MBNEP

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Tensaw East Watersheds Study

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1. Executive Summary

The study on the Tensaw East watersheds was performed to gain an understanding of the watersheds' response during rain events. Six individual watershed models between Bay Minette and Spanish Fort were developed. These baseline hydrologic models can be used for determining discharges for the design of future restoration projects and their impact on the watershed. The models can also be utilized 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 historic events for use in predicting watershed reaction to various land use changes.

During the evaluation period, the majority of the largest watershed (Bay Minette Creek watershed) experienced between a 5-year and 10-year 24-hour rainfall event on September 4, 2018 from Tropical Storm Gordon. On December 28, 2018 the watershed experienced a 1-year 1-hour rainfall event. Results of the findings for the Bay Minette Creek watershed indicate that storm events less than or equal to a 10-year recurrence interval produce discharges equivalent to its determined recurrence interval for a rural basin.

The four smaller basins north of the Bay Minette Creek watershed experienced between only a 1-year and 2-year 12-hour rainfall event on September 4, 2018. On April 14, 2019 the watersheds experienced a 1-year 1-hour event. Results of the findings for the four northern basins indicate that storm events less than or equal to a 1-year recurrence interval produce discharges equivalent to its determined recurrence interval for a rural basin. The small urban basin located in Spanish Fort experienced a 1-year 12-hour storm event on Sept 4, 2018 and on July 13, 2019.

For rain events (5-yr or less), the currently calibrated GSSHA models can be used as management tools for determining bank forming discharges throughout the watersheds. Future restoration projects may be able to utilize these discharges for bankfull analysis. For larger flood events, recalibration will most likely be necessary to account for changes in storage capacity and timing within the watershed.

2. Introduction

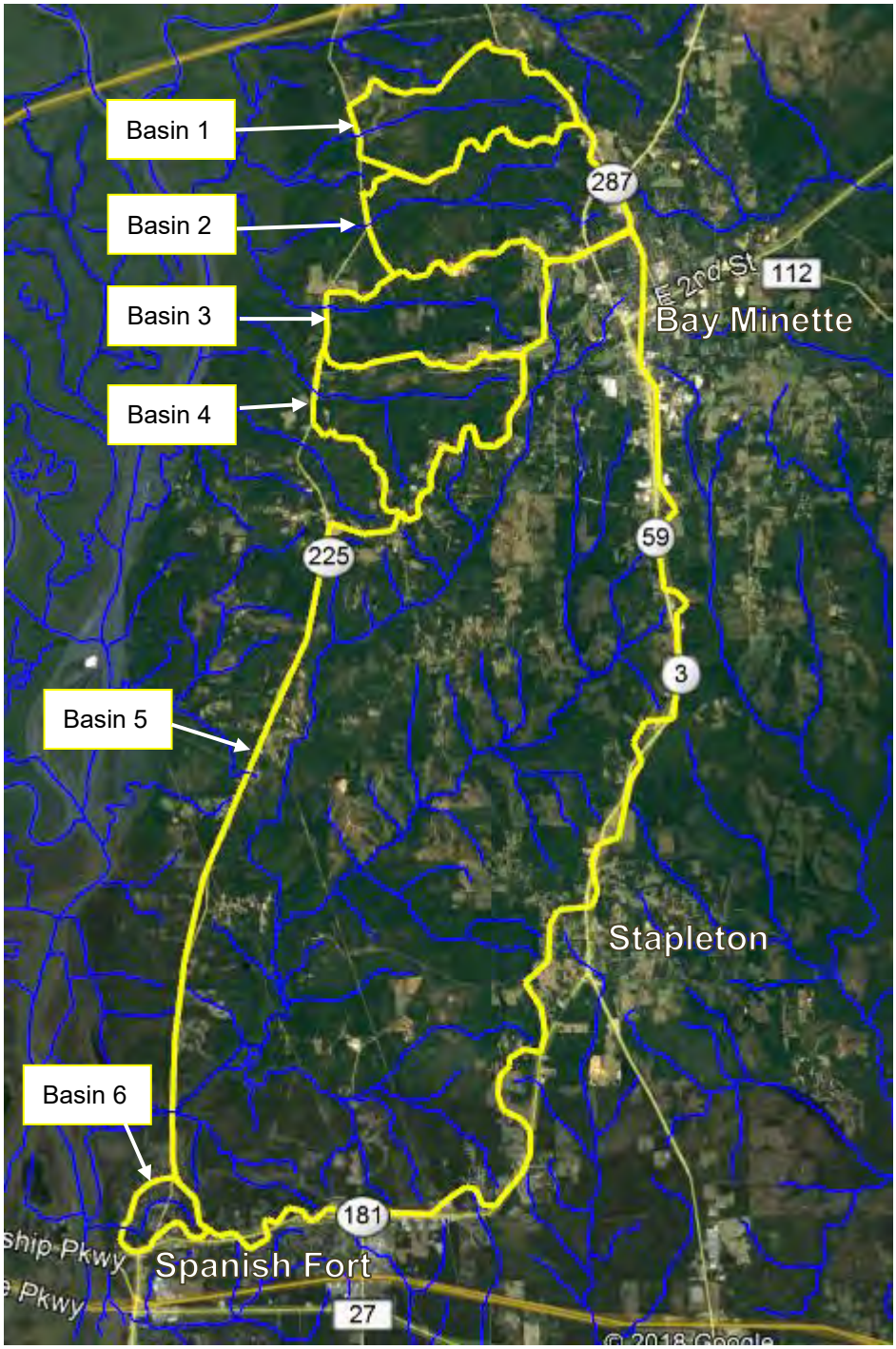
2.1. Description

For this study, the Tensaw East watersheds consist of 6 separate basins located mostly between I-65 and I-10 around and near the communities of Bay Minette, Stapleton, and Spanish Fort (Figure 2-1). The drainage basins range in size from 0.9 square miles to 71.2 square miles. The outlets of the basins were taken at SR 225 except for Basin 6 which was taken at Spanish Main Street. The basins eventually drain into the Mobile-Tensaw River Delta.

Basin 1 is located to the northwest of Bay Minette and is bound by SR 225 to the west, SR 287 to the east, and Kilcrease Road to the south. The main stream for the watershed is Dennis Creek. Basin 2 is also located to the northwest of Bay Minette and is bound by SR 225 to the west, SR 287 to the east, and Kilcrease Road to the north. The main stream for the watershed is Martin Branch. Basin 3 is located to the west of Bay Minette and is bound by SR 225 to the west and D'Olive Street to the south. The main stream for the watershed is Red Hill Creek. Basin 4 is located to the west of Bay Minette and is bound by SR 225 to the west and D'Olive Street to the north. The main stream for the watershed is Honeycut Creek. These four basins are generally the same size with an average drainage area of 5 square miles.

Basin 5 is the largest basin in the study area. The drainage area of the basin is approximately 71.2 square miles. The basin extends from Bay Minette down to Spanish Fort. Bay Minette Creek and Whitehouse Creek are the two main streams within the basin. Some of the other named tributaries include Wilson Creek, Hunawell Creek, and Sibley Creek. Basin 6 is the smallest basin and is located in Spanish Fort. The basin is mostly developed and the main stream located within the watershed is Spanish Fort Branch.

Figure 2-1
Location Map and Tensaw East Watershed Boundaries



2.2. Climate

Baldwin County has a mild but humid climate. According to the U.S. Climate Data website, the average rainfall for Baldwin County (Bay Minette area) is around 69 inches. July is typically the wettest month and October is usually the driest month. The average high and low temperatures are 77 degrees and 56 degrees respectively. The warmest months are July and August with the coldest month typically being January.

Although the yearly rainfall is generally well distributed, significant rainfall events can be experienced from both intense thunderstorms and from tropical storms or hurricanes coming from the Gulf of Mexico. The hurricane season usually occurs in the late summer to early fall. Table 2-1 lists select hurricanes indicated by the date of the occurrence, the hurricane name, and the range of rainfall related to the storm.

Table 2-1
Hurricane Event and Related Precipitation

Date	Hurricane	Precipitation (inches)
Oct 3-5, 1995	Opal	9-12
July 18-25, 1997	Danny	18-24
Sept 21-Oct 1, 1998	Georges	9-18
Sept 13-26, 2004	Ivan	7-10
July 5-13, 2005	Dennis	3-4
Aug 23-31, 2005	Katrina	2-3
Sept 1-4, 2011	Tropical Storm Lee	7-11
Oct 4-9, 2017	Hurricane Nate	4-7
Sept 2-11, 2018	Tropical Storm Gordon	4-8

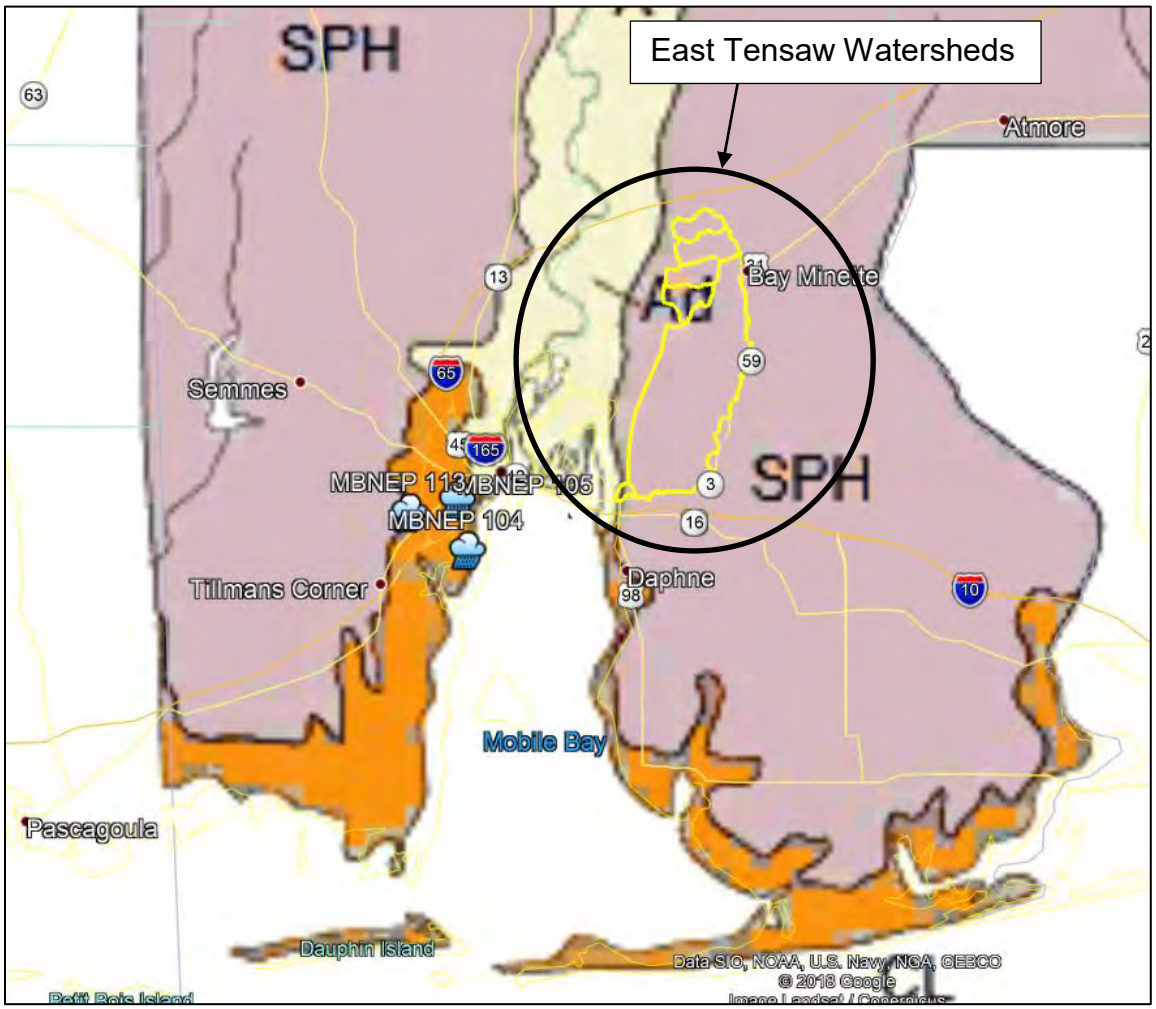
2.3. Physiography

All of the Tensaw East watersheds are located within the Southern Pine Hills physiographic section (Figure 2-2). The Southern Pine Hills is described with the following characteristics: Southward-sloping, dissected irregular plains, some open low hills, mostly broad gently sloping ridgetops with steeper side slopes near drainages; low to moderate gradient sand and clay bottomed streams; some sinkholes in eastern area (Griffith 2001). The watersheds drain to the Alluvial-deltaic Plain to the west. The area located within the Alluvial-deltaic Plain is described as having the following: Major river floodplains and associated low terraces; low gradient streams with sandy and silty substrates, oxbow lakes, ponds, swamps (Griffith 2001).

Descriptions regarding the different soil types for the watersheds were found from the Web Soil Survey. According to the website, “Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation’s counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information.”

Information from the website indicates that the majority of the soils in these basins consist of marine deposits derived from sedimentary rock. The major soil groups that encompass most of the area in these basins include 1) Bowie, Lakeland, and Cuthbert soils, 2) wet clayey alluvial land, 3) Lakeland loamy fine sand, 4) Hyde, Bayboro, and Muck, and 5) Cuthbert, Bowie, and Sunsweet soils. The Bowie, Cuthbert, and Sunsweet soils are generally categorized as a fine sandy loam, while the Lakeland soil is typically described as a loamy fine sand. The Hyde soil is categorized as a loamy sand, and the Bayboro soil is muck.

Figure 2-2
Physiographic Map and Tensaw East Watershed Boundaries



Map taken from Dept of Geography, College of Arts and Sciences, The University of Alabama

2.4. Land Use

The land use of the Tensaw East watersheds (Basins 1-5) consists mostly of undeveloped areas. Basin 6, located in Spanish Fort, is mostly developed with residential areas. On average, the land use for Basins 1-4 consists of approximately 60% forest, 18% shrub/scrub, 9% wetlands, 8% grasslands /pasture, and 5% developed areas. Basin 5 has a similar land use distribution; however, has a larger amount of woody wetlands (18%) and less forest area (47%). The land use distribution for Basin 6 is 50% developed 36% forest, 10% wetlands, and 4% shrubs and grasslands. Figures 2-3 through 2-5 contain Google Earth images indicating the changes in land use from 1998 to 2017.

Figure 2-3
Basins 1,2,3,4 with 1998 and 2017 Google Earth Aerials

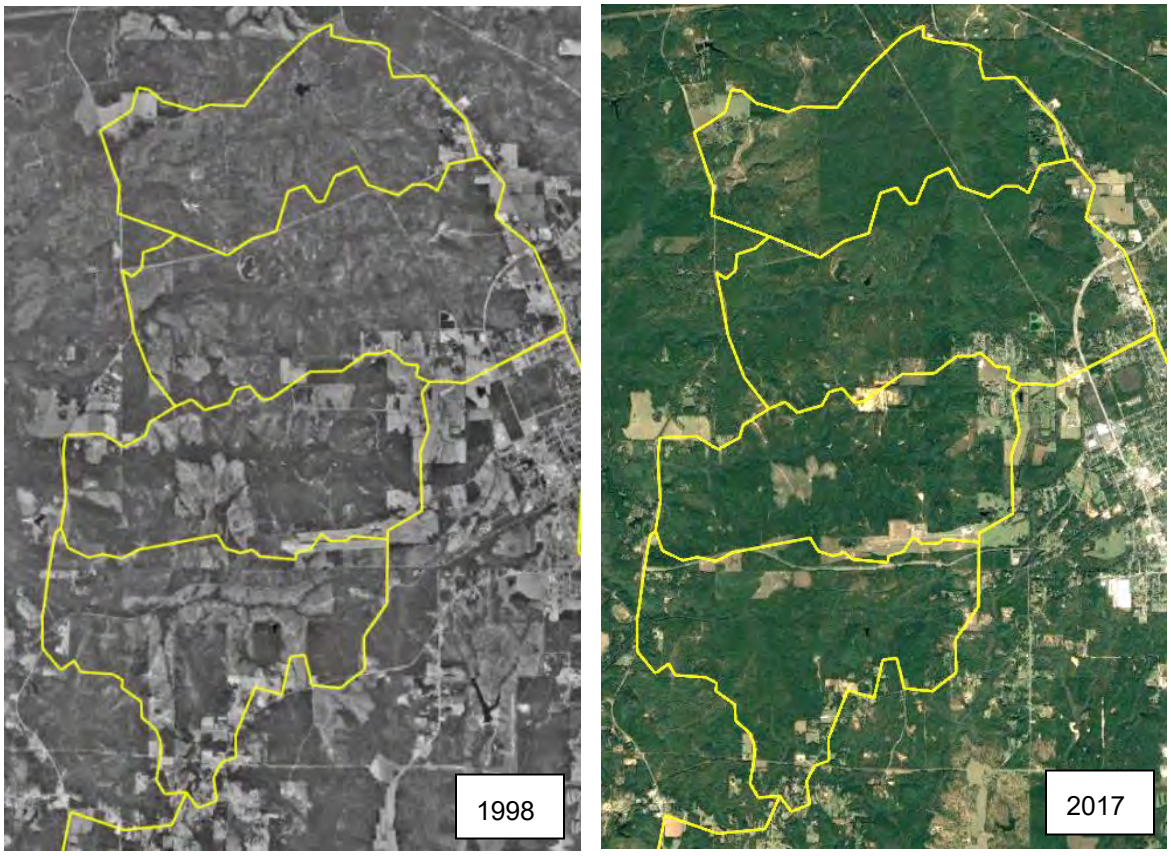


Figure 2-4
Basin 5 with 1998 and 2017 Google Earth Aerials

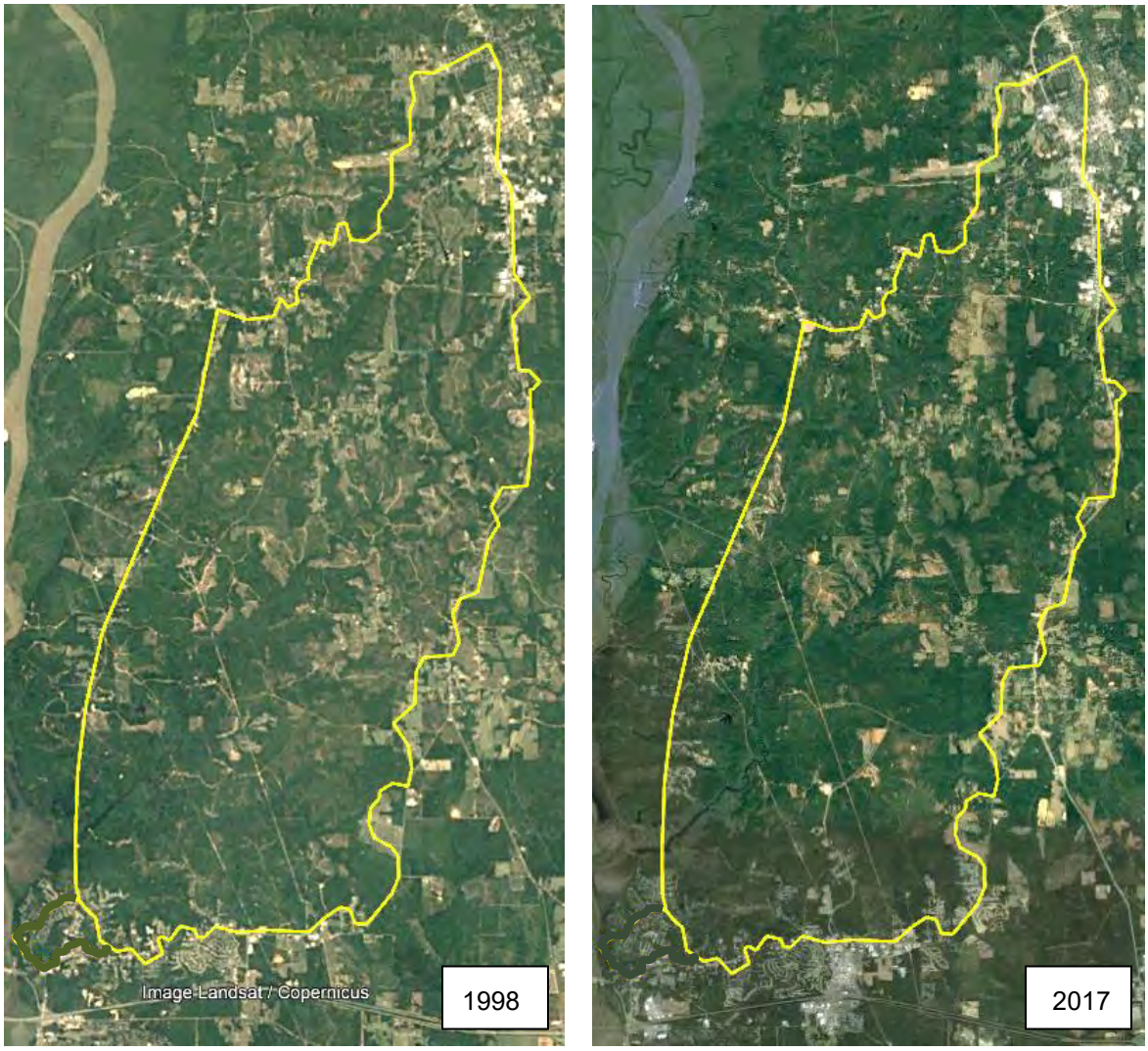


Figure 2-5
Basin 6 with 1998 and 2017 Google Earth Aerials

3. Hydrologic Model

3.1. General

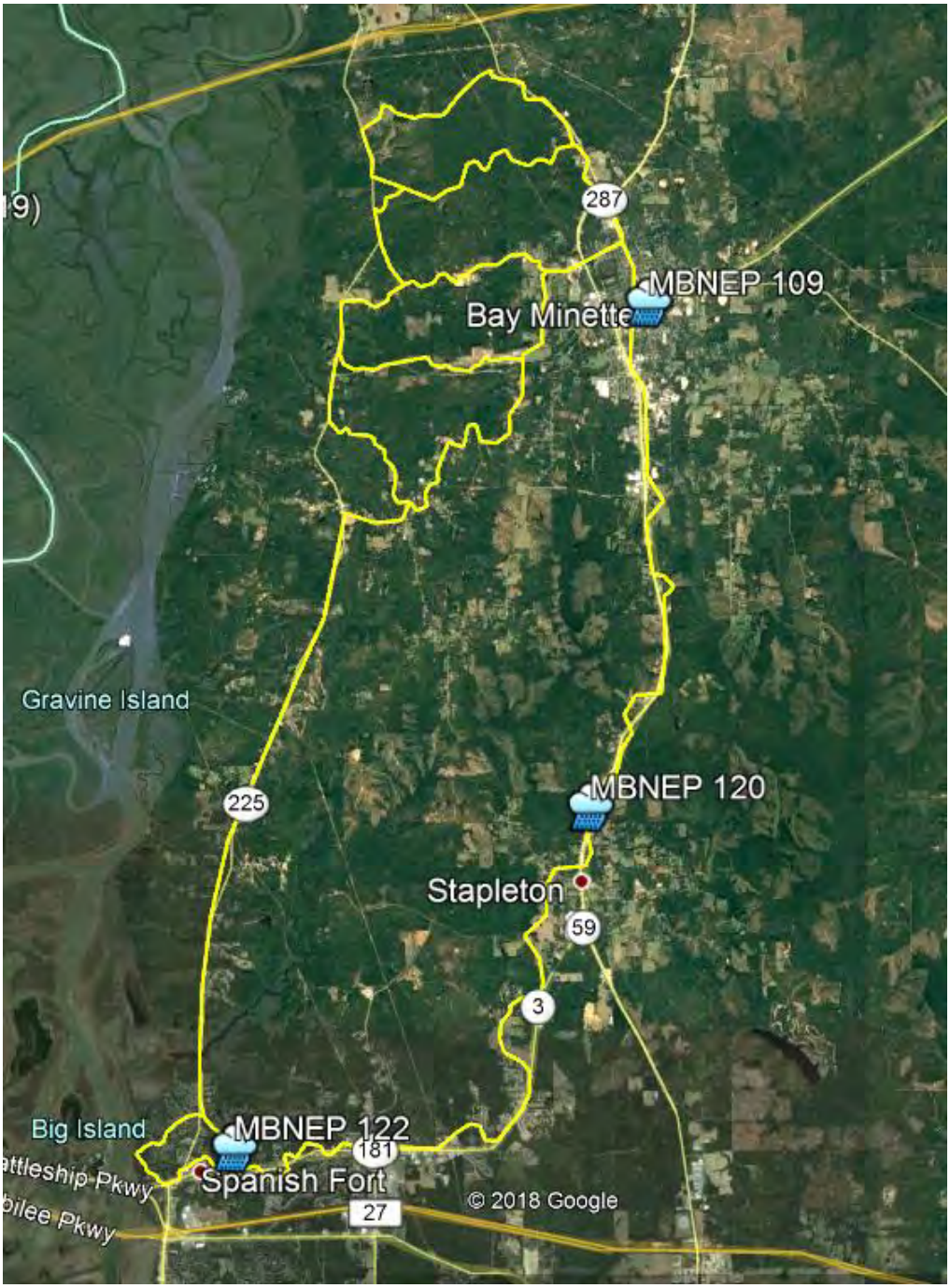
The hydrologic model used to evaluate the Tensaw East watersheds is the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model. GSSHA was developed and is maintained by the US Army Engineer Research and Development Center (ERDC) Hydrologic Modeling Branch, in the Coastal and Hydraulics Laboratory. 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.

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 personal weather stations installed throughout the watershed and from GRIB2 data.

Hydro deployed three total weather stations throughout the watershed (Figure 3-1). On September 13, 2018 one weather station (MBNEP 122) was installed at the Spanish Fort Fire Department. This weather station is located at the southern end of all of the watersheds. On December 13, 2018, one weather station (MBNEP 109) was installed at the Bay Minette Alabama Cooperative Extension Office. This weather station is located at the northern end of Basin 5 and to the east of Basins 1-4. The final weather station (MBNEP 120), located on the eastern edge of the Bay Minette Creek watershed, was installed at the Stapleton Volunteer Fire Department.

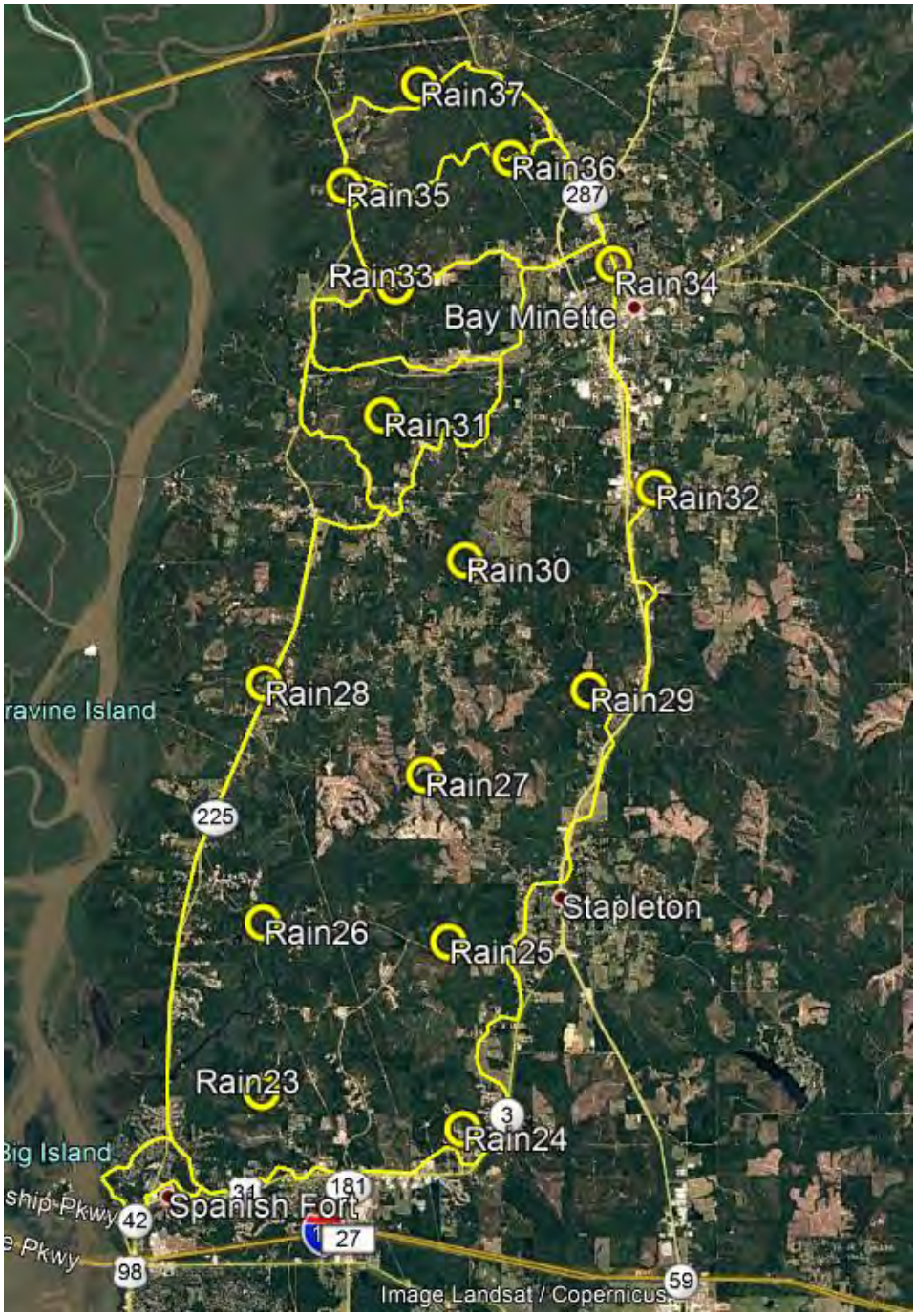
Figure 3-1
Tensaw East Watersheds with Weather Station Locations



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
Watersheds with NOAA GRIB2 Rainfall Point Locations



3.3. Digital Terrain Data

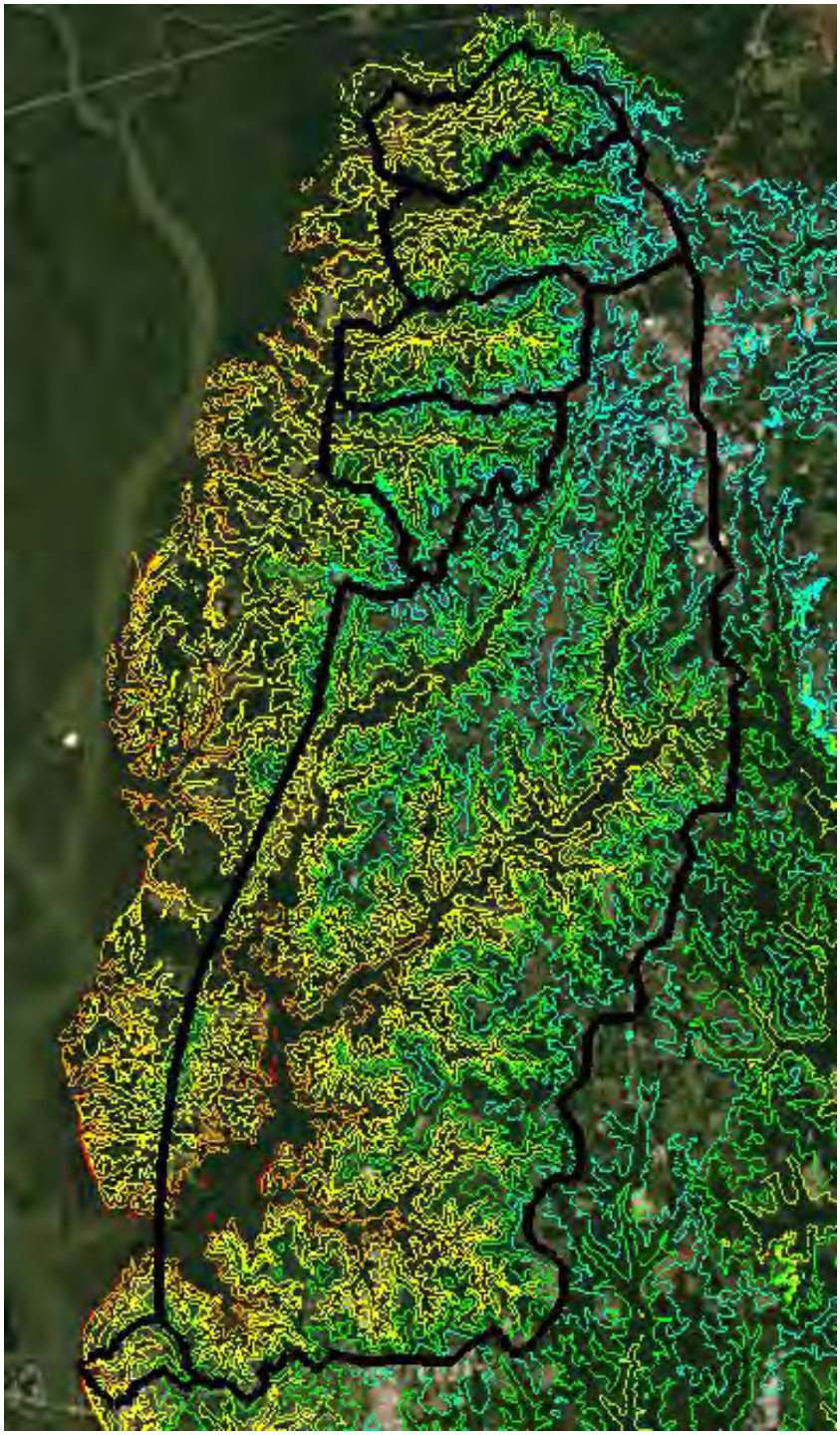
The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the model, elevation data was obtained from NOAA's National Centers for Environmental Information (NCEI). According to the website, "…NCEI is developing a suite of digital elevation models (DEMs) for the U.S. coast to support a variety of NOAA missions, including improved inundation modeling and mapping, habitat characterization, and visualization of Earth's surface."

For the area of interest, Continuously Updated Digital Elevation Model (CUDEM) - ninth arc-second resolution bathymetric-topographic tiles were downloaded. Each tile is in a .tif format and is approximately 14.85 miles wide and 17.22 miles high. After each tile was downloaded, it was converted to a digital elevation model (DEM) using the Watershed Modeling System (WMS). The DEM data can be used for automatic delineation of the basin, as well as, for generating cell elevations for the gridded model. The GSSHA model requires all units to be in the International System of Units. It was therefore necessary to convert the data to UTM Zone 16. The units were also converted from feet to meters. Figure 3-3 indicates the topographic date that was used for each basin.

The general web address for the data access viewer can be found at: https://coast.noaa.gov/dataviewer/#/lidar/search/

The individual tile data can be found at the following address: https://coast.noaa.gov/htdata/raster2/elevation/NCEI_ninth_Topobathy_2014_8483/

Figure 3-3
Watersheds with Topographic Contours



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 model 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. Figure 3-4 indicates the digitized land use assignments. Table 3-1 lists the land use types and the respective 'n' values assigned to them.

Figure 3-4
Watersheds with Digitized Land Use

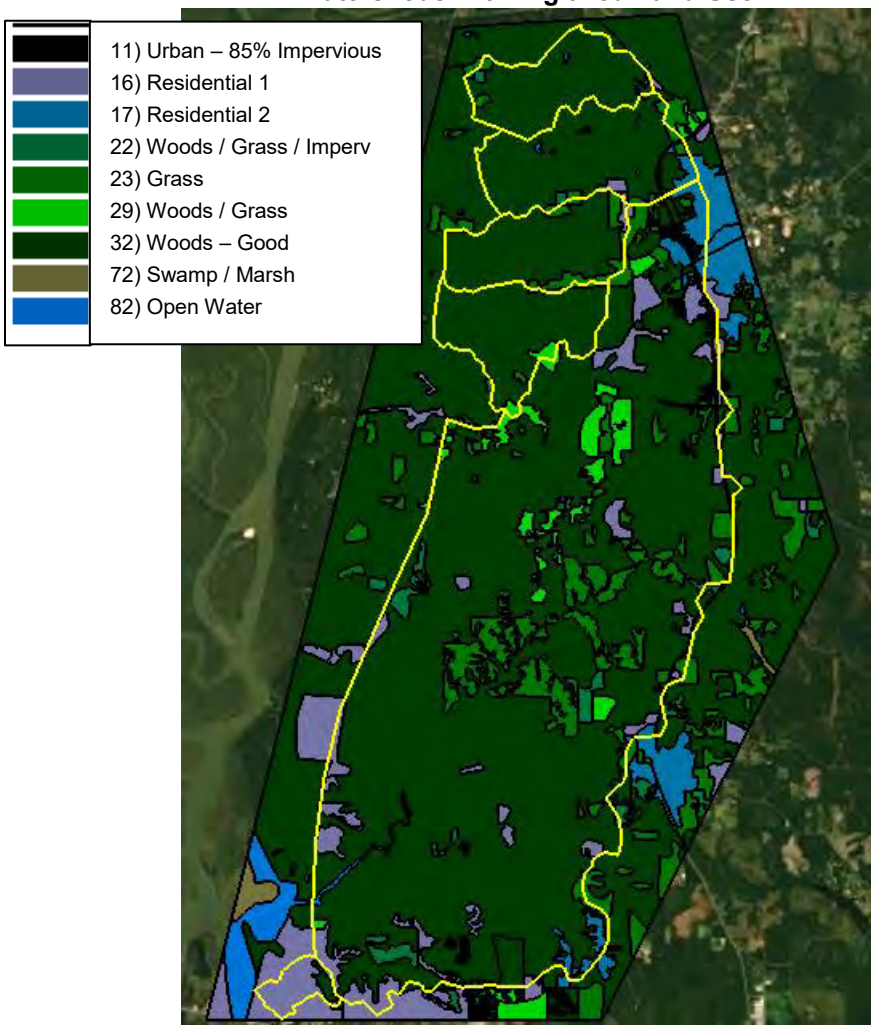


Table 3-1
Land Use and Manning's 'n' Values

GSSHA ID	Land Use	Manning's n (Basins 1-4, 6)	Manning's n (Basin 5)
11	Urban – 85% Impervious	0.011	0.011
16	Residential 1	0.040	0.030
17	Residential 2	0.080	0.040
22	Woods / Grass / Scattered Impervious	0.150	0.120
23	Grass	0.180	0.140
29	Woods / Grass	0.230	0.160
32	Woods – Good	0.250	0.200
72	Swamp/Marsh	0.250	n/a
82	Open Water	0.011	0.011

3.5. Soils

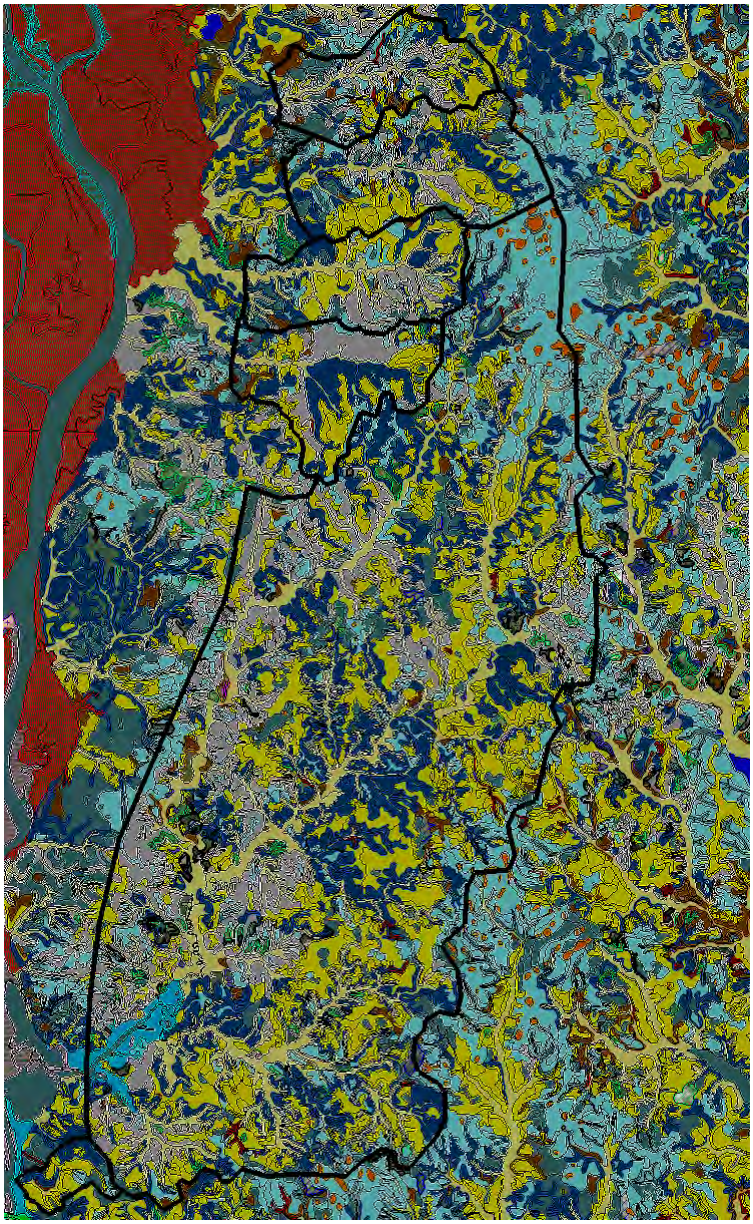
Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage can be used for defining infiltration into the soil or setting the initial soil moisture. Green and Ampt (G&A) with soil moisture redistribution 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 obtained from the Web Soil Survey (WSS). According to the website, "Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information." The web address for obtaining the shapefile information is as follows: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. Figure 3-5 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 infiltration and timing related to the ground cover and soil type.

Figure 3-5
Watersheds with Digitized Soil Types



3.7. Gridded Model

Once all of the variables mentioned above have been incorporated into the model it was necessary to divide the models into individual grid cells. As mentioned previously, the settings for GSSHA require the units to be in the International System of Units (SI). Table 3-2 lists the basin number, grid cell size, drainage area, and number of grid cells for each of the six Tensaw East basins.

Figures 3-6, 3-10, 3-14, 3-18, 3-22, and 3-26 indicate the gridded elevation data for all of the basins. Figures 3-7, 3-11, 3-15, 3-19, 3-23, and 3-27 indicate the gridded land use. Figures 3-8, 3-12, 3-16, 3-20, 3-24, and 3-28 indicate the gridded soil types. Figures 3-9, 3-13, 3-17, 3-21, 3-25, and 3-29 indicate the gridded combined land use/soil type layer for each basin.

Table 3-2
Basins with Grid Cell Size, Drainage Area, and Number of Cells

Basin	Grid Cell Size (Meter)	Grid Cell Size (Feet)	Drainage Area (Sq Miles)	Number of Grid Cells
1	23	75	4.17	20414
2	29	95	6.45	19878
3	24	79	4.51	20263
4	25	82	4.82	19983
5	95	312	71.16	20964
6	10	33	0.90	23378

Figure 3-6
Basin 1 – Gridded Contours

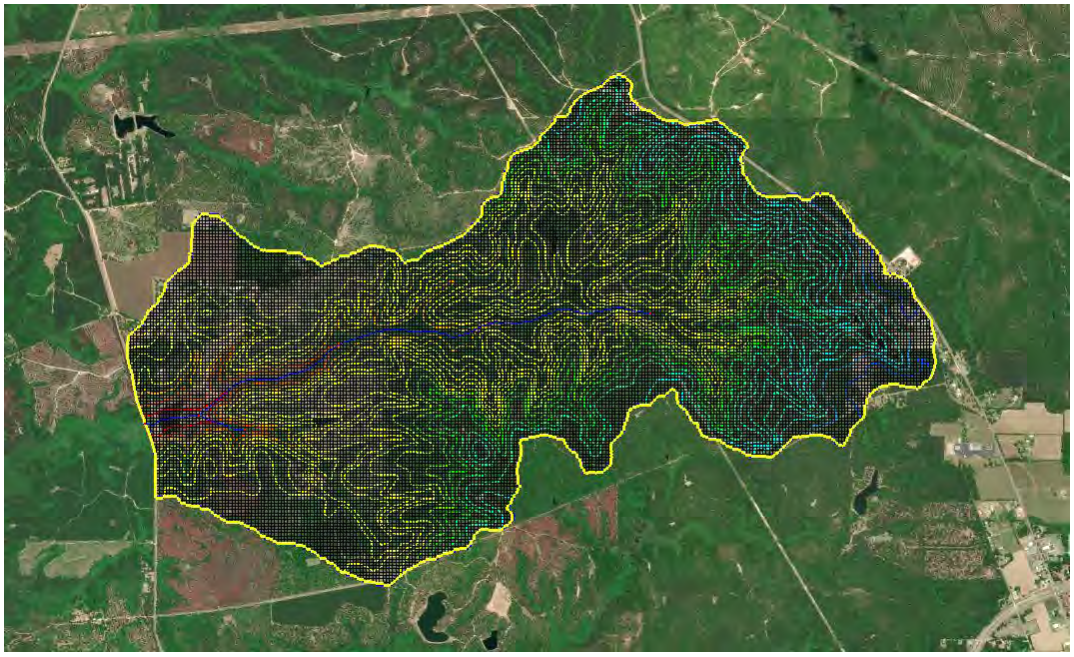


Figure 3-7
Basin 1 – Gridded Land Use

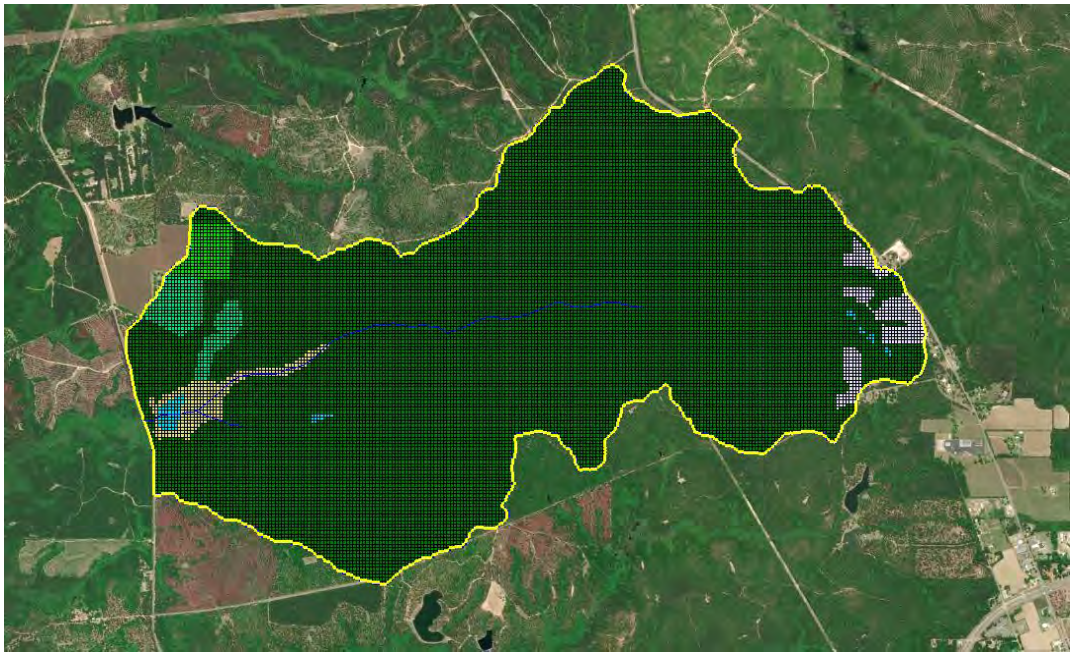


Figure 3-8
Basin 1 – Gridded Soils Data

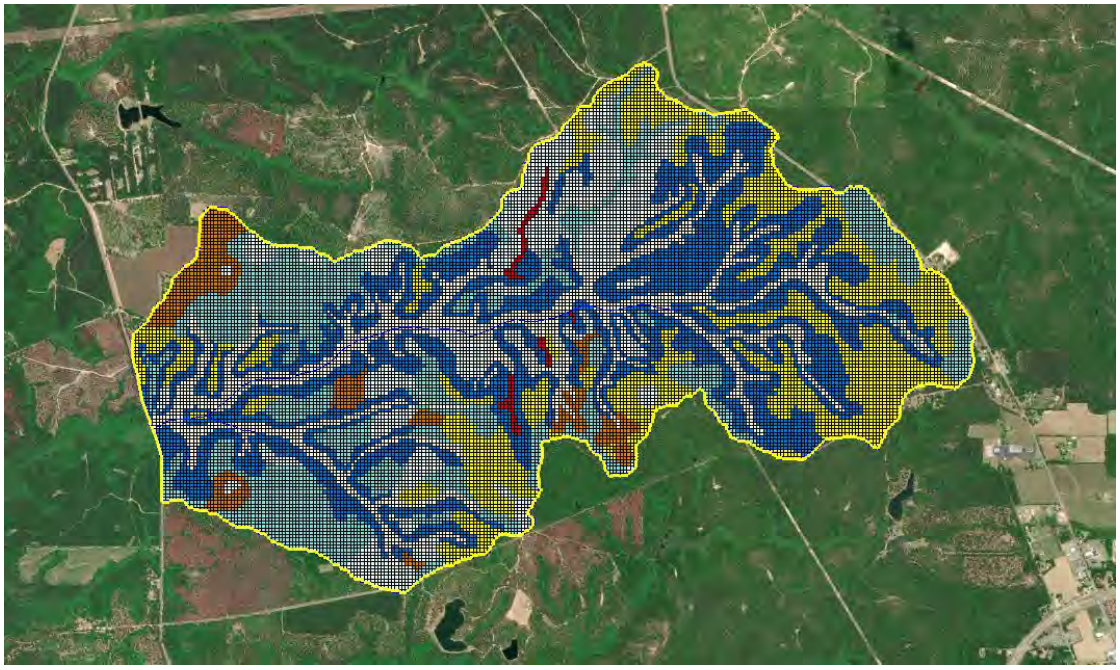


Figure 3-9
Basin 1 – Gridded Combined Land Use and Soil Type

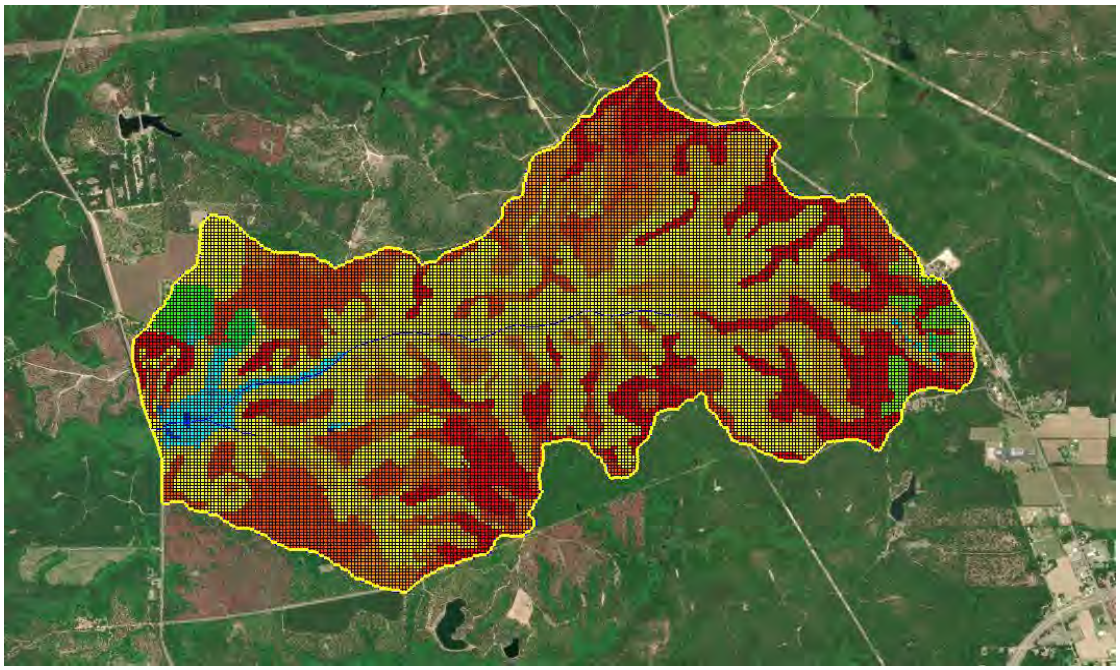


Figure 3-10
Basin 2 – Gridded Contours

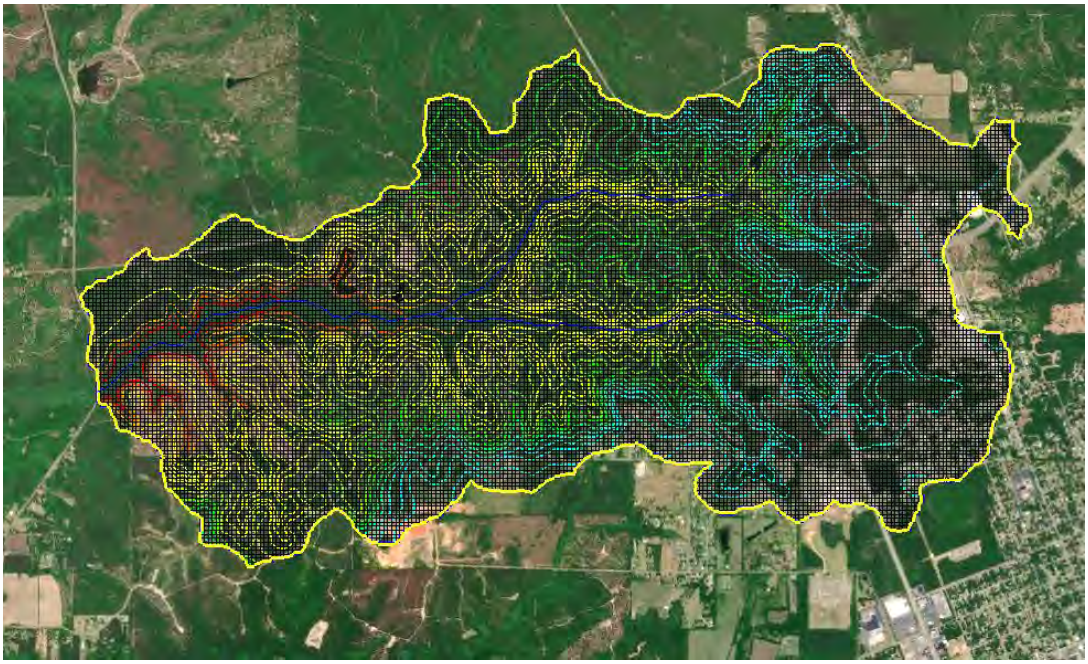


Figure 3-11
Basin 2 – Gridded Land Use

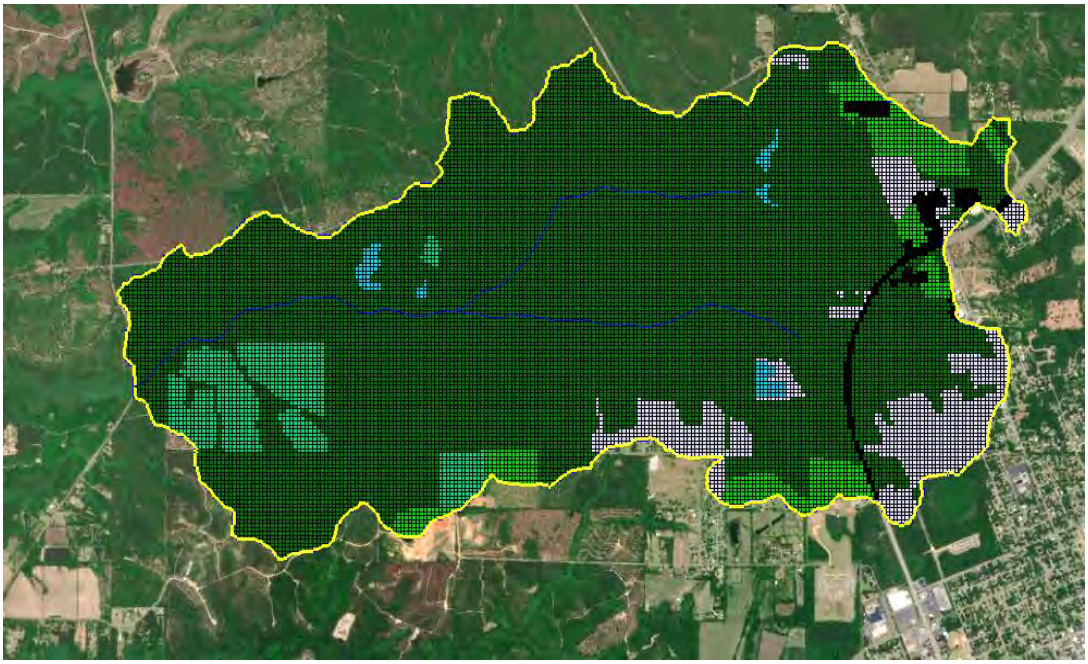


Figure 3-12
Basin 2 – Gridded Soil Type

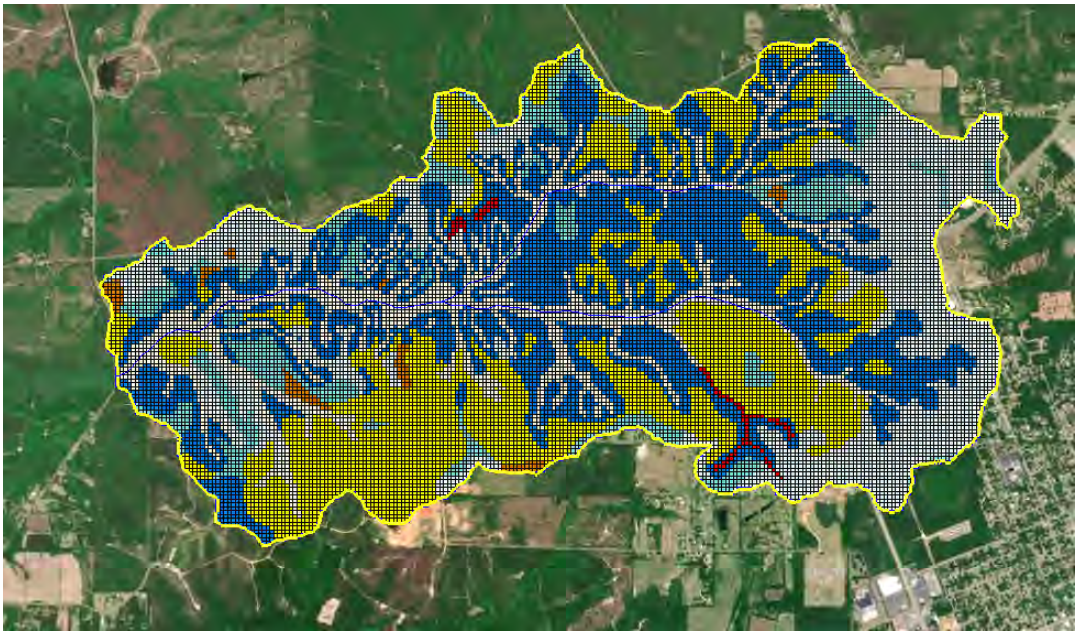


Figure 3-13
Basin 2 – Gridded Combined Land Use and Soil Type

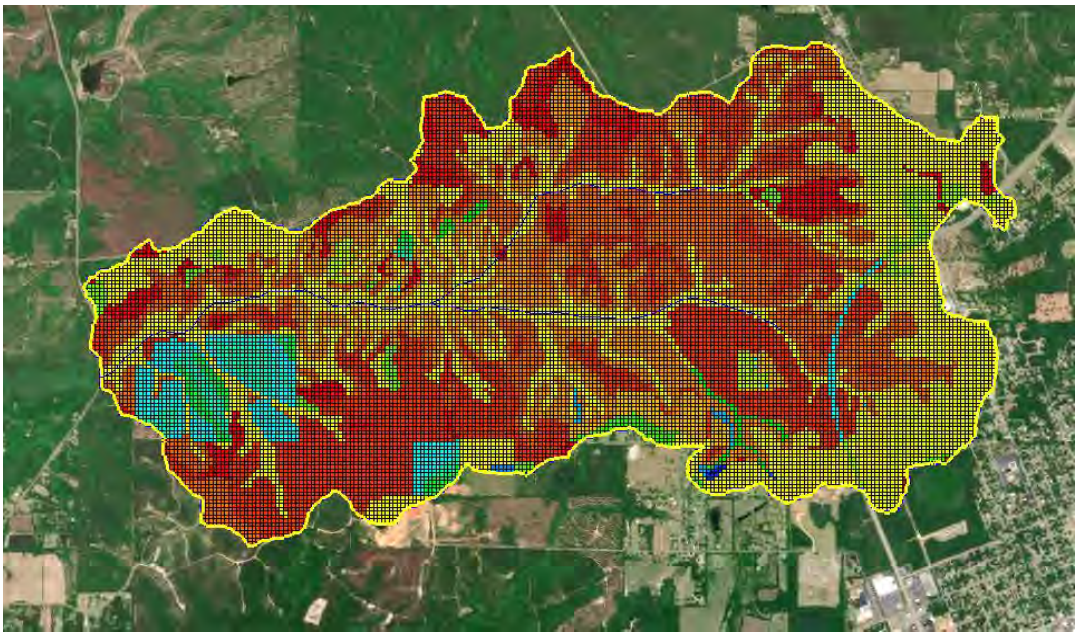


Figure 3-14
Basin 3 – Gridded Contours

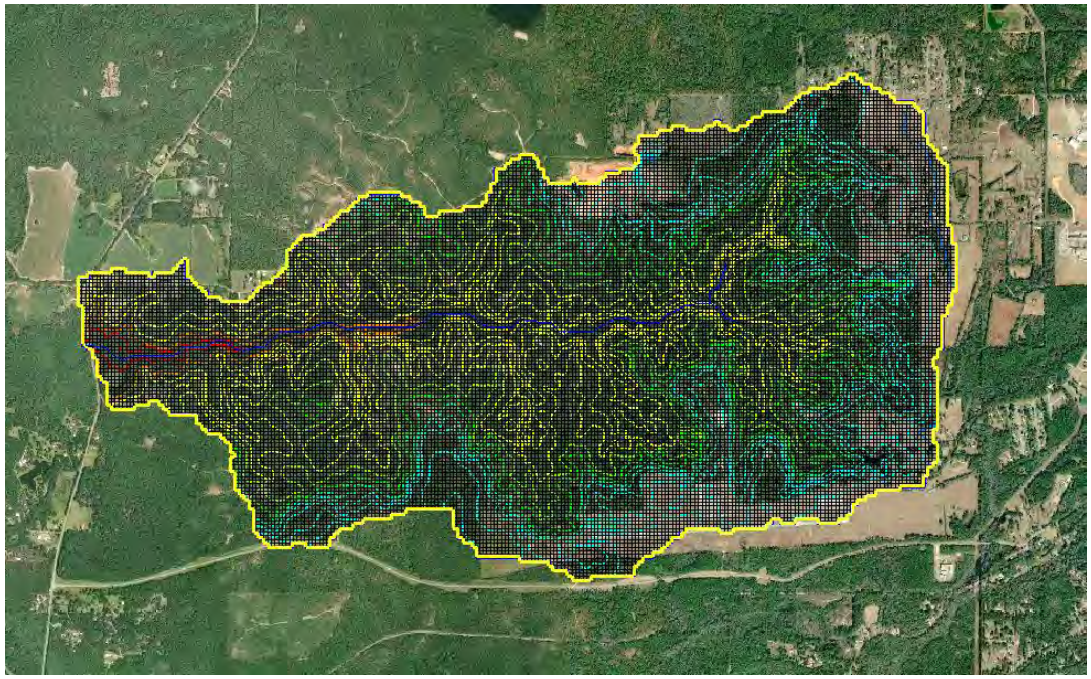


Figure 3-15
Basin 3 – Gridded Land Use

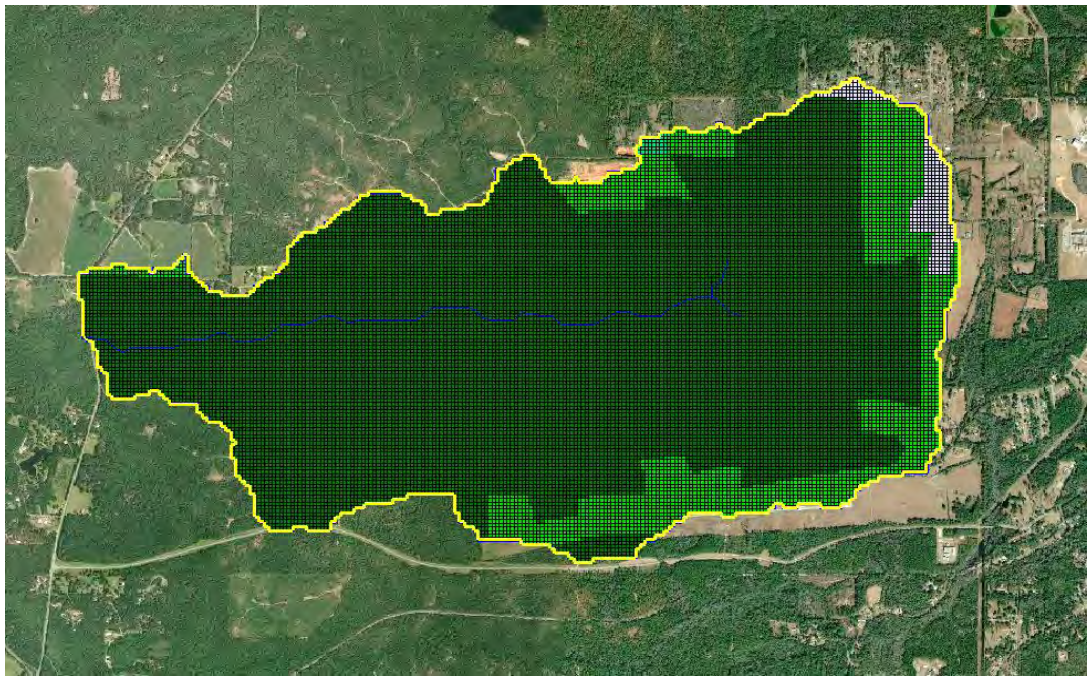


Figure 3-16
Basin 3 – Gridded Soil Type

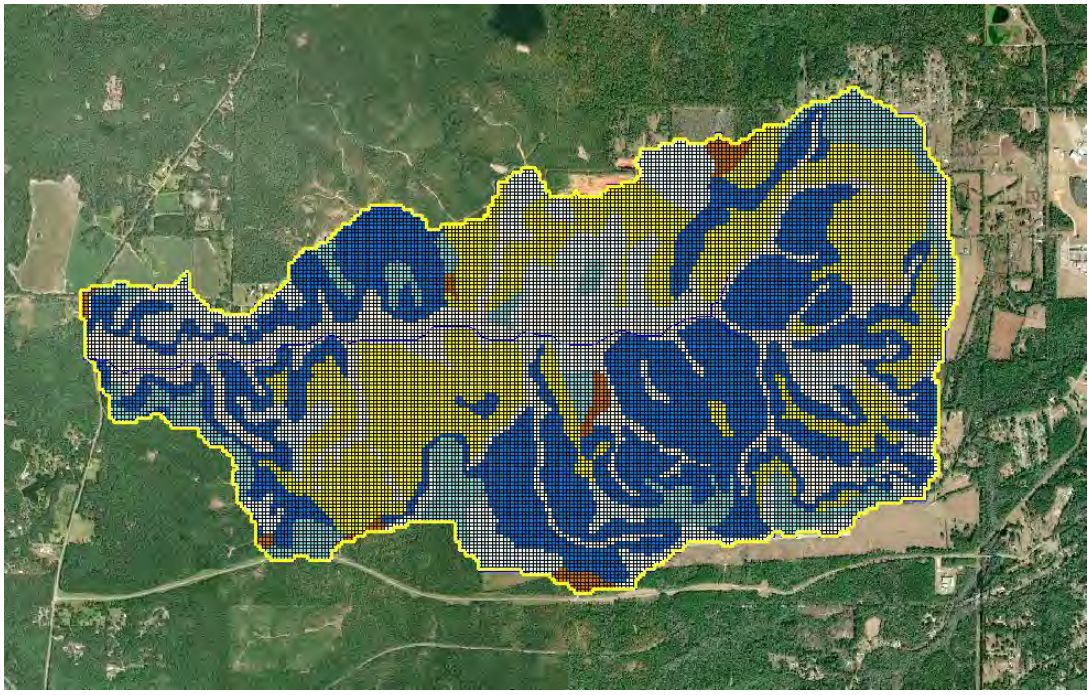


Figure 3-17
Basin 3 – Gridded Combined Land Use and Soil Type

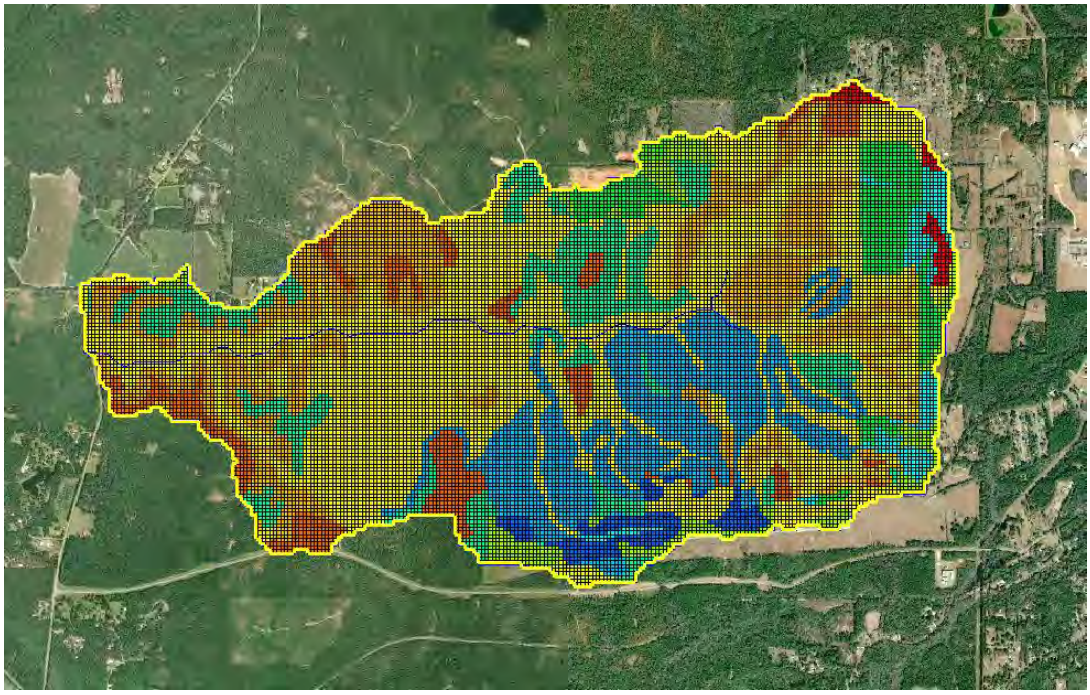


Figure 3-18
Basin 4 – Gridded Contours

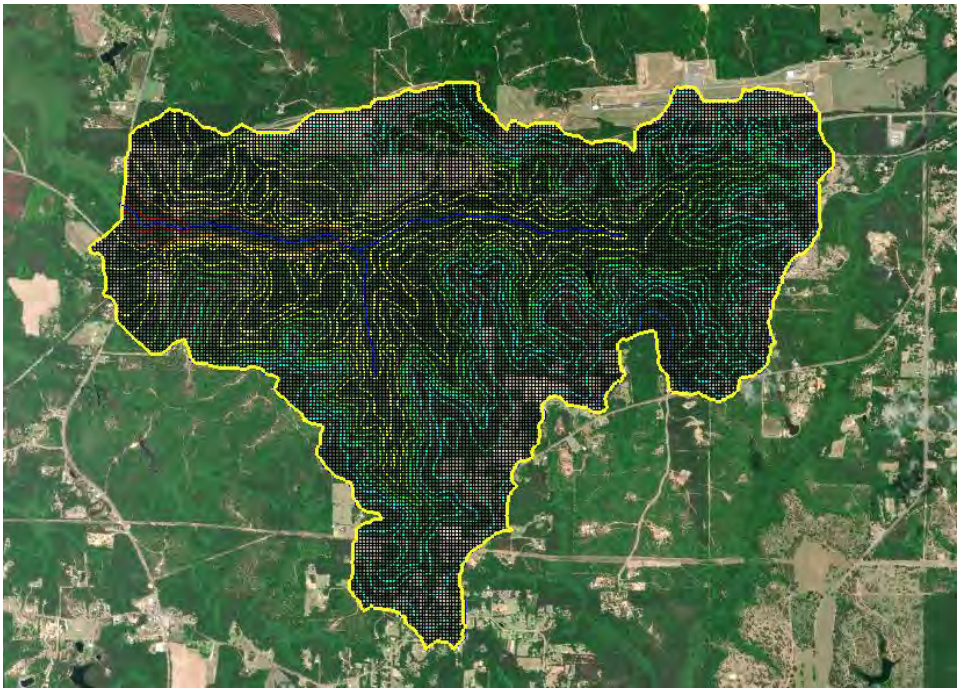


Figure 3-19
Basin 4 – Gridded Land Use

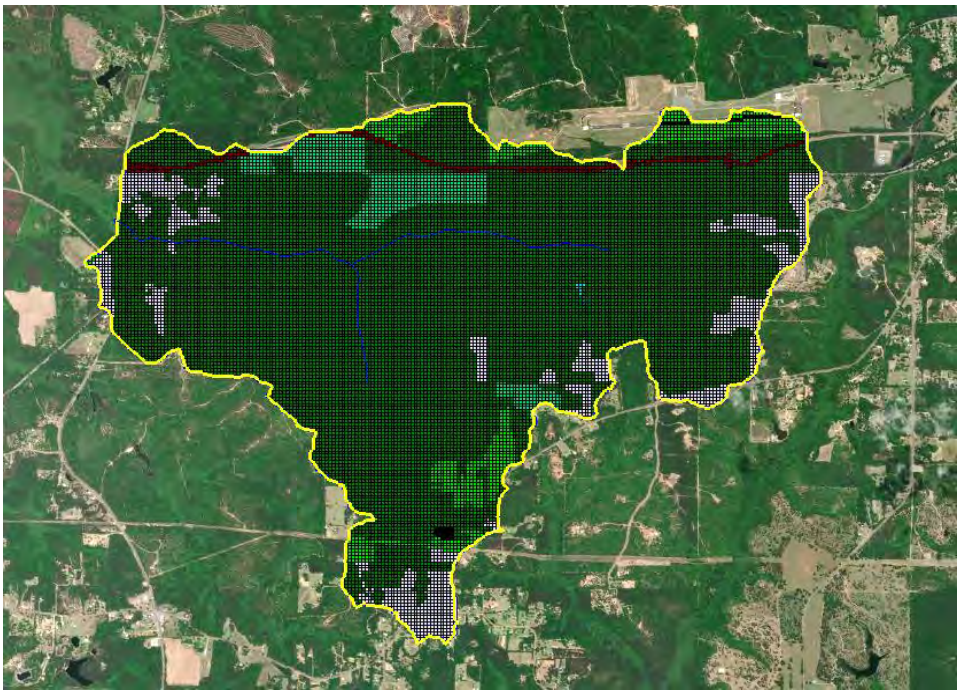


Figure 3-20
Basin 4 – Gridded Soil Type

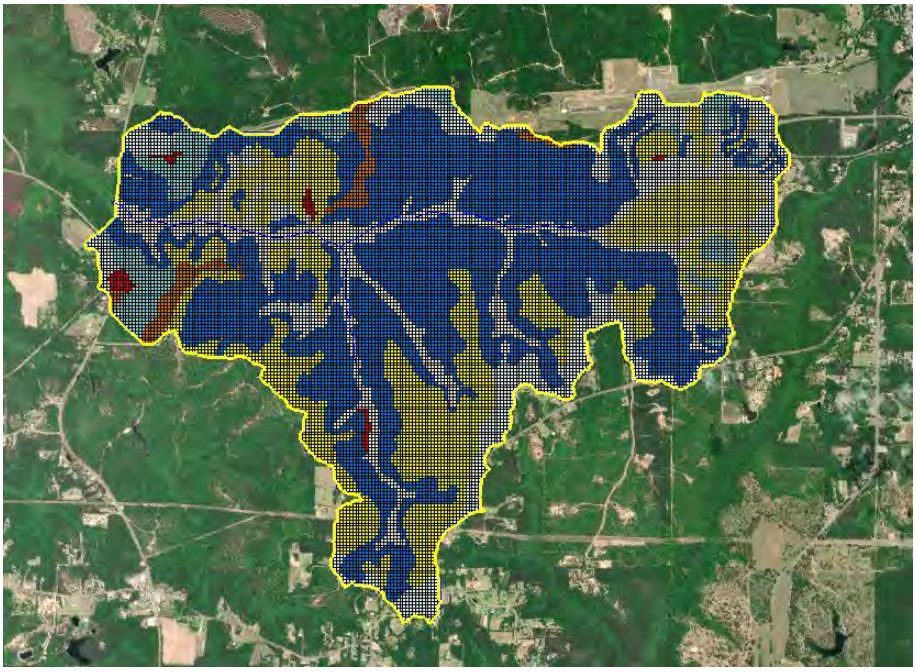


Figure 3-21
Basin 4 – Gridded Combined Land Use and Soil Type

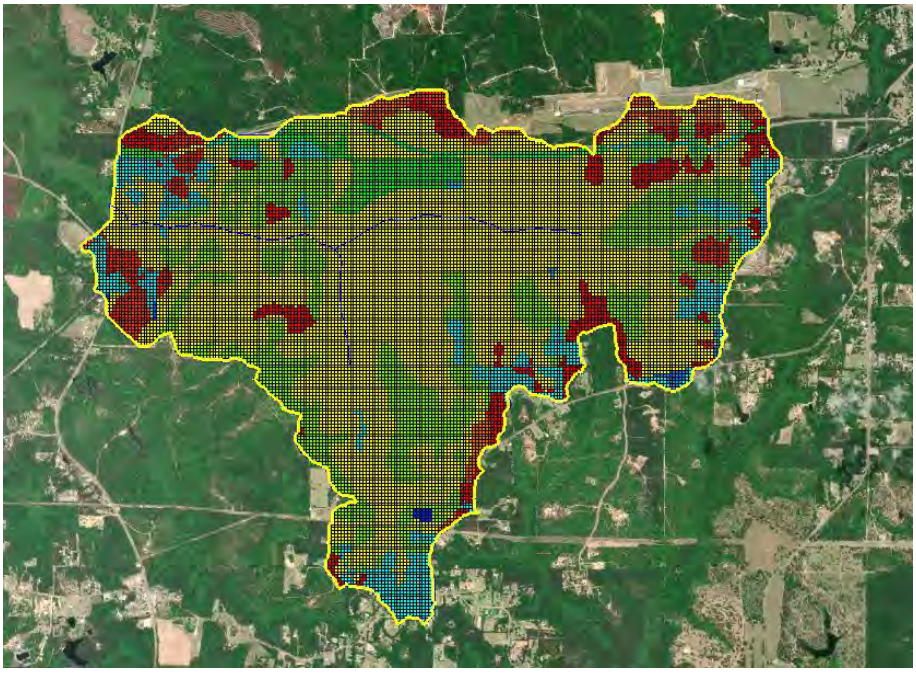


Figure 3-22
Basin 5 – Gridded Contours

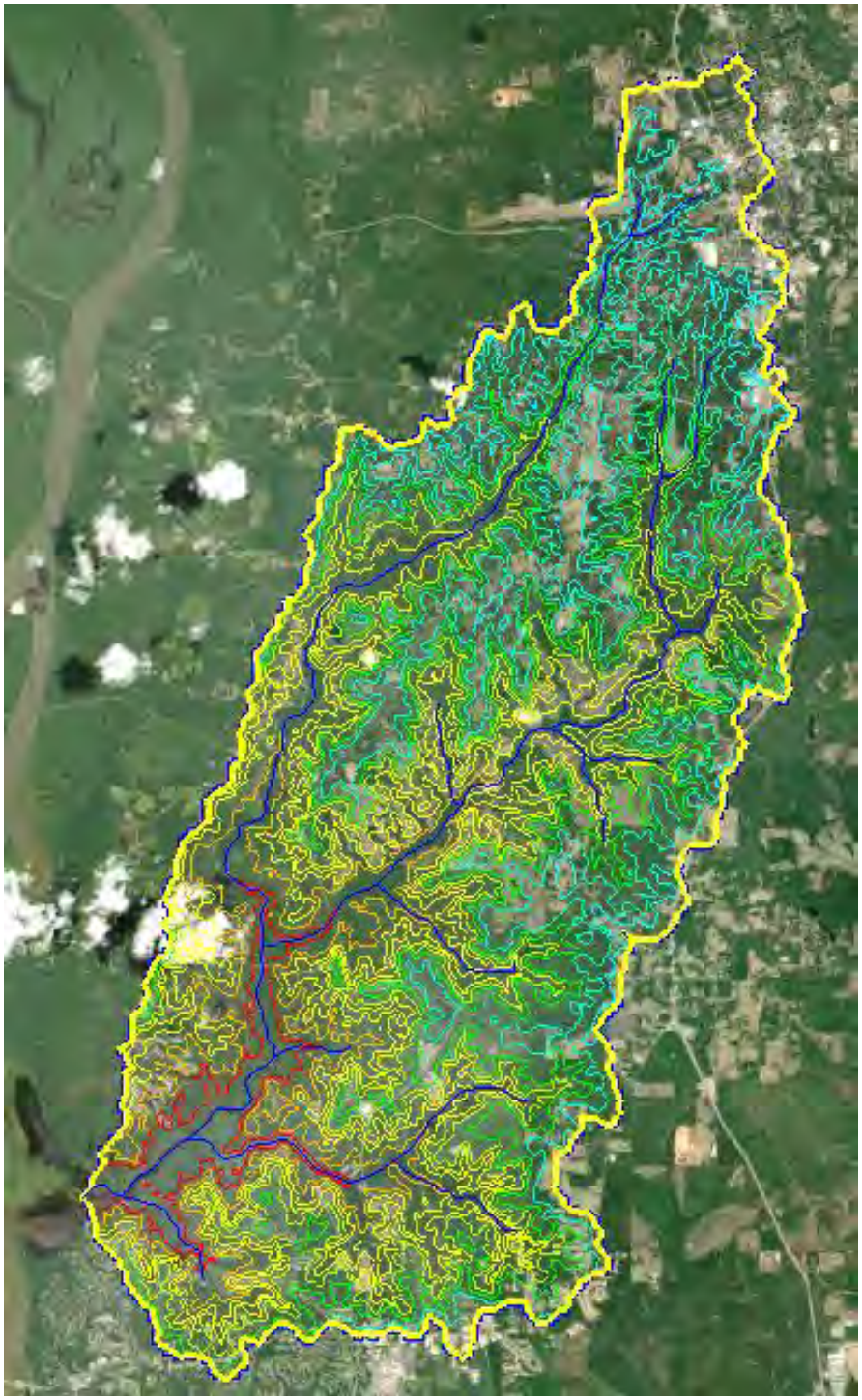


Figure 3-23
Basin 5 – Gridded Land Use

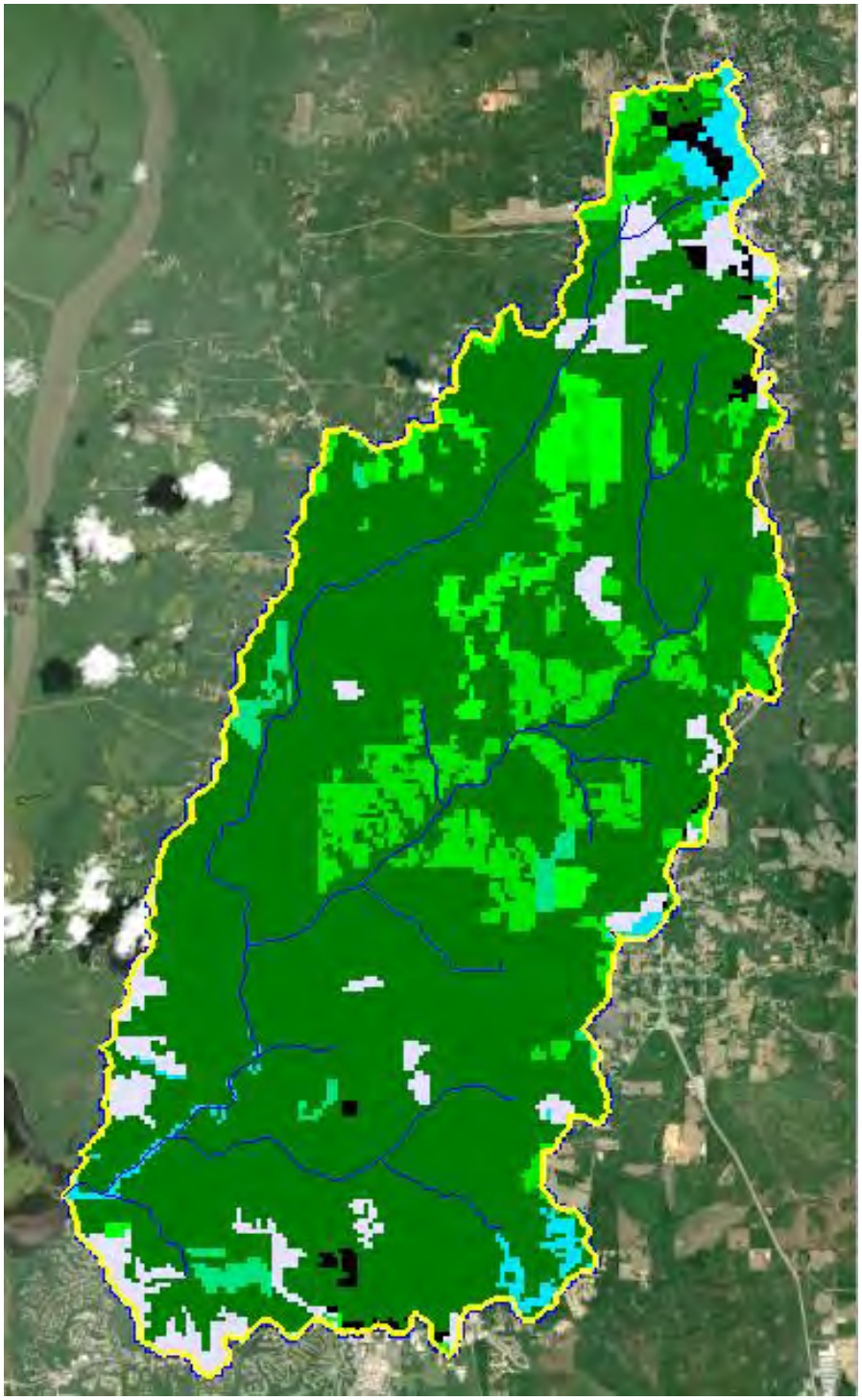


Figure 3-24
Basin 5 – Gridded Soil Type

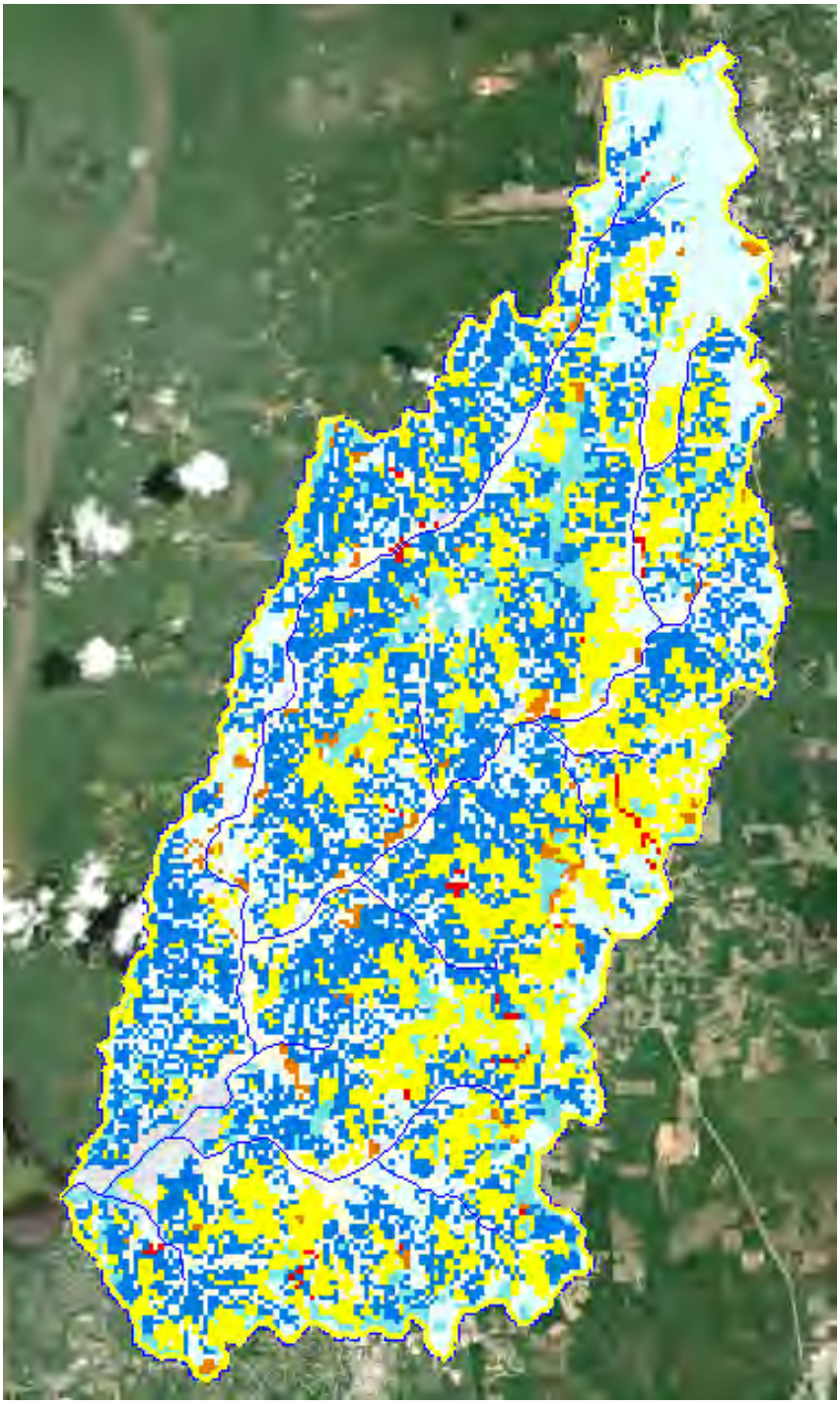


Figure 3-25
Basin 5 – Gridded Combined Land Use and Soil Type

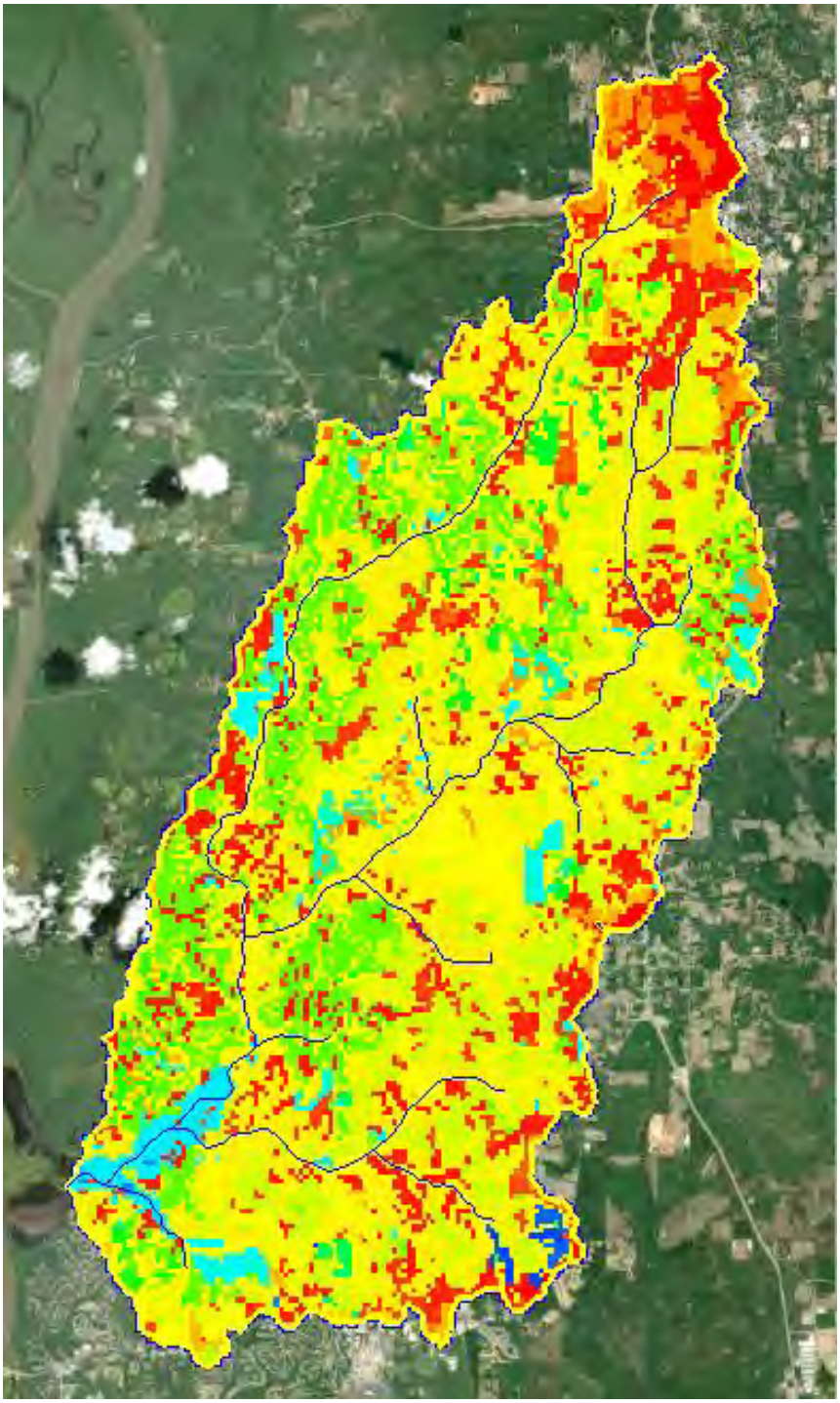


Figure 3-26
Basin 6 – Gridded Contours

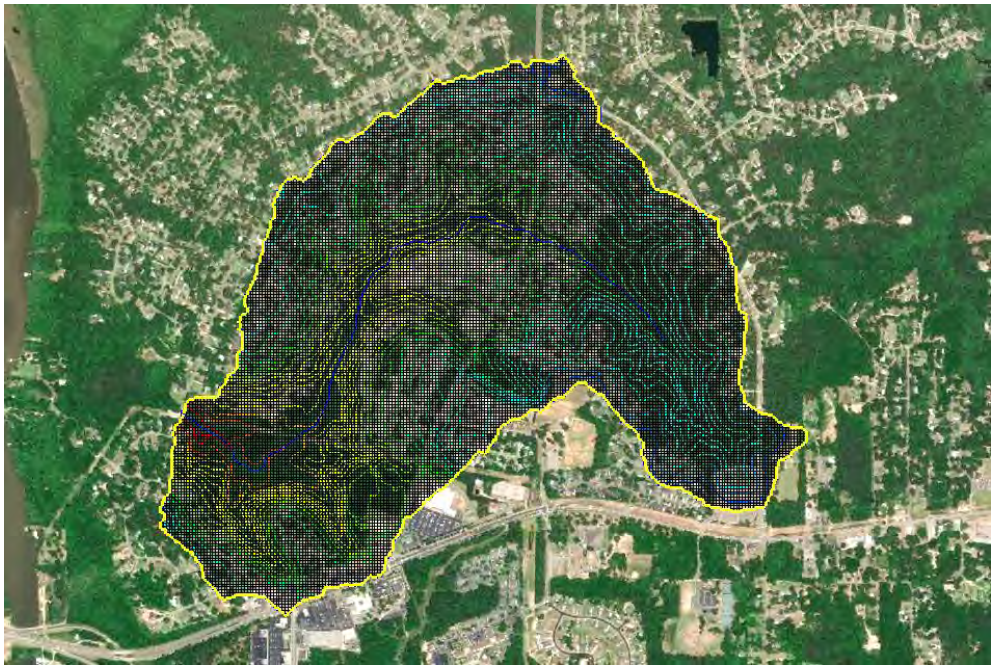


Figure 3-27
Basin 6 – Gridded Land Use

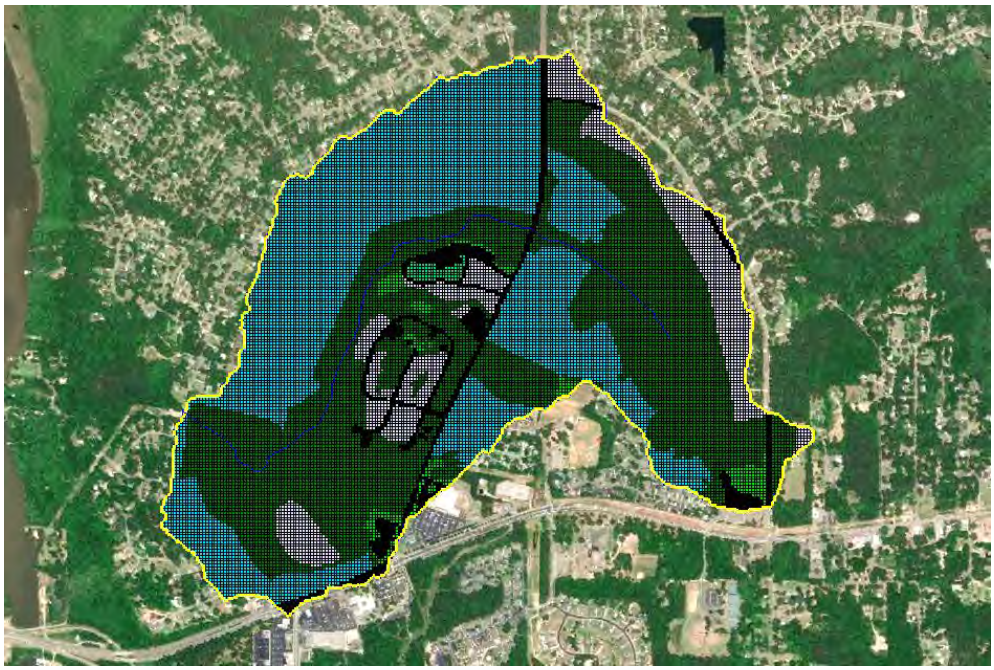


Figure 3-28
Basin 6 – Gridded Soil Type

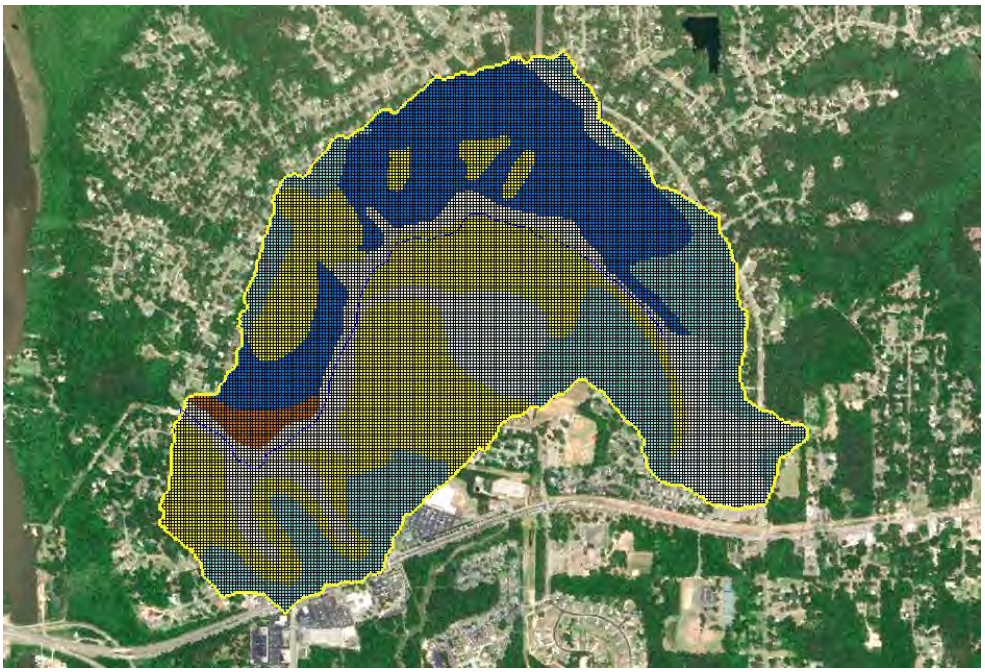
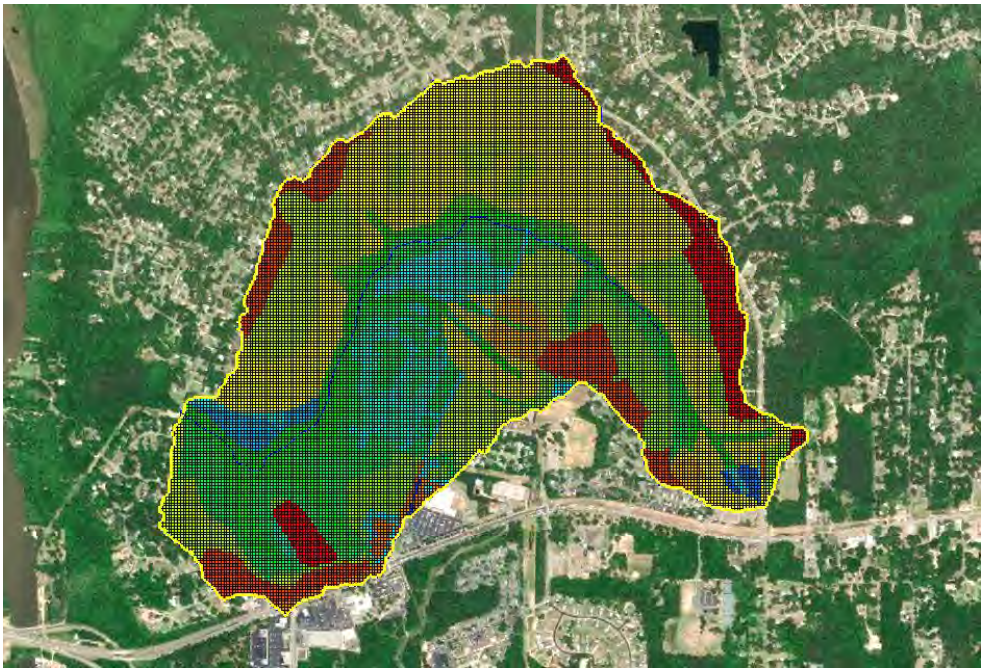


Figure 3-29
Basin 6 – Gridded Combined Land Use and Soil Type



4. Calibration

4.1. Tensaw East 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 distributions and river water surface elevations or discharge measurements during the rain event. With the rainfall distribution being obtained from the installed weather stations, 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 four 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. Between June 11 and June 13, 2018, the four gauges were installed and started recording data. A list of the gauges and locations can be found in Table 4-1.

Figure 4-1
Tensaw East Watersheds with Stream Gauge Locations

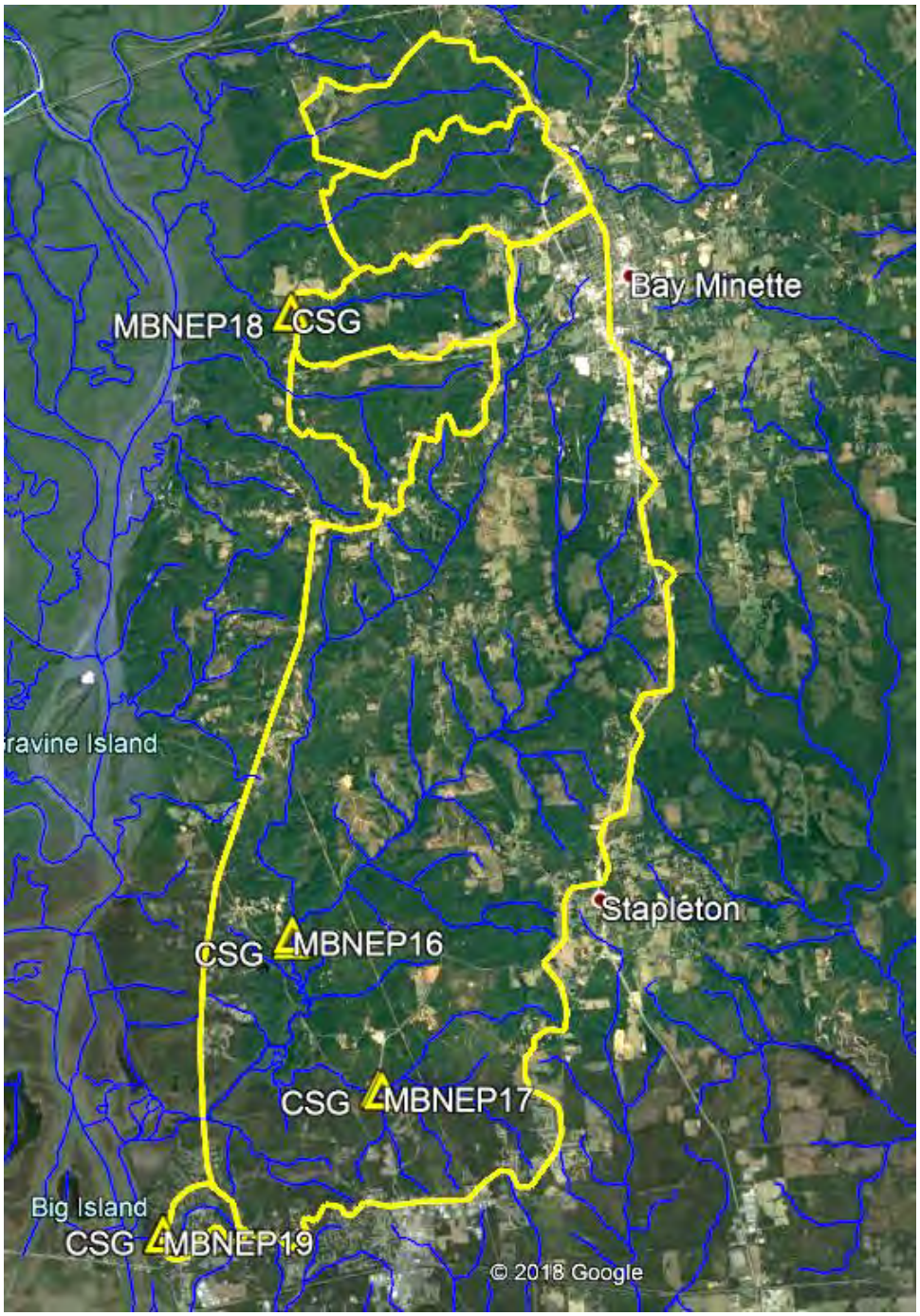


Table 4-1
Gauge Name, Stream, and Location

Gauge Name	Stream	Location
MBNEP 16	Bay Minette Creek	12' d.s of Bromley Rd CL
Cork Gauge 16	Bay Minette Creek	465' d.s. of MBNEP 16
MBNEP 17	Sibley Creek	30' d.s of Jimmy Faulkner Rd CL
Cork Gauge 17	Sibley Creek	320' d.s. of MBNEP 17
MBNEP 18	Red Hill Creek	40' d.s of SR 225
Cork Gauge 18	Red Hill Creek	175' d.s. of MBNEP 18
MBNEP 19	Bayou Sara	20' d.s. of Spanish Main St CL
Cork Gauge 19	Bayou Sara	55' u.s. of Spanish Main St CL

During the June 2018 to June 2020 evaluation period there were a couple of storm events that were possible candidates for beginning the calibration and validation process. From the stream gauge data (Figures 4-2 through 4-5), it was determined that a fairly adequate rainfall event occurred on September 4, 2018. This event produced approximately 6" of rain throughout the watershed in approximately 12 hours. Using NOAA Atlas 14 (Figure 4-6) for this rain depth and time period, it was determined that this rain event is equivalent to a 5-year storm. An initial calibration of the model was performed and compared to the stream gauge data.

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, and channel roughness. These values were adjusted until the model output best fit the observed data. Other factors that were considered were interception and retention. Due to the similarity in size, shape, and land cover, the calibration variables for Basin 3 were applied to Basins 1, 2, and 4.

Figure 4-2
MBNEP 16 Gauge Height Readings – June 2018 – June 2020

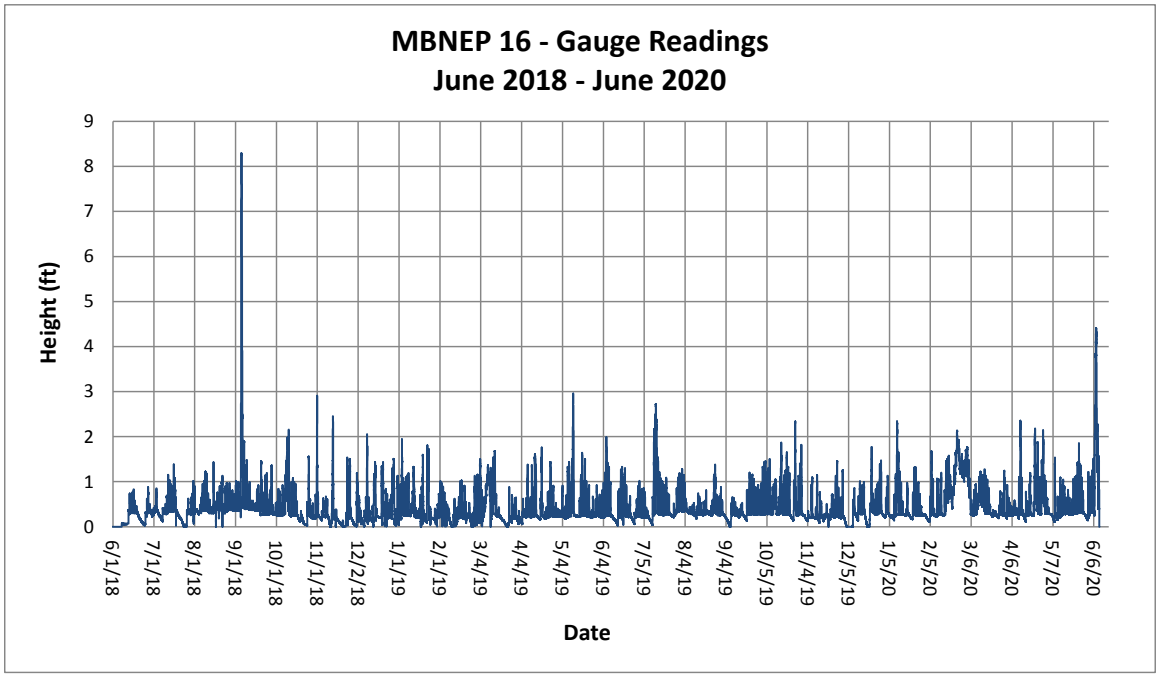


Figure 4-3
MBNEP 17 Gauge Height Readings – June 2018 – June 2020

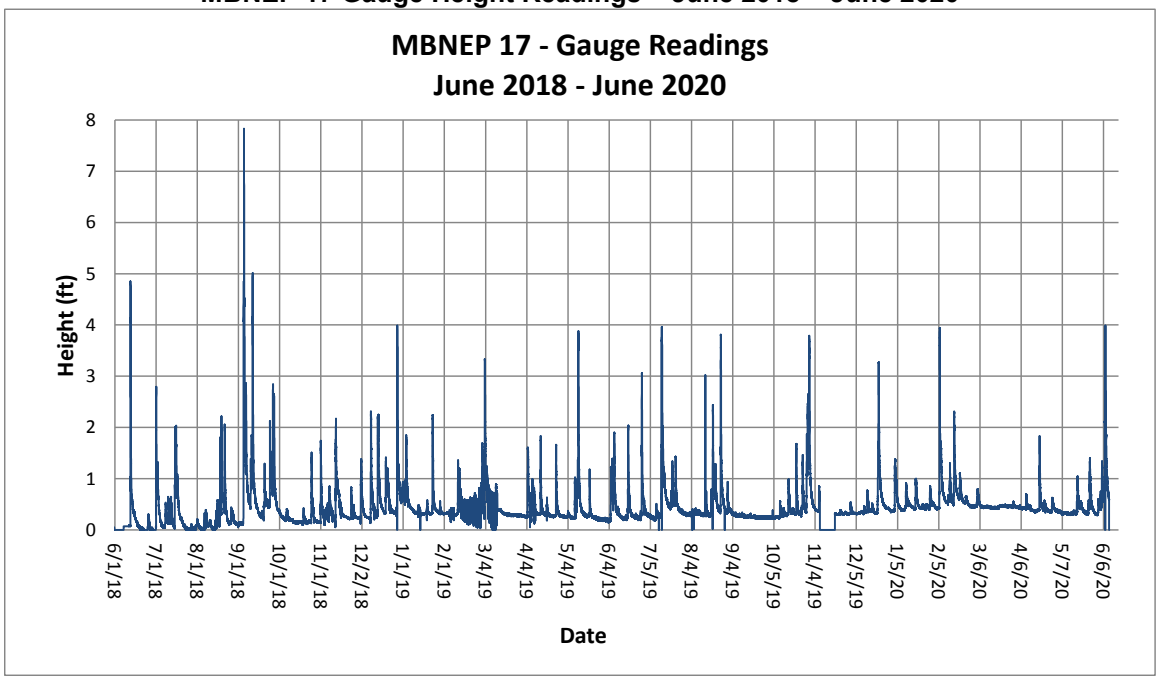


Figure 4-4
MBNEP 18 Gauge Height Readings – June 2018 – June 2020

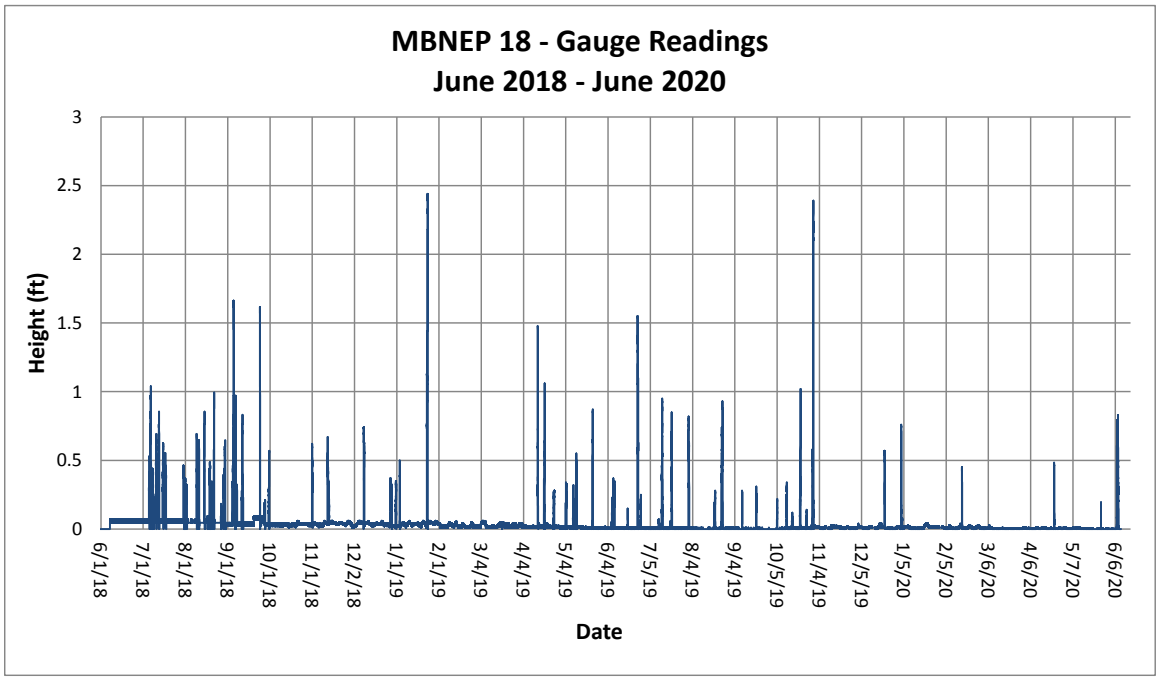


Figure 4-5
MBNEP 19 Gauge Height Readings – June 2018 – June 2020

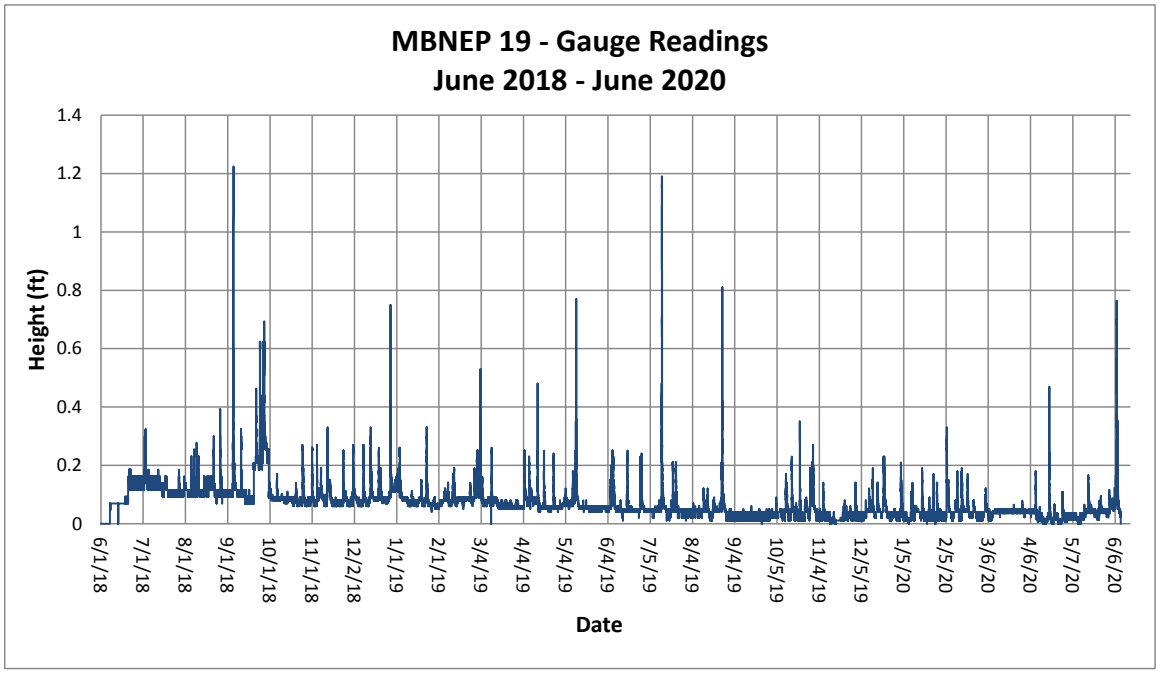


Figure 4-6
Point Precipitation Frequency Estimates

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]

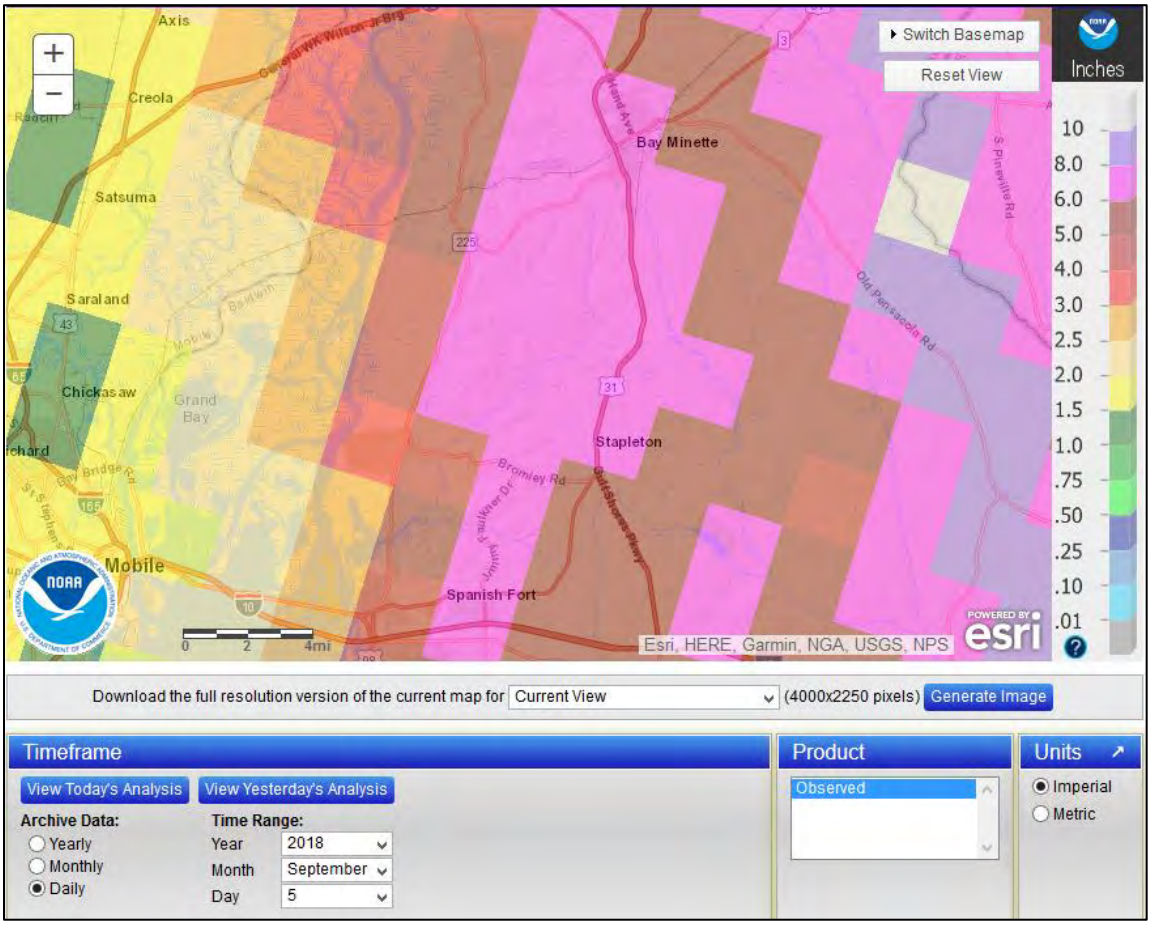
Duration	Average recurrence interval (years)								
	1	2	5	10	25	50	100	200	500
5-min	0.593 (0.481-0.723)	0.672 (0.544-0.820)	0.804 (0.649-0.983)	0.915 (0.734-1.12)	1.07 (0.830-1.35)	1.19 (0.903-1.52)	1.31 (0.963-1.72)	1.44 (1.01-1.93)	1.61 (1.09-2.21)
10-min	0.868 (0.704-1.06)	0.985 (0.797-1.20)	1.18 (0.950-1.44)	1.34 (1.08-1.64)	1.57 (1.22-1.98)	1.74 (1.32-2.23)	1.92 (1.41-2.51)	2.10 (1.48-2.82)	2.35 (1.60-3.23)
15-min	1.06 (0.858-1.29)	1.20 (0.972-1.47)	1.44 (1.16-1.76)	1.63 (1.31-2.01)	1.91 (1.48-2.41)	2.12 (1.61-2.72)	2.34 (1.72-3.06)	2.57 (1.81-3.44)	2.87 (1.95-3.94)
30-min	1.54 (1.25-1.88)	1.76 (1.42-2.15)	2.12 (1.71-2.59)	2.42 (1.94-2.97)	2.83 (2.20-3.58)	3.16 (2.40-4.04)	3.49 (2.56-4.57)	3.83 (2.70-5.13)	4.28 (2.91-5.89)
60-min	2.08 (1.69-2.54)	2.38 (1.92-2.90)	2.87 (2.31-3.51)	3.29 (2.64-4.04)	3.88 (3.02-4.92)	4.35 (3.31-5.58)	4.84 (3.56-6.34)	5.34 (3.77-7.18)	6.03 (4.09-8.31)
2-hr	2.62 (2.15-3.18)	2.99 (2.44-3.63)	3.62 (2.95-4.39)	4.16 (3.37-5.07)	4.93 (3.87-6.21)	5.55 (4.26-7.07)	6.19 (4.59-8.06)	6.86 (4.88-9.16)	7.77 (5.32-10.7)
3-hr	2.99 (2.46-3.61)	3.41 (2.80-4.12)	4.14 (3.39-5.00)	4.78 (3.89-5.80)	5.71 (4.52-7.18)	6.47 (4.99-8.23)	7.27 (5.42-9.46)	8.11 (5.80-10.8)	9.29 (6.39-12.7)
6-hr	3.64 (3.02-4.35)	4.16 (3.44-4.97)	5.09 (4.20-6.10)	5.94 (4.88-7.15)	7.23 (5.79-9.09)	8.32 (6.49-10.6)	9.48 (7.14-12.3)	10.7 (7.76-14.3)	12.5 (8.70-17.1)
12-hr	4.29 (3.59-5.09)	4.93 (4.12-5.85)	6.12 (5.10-7.28)	7.24 (6.00-8.66)	9.00 (7.31-11.3)	10.5 (8.30-13.3)	12.2 (9.27-15.8)	14.0 (10.2-18.6)	16.6 (11.7-22.6)
24-hr	4.95 (4.18-5.82)	5.74 (4.85-6.77)	7.26 (6.10-8.57)	8.71 (7.28-10.3)	11.0 (9.03-13.8)	13.0 (10.4-16.4)	15.2 (11.7-19.6)	17.6 (13.0-23.3)	21.2 (14.9-28.6)
2-day	5.68 (4.84-6.63)	6.64 (5.65-7.77)	8.48 (7.19-9.93)	10.2 (8.63-12.0)	13.0 (10.8-16.2)	15.4 (12.4-19.4)	18.1 (14.0-23.2)	21.1 (15.6-27.6)	25.4 (18.0-34.1)
3-day	6.22 (5.33-7.23)	7.21 (6.17-8.39)	9.12 (7.77-10.6)	11.0 (9.29-12.8)	13.9 (11.6-17.2)	16.5 (13.3-20.6)	19.3 (15.0-24.6)	22.5 (16.7-29.4)	27.1 (19.3-36.2)
4-day	6.68 (5.74-7.74)	7.66 (6.58-8.89)	9.57 (8.19-11.1)	11.4 (9.73-13.3)	14.4 (12.1-17.8)	17.0 (13.8-21.2)	20.0 (15.6-25.4)	23.2 (17.3-30.2)	27.9 (20.0-37.3)
7-day	7.81 (6.77-8.99)	8.76 (7.58-10.1)	10.6 (9.16-12.3)	12.5 (10.7-14.5)	15.5 (13.0-19.0)	18.1 (14.8-22.4)	21.1 (16.6-26.6)	24.4 (18.3-31.6)	29.2 (21.0-38.8)

* This chart was generated from the lat/long point of 30.8009, -87.8206

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

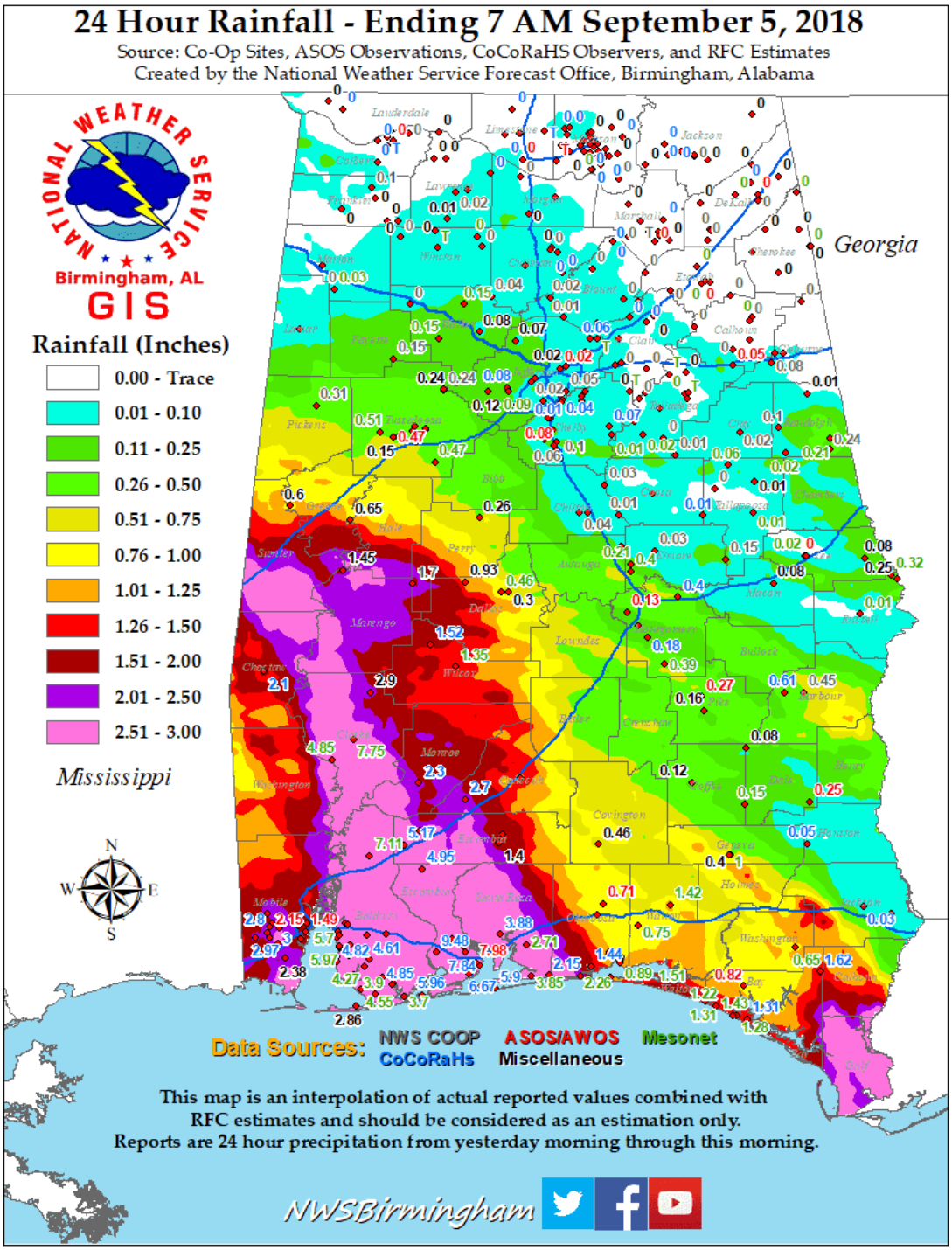
Figures 4-7 and 4-8 indicate the total rainfall maps for the September 4, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-9, 4-10, and 4-14 indicate the total rainfall distributions for Basin 5, Basins 1 to 4, and Basin 6, respectively. Figures 4-11, 4-12, 4-13, and 4-15 indicate the calibrated model output for Bay Minette Creek (B5), Sibley Creek (B5), Red Hill Creek (B3), and Spanish Fort Branch (B6), respectively.

Figure 4-7
Sept 4-5, 2018 – AHPS Total Rainfall Map



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

Figure 4-8
Sept 4-5, 2018 – Total Rainfall Map



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

Figure 4-9
Sept 4-5, 2018 – Total Rainfall Distribution in Basin 5

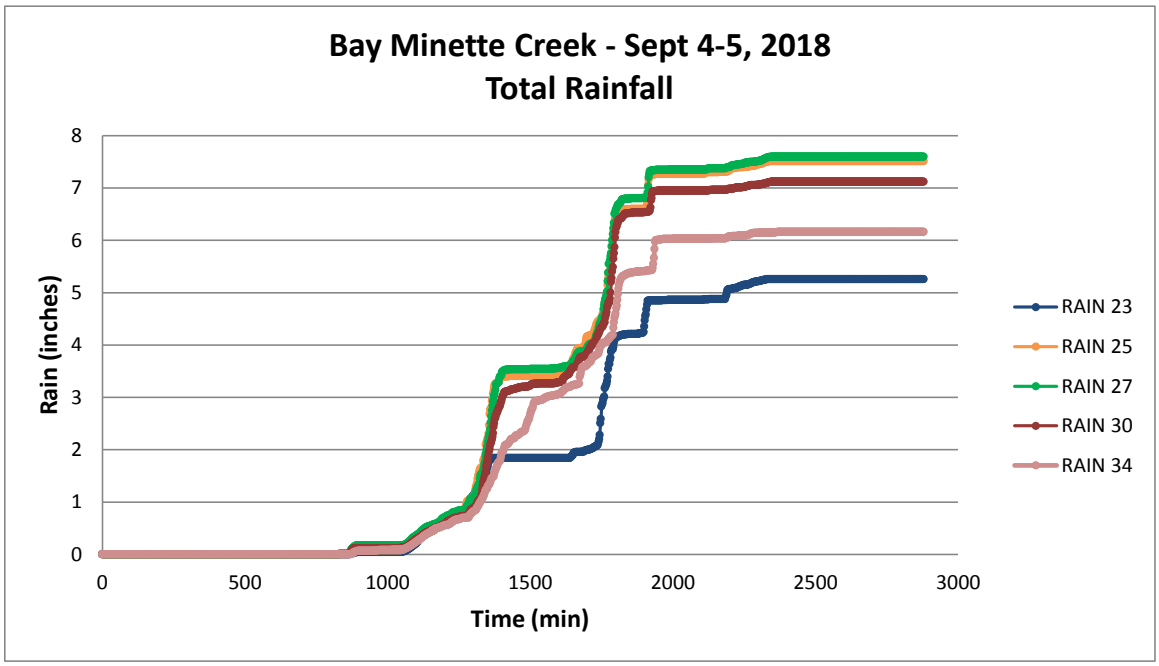


Figure 4-10
Sept 4-5, 2018 – Total Rainfall Distribution in Basins 1,2,3,4

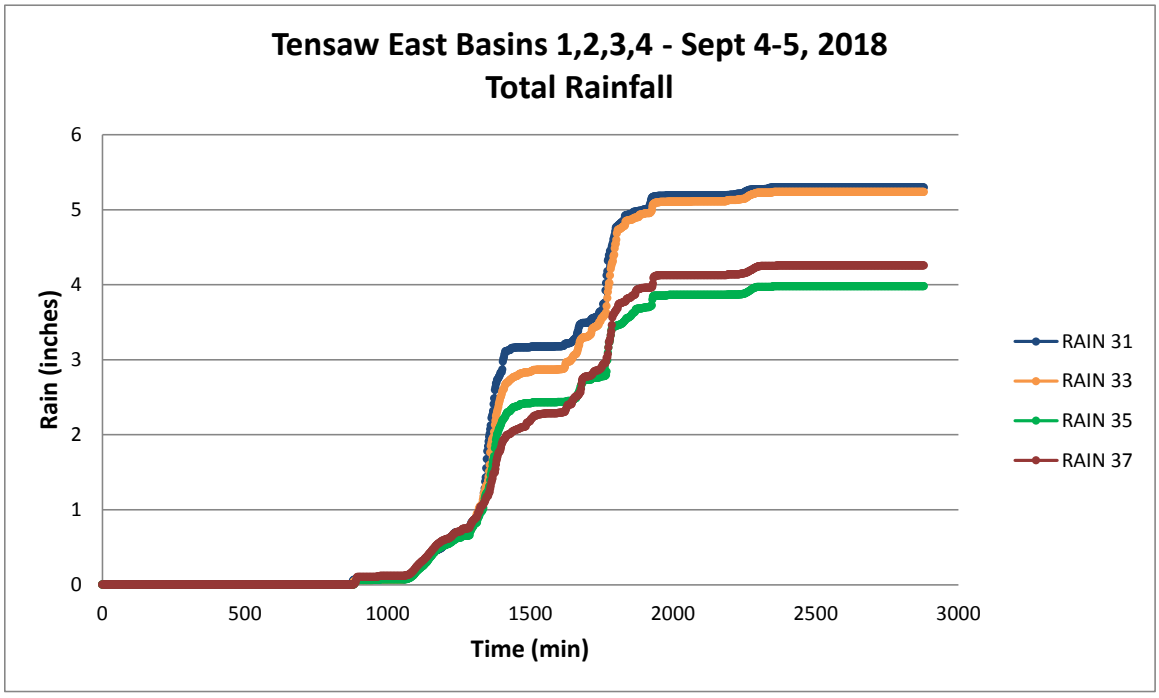


Figure 4-11
Sept 4-6, 2018 – Bay Minette Creek Calibration (B5)

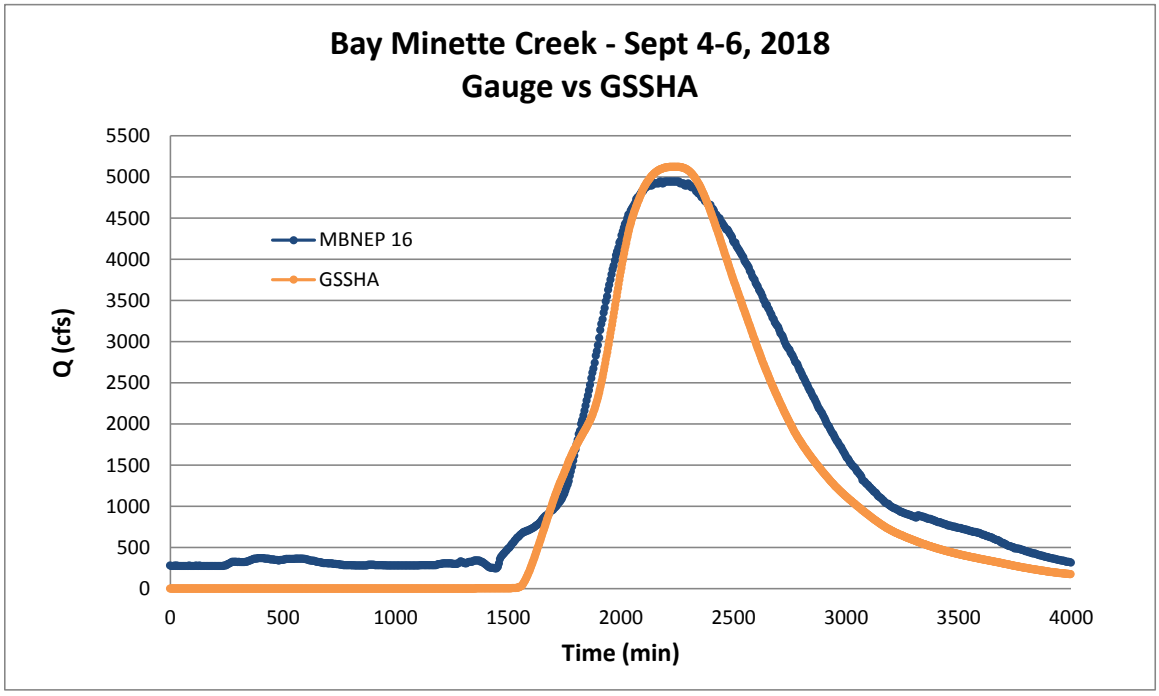


Figure 4-12
Sept 4-5, 2018 – Sibley Creek Calibration (B5)

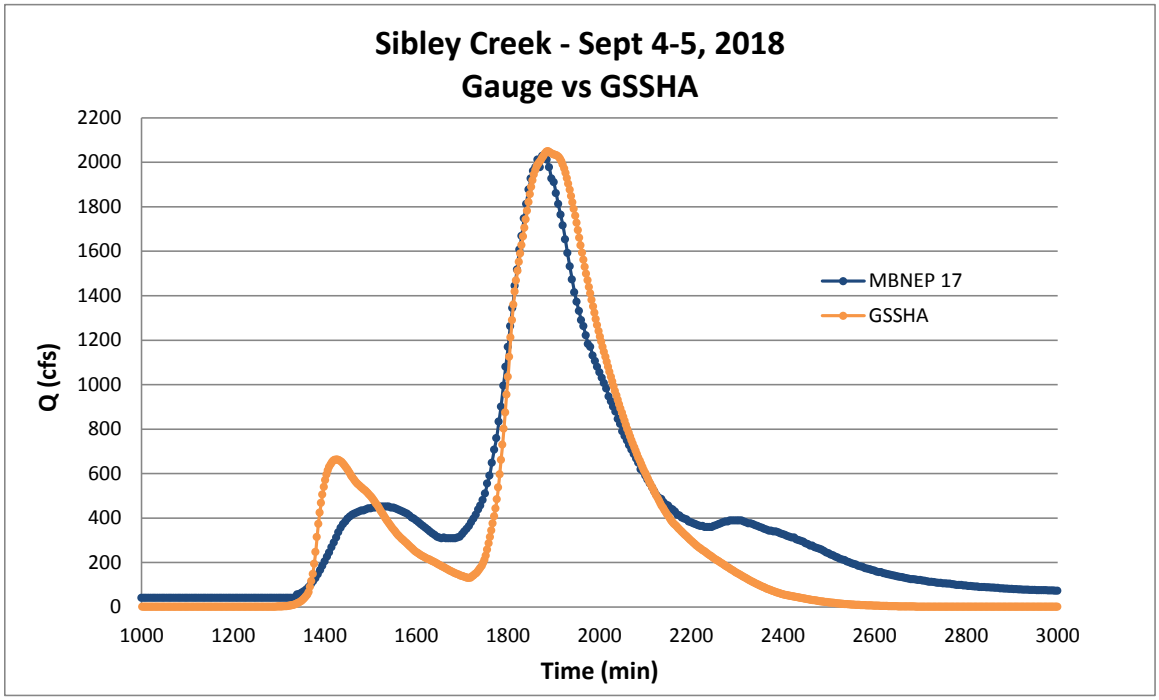


Figure 4-13
Sept 4-5, 2018 – Red Hill Creek Calibration (B3)

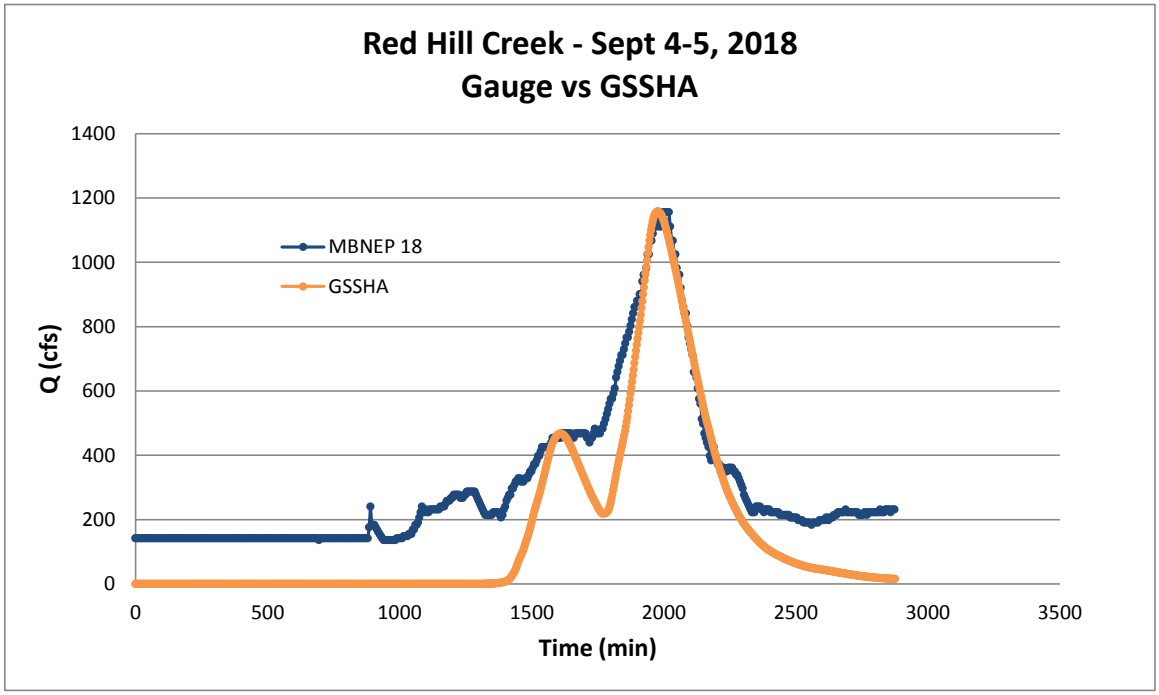


Figure 4-14
Sept 4-5, 2018 – Total Rainfall Distribution in Basin 6

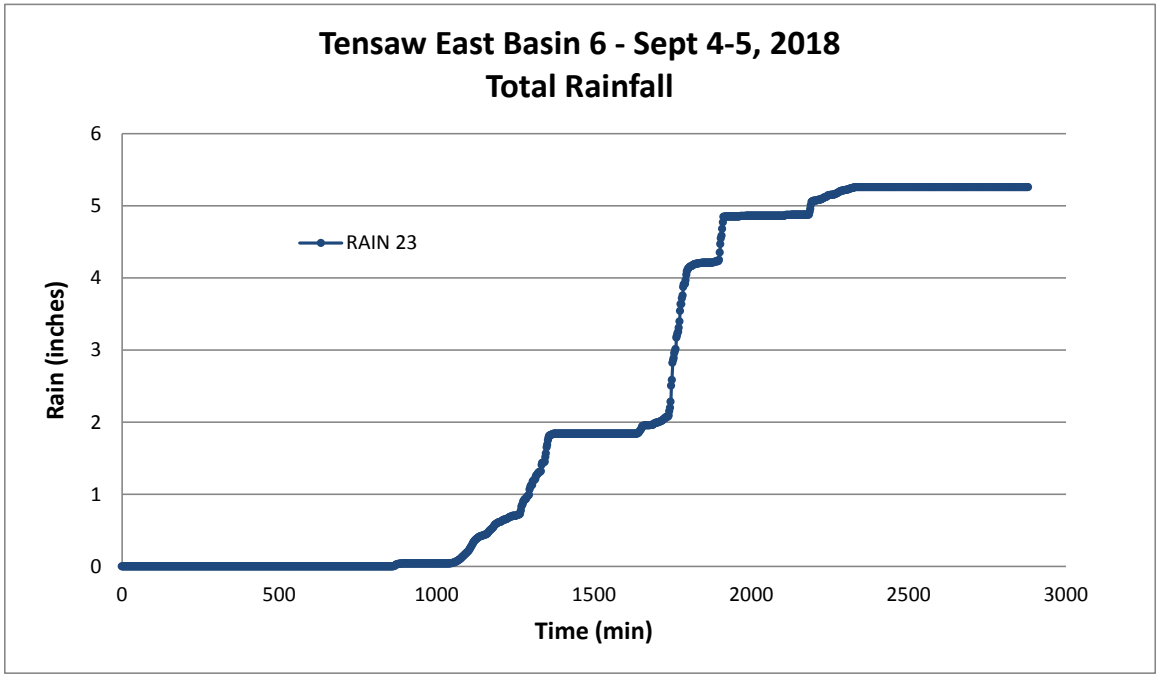
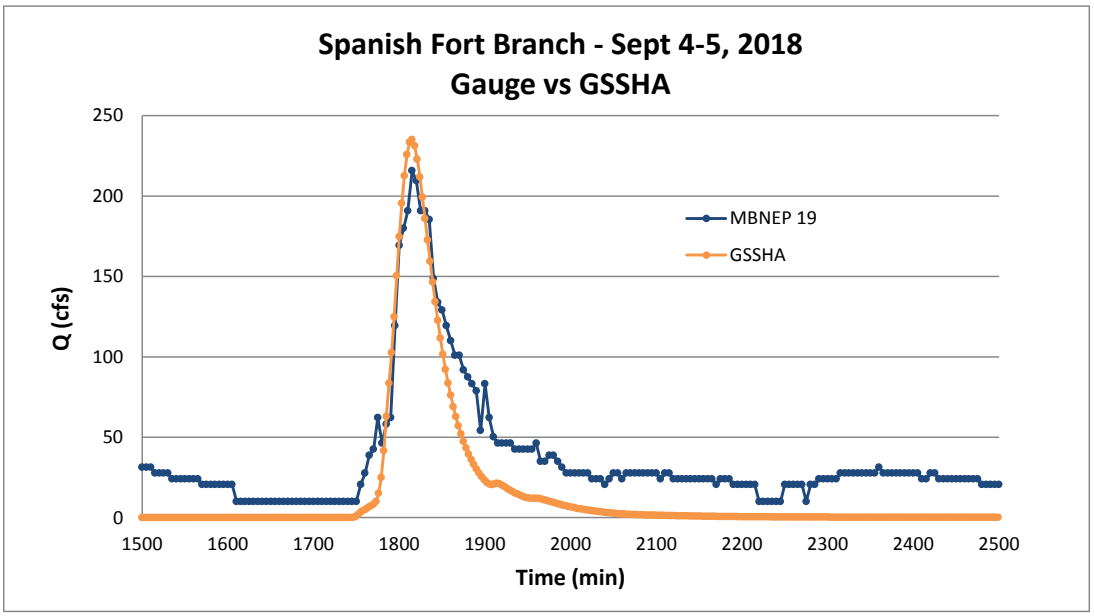


Figure 4-15
Sept 4-5, 2018 – Spanish Fort Branch Calibration (B6)



Figures 4-16 and 4-17 indicate the total rainfall maps for the December 28, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figure 4-18 indicates the total rainfall distribution for Basin 5. Figures 4-19 and 4-20 indicate the calibrated model output for Bay Minette Creek and Sibley Creek.

Figure 4-16
December 28-29, 2018 – AHPS Total Rainfall Map

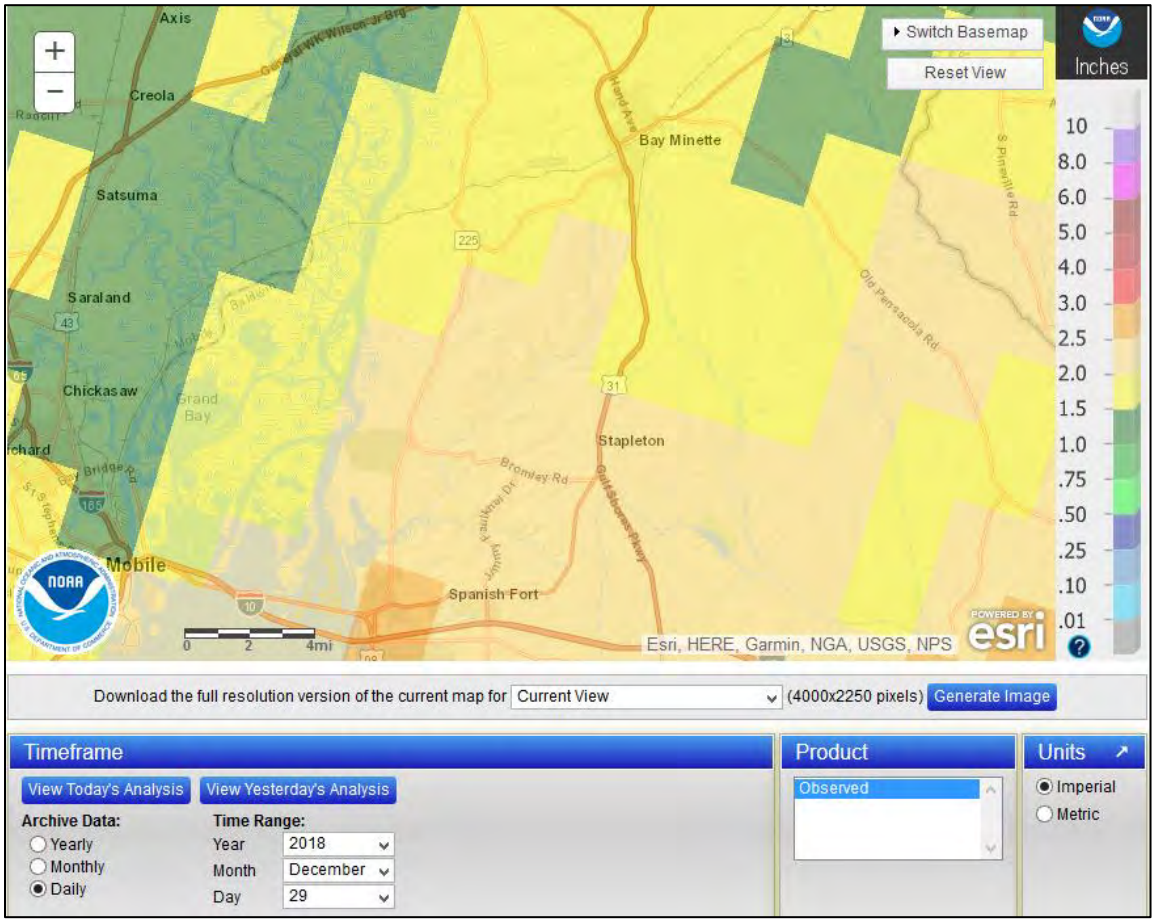


Figure 4-17
December 28-29, 2018 – Total Rainfall Map

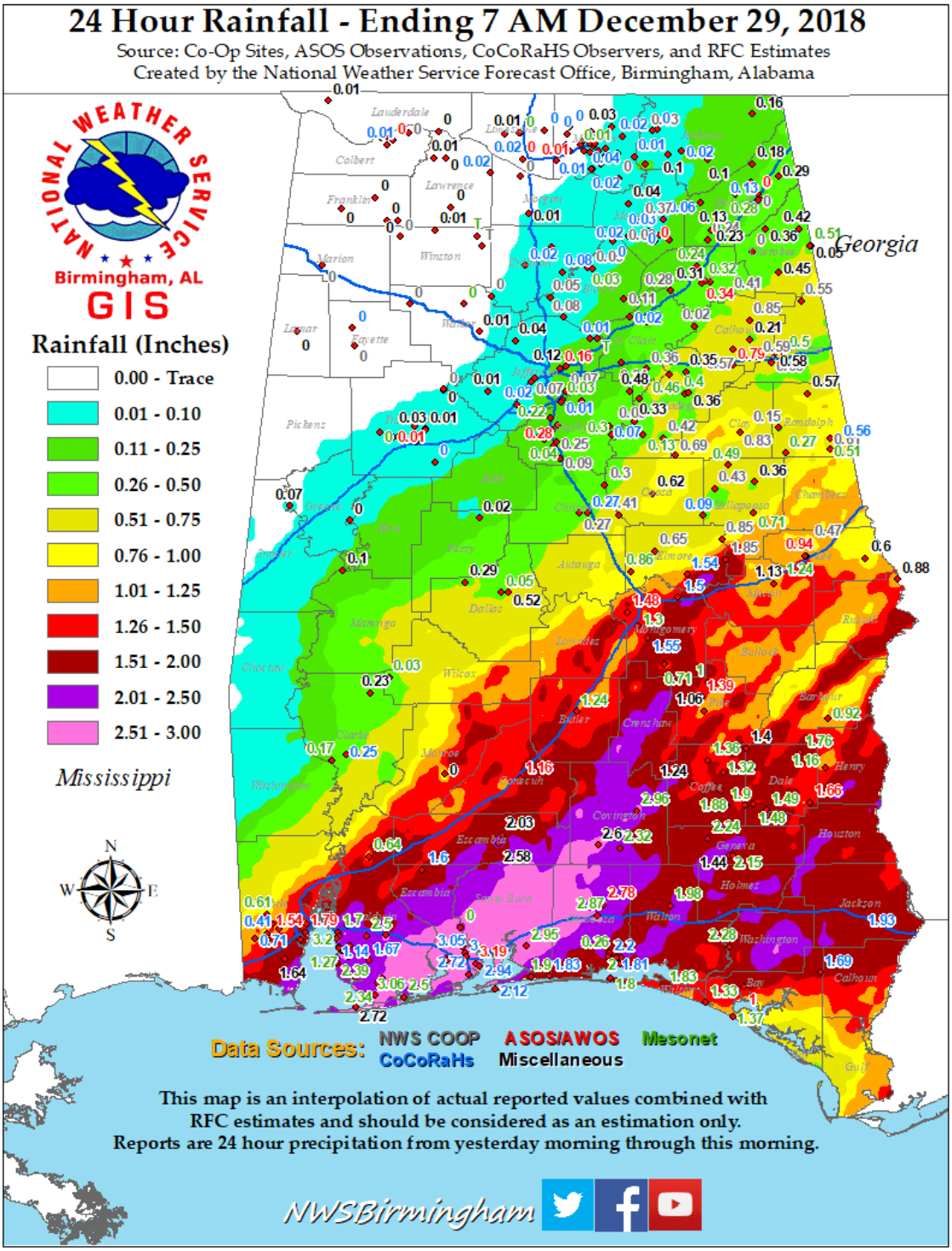


Figure 4-18
December 28, 2018 – Total Rainfall Distribution in Basin 5

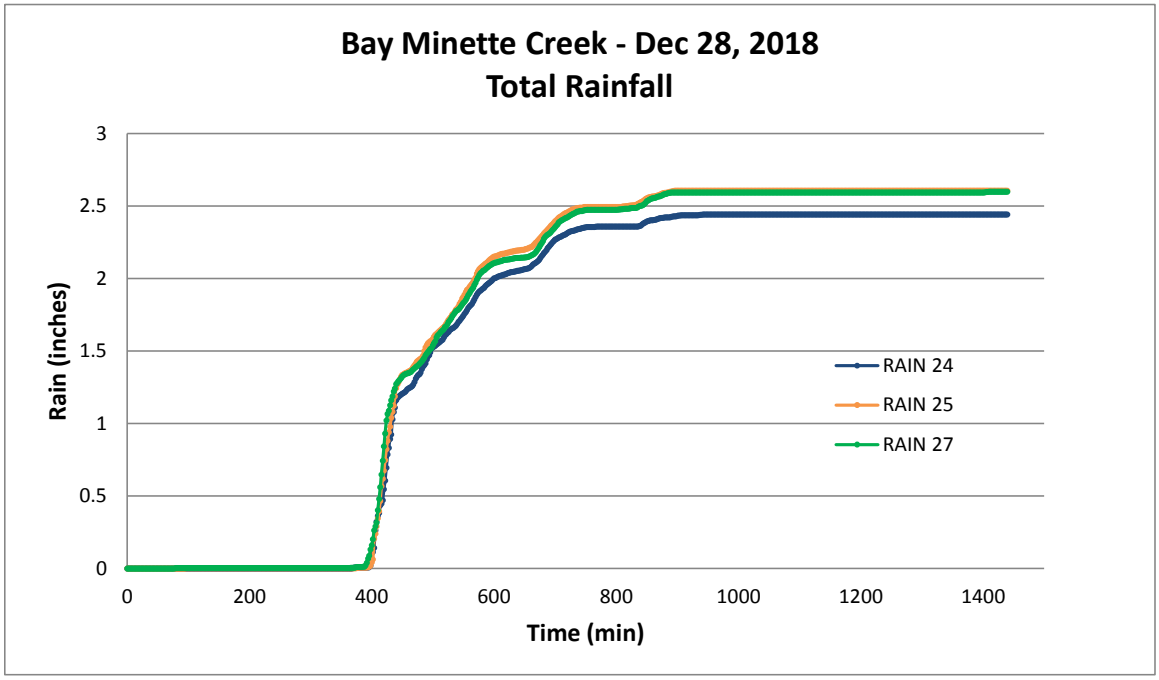


Figure 4-19
December 28-29, 2018 – Bay Minette Creek Calibration (B5)

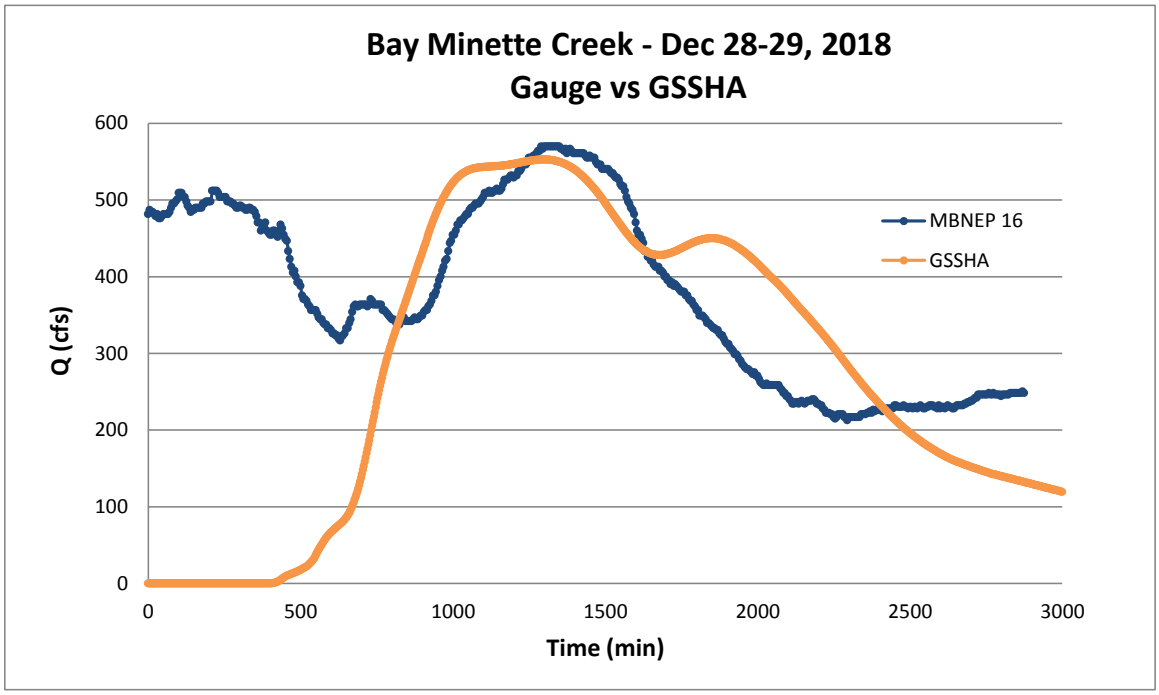
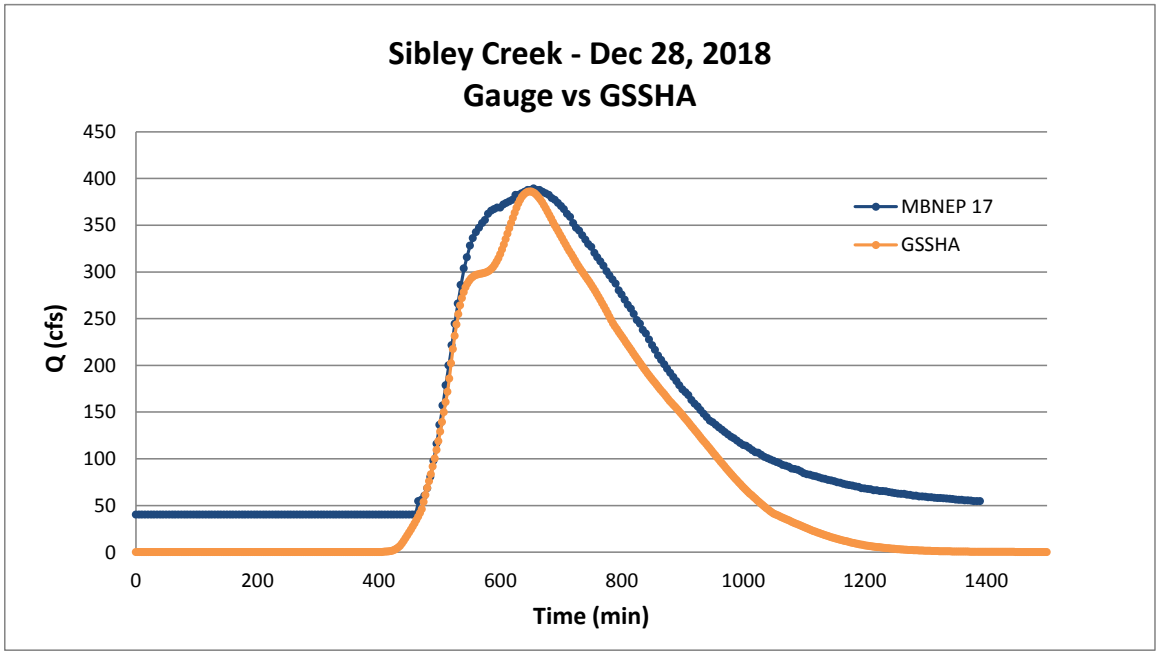


Figure 4-20
December 28, 2018 – Sibley Creek Calibration (B5)



Figures 4-21 and 4-22 indicate the total rainfall maps for the April 14, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-23 and 4-24 indicate the total rainfall distribution and calibrated model output.

Figure 4-21
April 14-15, 2019 – AHPS Total Rainfall Map

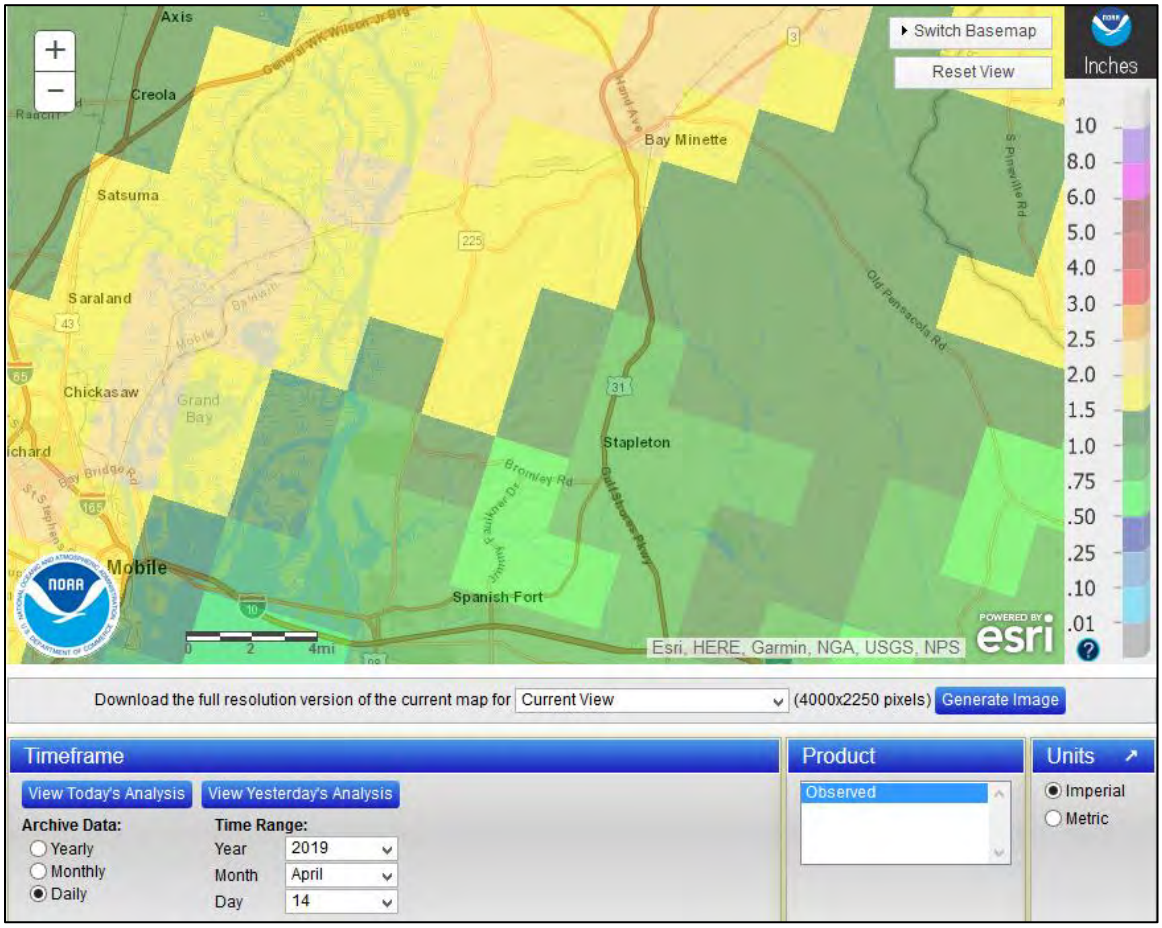


Figure 4-22
April 14-15, 2019 – Total Rainfall Map

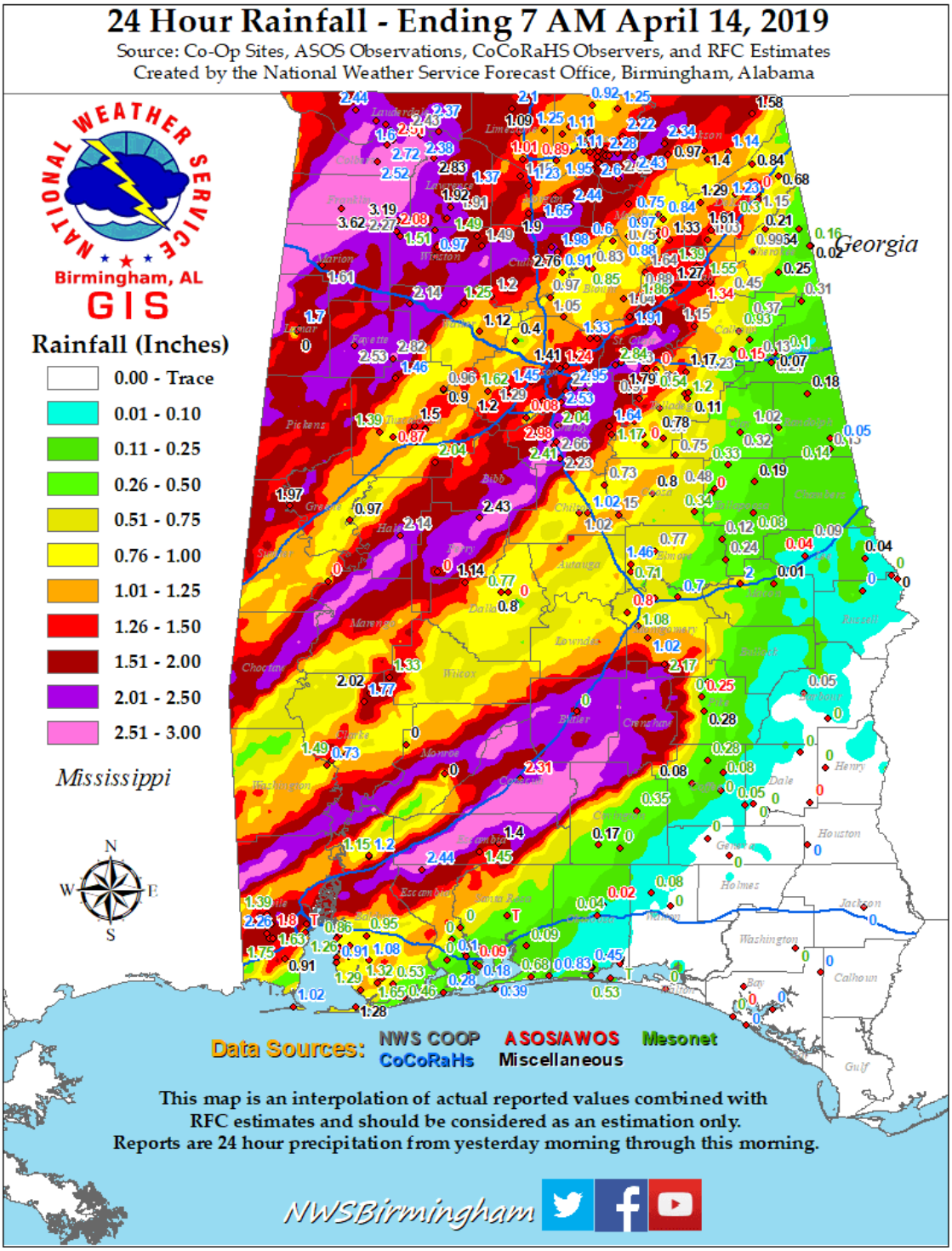


Figure 4-23
April 14, 2019 – Total Rainfall Distribution in Basin 3

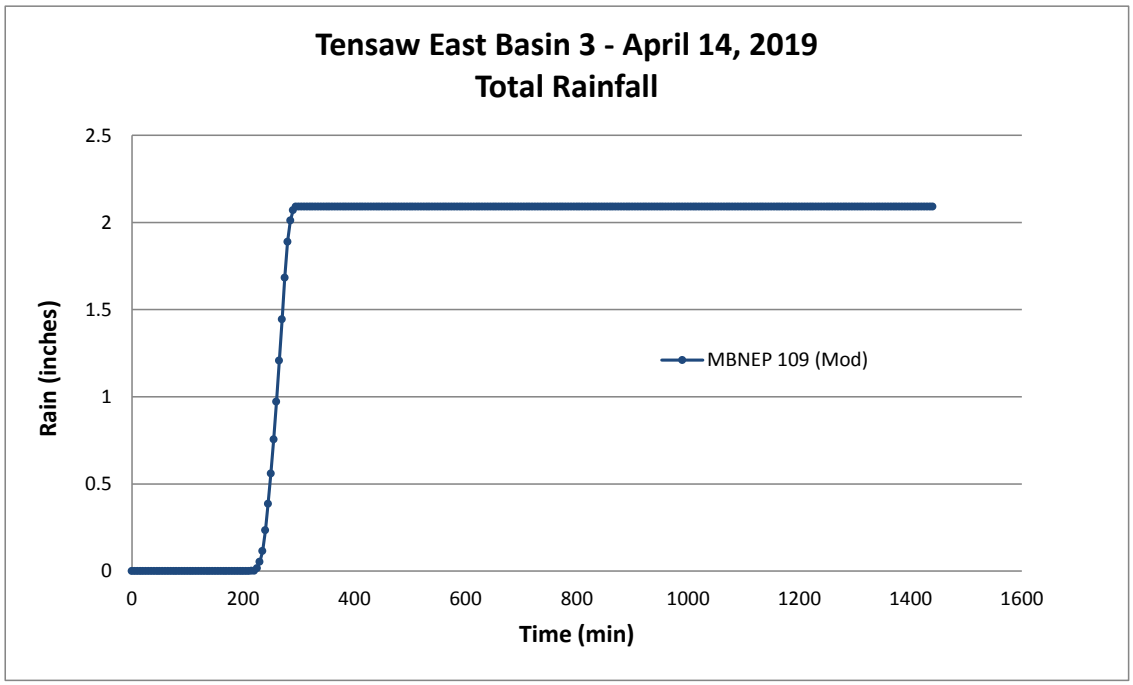
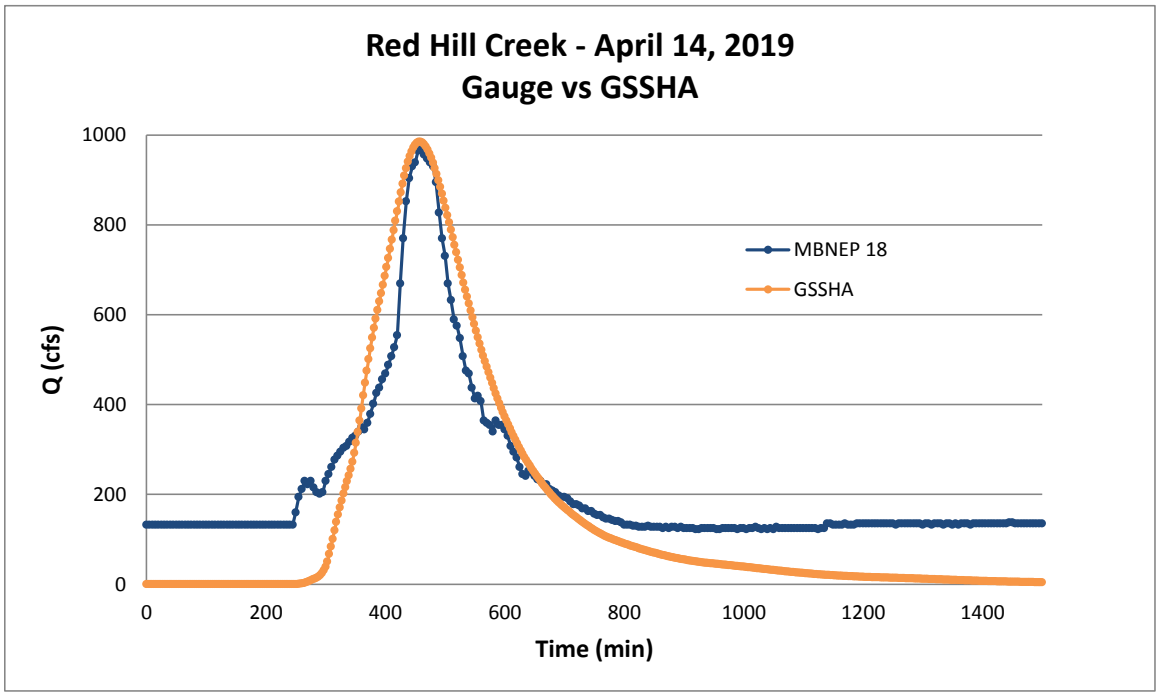


Figure 4-24
April 14, 2019 – Red Hill Creek Calibration (B3)



Figures 4-25 and 4-26 indicate the total rainfall maps for the July 13, 2019 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-27 and 4-28 indicate the total rainfall distribution and calibrated model output.

Figure 4-25
July 13-14, 2019 – AHPS Total Rainfall Map

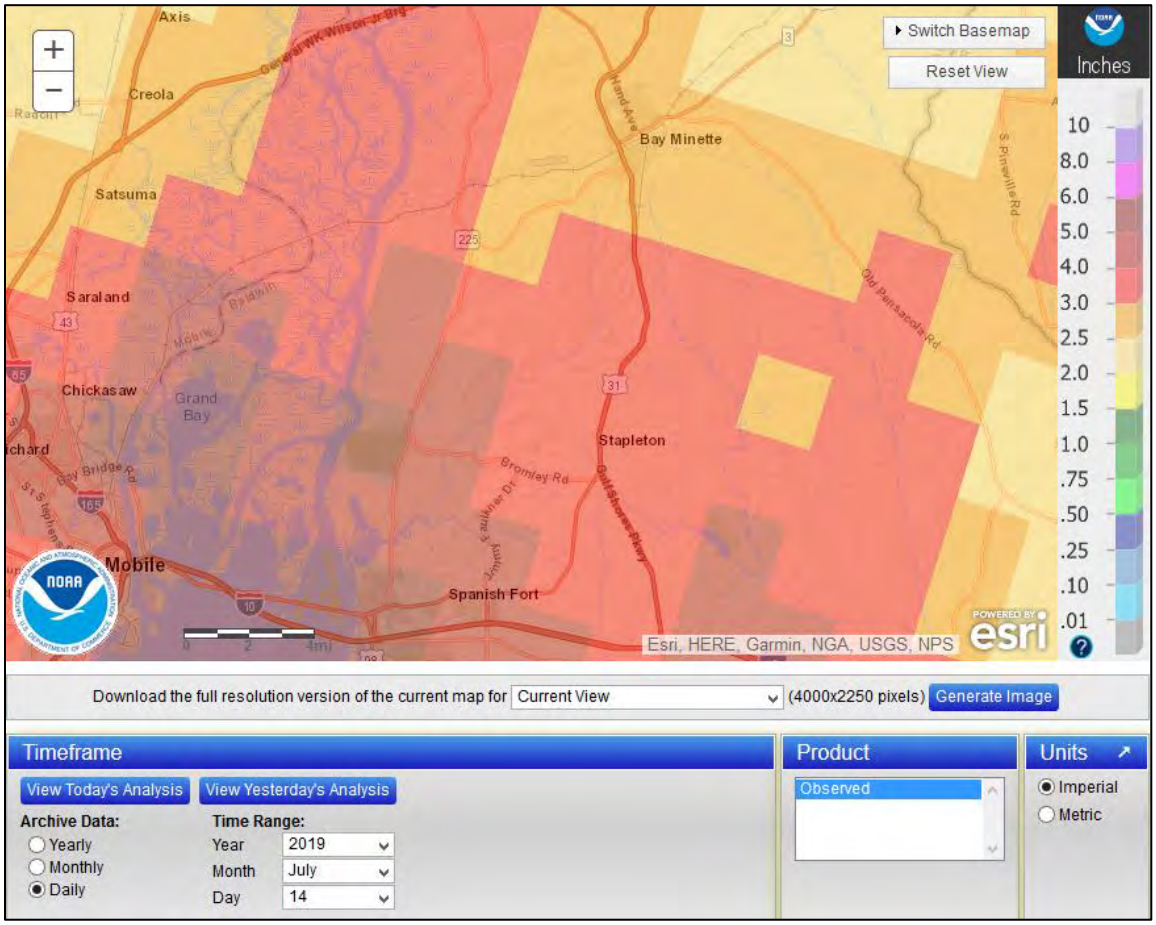


Figure 4-26
July 13-14, 2019 – Total Rainfall Map

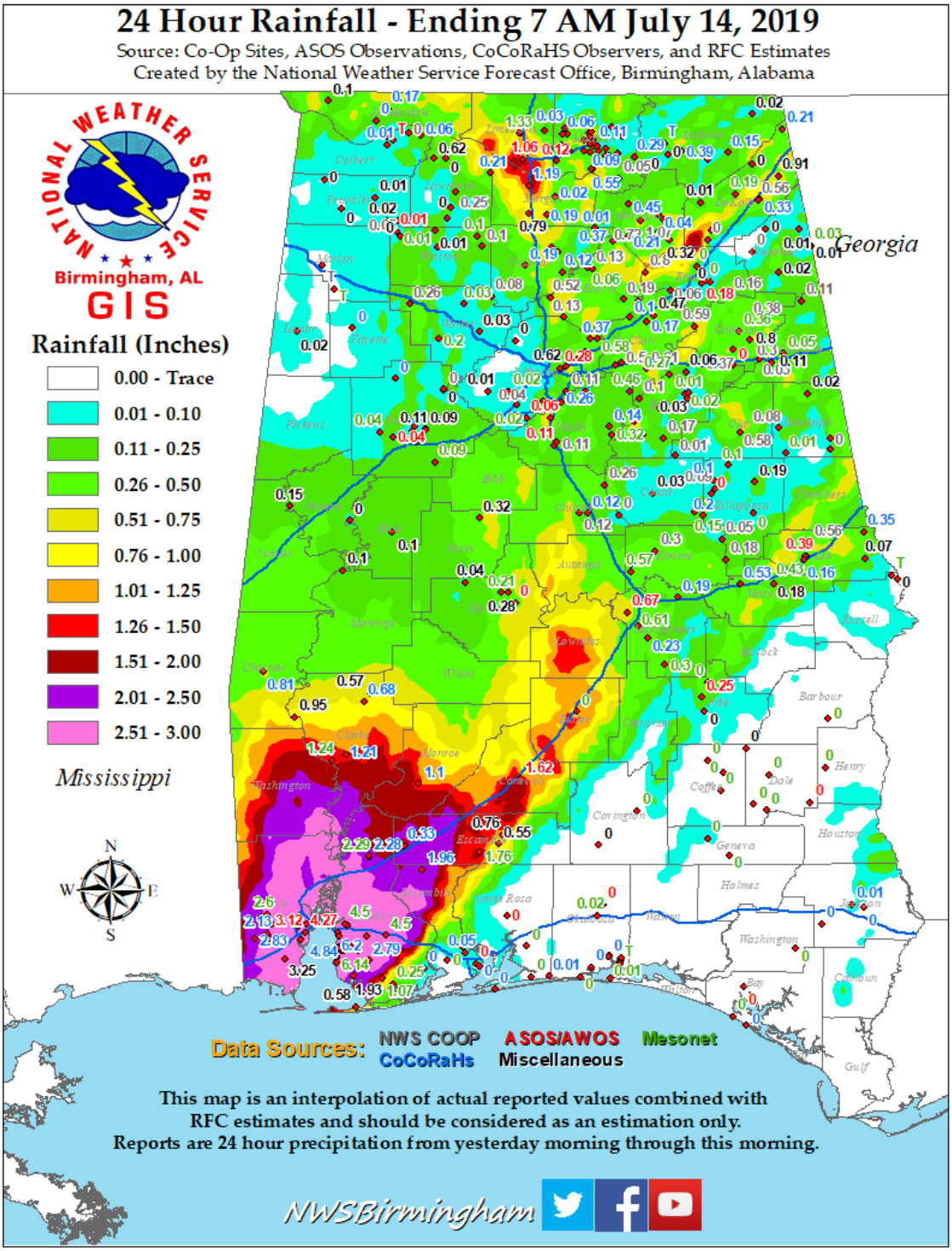


Figure 4-27
July 13, 2019 – Total Rainfall Distribution in Basin 6

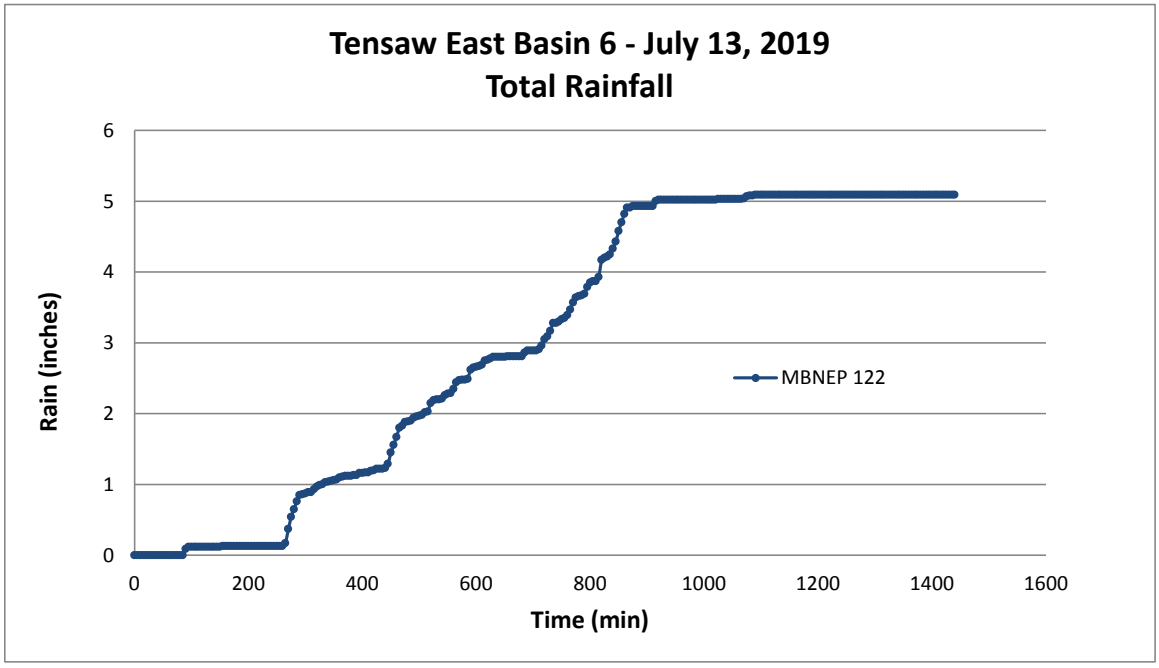
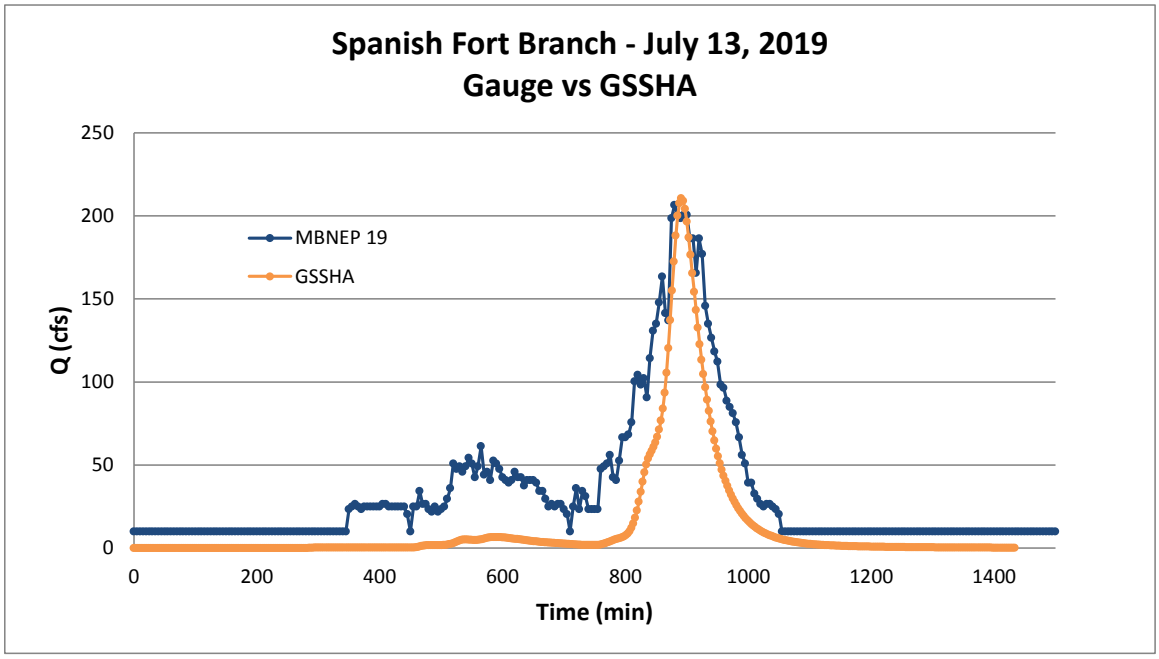


Figure 4-28
July 13, 2019 – Spanish Fort Branch Calibration (B6)



Figures 4-29 and 4-30 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. Figures 4-31 and 4-32 indicate the total rainfall distribution and calibrated model ouput.

Figure 4-29
August 26-27, 2019 – AHPS Total Rainfall Map

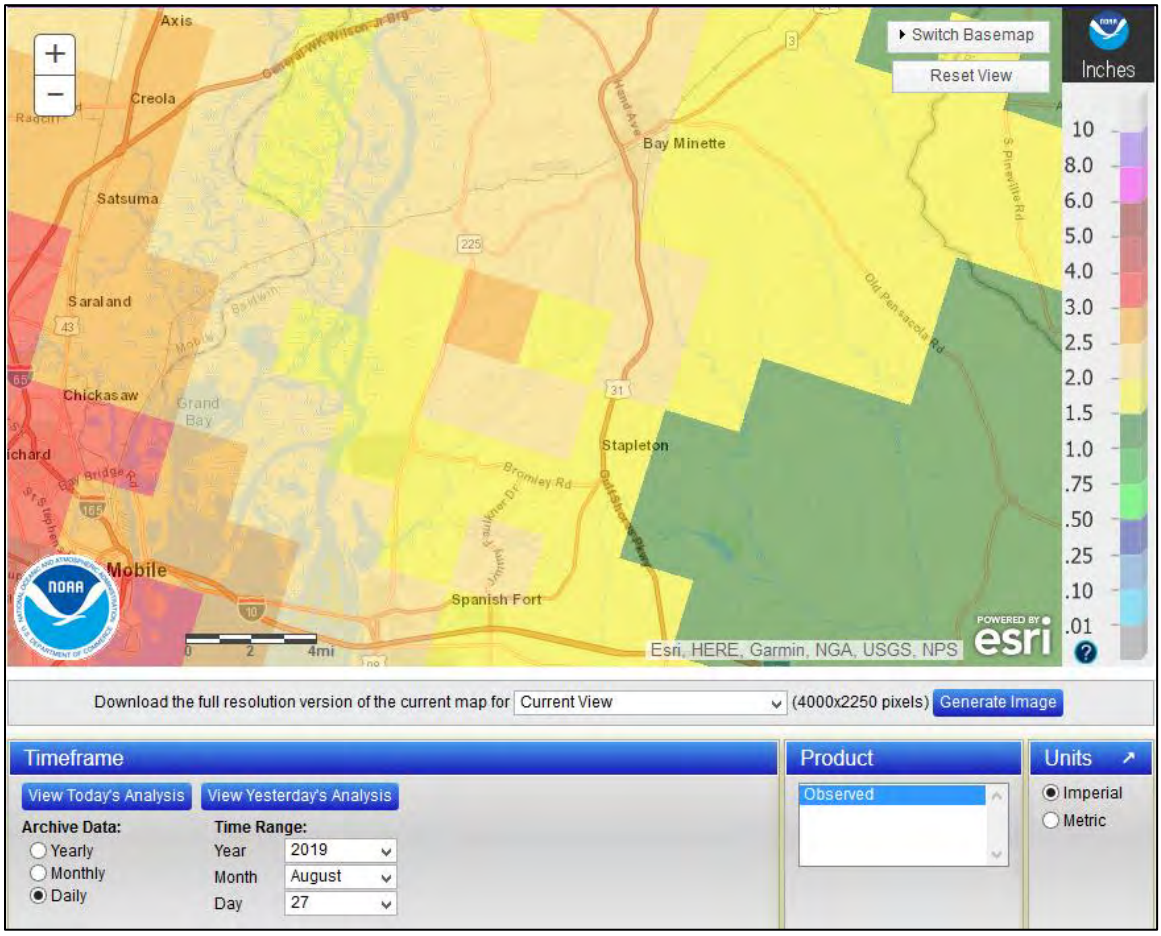


Figure 4-30
August 26-27, 2019 – Total Rainfall Map

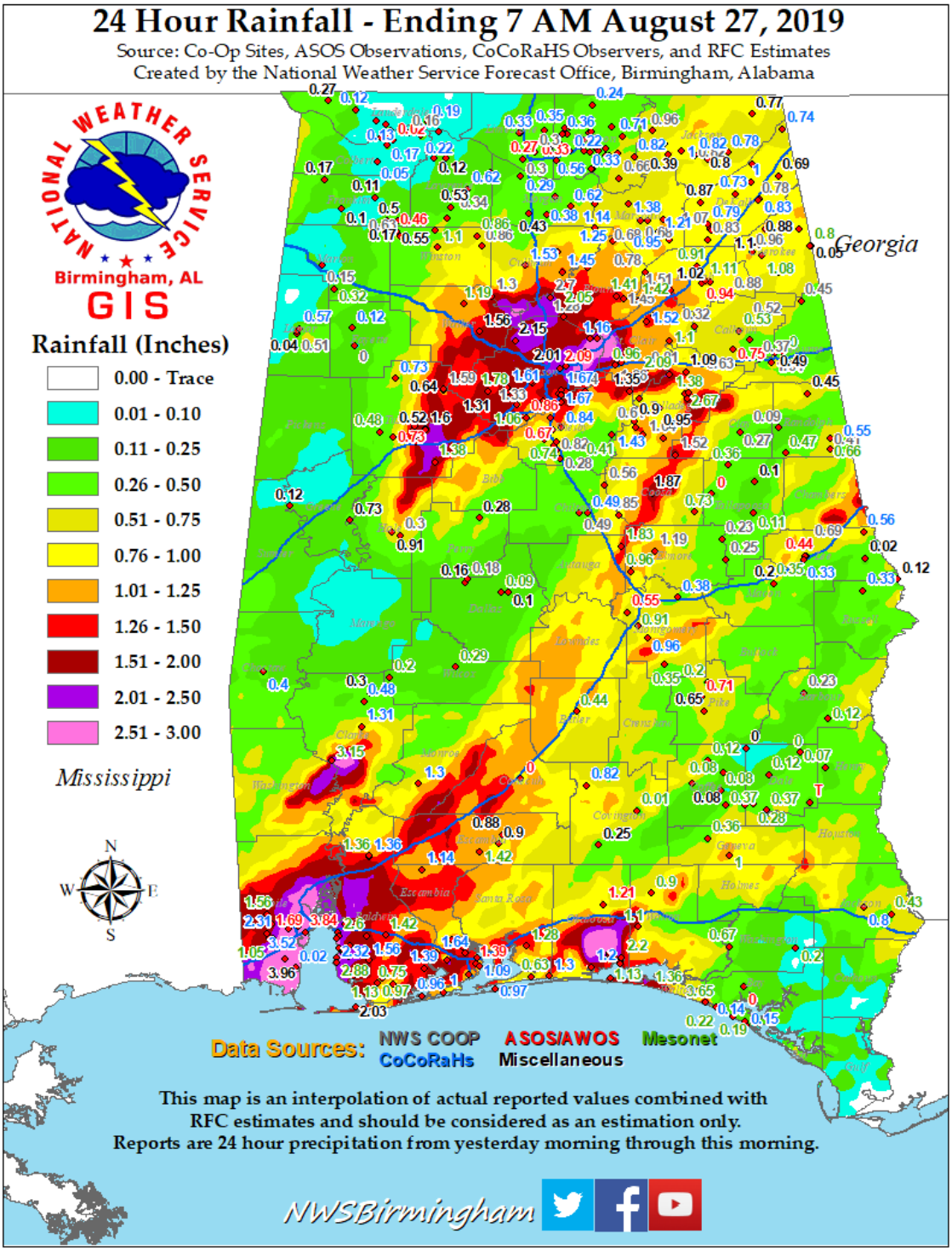


Figure 4-31
August 26, 2019 – Total Rainfall Distribution in Basin 6

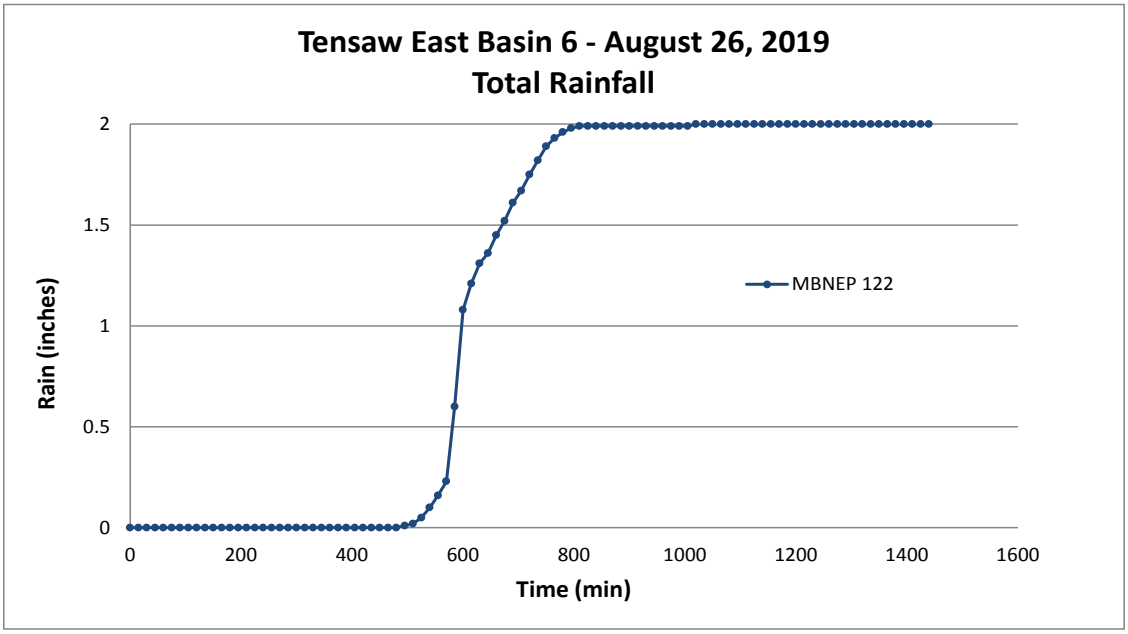
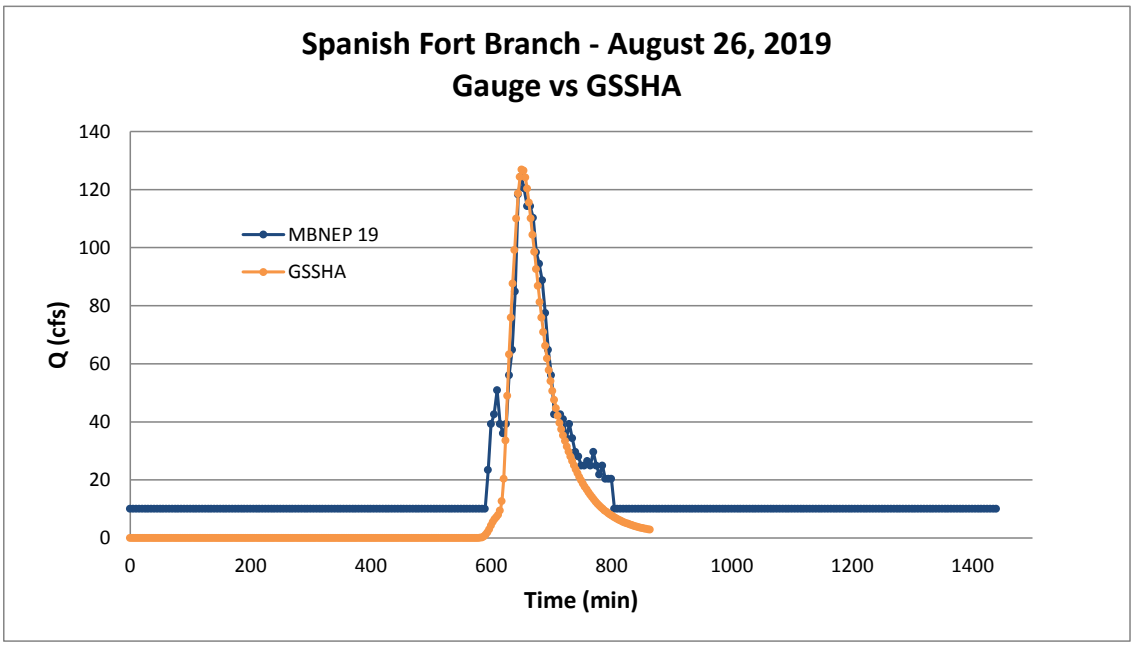


Figure 4-32
August 26, 2019 – Spanish Fort Branch Calibration (B6)



5. Results and Conclusions

5.1. Results

During the evaluation period between the middle of June 2018 and June 2020 the Tensaw East watersheds 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, and 4-5 the largest events were chosen for model calibration. During this study, the largest event occurred on September 4-5, 2018 from the result of Tropical Storm Gordon. This tropical storm produced approximately 7.6 inches of rain in 24 hours for the Bay Minette Creek basin. Using Figure 4-6, it was determined that this amount of rainfall in a 24-hour period is between a 5-year and 10-year recurrence interval. For the four basins located just west of Bay Minette, the rainfall total was approximately 4.6 inches in a 12-hour period. This was determined to be between a 1-year and 2-year recurrence interval. Comparing the measured discharges to the discharges determined from the rural regression equations, it can be seen that the storm event produces discharges in line with the rural regression equations.

The next largest event occurred on July 13, 2019. This event occurred locally in the Spanish Fort Branch watershed. During this event the watershed experienced 4.8” of rain in 12 hours which is just below a 2-year storm event. The additional events used for calibration were either equal to a 1-year event or just below a 1-year event. On December 28, 2018 the Sibley Creek watershed experienced approximately 2.5” in 6-hours. This translates to an event less than a 1-year event. On April 14, 2019 the Red Hill basin experienced 2” of rain in 1 hour which equates to a 1-year event.

5.2. Conclusions

After analysis of the discharges and rainfall events that occurred between June 2018 and June 2020, it has been determined that 1-year or 2-year rainfall events produce discharges equal to that of their equivalent recurrence interval. All of the watersheds (except the Spanish Fort Branch basin) have very little development and are covered with evergreen forest and woody wetlands. This allows for lower, more attenuated discharge hydrographs. The land cover contributes to interception of the rainfall as well as reducing overland travel time.

For smaller rain events (<= 5-year), the currently 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 discharge events, the models will need to be reevaluated to determine if further calibration is required. This is due to the uncertainty of the amount of impact the storage within the watershed will have on the timing and peak discharges during a large flood event.

6. References

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