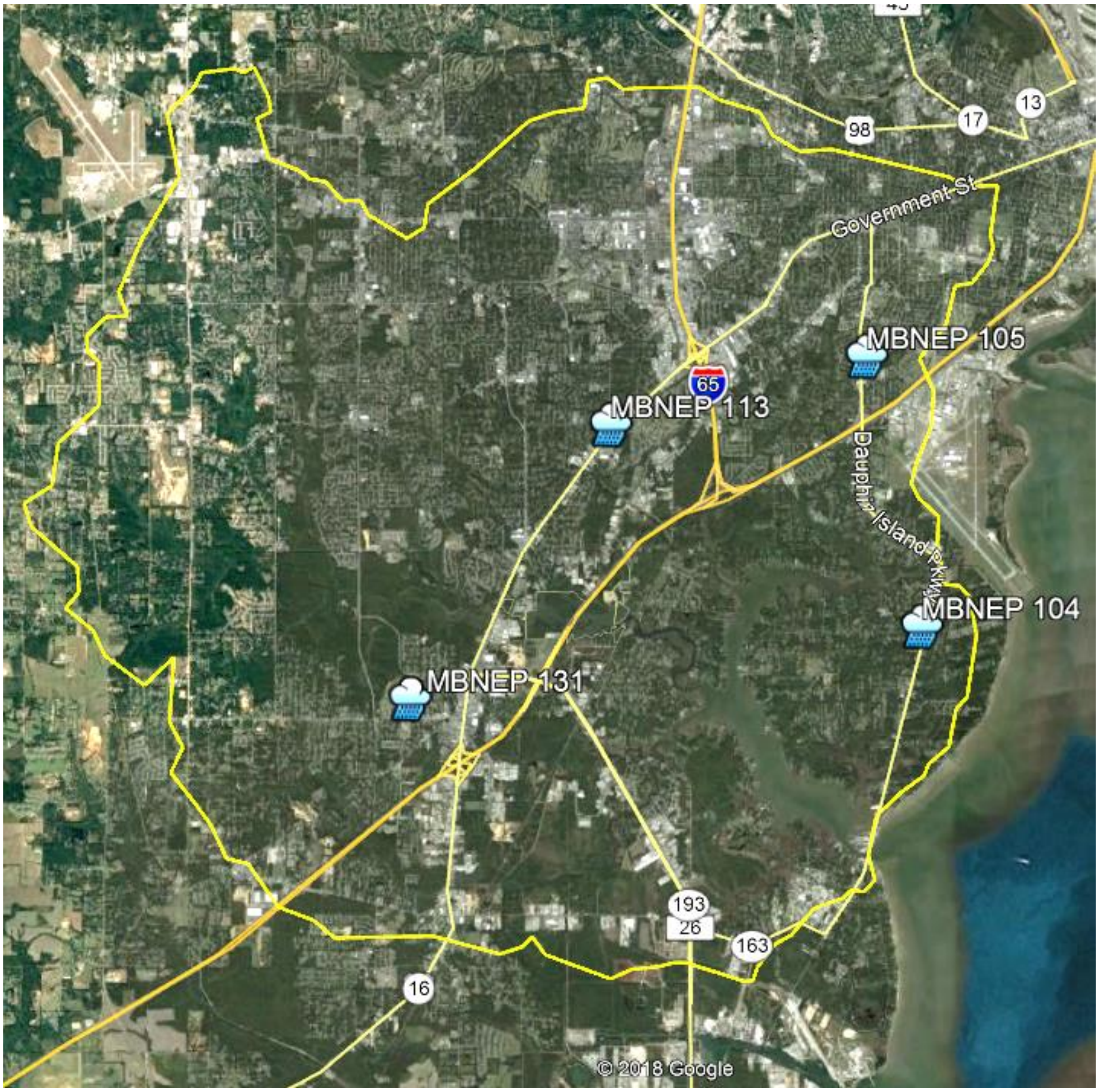
The hydrologic model used to evaluate the Dog River watershed is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA is developed and maintained by the US Army Engineer Research and Development Center (ERDC) Hydrologic Modeling Branch, in the Coastal and Hydraulics Laboratory. GSSHA is a 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 interface for building the GSSHA model is the Watershed Modeling System (WMS) developed by Aquaveo.

3.2. Rainfall Data

One of the strengths of the GSSHA model is the ability to perform long-term simulations utilizing rainfall distributions longer than just a 24-hour storm. A key element in forecasting discharges for future storm occurrences depends upon good rainfall data. For the rainfall component used in the simulations, Hydro-Engineering Solutions (Hydro) obtained storm data from three different data sources.

The first source for gathering rainfall data is from weather stations that Hydro deployed throughout the watershed (Figure 3-1). On September 13, 2018, three weather stations were installed. The first weather station (MBNEP 104) was installed off of Dauphin Island Parkway at the LL Petrey Fire Station. The second weather station (MBNEP 105) was installed off of Dauphin Island Parkway at the Louis Lathan Fire Station. The third weather station (MBNEP 113) was installed off of Azalea Road at the McCosker Fire Station. The final weather station (MBNEP 131) was installed on December 13, 2018 off of Three Notch Kroner Road at the WC Griggs Elementary School.

Figure 3-1
Watershed with Hydro Weather Station Locations



The Davis Instruments, Corp.'s Vantage Pro 2 Precision Weather Station was used for data collection. Information collected from this weather station include: rainfall, temperature, humidity, wind speed, and barometric pressure. The data is sent to Weatherlink.com, which is Davis' global weather network. Data can be transferred using a wireless console connected to a nearby computer with internet or via Davis' Vantage Connect®. According to the website, Vantage Connect® is a "cellular-based, solar-powered unit that sends remote weather station data to the internet." Weatherlink software was used for data retrieval for each station. After a storm event, data would be retrieved and then processed for use in the GSSHA model.

The second source of data was obtained from Gridded Binary (GRIB2) rainfall data provided by the National Weather Service. GRIB2 is the second version of the World Meteorological Organization's (WMO) standard for distributing gridded data. The major advantages of the GRIB files are that they are typically 1/2 to 1/3 the size of normal binary files (floats), the fields are self-describing, and GRIB is an open, international standard. A decoder is required to view or use the information. Once decoded, the GRIB2 data is in 2-minute increments which provide a good rainfall distribution for calibrating the timing aspect of the model. When there is a lack of information between the installed Hydro weather stations or any Wundermap gauges, GRIB2 data was utilized to get storm distributions. Oftentimes the total rainfall accumulation is low and needs to have a correction factor applied to it. Rainfall totals from other sources (e.g. Hydro Weather Stations, Weather Underground, NWS maps, etc) are used to correct the rainfall amounts when needed. Figure 3-2 indicates the selected locations for the NOAA GRIB2 rainfall points.

The third source of rainfall data was obtained from Weather Underground. Weather Underground is a weather service that provides real-time weather information over the internet. According to their website, "Our brand mission is to make quality weather information available to every person on this planet." The service makes use of "the generous and passionate community of weather enthusiasts that share weather data and content..." The information is obtained from the members who send real-time data from their personal weather stations. The weather stations available are plotted on a map (Wundermap) based on the parameter selected. The parameters available in which to sort the gauges are temperature/wind, temperature, dew point/humidity, and precipitation. Figure 3-3 indicates the number of available precipitation gauges that can be used for analyzing the watershed.

Figure 3-2
Watershed with NOAA GRIB2 Rainfall Point Locations

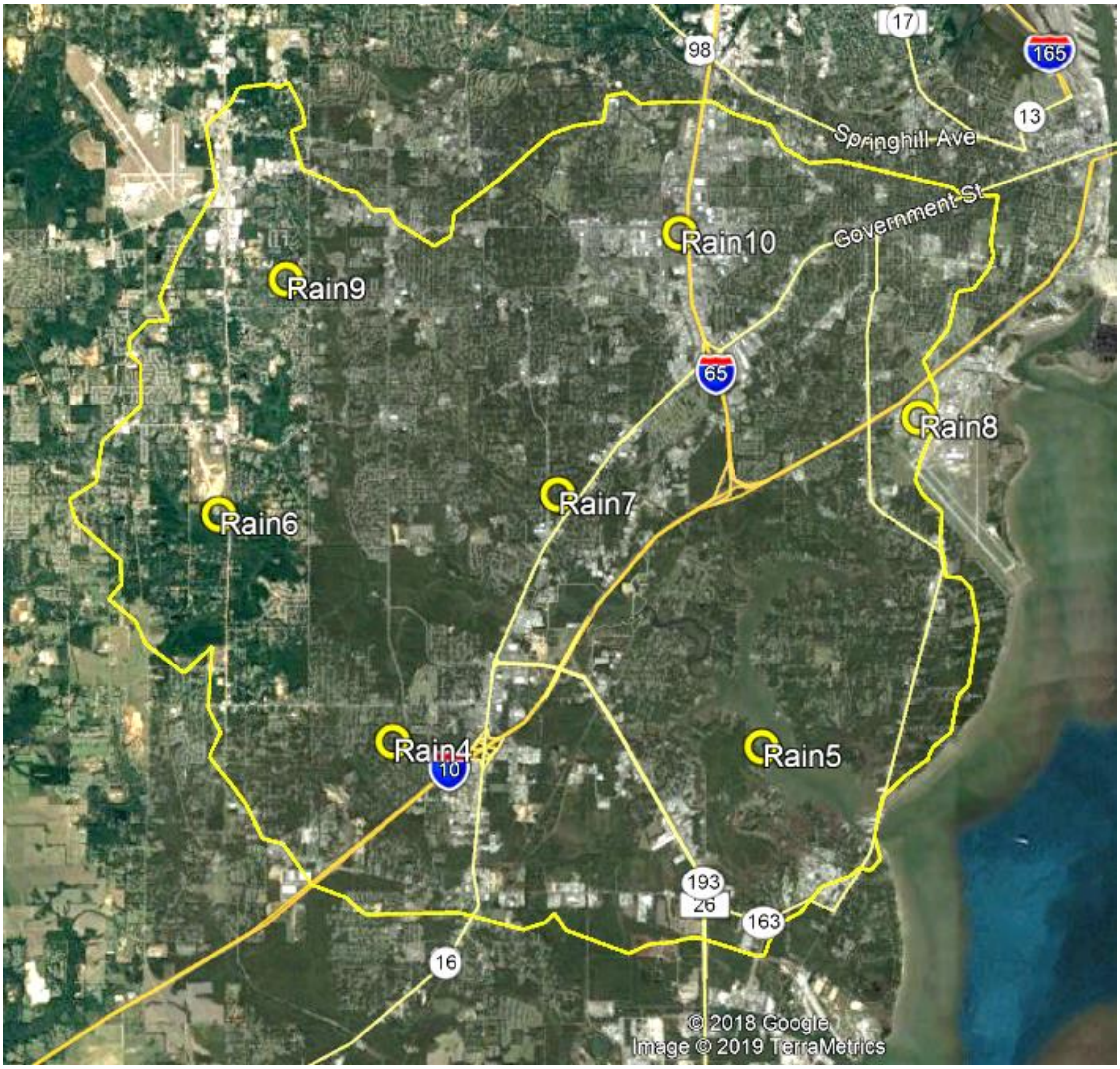
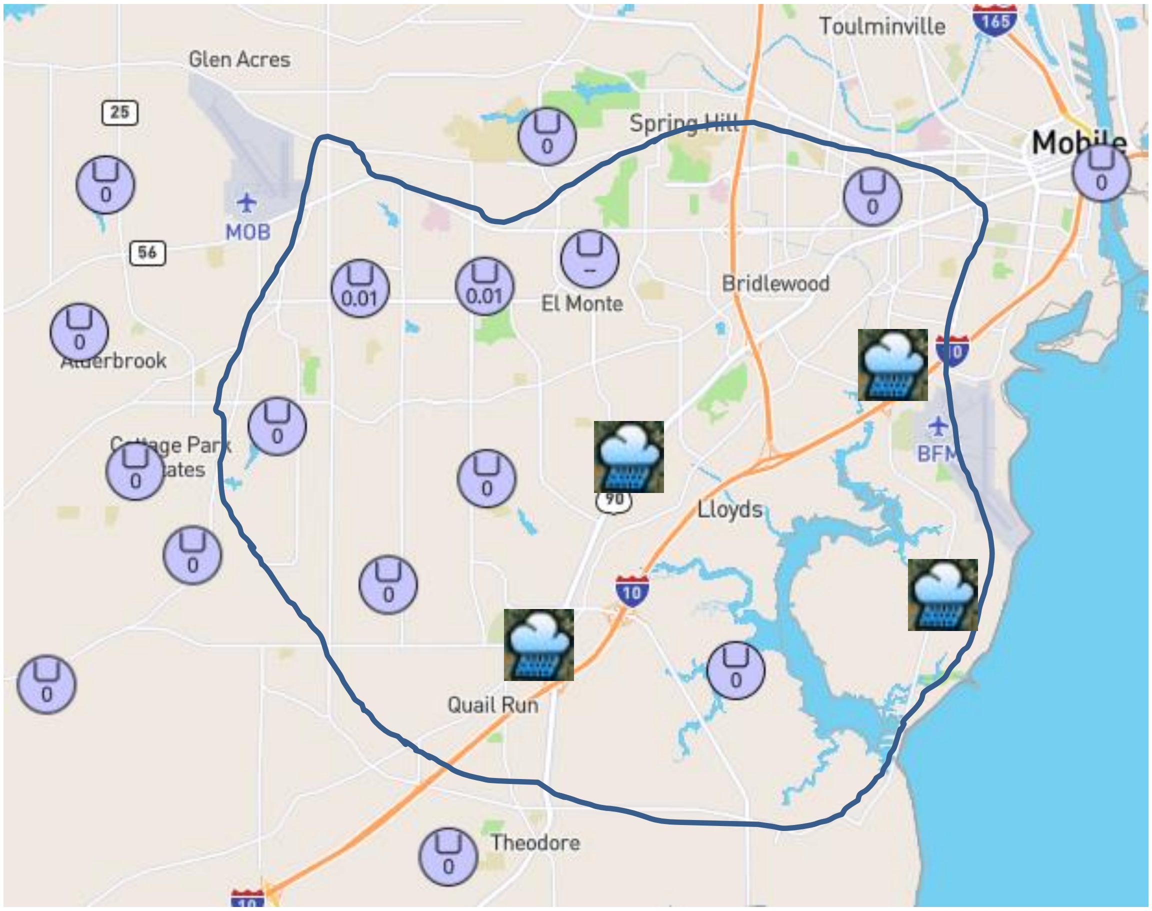


Figure 3-3
Watershed with Weather Station and Wundermap Gauge Locations



Source: https://www.wunderground.com/wundermap

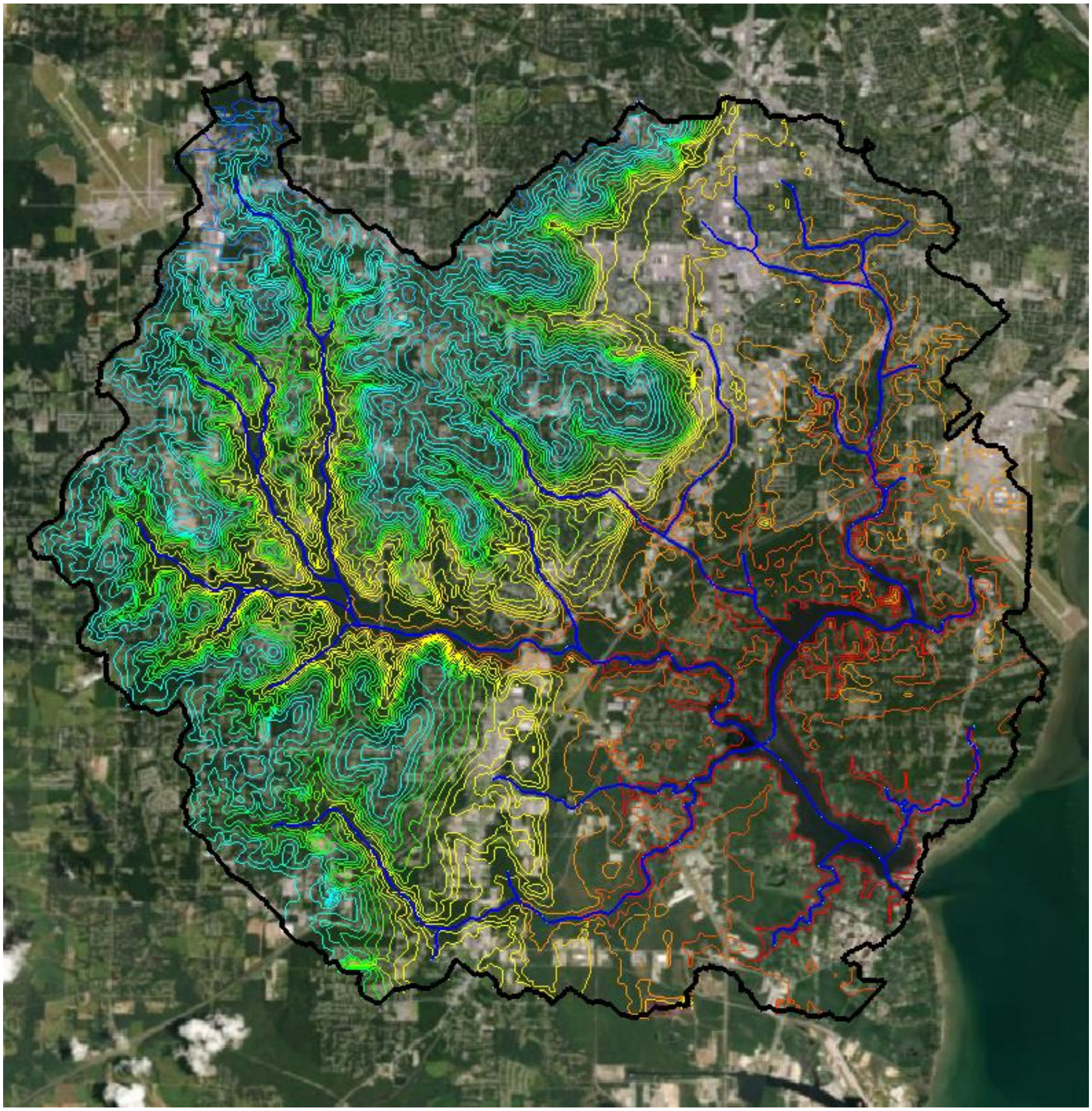
3.3. Digital Terrain Data

The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the model, Light Detection and Ranging (LiDAR) data was obtained from the 2014 Mobile County Lidar DEM (AL) dataset. This information is warehoused by the Office of Coastal Management of the National Oceanic and Atmospheric Administration (NOAA). The raster data is saved as a .tif file, with each file encompassing around 1.29 square miles (6000' x 6000'). The coordinate system for the raster data is to State Plane AL-W and the units are in feet. The information can be found at the following web address: https://coast.noaa.gov/htdata/raster2/elevation/Mobile_DEM_2014_5169/.

In order to get digital elevation data for basin delineation, each .tif was converted individually to a DEM. Each conversion utilized a 40-foot point spacing. For easier data manipulation, the individual DEM was converted to a .dwg. Once all of the individual DEM files were converted to a .dwg, they were merged into one file using Microstation. The complete basin .dwg was then imported back into WMS for a conversion back to a single DEM.

The GSSHA model requires all units to be in the International System of Units. It was therefore necessary to convert the State Plane AL-W data to UTM Zone 16 data. The units were also converted from feet to meters. After proper conversion, the DEM data can be used for automatic delineation of the basin, as well as, for generating cell elevations for the gridded model. Figure 3-4 indicates the topographic data that was used for the hydrologic model.

Figure 3-4
Watershed with Topographic Data



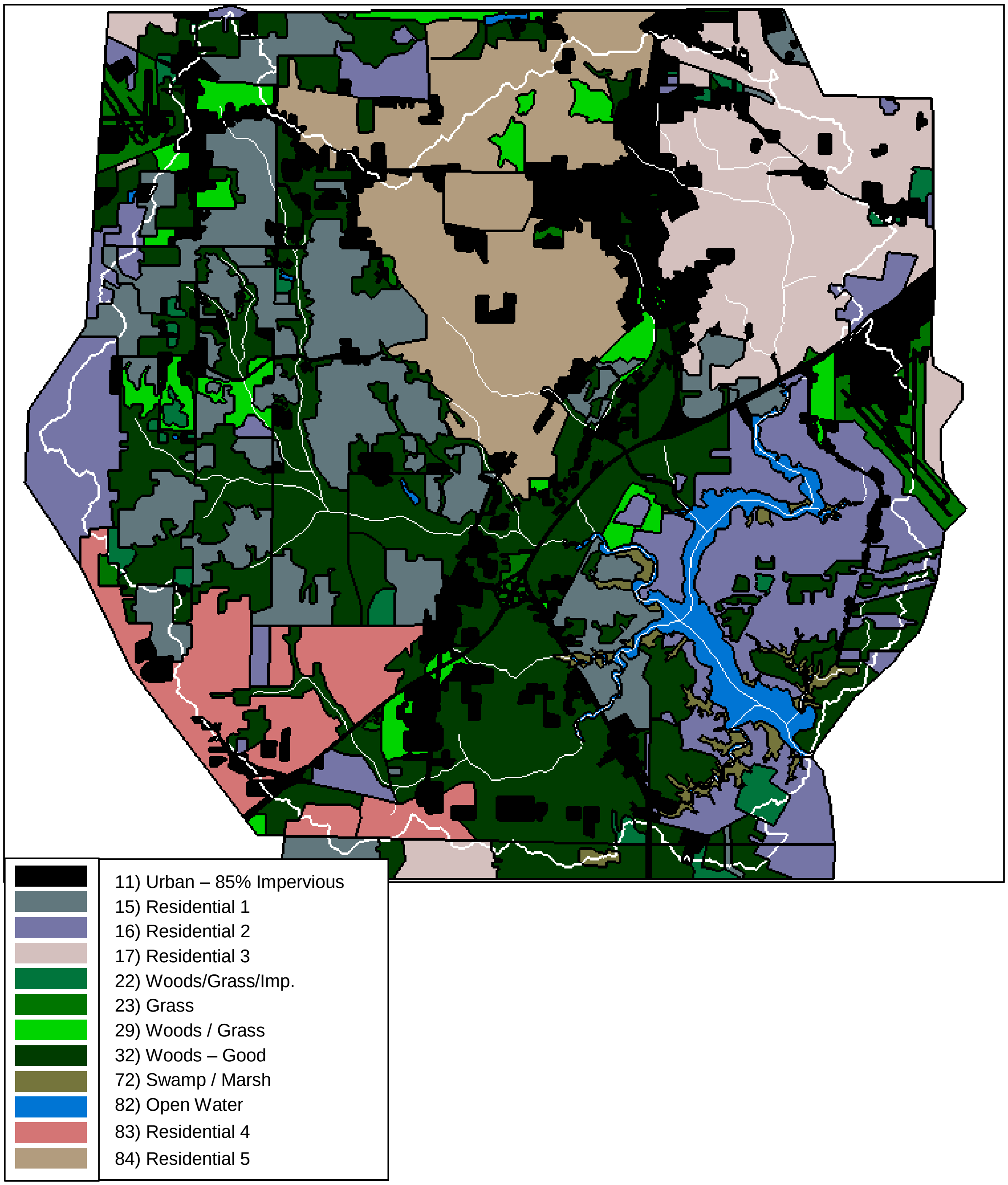
3.4. Land Use

The land use component of the model is necessary to define the various overland flow types throughout the basin. Land use was delineated using geo-referenced aerial imagery. WMS was used to automatically import the latest version of Esri's World Imagery map. (more information can be found at http://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer) The GSSHA utilizes the land use coverage by assigning a value to describe the overland roughness. The roughness of each land use type is described by an overland Manning's 'n' value. Table 3-1 lists the land use types and the respective 'n' values assigned to them. Figure 3-5 indicates the land use assignments.

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

GSSHA ID	Land Use	Manning's 'n'
11	Urban – 85% Impervious	0.011
15	Residential 1	0.050
16	Residential 2	0.040
17	Residential 3	0.013
22	Woods / Grass / Scattered Impervious	0.150
23	Grass	0.180
29	Woods / Grass	0.200
32	Woods – Good	0.250
72	Swamp/Marsh	0.250
82	Open Water	0.011
83	Residential 4	0.030
84	Residential 5	0.030

Figure 3-5
Watershed with Digitized Land Use



3.5. Soils

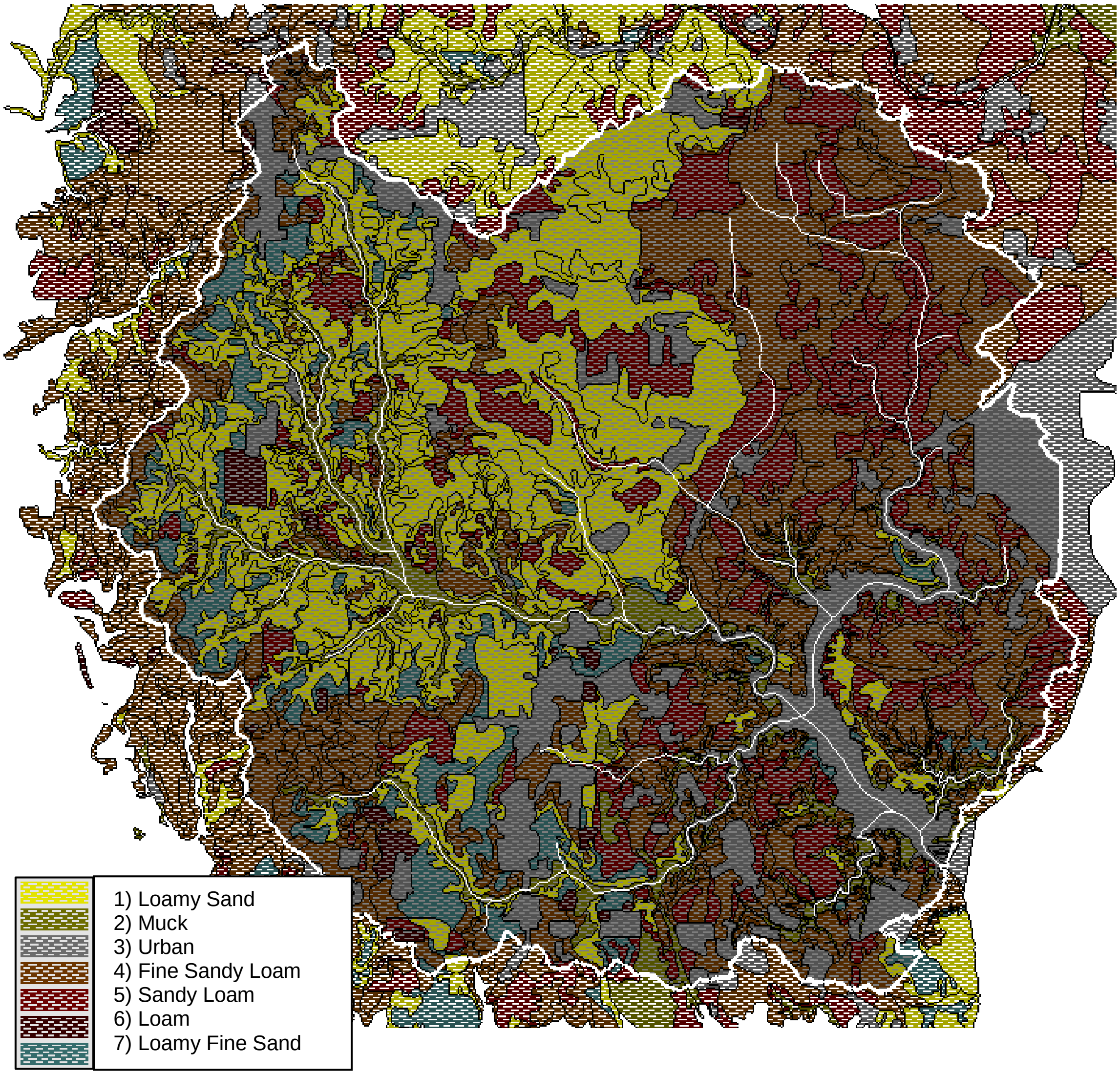
Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage can be used for defining infiltration into the soil or setting the initial soil moisture. Green and Ampt (G&A) with soil moisture redistribution was used for determining the infiltration of rainfall throughout the basin. Soil parameters used by the G&A method include hydraulic conductivity, porosity, capillary head, pore distribution index, residual saturation, and field capacity. These infiltration values allow the GSSHA model to evaluate the soil's ability to infiltrate stormwater for calculating peak discharge and volume of storm events.

Soils data shapefiles were provided by the Mobile Bay National Estuary Program (MBNEP). According to the metadata provided with the shapefiles, this soil survey is an update to the 1980 soil survey of Mobile County. According to the metadata, "The Soil Survey information was updated using the latest advanced geospatial software ArcGIS 10.3 ArcInfo…. The U.S. Department of Agriculture, Natural Resources Conservation Service, should be acknowledged as the data source in products derived from these data." Figure 3-6 indicates the soil data that has been incorporated into the GSSHA model. Infiltration can be defined through the soils coverage alone or through a combined land use / soils data coverage.

3.6. Combined Coverage

A combined land use / soils coverage layer can be generated in order to incorporate a more detailed way to specify infiltration. Instead of defining the infiltration parameters with just soils, it can be defined based on a soil type and specific land use. For example, a sandy loam may have woods described as the land use in one part of the watershed and a parking lot in another. Instead of applying the infiltration values for just a sandy loam, a combined coverage can utilize an infiltration value for the woods and a separate one for the parking lot. This can help better replicate the timing and infiltration related to the ground cover and soil type.

Figure 3-6
Watershed with Digitized Soil Type



3.7. Gridded Model

Once all of the variables mentioned above have been incorporated into the model it was necessary to divide the model into individual grid cells. For the Dog River model a 60 meter x 60 meter (197 feet x 197 feet) grid size was utilized (Figure 3-7). As mentioned previously, the settings for GSSHA require the units to be in the International System of Units (SI). The total drainage area to the confluence with Mobile Bay is approximately 93.3 square miles. Over the entire watershed this generates approximately 67,140 grid cells. Figures 3-7 to 3-10 indicate the gridded elevation, gridded land use, gridded soils data, and gridded combined layer.

Figure 3-7
Watershed with Gridded Elevation Data

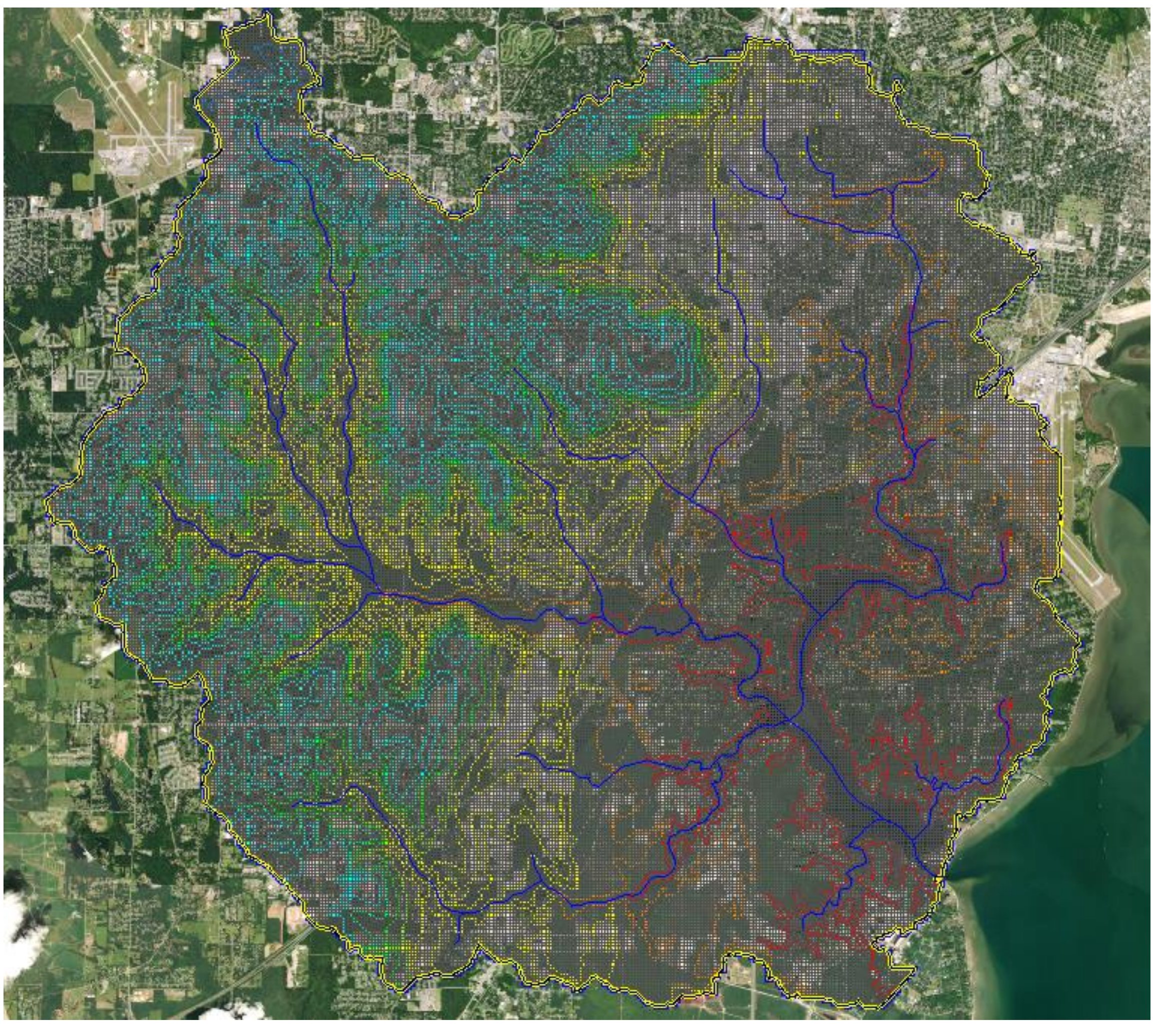


Figure 3-8
Watershed with Gridded Land Use Data

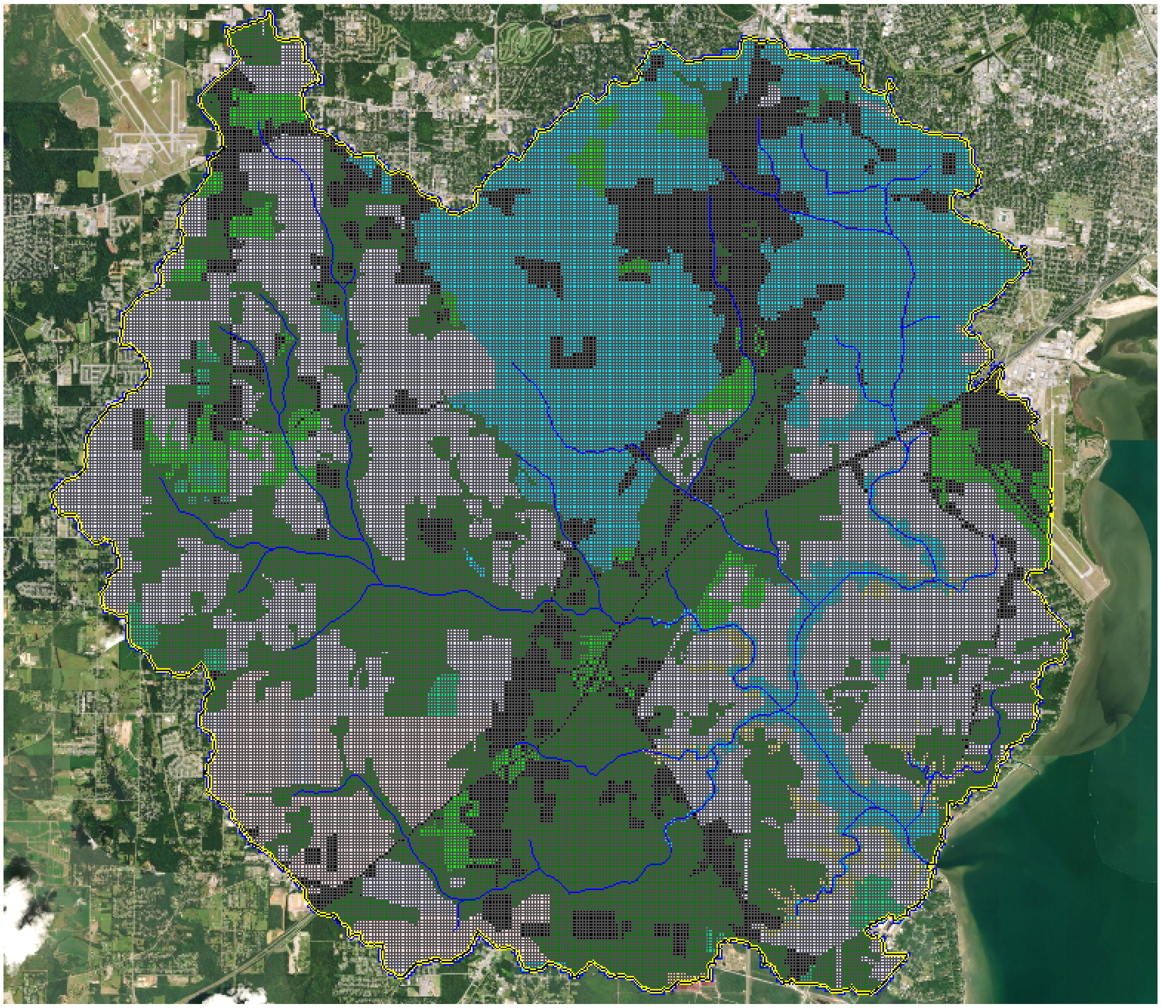


Figure 3-9
Watershed with Gridded Soils Data

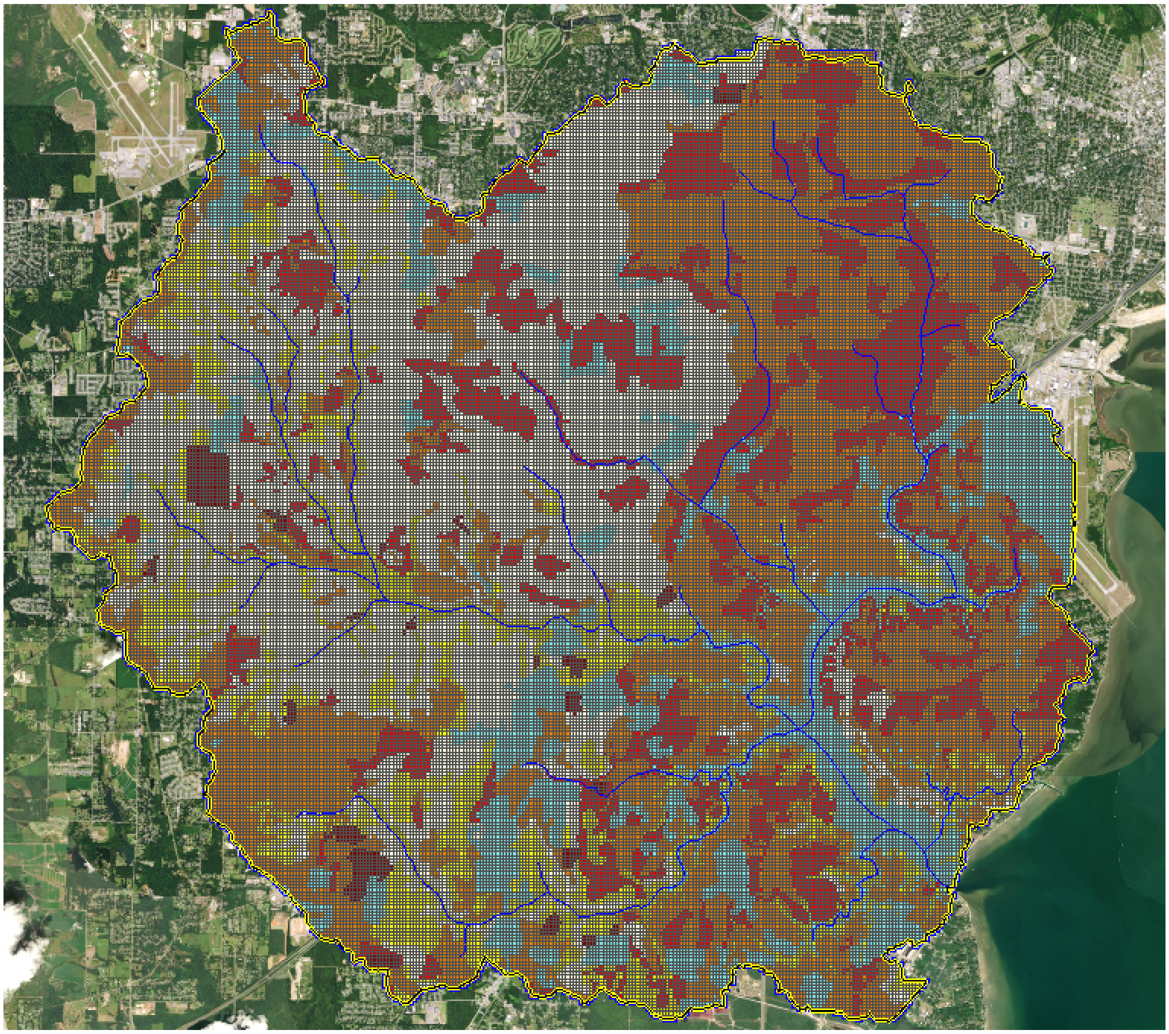
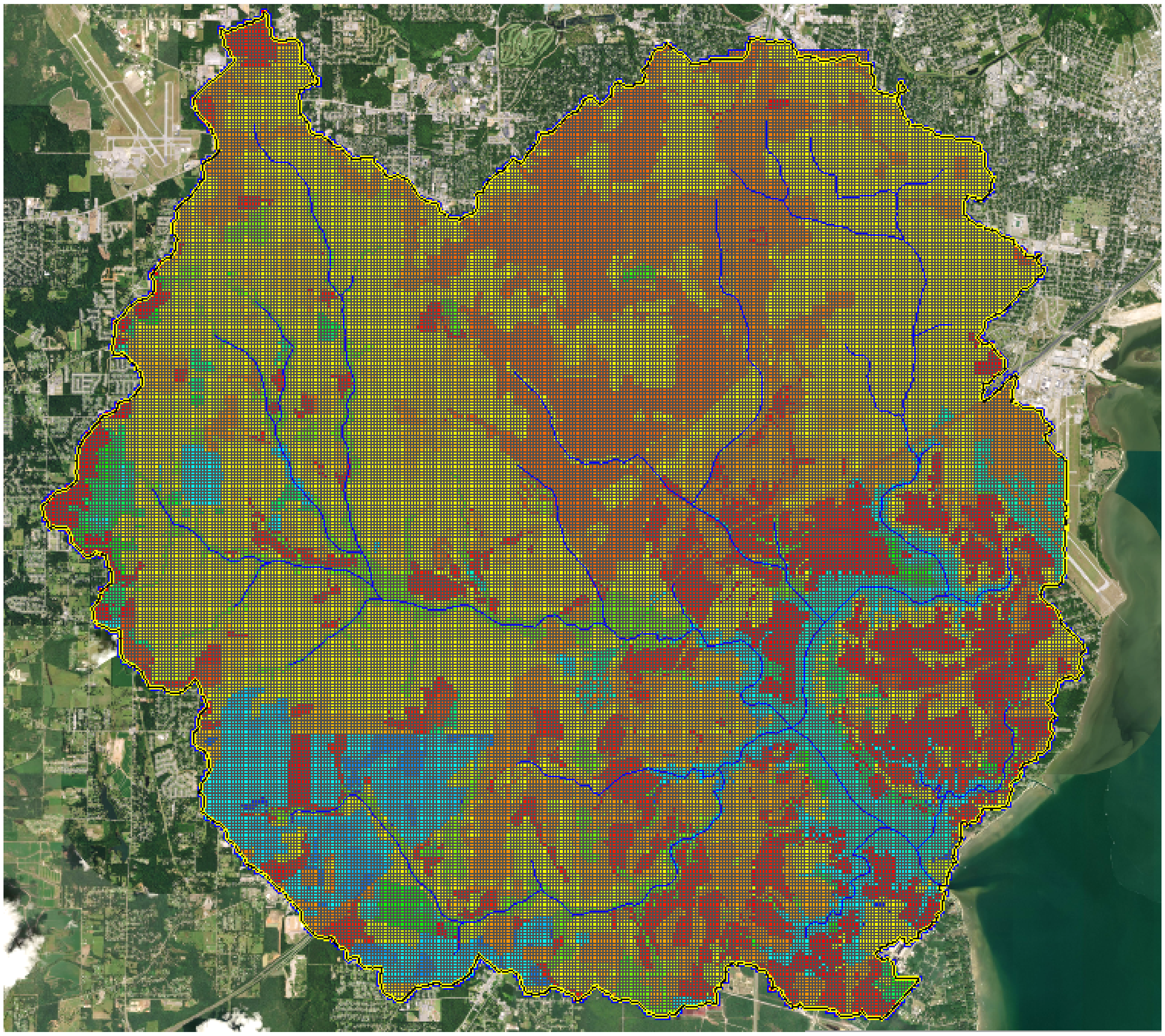


Figure 3-10
Watershed with Gridded Combined Data



4. Calibration

4.1. Dog River 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 distribution and river water surface elevations or discharge measurements during the rain event. With the rainfall distribution being obtained from the installed rain gauges, it was necessary to find or install gauges in the watershed to determine stream stages. Telog RU-33 gauges with level logger sensors were used for measuring stream data. These gauges contain a Recording Telemetry Unit (RTU) which forwards data wirelessly to a host computer which can be accessed through the internet. After a rain event, level data can easily be downloaded from the Telog Enterprise website. A site visit was performed in order to determine the best location for installing the monitoring gauges.

In addition to the RU-33 gauges, crest stage gages were also installed either upstream or downstream in order to record another highwater mark. These simple gages were constructed with PVC pipe, a wooden rod, and some crushed cork. During a flooding event, the cork would rise with the water level and then be deposited on the wooden rod. A measurement of the cork marking can be used to determine maximum stage height during the storm. These cork gauge marks were used in conjunction with the RU-33 highwater readings in order to obtain the water surface slope during the flood event.

There were five locations within the watershed that were deemed useful for monitoring (Figure 4-1). These locations were located near existing drainage structures to help with ease of access. Variables that come into consideration for a gauge location are dependent on location in the watershed, backwater effects, and the possibility of the gauge being vandalized. The five gauges were installed and started recording data between June 11 and June 13, 2018. A list of gauges and locations can be found in Table 4-1.

Figure 4-1
Watershed with Stream Gauge Locations

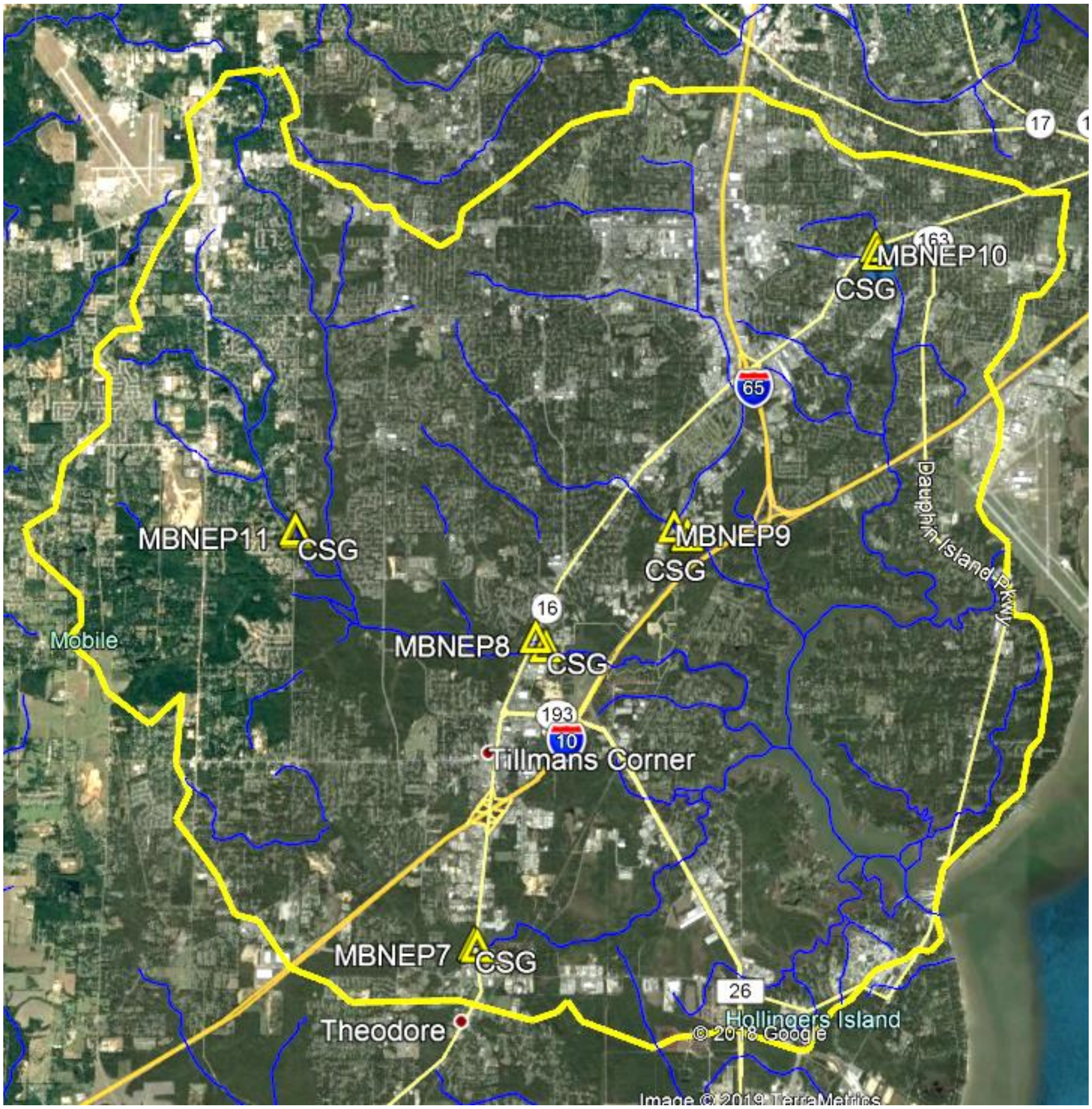


Table 4-1
Installed Gauge, Stream, and Location

Gauge Name	Stream	Location
MBNEP 7	Rabbit Creek	105’ d.s. of Government Blvd CL
Cork Gauge 7	Rabbit Creek	85’ u.s. of Government Blvd CL
MBNEP 8	Halls Mill Creek	60’ d.s. of Government Blvd CL
Cork Gauge 8	Halls Mill Creek	70’ u.s. of Halls Mill Rd CL
MBNEP 9	Moore Creek	10’ d.s. of Halls Mill Rd CL
Cork Gauge 9	Moore Creek	940’ d.s. of MBNEP 9
MBNEP 10	Woodcock Branch	125’ d.s. of Government Blvd CL
Cork Gauge 10	Woodcock Branch	470’ d.s. of MBNEP 10
MBNEP 11	Second Creek	65’ d.s of Sollie Rd CL
Cork Gauge 11	Second Creek	190’ d.s. of MBNEP 11

During the June 2018 to June 2020 time period there were a couple of storm events that were possible candidates for calibration and validation. From the stream gauge data (Figures 4-2 through 4-6) it was determined that a small rainfall event occurred on September 4-5, 2018 due to Tropical Storm Gordon. At this time, the weather stations were not installed therefore NOAA data needed to be used. This event produced an average of 2.5” of rain (uncorrected) throughout the watershed in approximately 5 hours. Using NOAA Atlas 14 (Figure 4-7) for this rain depth and time period, it was determined that this rain event is just under a 1-year storm.

Typically calibrations are not performed using such low storm events as the model variables usually do not translate to larger flooding events (25+ yr). This event was used, however, in order to get an initial understanding of how the watershed reacts. An initial calibration of the model was performed and compared to the stream gauge data. Figures 4-8 and 4-9 indicate the total rainfall maps for the September 4, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-10, and Figures 4-11 through 4-13, indicate the total rainfall distribution and the calibrated model output, respectively.

In order to compare discharges from the hydrologic model to the discharges in the field, it was necessary to build a hydraulic model of the stream in the location of the stream gauge. Information required for the hydraulic model includes a field surveyed cross-section at the location of the RU-33 gauge, Manning's 'n' values for the channel and floodplain, discharges, and a stream slope. The stream slope was determined from the difference in elevation of the peak stage at the RU-33 gauge and at the crest stage gage divided by the distance between them. A range of discharges were entered into the hydraulic model along with the stream slope in order to develop a rating curve. This curve was plotted in Excel against the discharge output from the hydrologic model. If any additional model cross-sections were necessary for enhancing the hydraulic model, they were cut using the LiDAR data obtained from NOAA.

Calibration of the model requires adjustment of the key parameters that affect infiltration, overland flow, and channel routing. The three main variables that are usually examined are hydraulic conductivity, overland roughness, soil moisture depth, top layer depth, and channel roughness. These values were adjusted until the model output best fit the observed data. Other factors that were considered are interception and retention.

Figure 4-2
MBNEP 7 Gauge Height Readings – June 2018-June 2020

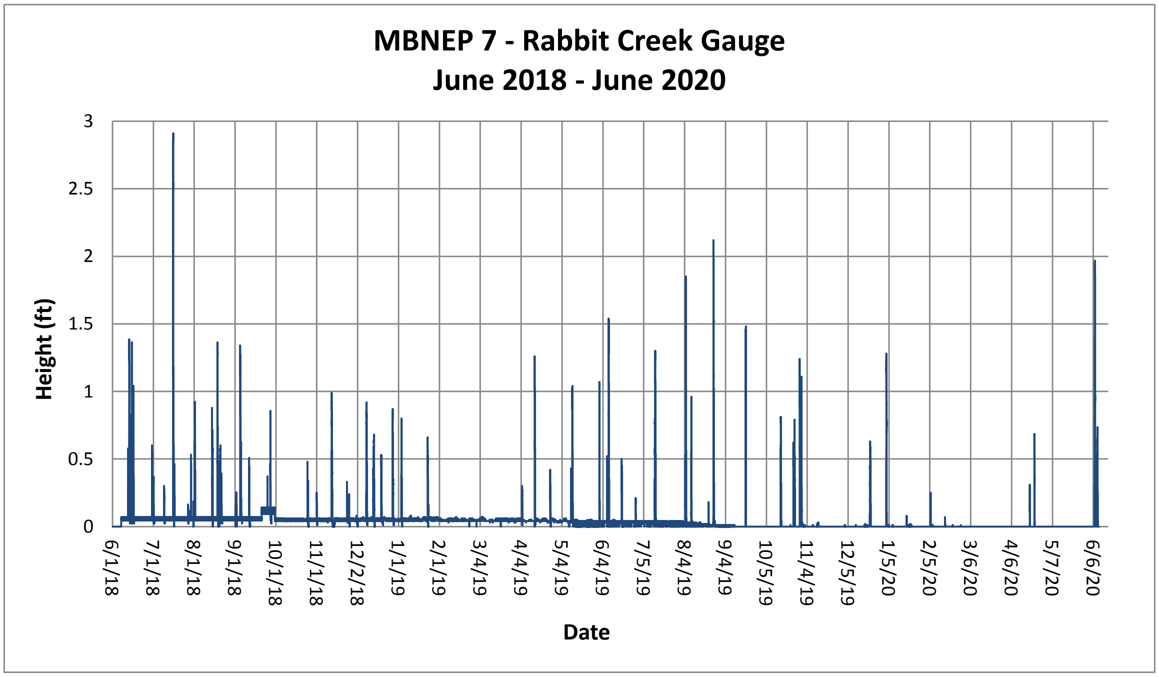


Figure 4-3
MBNEP 8 Gauge Height Readings – June 2018-June 2020

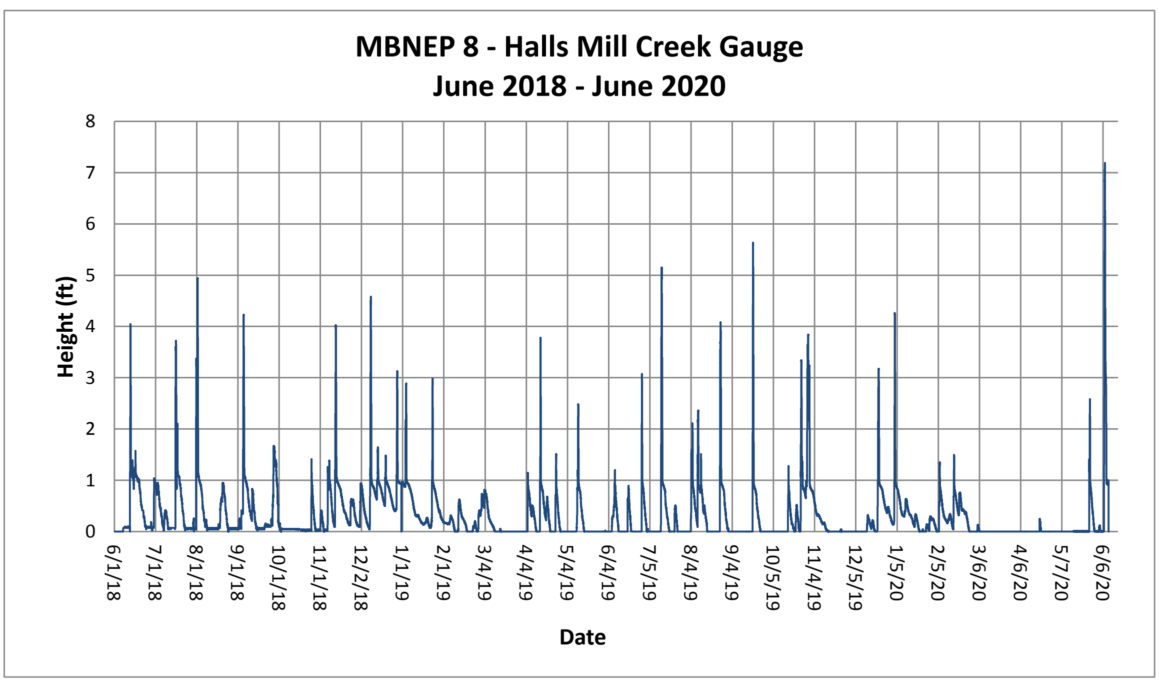


Figure 4-4
MBNEP 9 Gauge Height Readings – June 2018-June 2020

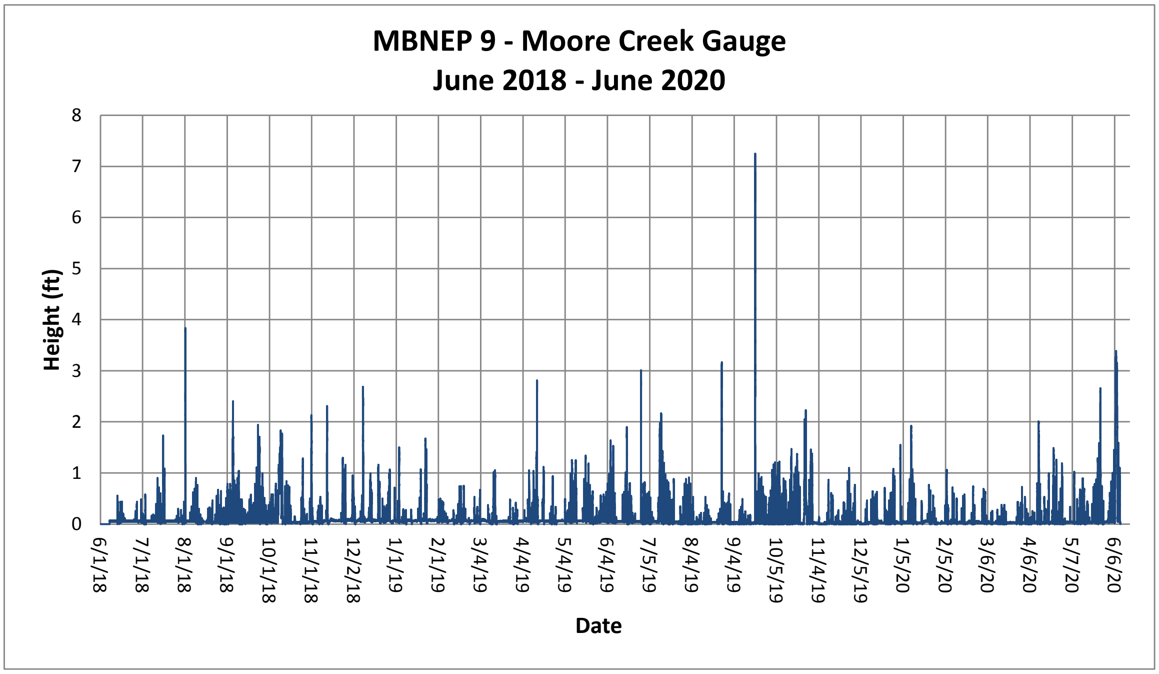


Figure 4-5
MBNEP 10 Gauge Height Readings – June 2018-June 2020

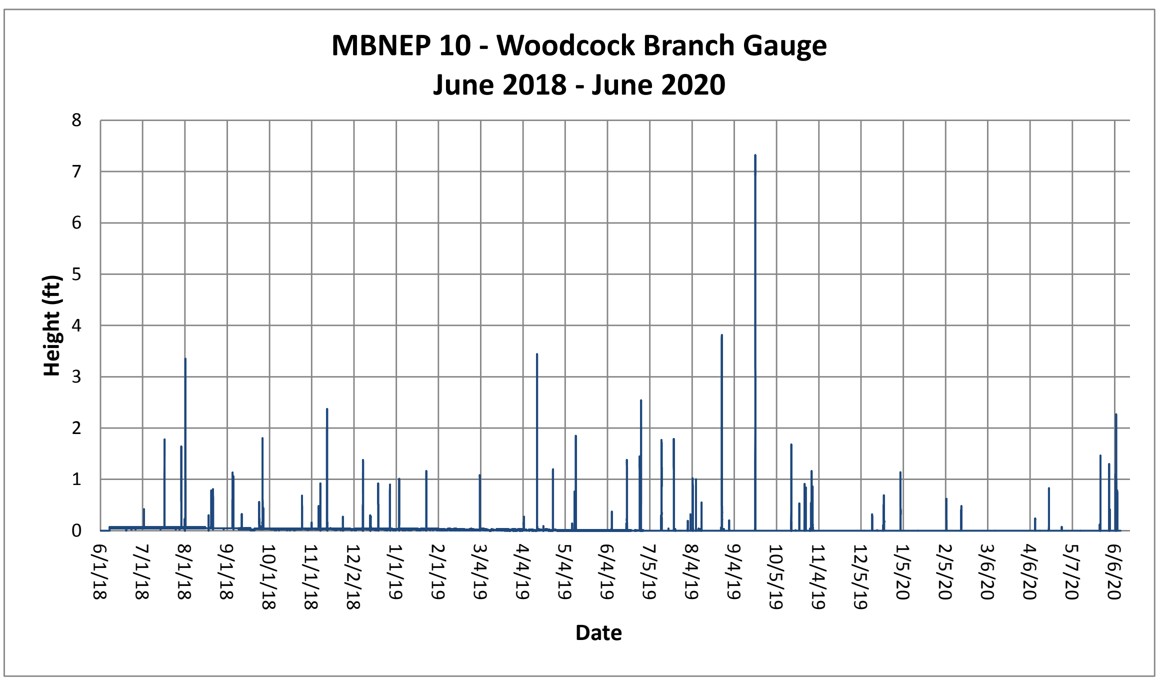


Figure 4-6
MBNEP 11 Gauge Height Readings – June 2018-June 2020

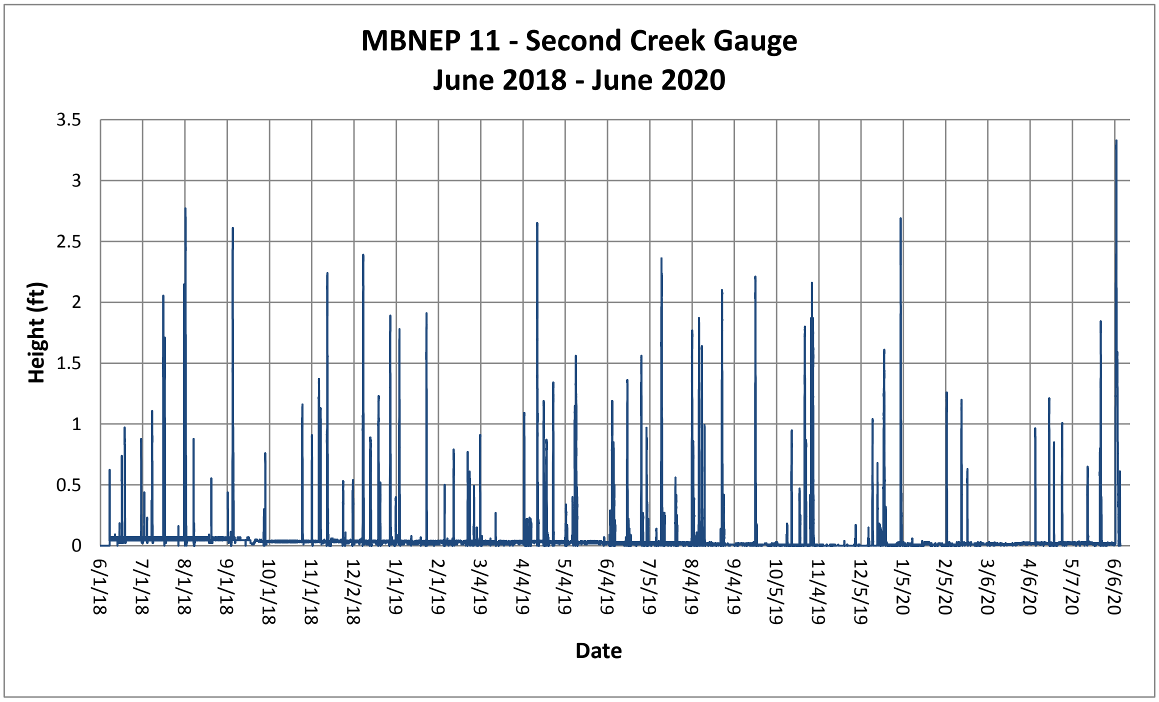


Figure 4-7
Point Precipitation Frequency Estimates

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 9, Version 2

PF tabular | PF graphical | Supplementary information | Print page

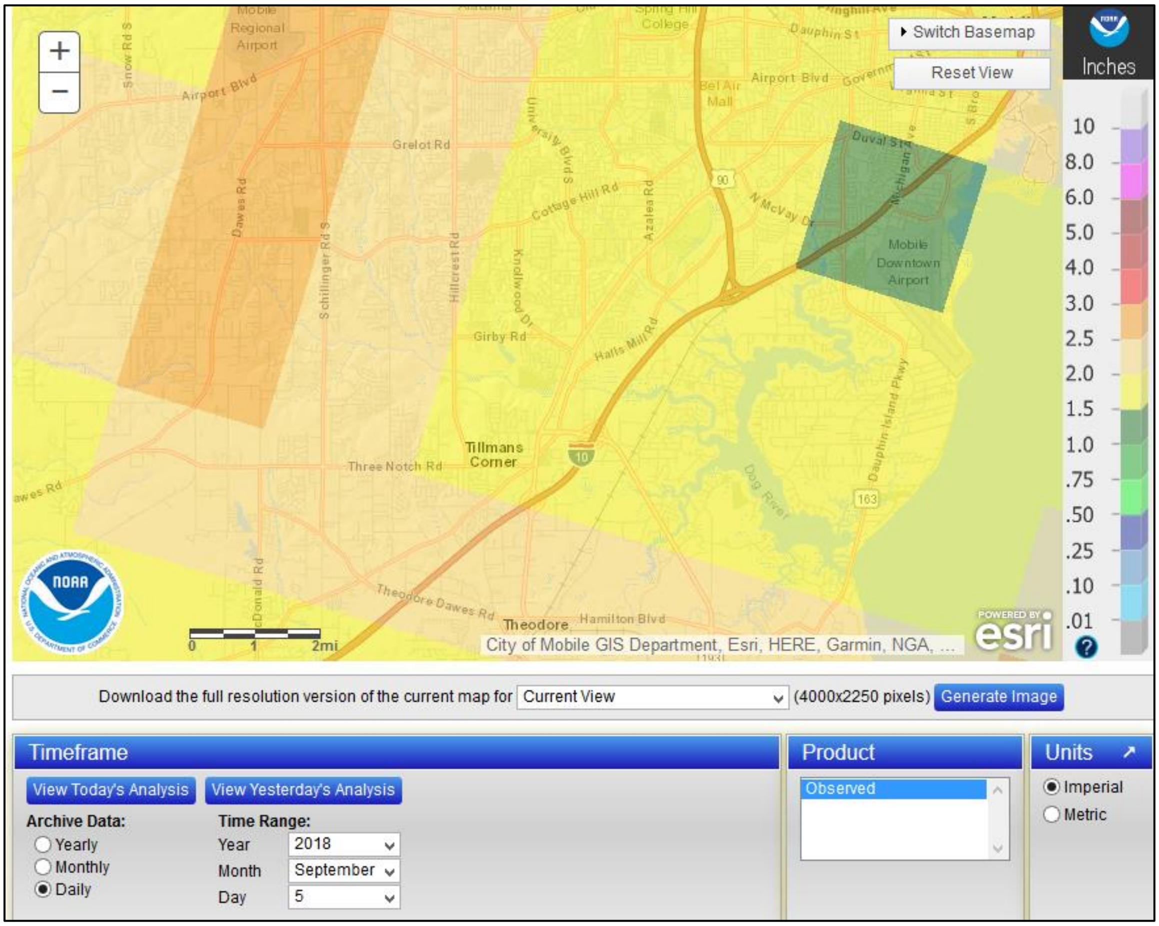
PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)								
	1	2	5	10	25	50	100	200	500
5-min	**0.623** (0.511-0.758)	**0.709** (0.580-0.863)	**0.849** (0.693-1.04)	**0.967** (0.785-1.18)	**1.13** (0.887-1.42)	**1.26** (0.964-1.60)	**1.39** (1.03-1.80)	**1.52** (1.08-2.01)	**1.70** (1.16-2.30)
10-min	**0.913** (0.748-1.11)	**1.04** (0.850-1.26)	**1.24** (1.01-1.52)	**1.42** (1.15-1.73)	**1.66** (1.30-2.08)	**1.84** (1.41-2.34)	**2.03** (1.50-2.63)	**2.23** (1.58-2.95)	**2.48** (1.69-3.37)
15-min	**1.11** (0.912-1.35)	**1.27** (1.04-1.54)	**1.52** (1.24-1.85)	**1.73** (1.40-2.12)	**2.02** (1.58-2.54)	**2.25** (1.72-2.85)	**2.48** (1.83-3.21)	**2.71** (1.92-3.59)	**3.03** (2.06-4.10)
30-min	**1.58** (1.30-1.92)	**1.81** (1.48-2.20)	**2.19** (1.78-2.67)	**2.50** (2.03-3.06)	**2.93** (2.30-3.68)	**3.27** (2.50-4.14)	**3.60** (2.66-4.67)	**3.95** (2.79-5.22)	**4.40** (3.00-5.96)
60-min	**2.11** (1.73-2.57)	**2.40** (1.96-2.92)	**2.89** (2.35-3.52)	**3.30** (2.68-4.05)	**3.91** (3.07-4.92)	**4.39** (3.36-5.59)	**4.88** (3.62-6.34)	**5.40** (3.83-7.18)	**6.11** (4.17-8.30)
2-hr	**2.64** (2.18-3.18)	**2.99** (2.46-3.61)	**3.59** (2.94-4.34)	**4.11** (3.36-5.00)	**4.88** (3.87-6.12)	**5.51** (4.26-6.98)	**6.16** (4.60-7.97)	**6.86** (4.90-9.06)	**7.83** (5.38-10.6)
3-hr	**3.00** (2.48-3.60)	**3.39** (2.80-4.07)	**4.07** (3.36-4.91)	**4.69** (3.84-5.67)	**5.61** (4.48-7.04)	**6.38** (4.96-8.08)	**7.20** (5.40-9.30)	**8.08** (5.81-10.7)	**9.32** (6.44-12.6)
6-hr	**3.62** (3.02-4.31)	**4.13** (3.44-4.92)	**5.05** (4.19-6.04)	**5.89** (4.86-7.07)	**7.18** (5.78-8.98)	**8.27** (6.48-10.4)	**9.44** (7.14-12.1)	**10.7** (7.76-14.1)	**12.5** (8.71-16.8)
12-hr	**4.23** (3.55-5.00)	**4.94** (4.14-5.84)	**6.21** (5.19-7.37)	**7.38** (6.13-8.79)	**9.16** (7.43-11.4)	**10.7** (8.40-13.3)	**12.3** (9.33-15.7)	**14.0** (10.2-18.3)	**16.5** (11.6-22.0)
24-hr	**4.91** (4.15-5.76)	**5.78** (4.88-6.79)	**7.36** (6.19-8.67)	**8.83** (7.38-10.4)	**11.1** (9.05-13.7)	**13.0** (10.3-16.2)	**15.0** (11.5-19.1)	**17.3** (12.7-22.4)	**20.5** (14.5-27.2)
2-day	**5.72** (4.87-6.66)	**6.65** (5.65-7.75)	**8.39** (7.11-9.80)	**10.0** (8.46-11.8)	**12.6** (10.4-15.5)	**14.8** (11.9-18.4)	**17.3** (13.4-21.8)	**19.9** (14.8-25.8)	**23.8** (16.9-31.4)
3-day	**6.23** (5.32-7.21)	**7.23** (6.17-8.39)	**9.10** (7.74-10.6)	**10.9** (9.18-12.7)	**13.6** (11.3-16.7)	**16.0** (12.8-19.7)	**18.5** (14.4-23.3)	**21.3** (15.9-27.4)	**25.4** (18.1-33.4)
4-day	**6.65** (5.70-7.68)	**7.70** (6.59-8.90)	**9.64** (8.22-11.2)	**11.5** (9.71-13.3)	**14.3** (11.8-17.4)	**16.7** (13.4-20.5)	**19.3** (15.0-24.2)	**22.2** (16.5-28.4)	**26.3** (18.8-34.5)
7-day	**7.78** (6.70-8.92)	**8.83** (7.60-10.1)	**10.8** (9.25-12.4)	**12.6** (10.8-14.6)	**15.5** (12.9-18.7)	**17.9** (14.5-21.8)	**20.5** (16.1-25.6)	**23.4** (17.6-29.8)	**27.6** (19.9-36.0)

* This chart was generated from the lat/long point of 30.625, -88.156

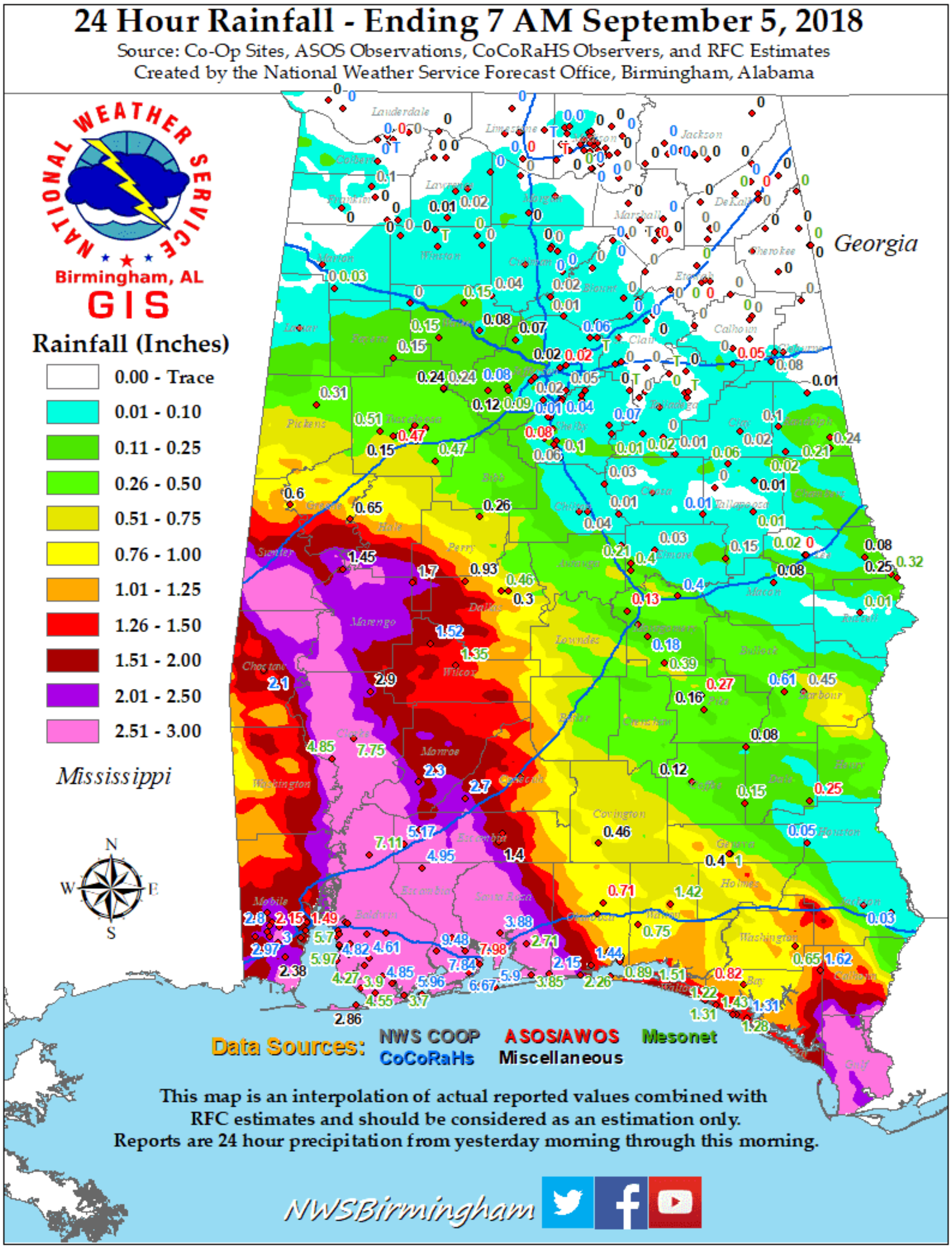
Source: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=al

Figure 4-8
September 4-5, 2018 – AHPS Total Rainfall Map



Source: https://water.weather.gov/precip/

Figure 4-9
September 4-5, 2018 – Total Rainfall Map



Source: https://www.weather.gov/bmx/rainfallplots

Figure 4-10
September 4-5, 2018 – Total Rainfall Distribution

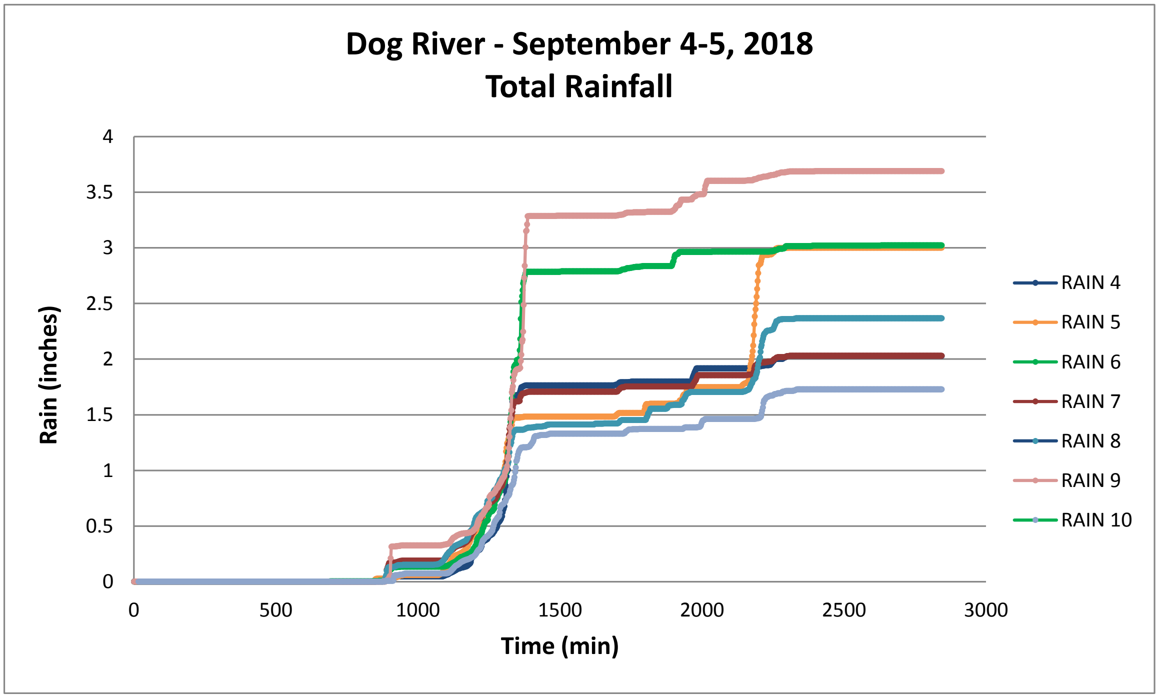


Figure 4-11
September 4-5, 2018 – Rabbit Creek Calibration

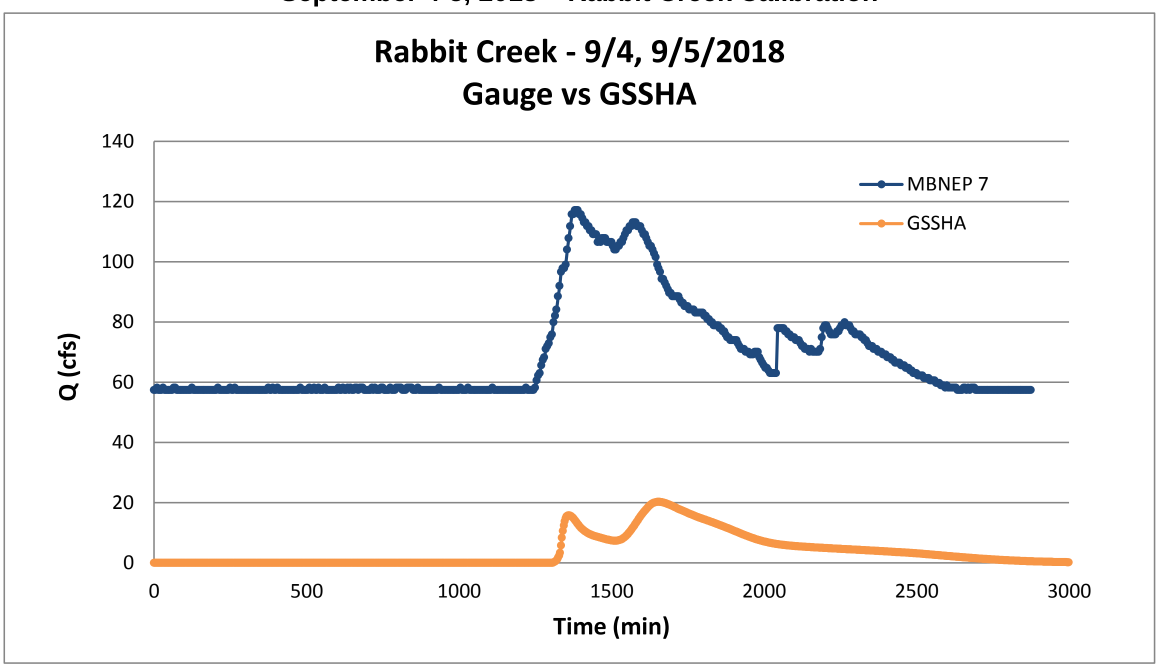


Figure 4-12
September 4-5, 2018 – Halls Mill Creek Calibration

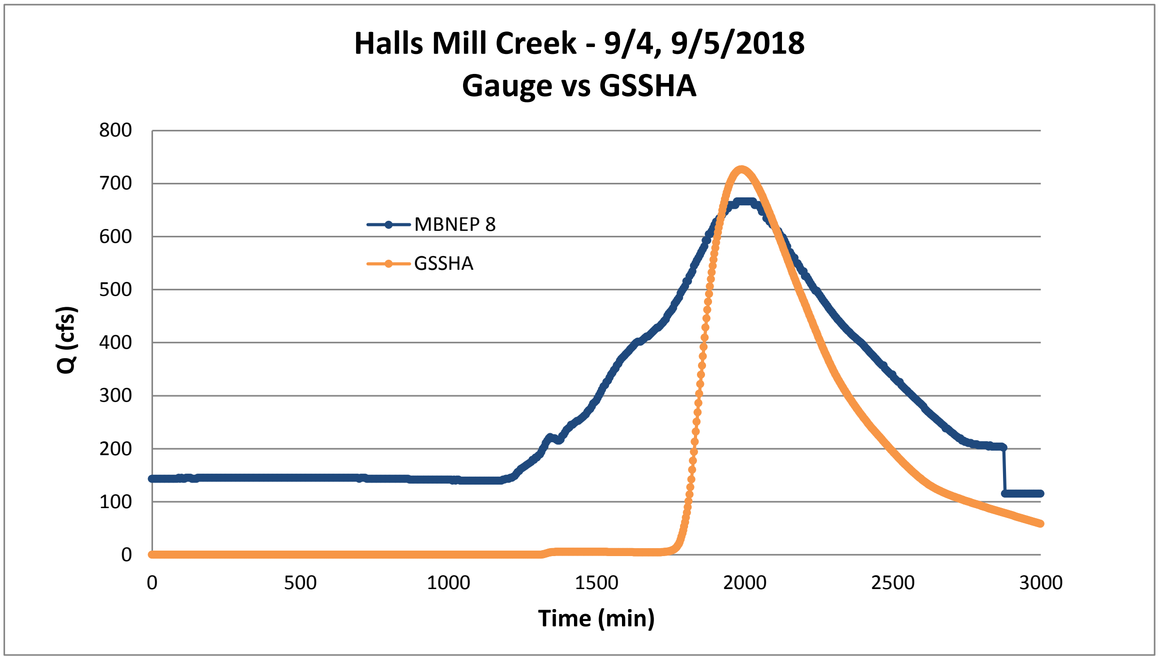
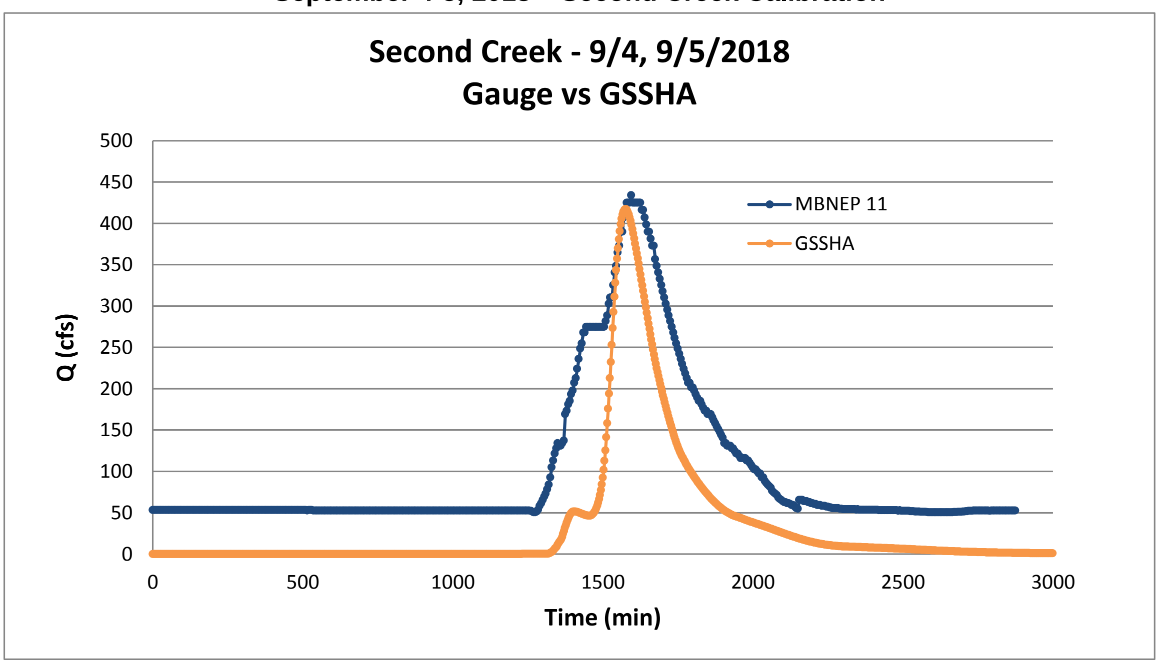


Figure 4-13
September 4-5, 2018 – Second Creek Calibration



A second rainfall event occurred on December 8, 2018 when, on average, approximately 2.8” of rain fell in 12 hours. Using Figure 4-7, it was determined that this event was less than a 1-year storm. Locally the highest amount of rainfall fell in the northeastern portion of the watershed near the intersection of Airport Road and I-65. Figures 4-14 and 4-15 indicate the total rainfall maps for the December 8, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-16, and Figures 4-17 through 4-21, indicate total rainfall distribution and the calibrated model output, respectively.

Figure 4-14
December 8-9, 2018 – AHPS Total Rainfall Map

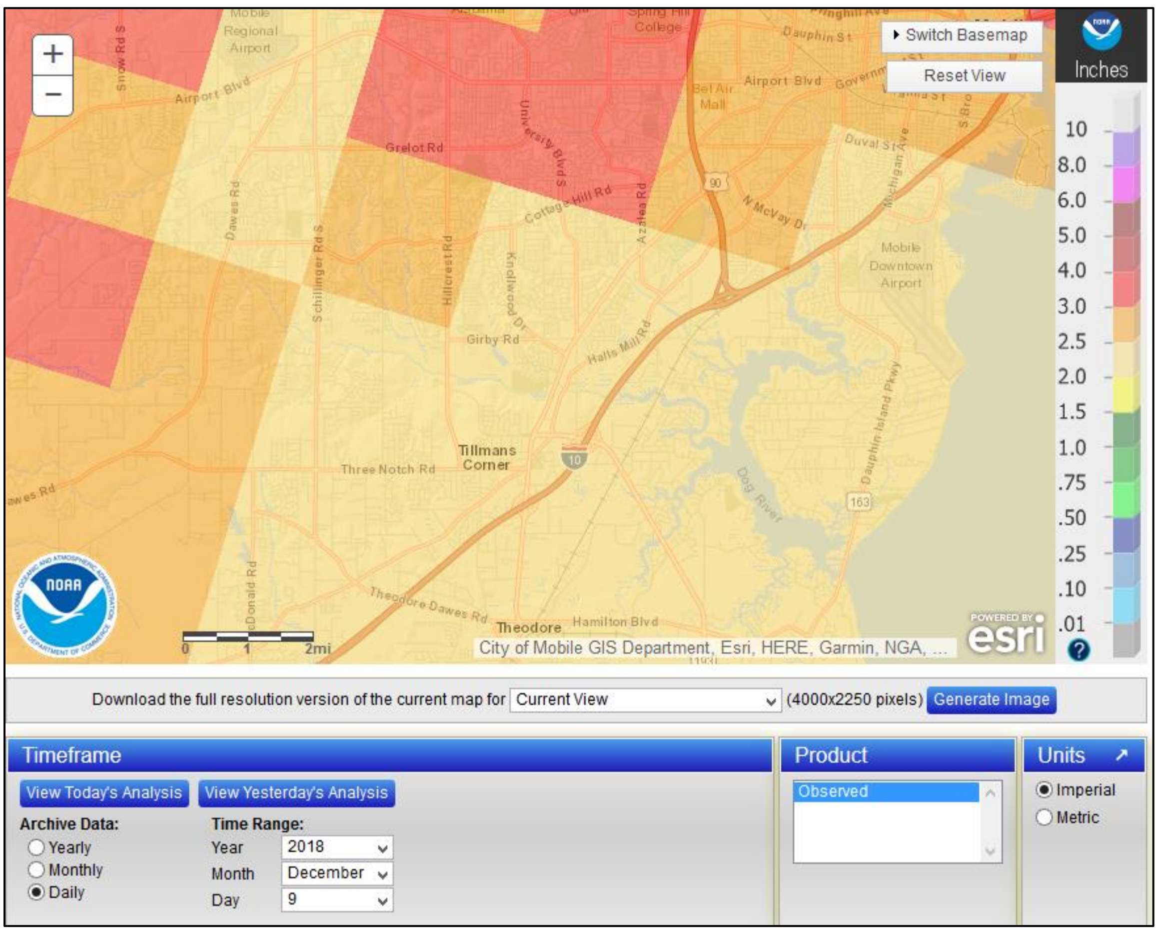


Figure 4-15
December 8-9, 2018 – Total Rainfall Map

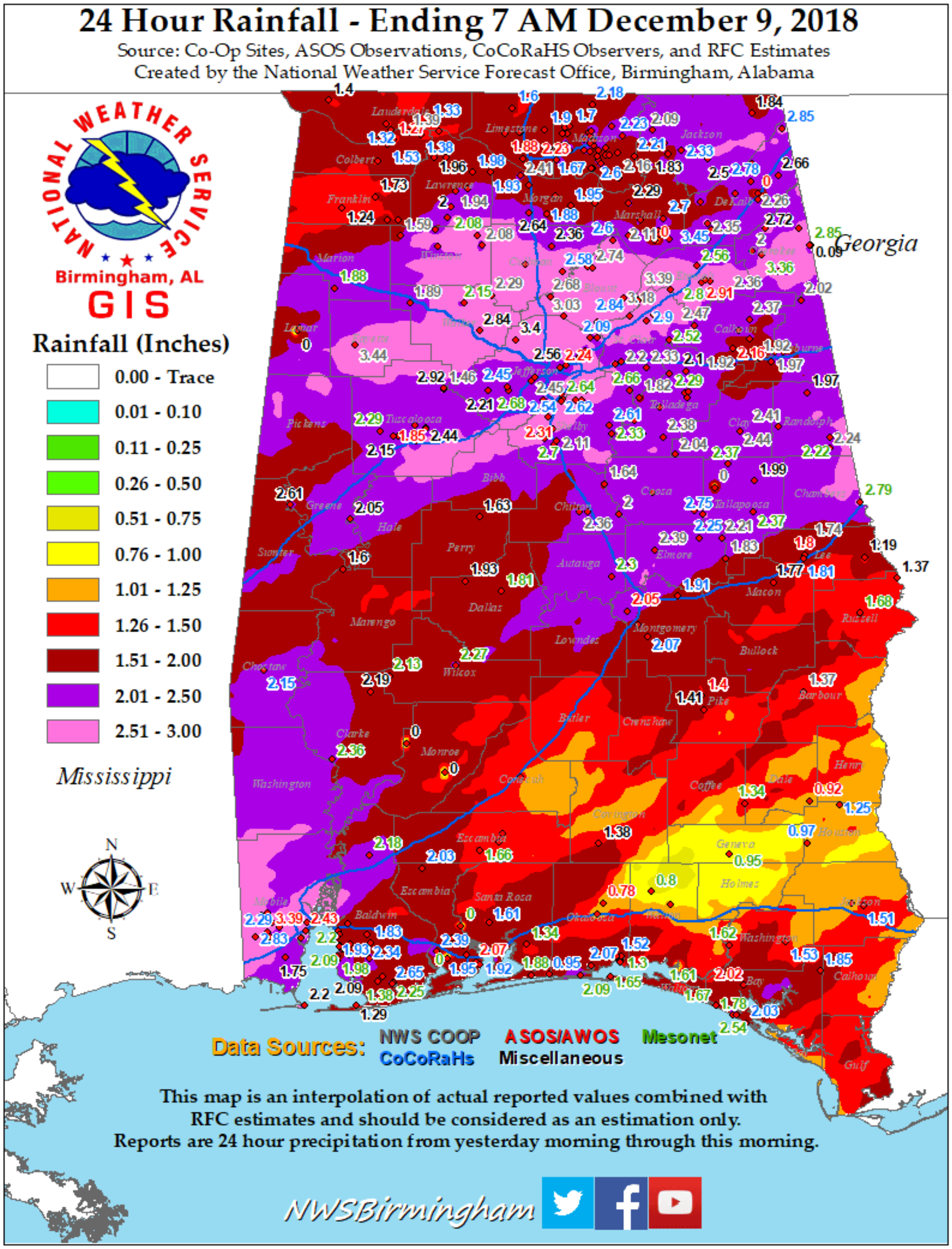


Figure 4-16
December 8, 2018 – Total Rainfall Distribution

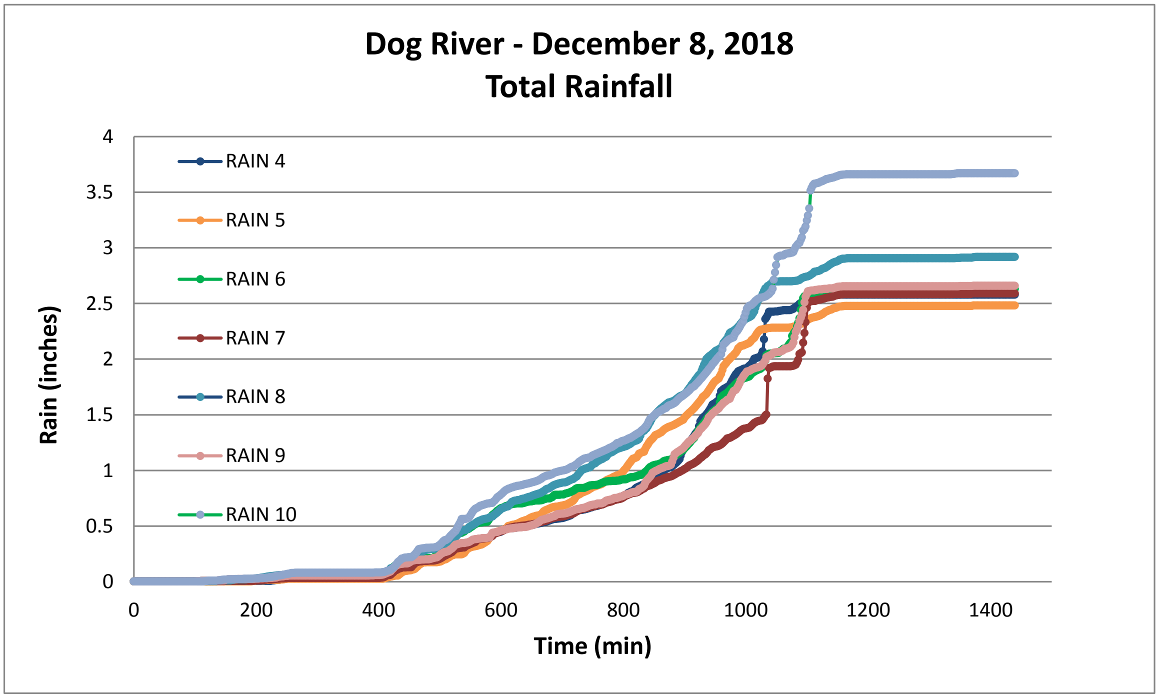


Figure 4-17
December 8-9, 2018 – Rabbit Creek Calibration

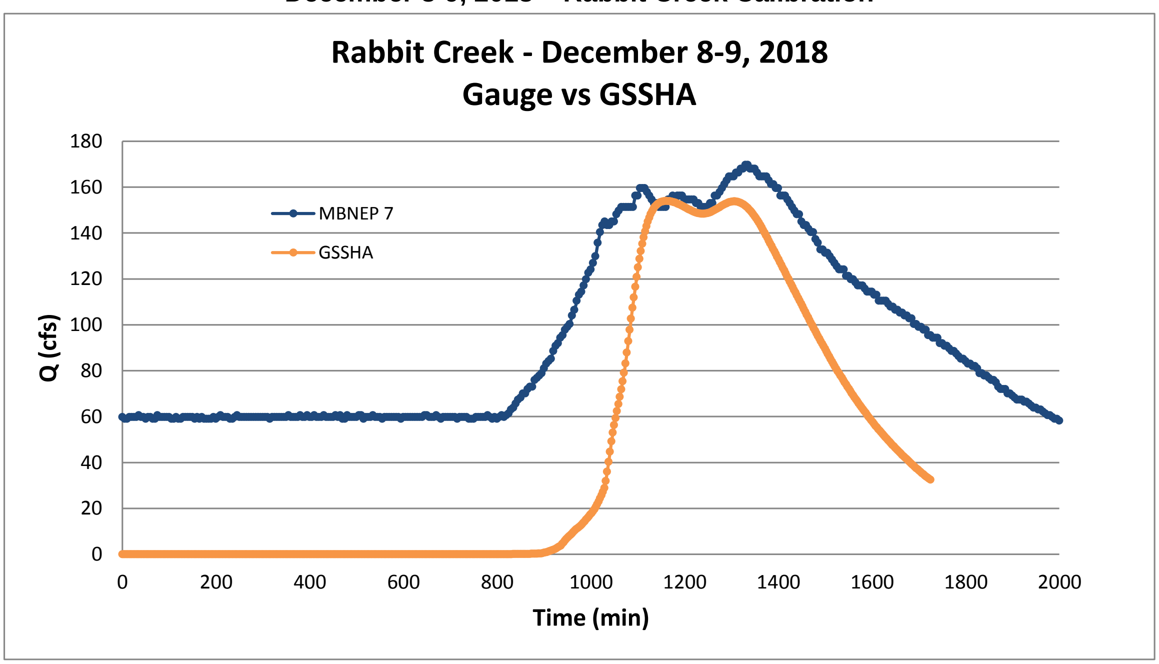


Figure 4-18
December 8-9, 2018 – Halls Mill Creek Calibration

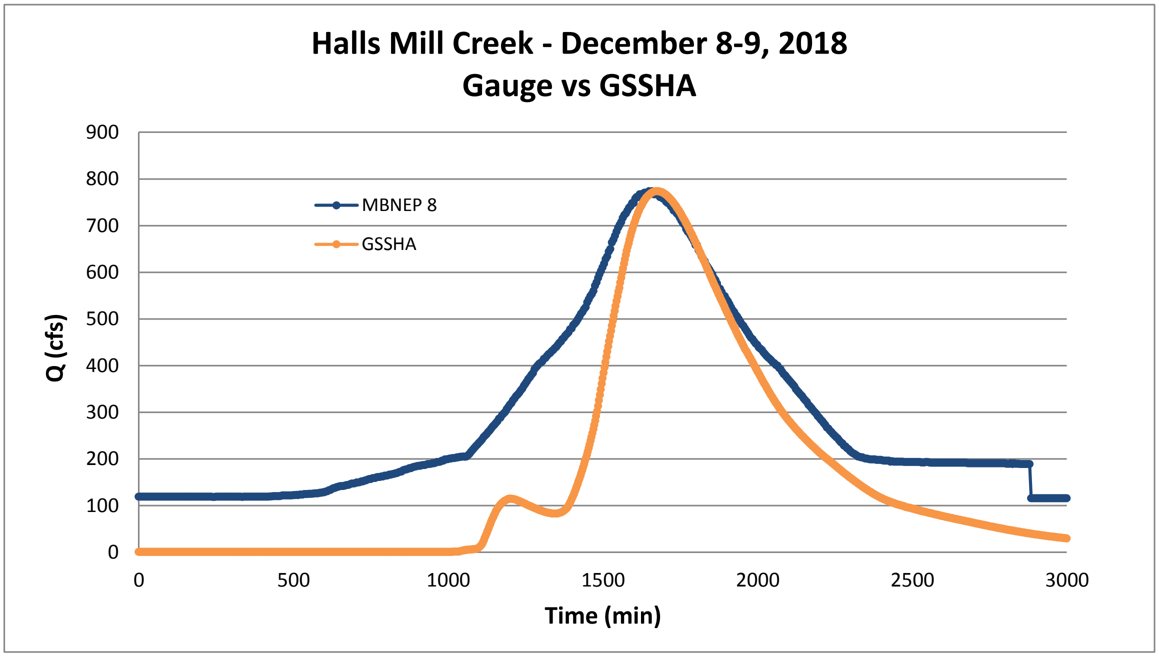


Figure 4-19
December 8-9, 2018 – Moore Creek Calibration

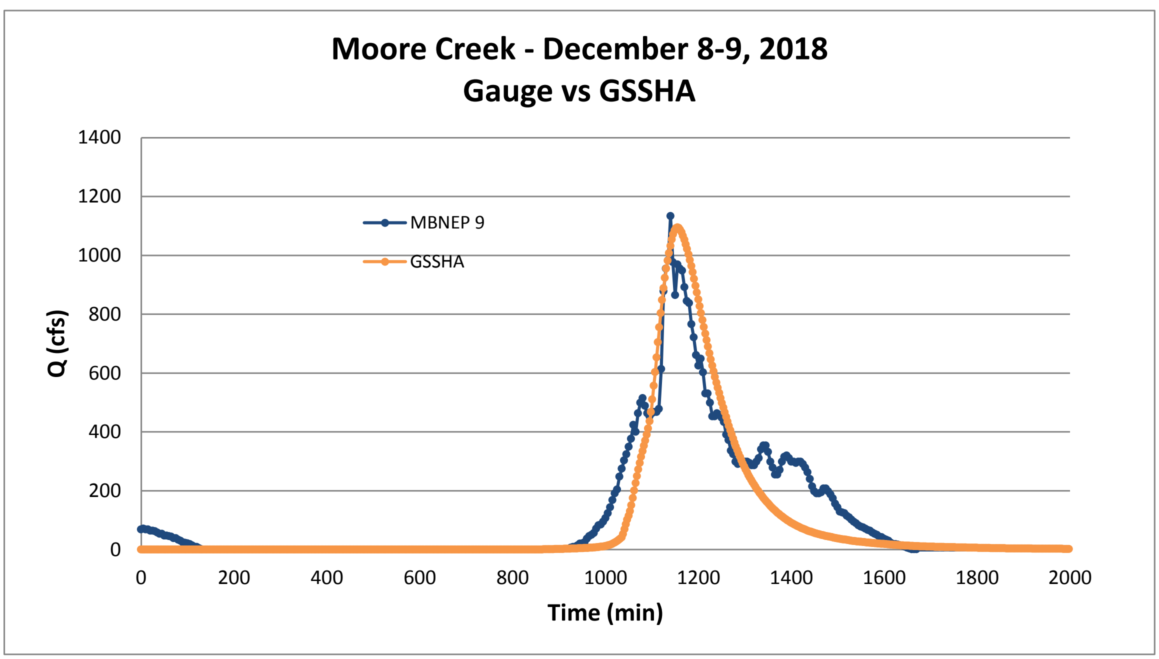


Figure 4-20
December 8-9, 2018 – Woodcock Branch Calibration

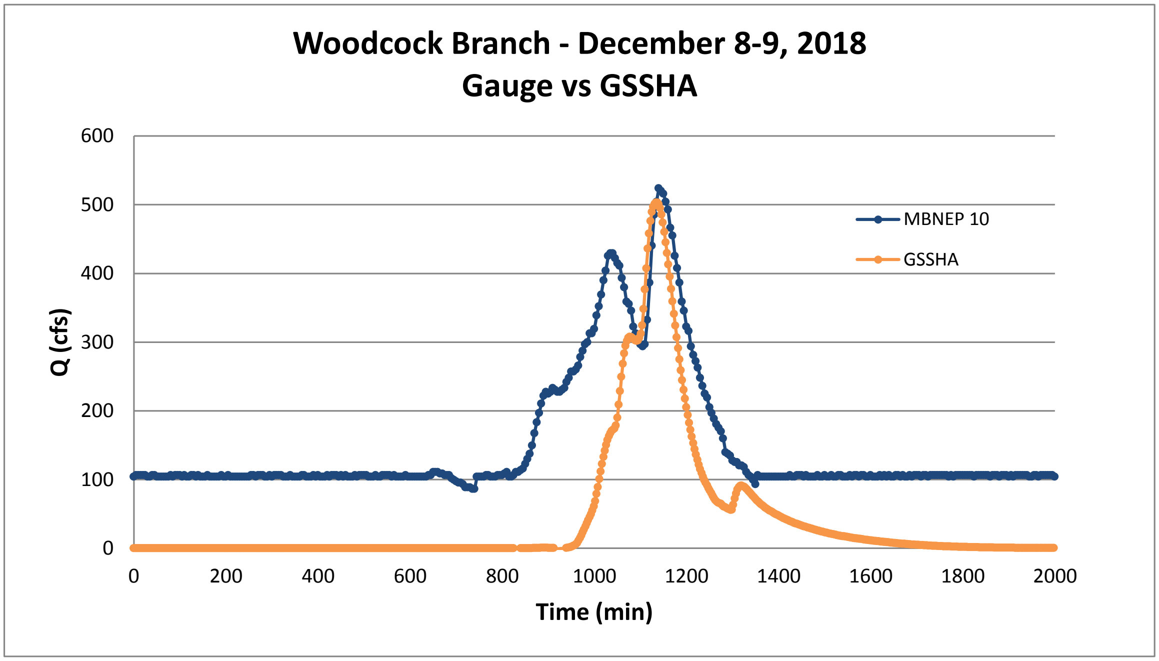
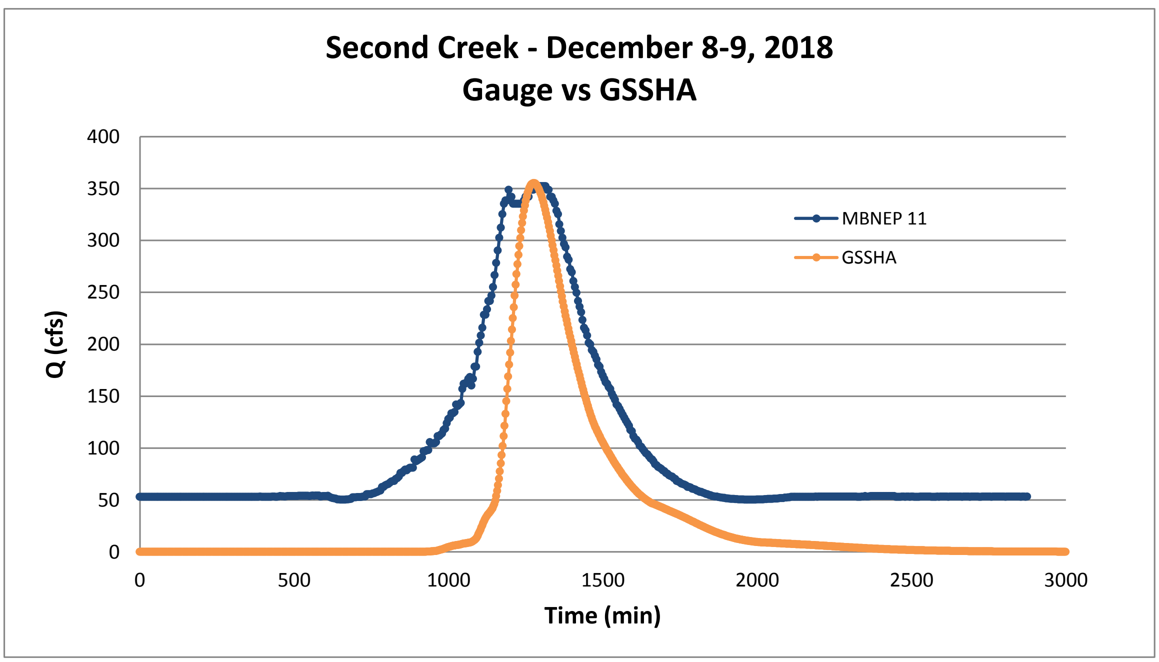


Figure 4-21
December 8-9, 2018 – Second Creek Calibration



The next event that was used for calibration occurred on August 26, 2019. This storm produced approximately 3.7" of rain in 6 hours. Utilizing Figure 4-7, it was determined that amount of rain is equivalent to a 1-year event. Locally, the middle of the watershed experienced 4 to 4.5 inches of rain in the same time frame. This was determined to be greater than a 2-year storm. The streams most impacted by these local rains are Halls Mill Creek and Moore Creek.

Figures 4-22 and 4-23 indicate the total rainfall maps for the August 26, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-24, and Figures 4-25 through 4-29, indicate total rainfall distribution and the calibrated model output, respectively.

Figure 4-22
August 26-27, 2019 – AHPS Total Rainfall Map

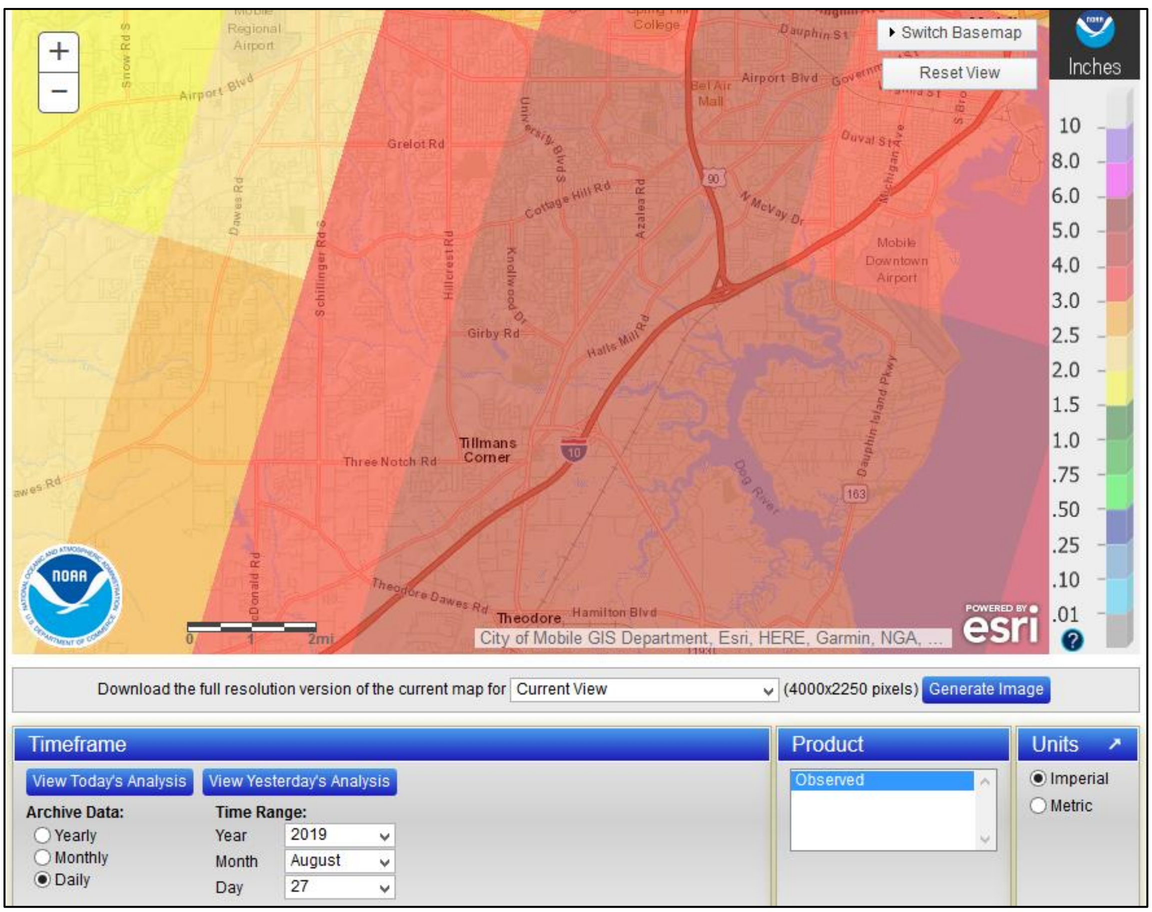


Figure 4-23
August 26-27, 2019 – Total Rainfall Map

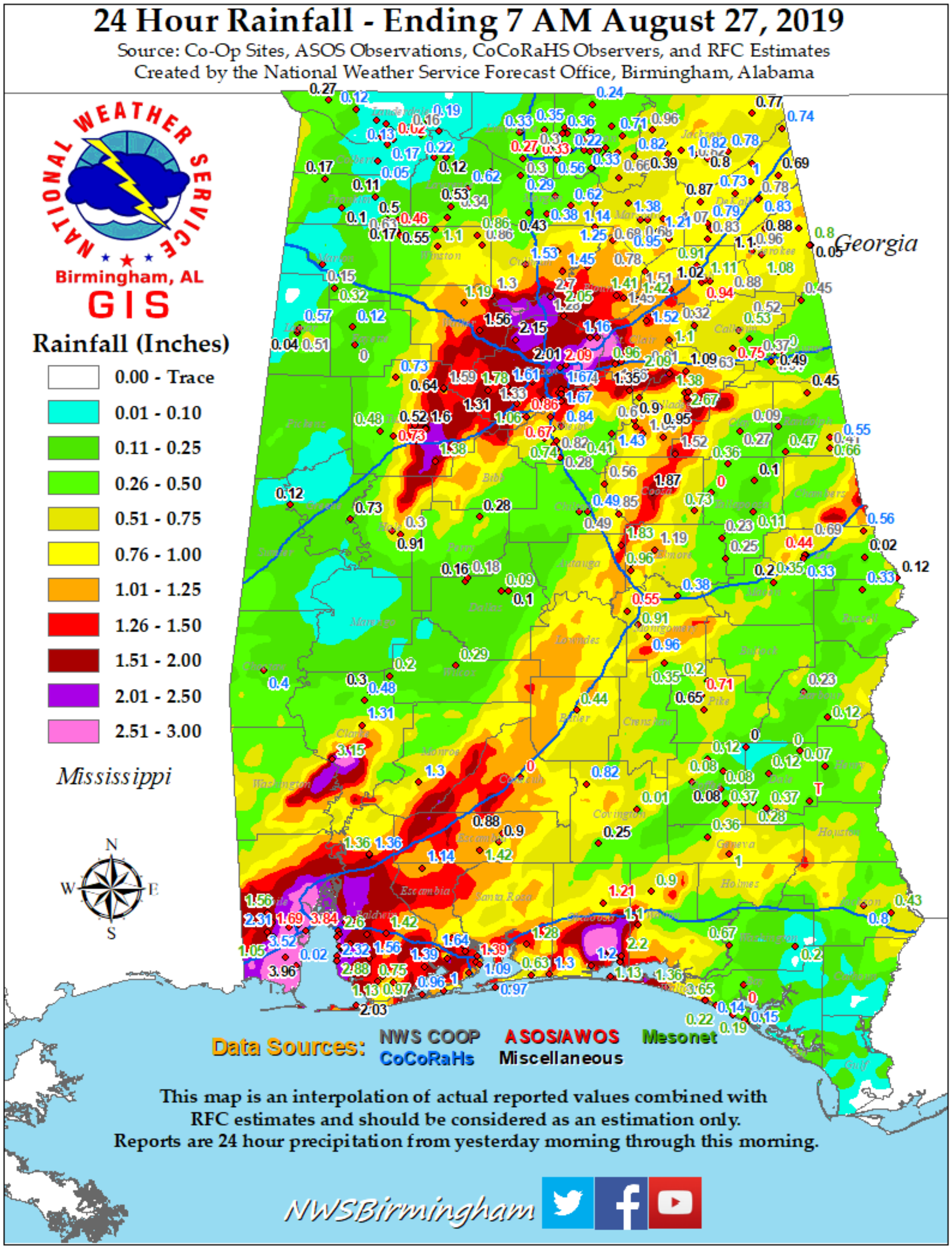


Figure 4-24
August 26, 2019 – Total Rainfall Distribution

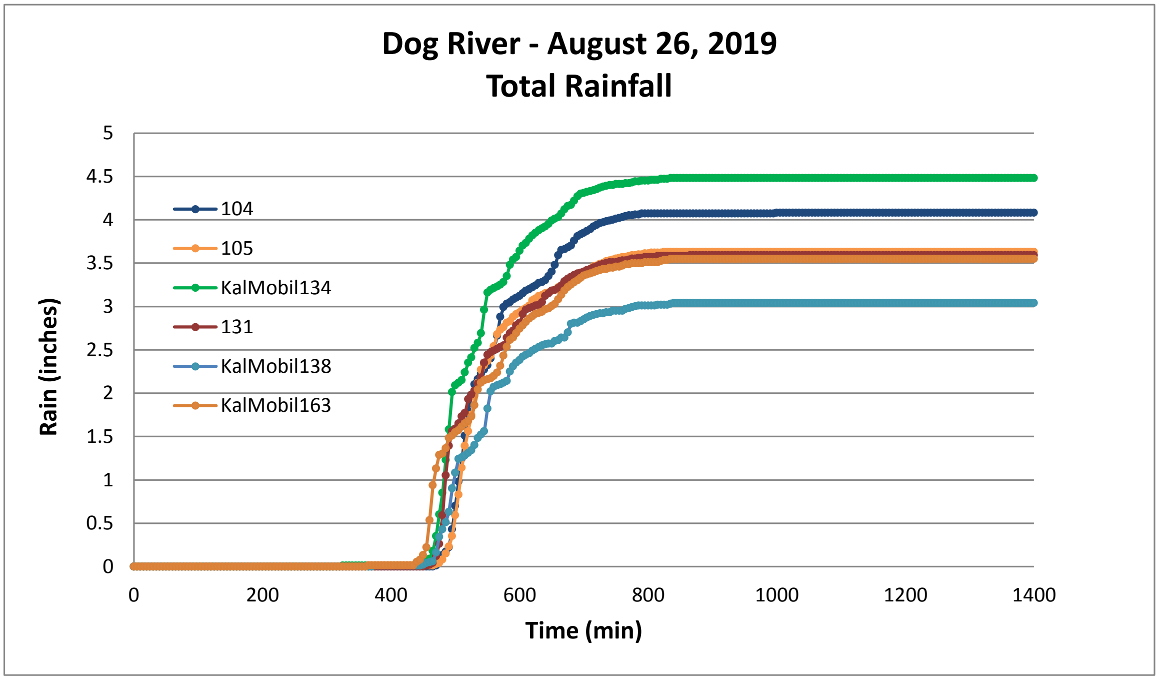


Figure 4-25
August 26, 2019 – Rabbit Creek Calibration

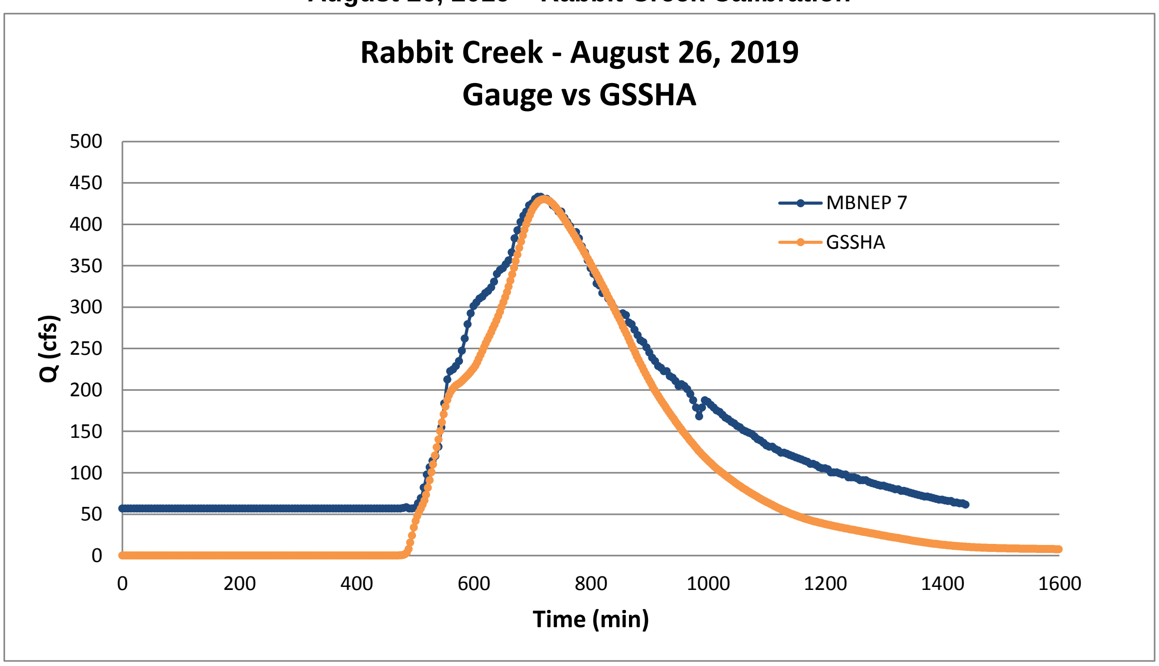


Figure 4-26
August 26-27, 2019 – Halls Mill Creek Calibration

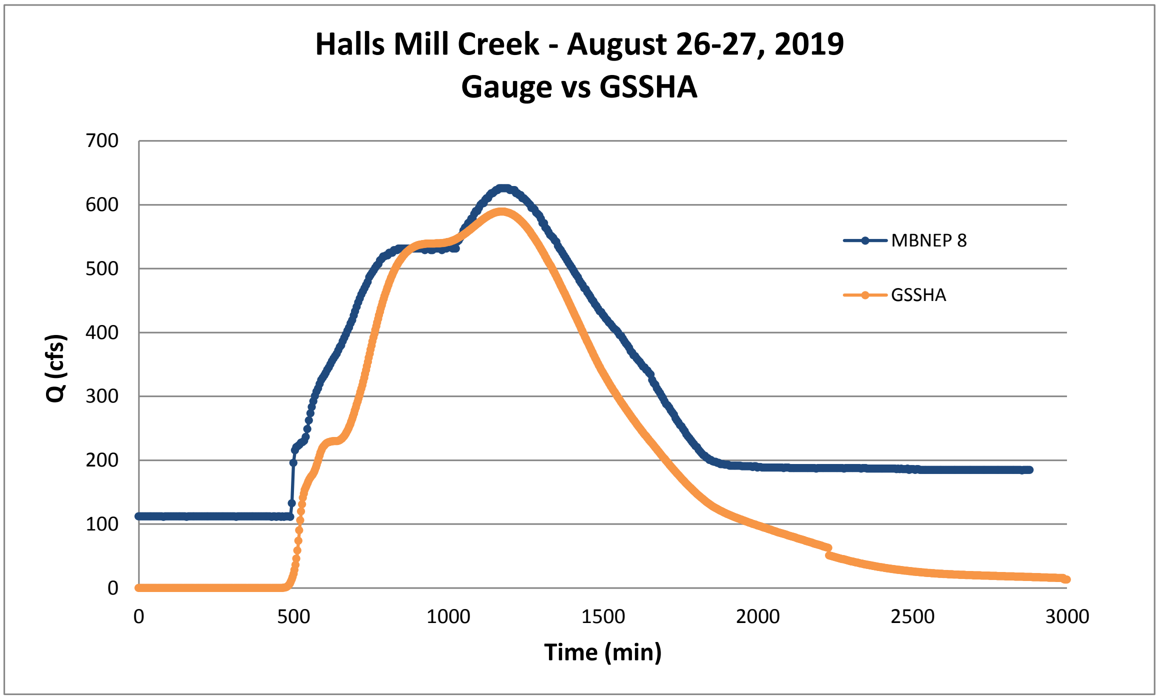


Figure 4-27
August 26, 2019 – Moore Creek Calibration

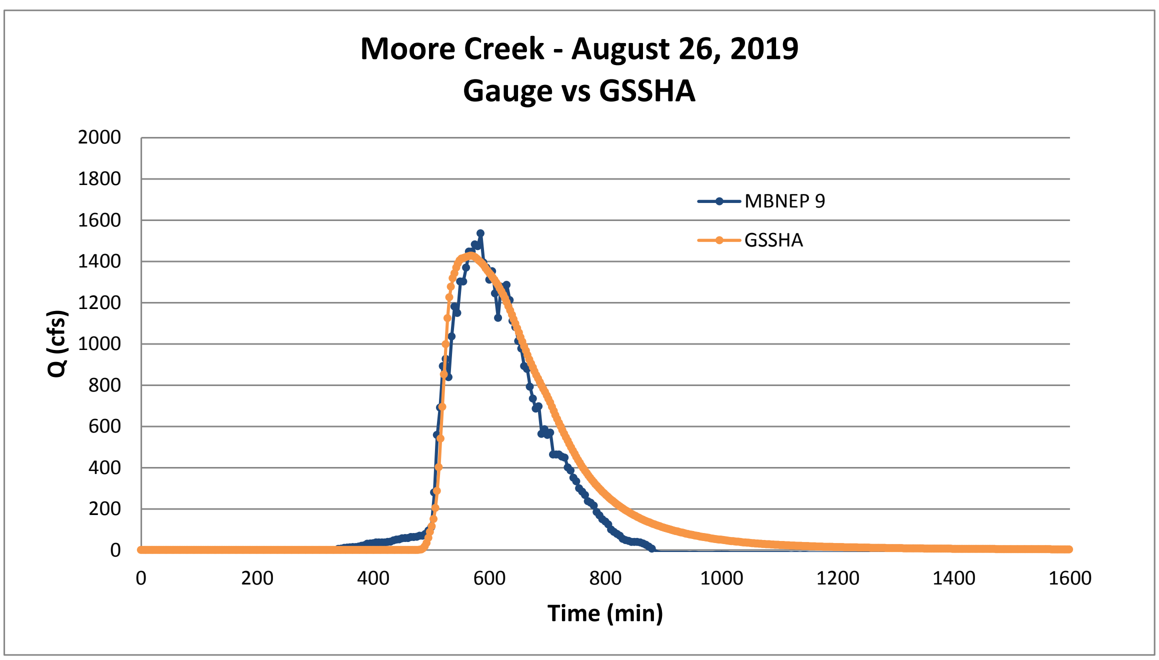


Figure 4-28
August 26, 2019 – Woodcock Branch Calibration

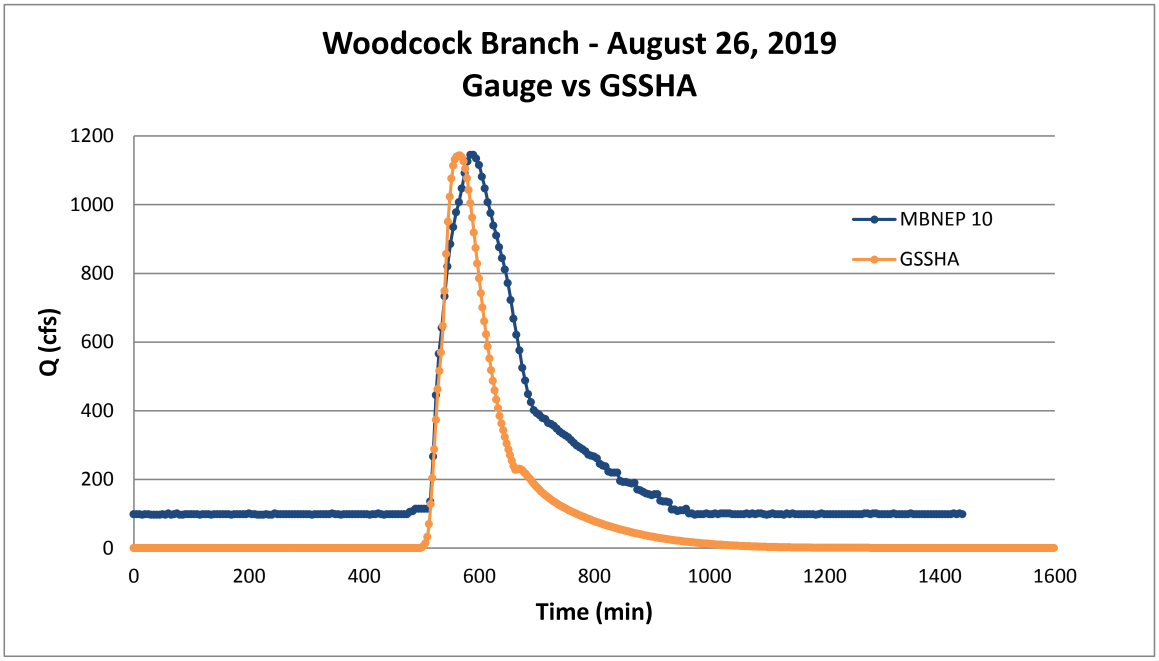
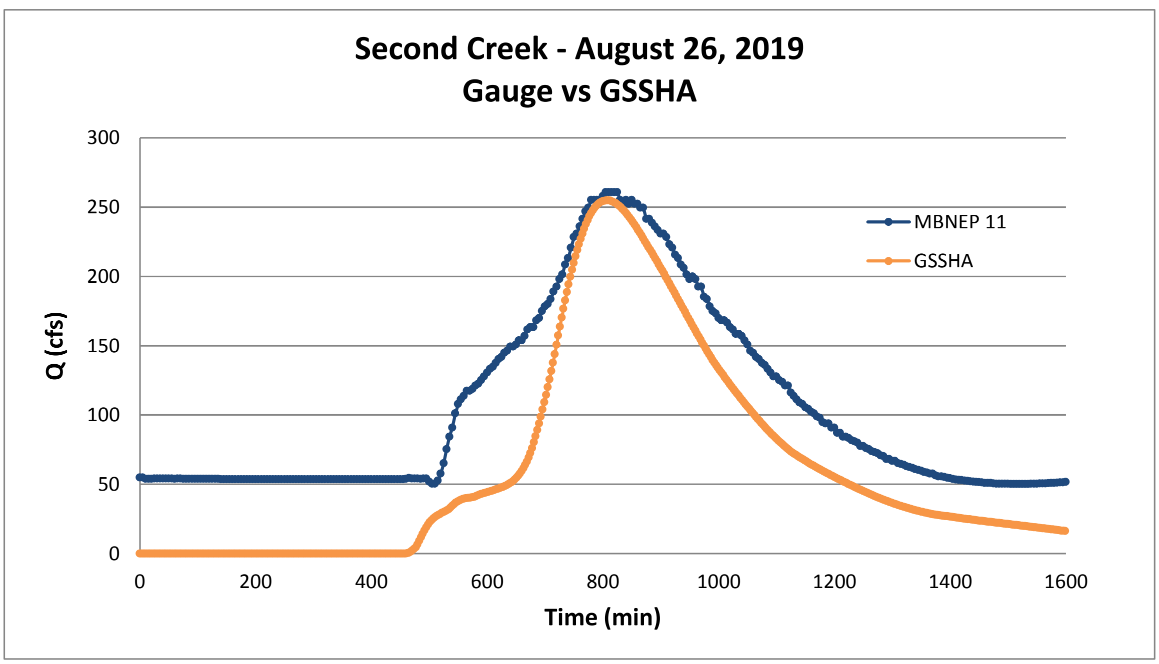


Figure 4-29
August 26, 2019 – Second Creek Calibration



The largest overall event used for analyzing the basin occurred on September 19, 2019. During this rain event, the northeast part of the watershed experienced, on average, 8” of rain in 3 hours (Figure 4-30). Using NOAA Atlas 14 (Figure 4-7) for this rain depth and time period, it was determined that this rain event is approximately a 200-year storm. At one location, the rainfall exceeded 9” of rain in 3 hours. The remainder of the watershed experienced approximately 5” of rain in 3 hours (Figure 4-30). This rain depth and time period equates to a storm event between a 10-year and 25-year event.

Figures 4-31 and 4-32 indicate the total rainfall maps for the September 19, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-33 and 4-34 indicate the total rainfall distribution for the northeastern part of the watershed and the western part of the watershed, respectively. Figures 4-35 through 4-39 indicate the calculated field data discharges and the calibrated model output discharges. It should be noted that during the storm the stream gauge on Rabbit Creek malfunctioned and did not read the stream depths correctly. This is evident in the comparison plot found in Figure 4-35.

Figure 4-30
September 19, 2019 – Gauge Locations with Total Rainfall

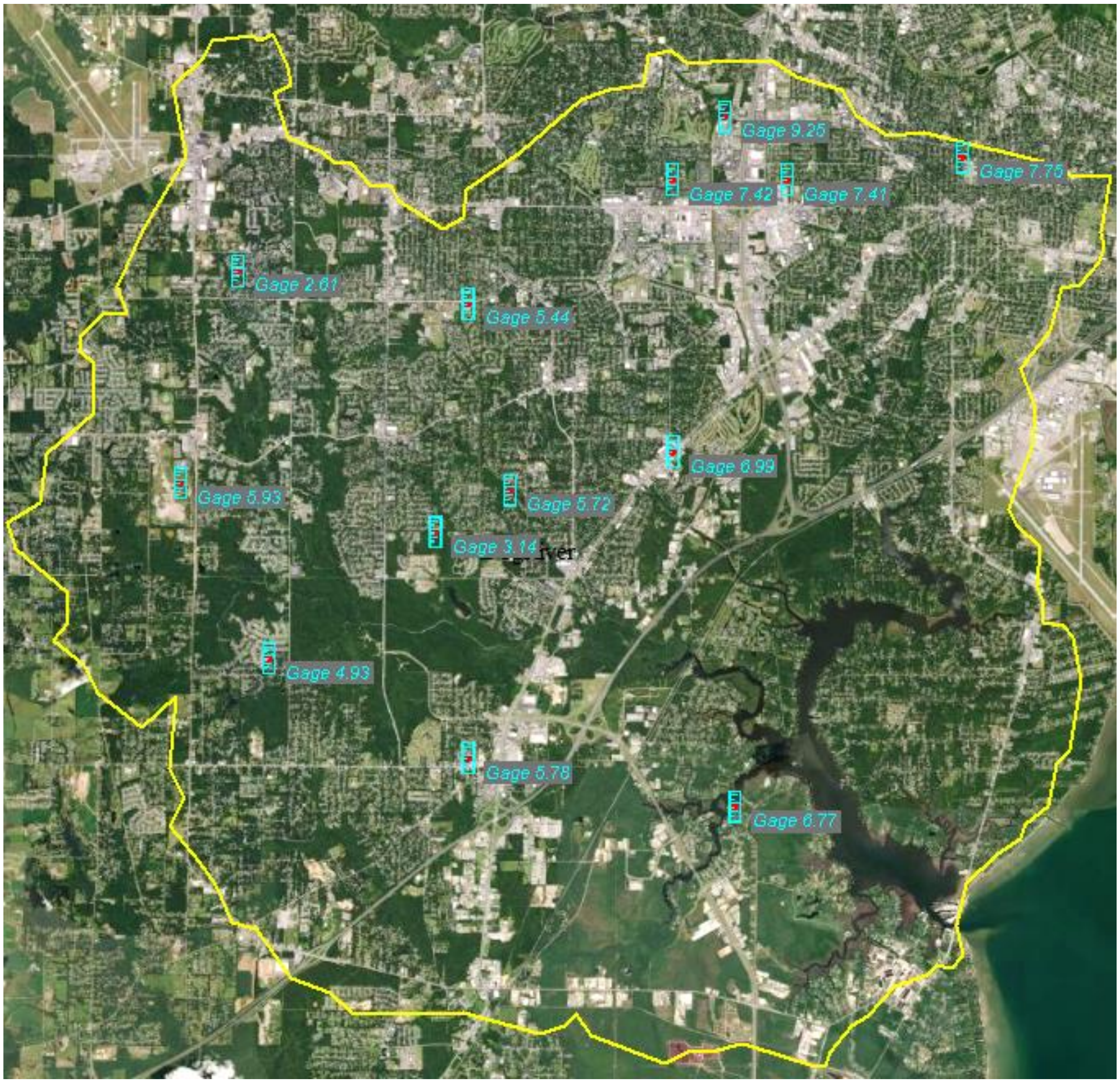


Figure 4-31
September 19-20, 2019 – AHPS Total Rainfall Map

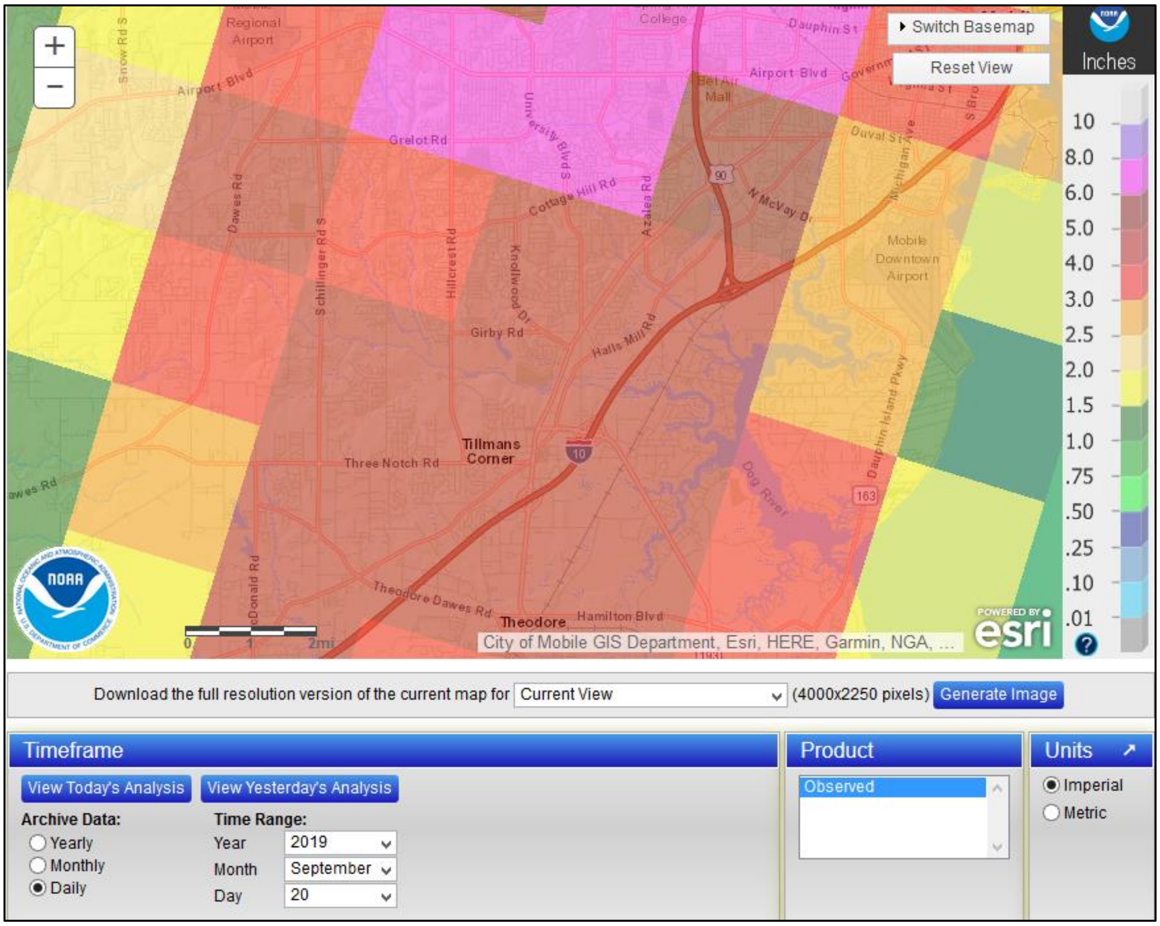


Figure 4-32
September 19-20, 2019 – Total Rainfall Map

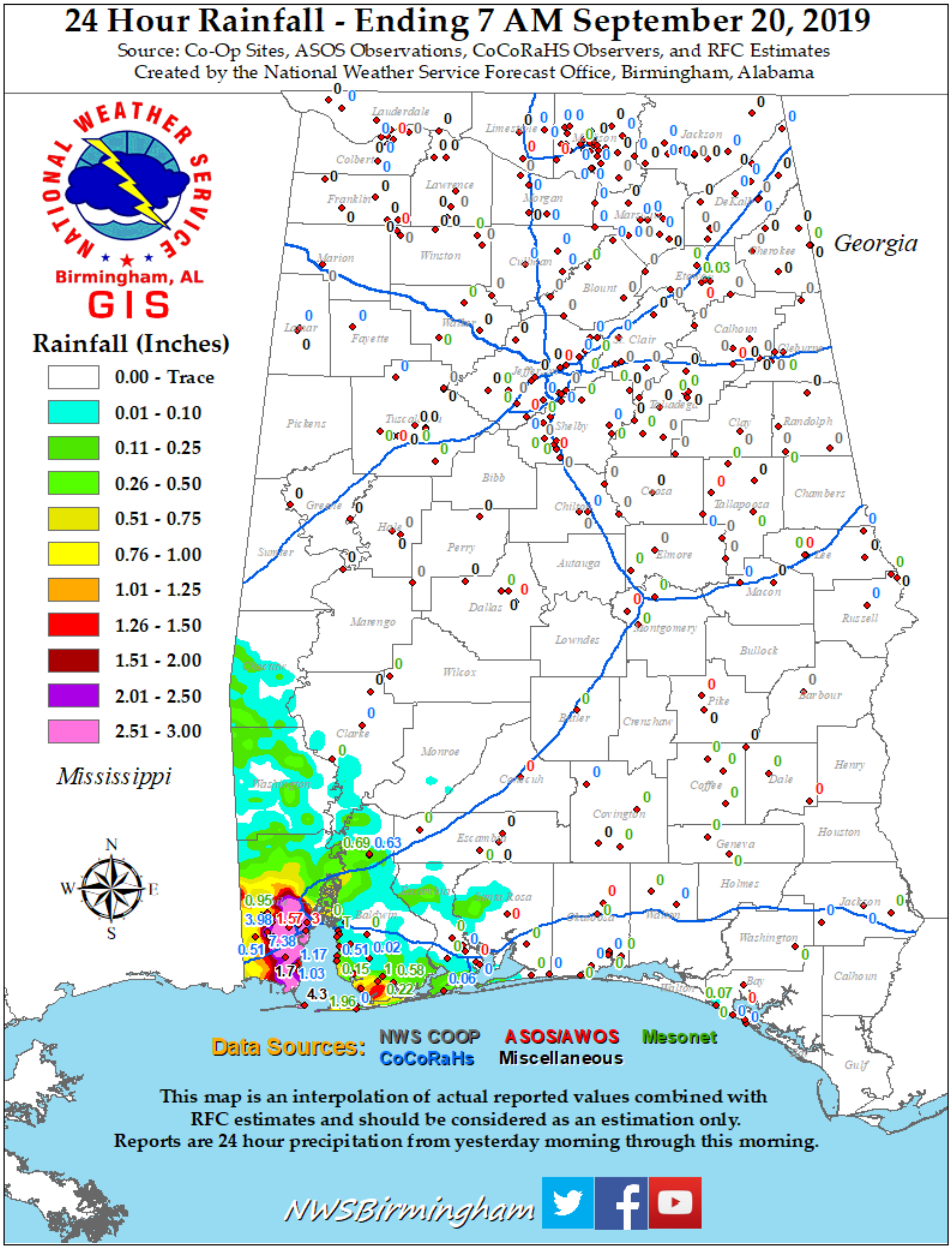


Figure 4-33
September 19, 2019 – Total Rainfall Distribution (Northeast)

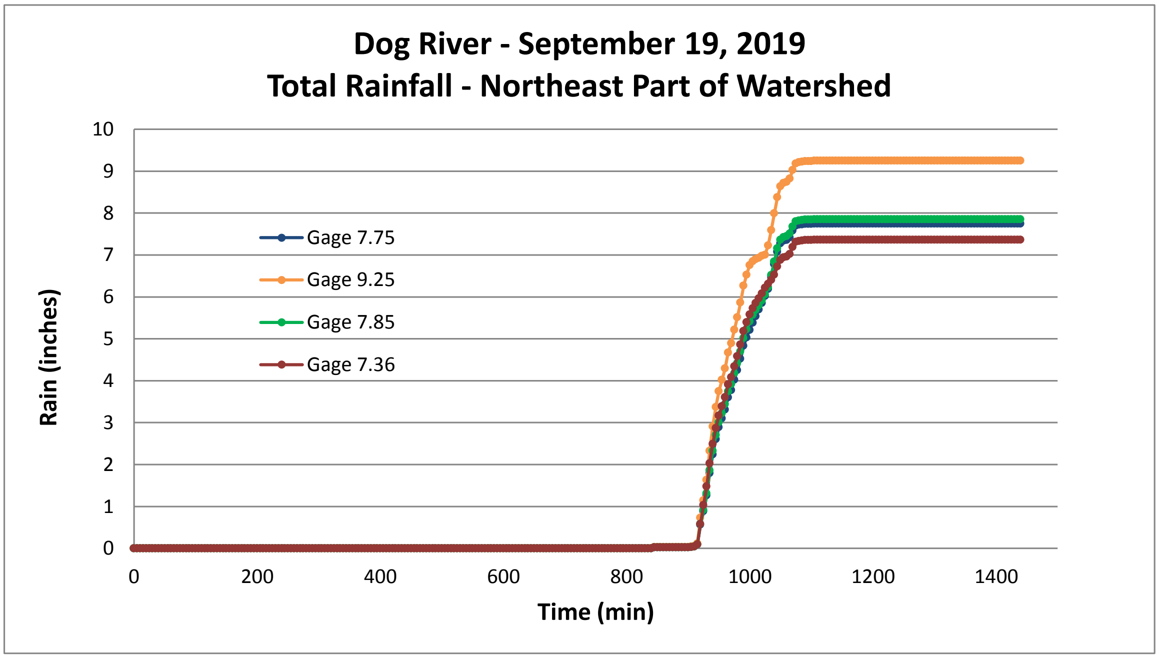


Figure 4-34
September 19, 2019 – Total Rainfall Distribution (West)

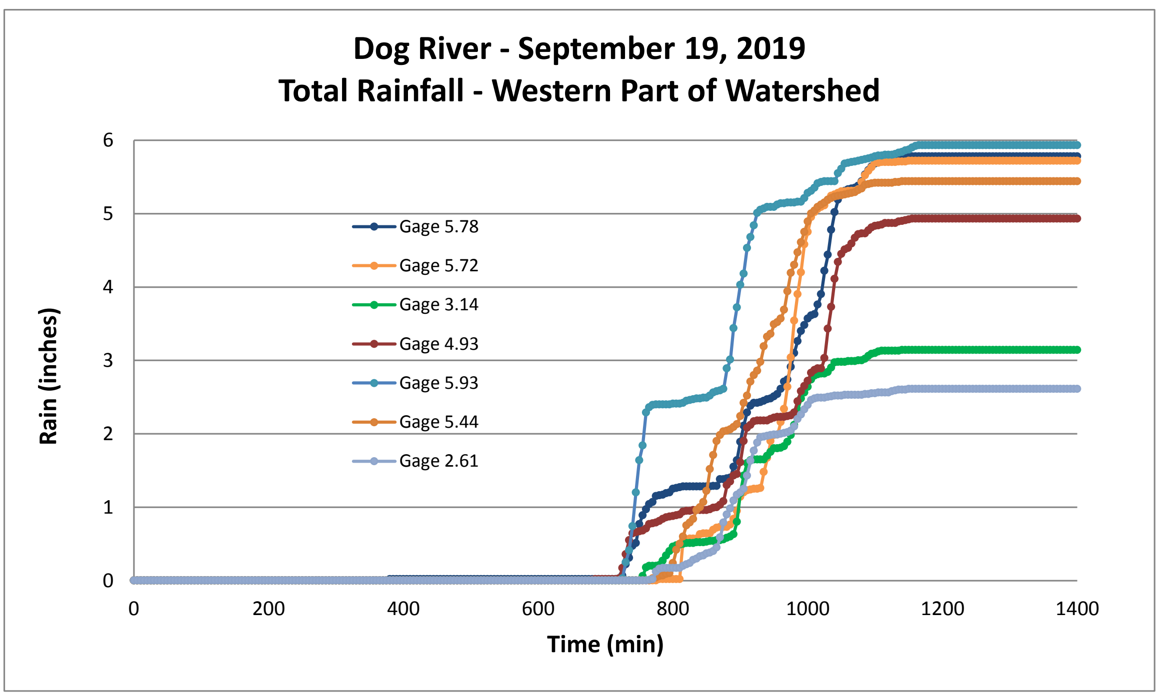


Figure 4-35
September 19-20, 2019 – Rabbit Creek Calibration

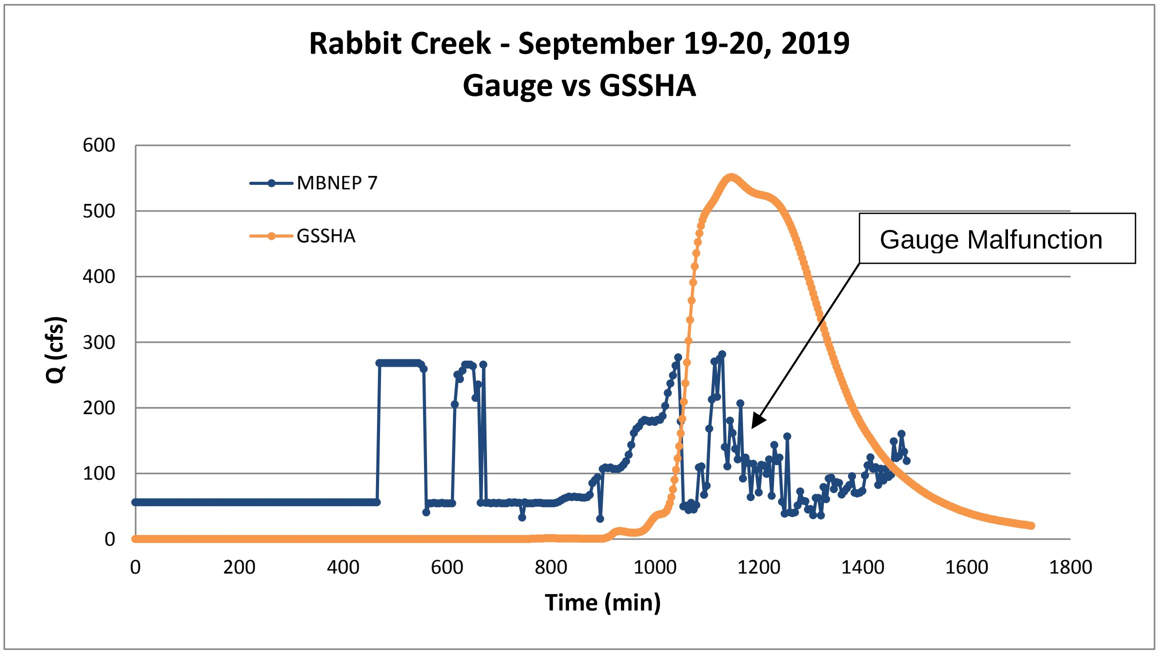


Figure 4-36
September 19-20, 2019 – Halls Mill Creek Calibration

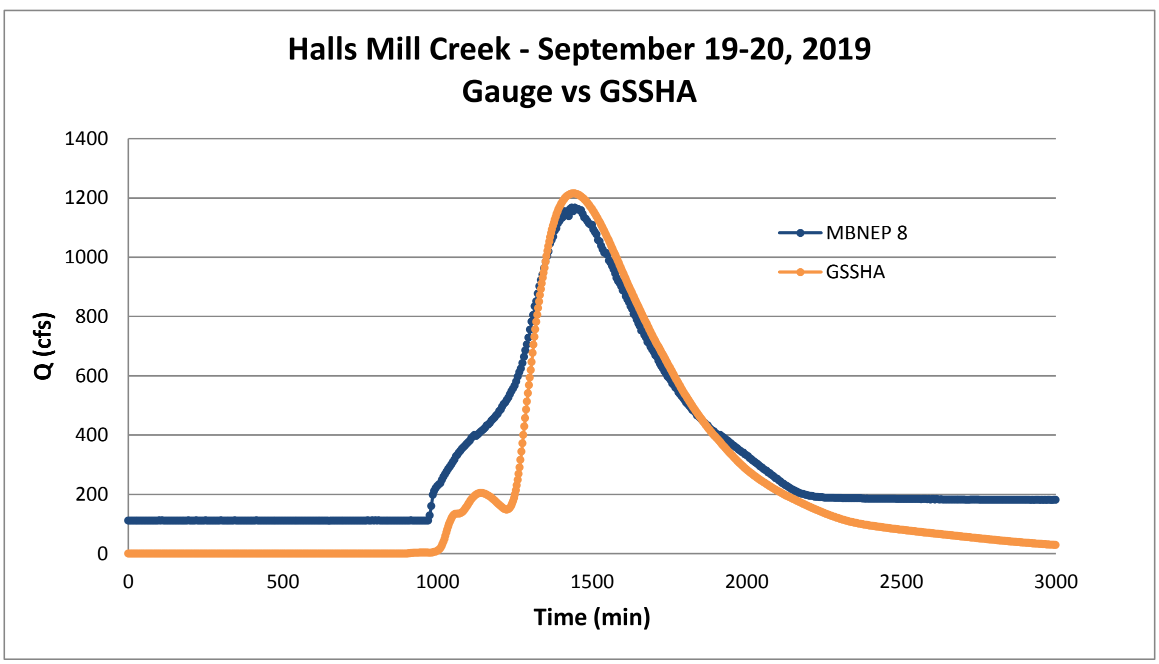


Figure 4-37
September 19-20, 2019 – Moore Creek Calibration

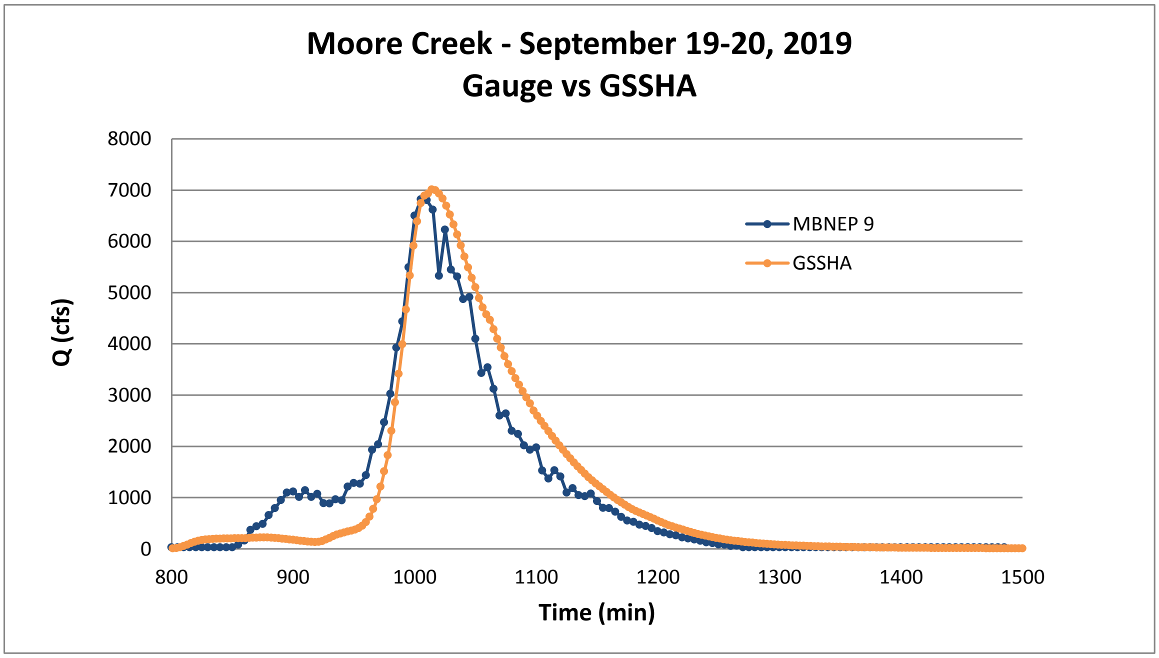


Figure 4-38
September 19-20, 2019 – Woodcock Branch Calibration

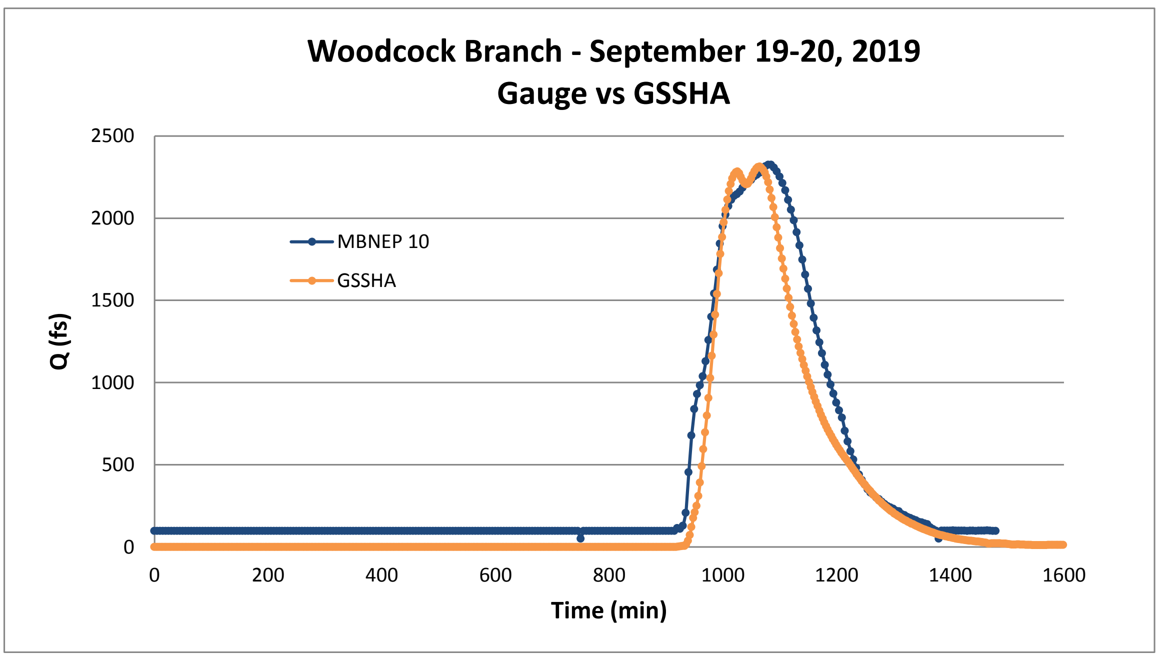
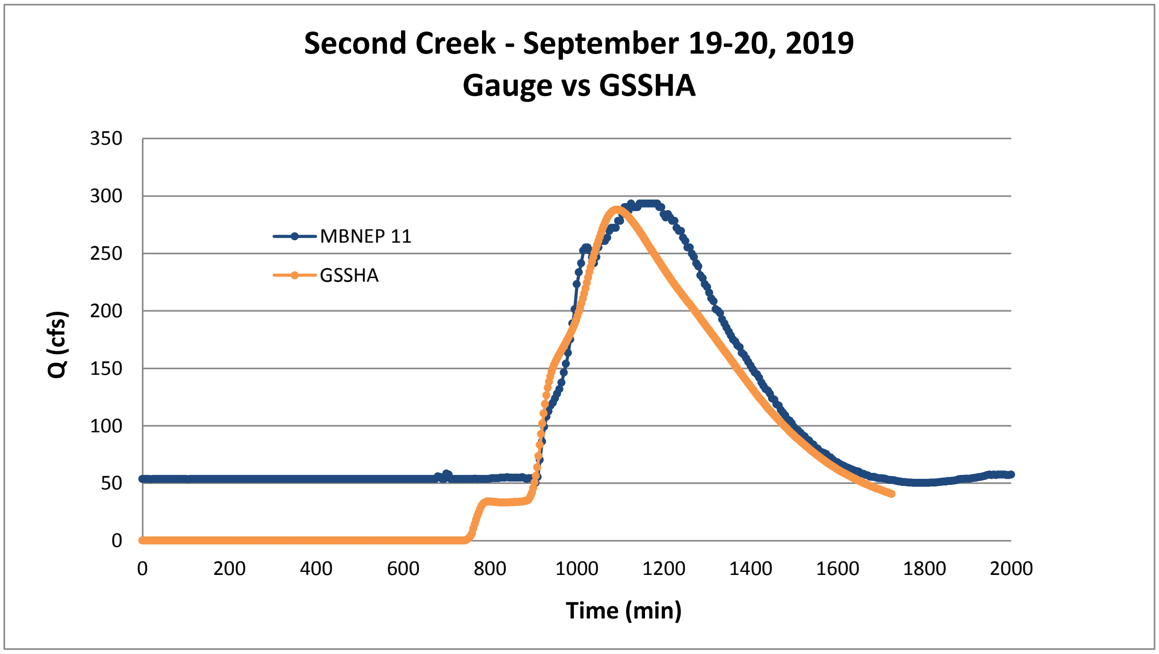


Figure 4-39
September 19-20, 2019 – Second Creek Calibration



The final event used for analyzing the watershed occurred on June 6-8, 2020. During this rain event, the Second Creek gauge and the Halls Mill Creek gauge reached its highest stage. The northwest part of the watershed experienced, on average, 4.9” of rain in 12 hours due to Tropical Storm Cristobal. Using NOAA Atlas 14 (Figure 4-7) for this rain depth and time period, it was determined that this rain event is approximately a 2-year storm. Although this was only classified as a 2-year rain event, the discharges were higher due to rains that occurred during the previous 4 out of 5 days.

Figures 4-40 and 4-41 indicate the total rainfall maps for the June 7, 2020 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-42 and 4-43 indicate the total rainfall distribution for the northwestern part of the watershed and location of the GRIB rainfall points used in the analysis, respectively. Figures 4-44 and 4-45 indicate the calculated field data discharges and the calibrated model output discharges for Second Creek and Halls Mill Creek.

Figure 4-40
June 7-8, 2020 – AHPS Total Rainfall Map

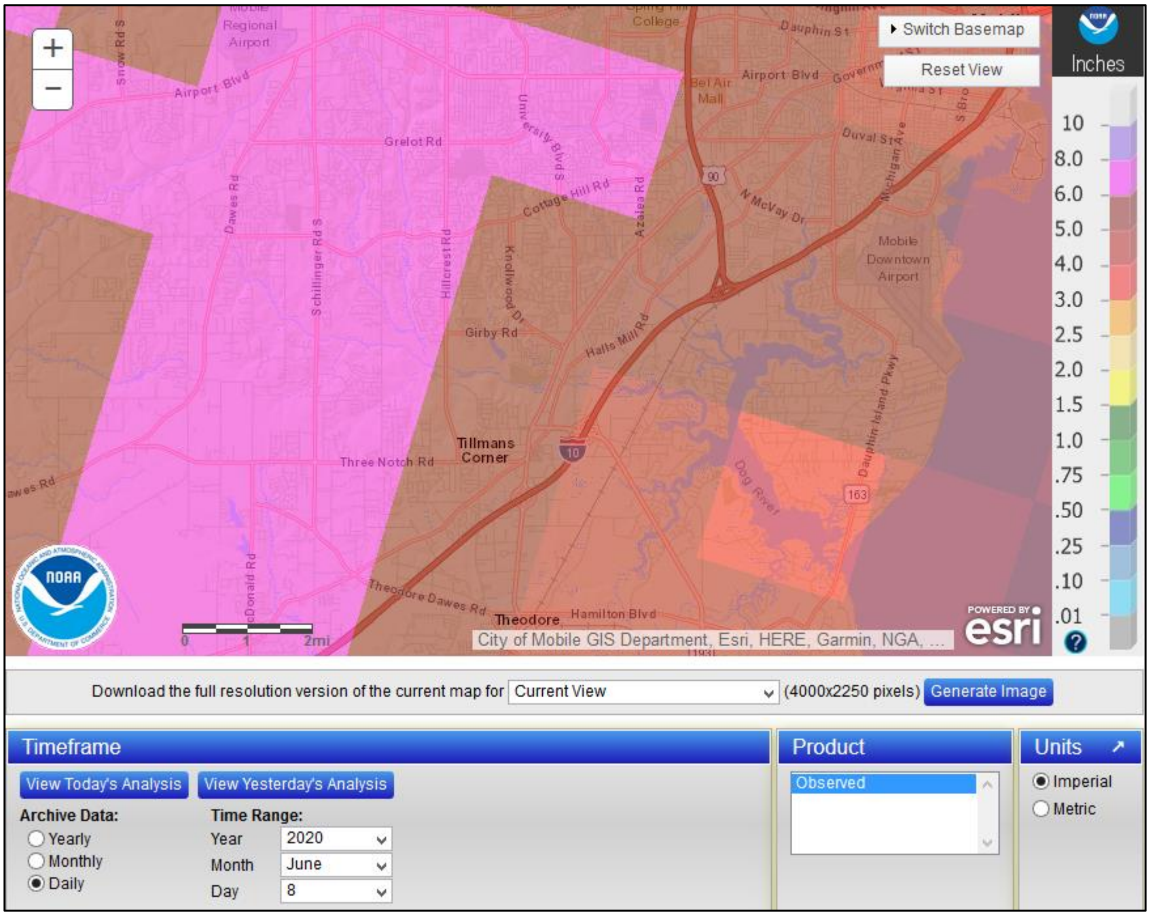


Figure 4-41
June 7-8, 2020 – Total Rainfall Map

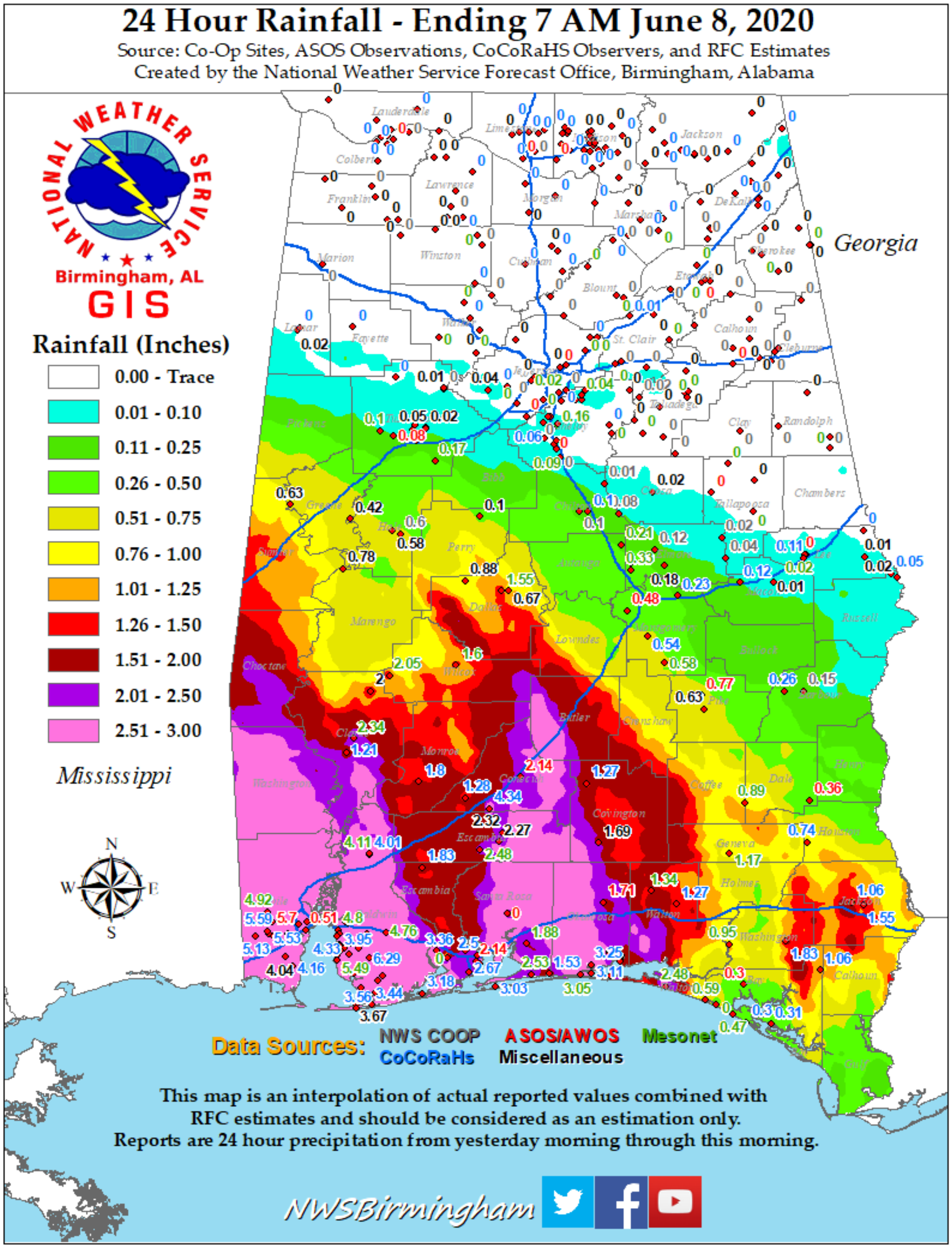


Figure 4-42
June 6-8, 2020 – Total Rainfall Distribution

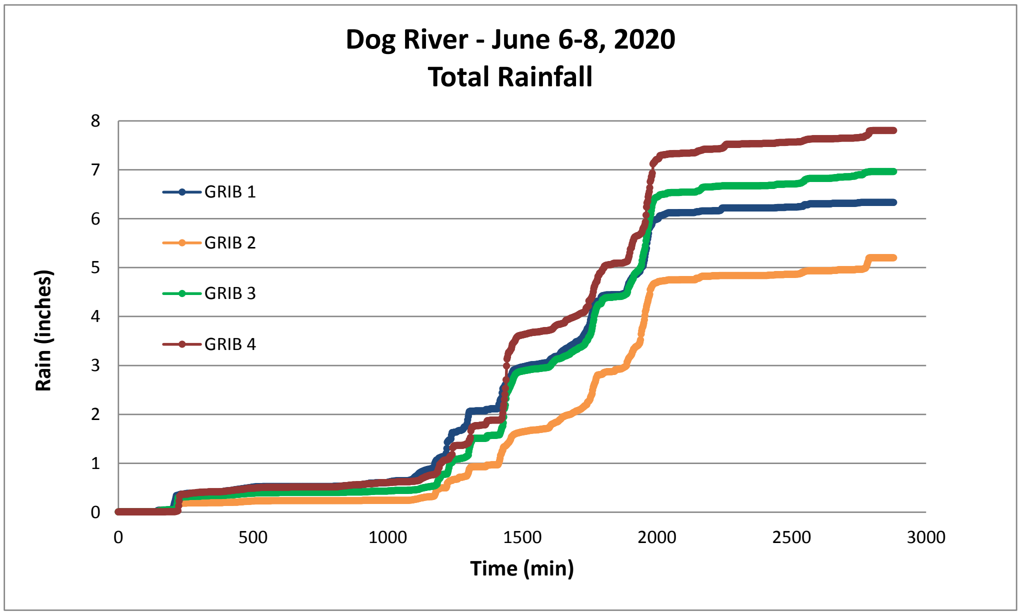


Figure 4-43
June 6-8, 2020 – GRIB Rainfall Point Locations

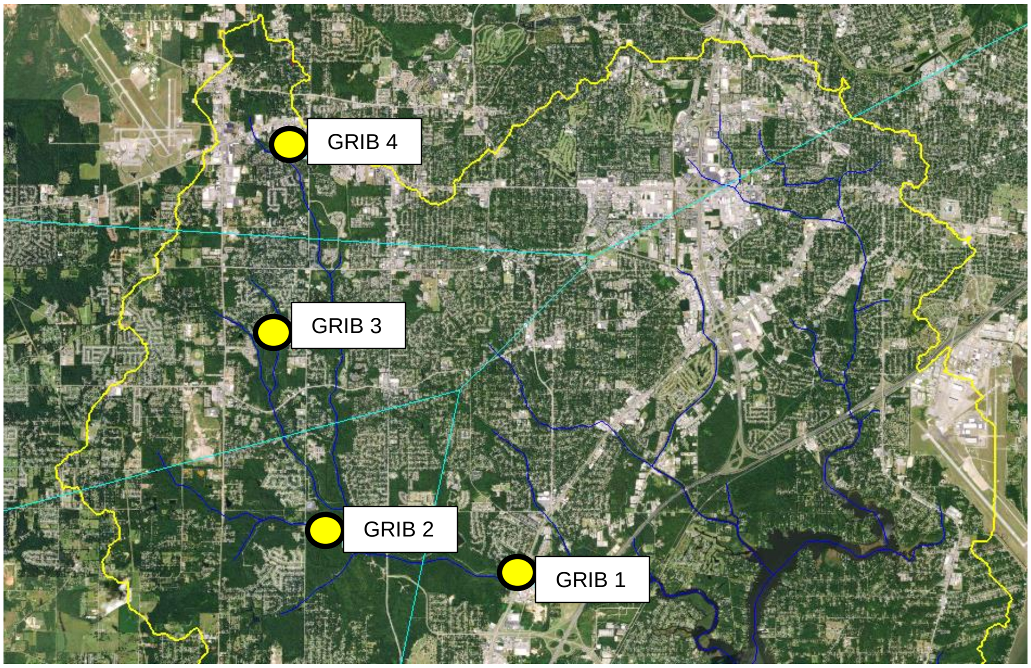


Figure 4-44
June 6-8, 2020 – Halls Mill Creek Calibration

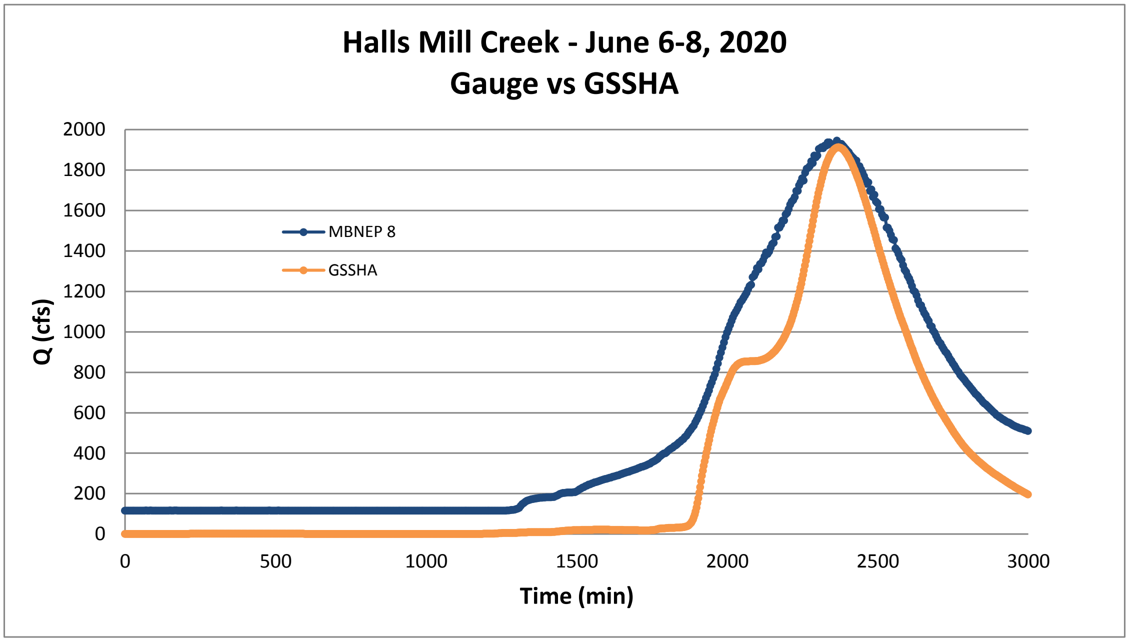
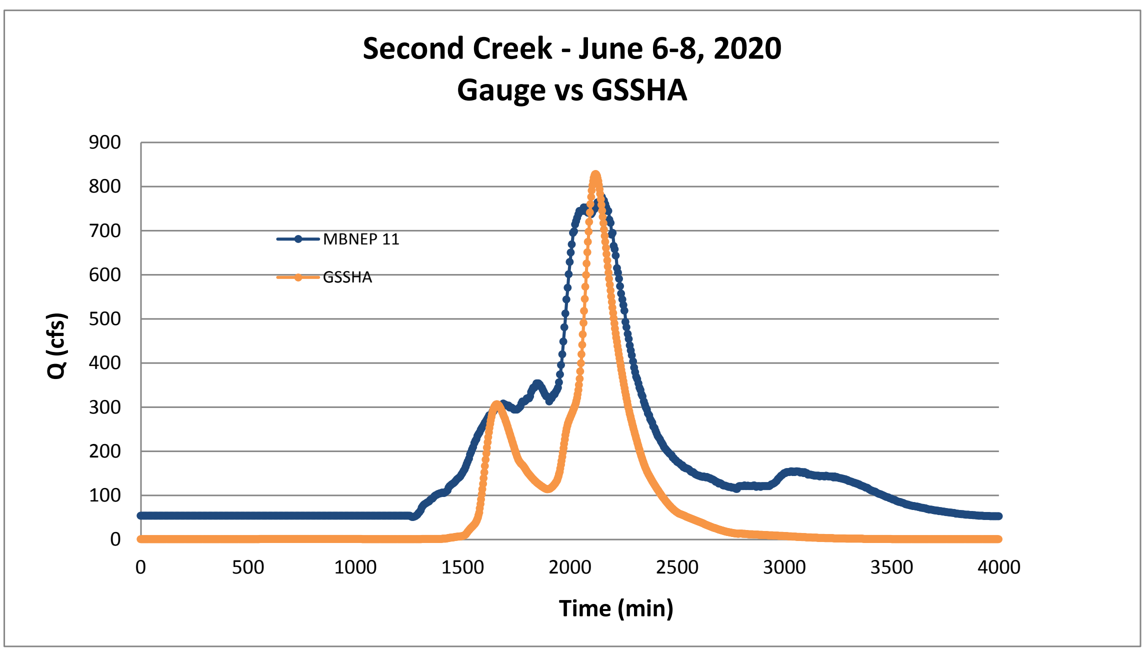


Figure 4-45
June 6-8, 2020 – Second Creek Calibration



5. Results and Conclusions

5.1. Results

During the evaluation period between the middle of June 2018 and June 2020 the Dog River watershed experienced multiple small rain storms. These rain storms typically produced less than 2 or 3 inches per event. Using the stream gauge plots found in Figures 4-2, 4-3, 4-4, 4-5, and 4-6, the largest events were chosen for model calibration. The initial calibration was performed using the September 4, 2018 rainfall from Tropical Storm Gordon. This storm produced an average of 2 inches of rain in 5 hours over the entire watershed. Using Figure 4-7 it was determined that this is less than a 1-year storm. While this event did not produce much discharge, it was used for getting an initial estimate of the timing throughout the basin.

The next rainfall used during the calibration process occurred on December 8, 2018. This storm produced an average of 2.78 inches of rain over a 12 hour period. Again this was another rainfall determined to be less than a 1-year storm event. The measured hydrographs indicated more storm volume than from the calibrated model, however peak discharges and timing were further refined. On August 26, 2019 there was a rainfall event that produced 2 inches in 1 hour and 3.7 inches in 6 hours. This is equivalent to a 1-year storm. Some areas of the watershed experienced just over 4 inches of rain in the 6 hour period which equated to a 2-year storm event. The modeled discharges were further refined and exhibited a good match to the timing, peak discharge, and volume of the field measured data.

The largest event for the Dog River watershed occurred on September 19, 2019. Overall, the entire Dog River watershed experienced a 10-year to 25-year event. The model was recalibrated in order to better replicate the hydrographs produced by the larger flood event. The Manning's n-values in the channel needed to be corrected to account for the additional flood flow in the overbanks. Infiltration values needed to be adjusted as well. For the smaller rain events (<2-year), the infiltration values need to be relatively low in order for the model to produce discharges and not have the rainfall completely infiltrated. If these variables are used for the larger flood events, the discharges would be outside of the standard range of error. The newly calibrated model matched the measured field data well. This event provided a calibrated model that can be used to determine impacts from future developments during larger storm events.

5.2. Conclusions

After analysis of the discharges and rainfall events that occurred between June 2018 and June 2020, it has been determined that a 1-year rainfall event occurring in the Woodcock Branch watershed produces discharges greater than the 1-year discharges calculated from the urban regression equations. The Moore Creek watershed generates discharges less than a 1-year urban discharge but greater than a 2-year rural discharge. The Second Creek watershed located in the western portion of the watershed produces discharges equivalent to the rural regression equations for a given storm event. The same is true for the Halls Mill Creek watershed and the Rabbit Creek watershed. While there is a significant amount of residential development in these three basins, there is also an adequate amount of evergreen forest and woody wetlands to help offset the discharge increases associated with the development.

Tables 5-1 and 5-2 summarize the discharges for the August 26, 2019 storm event and the September 19, 2019 storm event, respectively. The tables list the name of the stream, storm event recurrence interval, rural regression discharges, urban regression discharges, and the calibrated GSSHA discharges. Table 5-1 provides the 1-year and 2-year rural and urban regression equation discharges while Table 5-2 provides the nearest recurrence interval discharges for both the rural and urban equations.

Table 5-1
Stream, Recurrence Interval, Rural Qs, Urban Qs, and GSSHA Qs

Stream	Recurrence Interval	1yr Rural Q (cfs)	2yr Rural Q (cfs)	1yr Urban Q (cfs)	2 yr Urban Q (cfs)	GSSHA Q (cfs)
Rabbit Creek	1 yr	190	670	1070	1520	430
Halls Mill Creek	1 yr	470	1550	2830	3710	590
Moore Creek	1 yr	330	1130	2540	3250	1430
Woodcock Br	1 yr	120	410	760	1060	1140
Second Creek	< 1 yr	170	600	960	1370	250

* These values are for the August 26, 2019 storm event

Table 5-2
Stream, Recurrence Interval, Rural Qs, Urban Qs, and GSSHA Qs

Stream	Recurrence Interval	1yr Rural Q (cfs)	2yr Rural Q (cfs)	1yr Urban Q (cfs)	GSSHA Q (cfs)
Rabbit Creek	2-5 yr (25% of Basin) 5-10 yr (75% of Basin)	190	670	1070	550
Stream	Recurrence Interval	1yr Rural Q (cfs)	2yr Rural Q (cfs)	1yr Urban Q (cfs)	GSSHA Q (cfs)
Halls Mill Creek	<1 yr (50% of Basin) 2-5 yr (50% of Basin)	470	1550	2830	1210
Stream	Recurrence Interval	100yr Rural Q (cfs)	200yr Rural Q (cfs)	10yr Urban Q (cfs)	GSSHA Q (cfs)
Moore Creek	100 yr (30% of Basin) 10 yr (30% of Basin) 25 yr (40% of Basin)	6300	7570	6350	7010
Stream	Recurrence Interval	100yr Rural Q (cfs)	200yr Rural Q (cfs)	25yr Urban Q (cfs)	GSSHA Q (cfs)
Woodcock Branch	500 yr (20% of Basin) 100-200 yr (80% of Basin)	2300	2760	2390	2310
Stream	Recurrence Interval	1yr Rural Q (cfs)	2yr Rural Q (cfs)	1yr Urban Q (cfs)	GSSHA Q (cfs)
Second Creek	<1 yr (50% of Basin) 5 yr (50% of Basin)	170	600	960	290

* These values are for the September 19, 2019 storm event

During the evaluation period the watershed experienced both low 1-year rainfall events, as well as, one large flooding event. Hydrologic models calibrated to the smaller events usually do not translate to higher flooding events; therefore two calibrated models were necessary. For 2-year rain events or less, the first calibrated GSSHA model can be used as a management tool for determining bank forming discharges throughout the watershed. Future restoration projects may be able to utilize these discharges for bankfull analysis. For larger flood events (10-yr+), the second calibrated model can be used to analyze the impacts of future developments on stormwater runoff.

6. References

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