MBNEP

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Bon Secour River Watershed Study

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1. Executive Summary

The study on the Bon Secour 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. The model 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 available rain events from September 2018 to June 2020.

During the evaluation period, the Bon Secour River watershed experienced rainfall events no greater than a 1-year recurrence interval. The first rainfall event that was analyzed occurred on September 4, 2018 due to Tropical Storm Gordon. The next calibration event occurred on December 13, 2018. These two events were determined to be less than a 1-year 24-hour rainfall and less than a 1-year 6-hour rainfall, respectively. The final two rainfall events that were analyzed occurred on December 28, 2018 and June 7, 2020. Both of these were also classified as being less than a 1-year 12-hour event and a 1-year 24-hour event, respectively.

Results of the findings for the Bon Secour River watershed indicate that storm events less than or equal to a 1-year recurrence interval produce discharges greater than its determined recurrence interval for a rural basin. Because of development within the headwaters of the watershed, a 1-year rainfall produces rural discharges comparable to a 2-year to 5-year storm event.

For rain events (1-year or less), 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 flood events, recalibration of the hydrologic model will most likely be necessary to account for changes in storage capacity and timing within the watershed.

2. Introduction

2.1. Description

Bon Secour River is a tidally influenced river located in southwestern Baldwin County, flowing into the southeastern portion of Mobile Bay by way of Bon Secour Bay[5]. Because of the tidal nature, large expanses of marsh exist near the river's mouth[5]. The drainage area of the Bon Secour River watershed is approximately 31.7 square miles (Figure 2-1). The drainage area includes portions of the cities of Foley and Gulf Shores and the community of Bon Secour. It is bordered to the south by the Oyster Bay watershed and to the west by the Skunk Bayou watershed. The watershed is mostly rural with mixed areas of residential and commercial urban development.

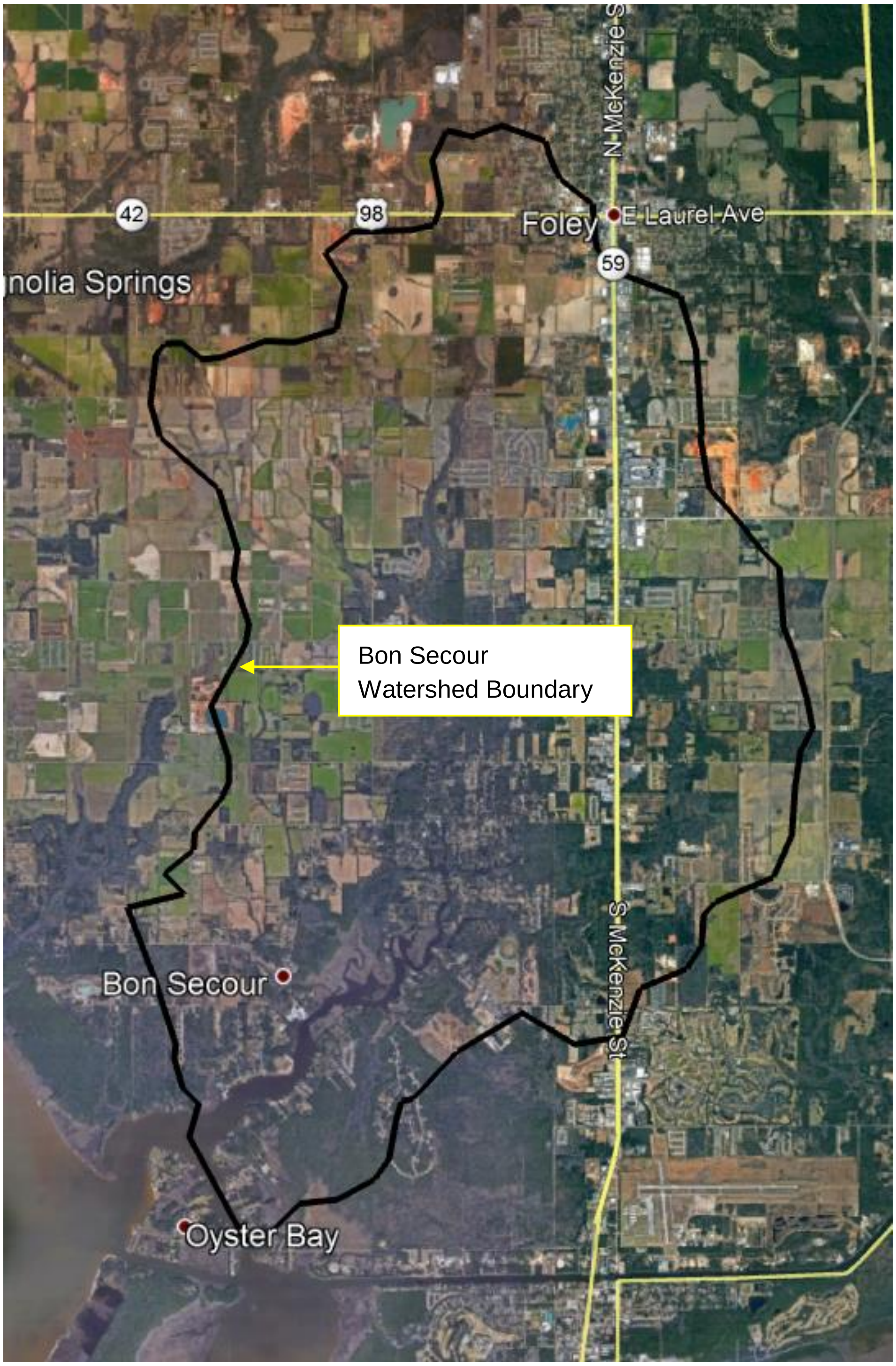
The Bon Secour watershed is defined by the U.S. Geological Survey (USGS) 12 digit hydrologic unit code (HUC) as HUC 031602050310. Bon Secour River is approximately 8 miles long and receives drainage from numerous small tributaries. The major tributaries include Bright's Creek, Shutt Creek, Miller's Bayou, and Boggy Branch.

2.2. Climate

According to the ADEM 1996 publication A *Survey of the Bon Secour River Watershed*, "The climate of the BRW is essentially subtropical with long humid summers and short mild winters. The area is strongly influenced by the Gulf of Mexico which tends to moderate temperatures throughout the year (O'Neil and Mette 1982). The summer months are especially affected by the Bermuda High, a seasonal high-pressure system that spreads over much of the eastern gulf and south Atlantic coast from May through September (O'Neil and Mettee 1982; SARPC 1993). The prevailing southerly winds produced by the Bermuda High are high in moisture content which keeps summer temperature along the coast lower than those inland. The afternoon high in July, the hottest month, is 32° C (90° F)."

ADEM 1996 also states, "Winters are typified by prevailing northerly winds, strong frontal systems and cold, continental air masses. The oceanic nature of the climate tends to "cushion" the effects of such weather complexes and leads to mild winter temperatures ranging from average daily lows of 6°C (43°F) to average daily highs of 15°C (60°F) in January, the coldest month for the area (O'Neil and Mettee 1982)."

Figure 2-1
Location Map and Watershed Boundary



2.3. Physiography

The Final Draft, Bon Secour River Watershed Management Plan (WMP) – March 2004 states, "Baldwin County is located in the southwest corner of Alabama, in the coastal plain region of the state, in the Southeastern Plains and Southern Coastal Plains Level III ecoregions. Most of the soils in this coastal plain area are derived from marine and fluvial sediments eroded from the Appalachian and Piedmont plateaus from North Alabama. The topography is essentially a flat to gently undulating plain, with surface elevations that do not exceed 30 meters throughout the Bon Secour River Watershed.

The 2004 WMP also states, "There are three general areas within the watershed with differing soil characteristics. The Natural Resources Conservation Services (NRCS) classifies these areas as the Lakewood-St. Lucie-Leon, the Marlboro-Faceville-Greenville Association and the Norfolk-Klej-Goldsboro Association. Soils in the lower lying areas of the Lakewood-St. Lucie-Leon comprise 20-25 percent of the watershed. These soils typically have poor drainage properties that are not well suited for construction and agriculture, and are normally associated with swamp-forest or marsh vegetation. The Marlboro-Faceville-Greenville Association in the northwestern area comprises approximately 15-20% of the total watershed area. This upland area bears a gentle slope, therefore the mix of grayish-brown and sandy loam with darker red and brown loam soil is well-drained with good agricultural potential. The Norfolk-Klej-Goldsboro Association is the largest of the three soil type areas, comprising 60-65 percent of the land within the basin. The land is generally level or gently sloping, with soils that are dark grayish sandy loam to dark grayish loamy sand. Overall the soils drain well in this association, although some depressions or bottom lands in the area are exceptions and drain poorly (ADEM, 1996)."

2.4. Land Use

The majority of the Bon Secour watershed cover is agriculture, however the percentage of agricultural cover has decreased from 64% in the 1980s to 39% in 2011 (Volkert, 2017). Volkert 2017 states, "Urban and residential use skyrocketed from 9% in 1970 to 1985 to 25% of the total area of the watershed by 2011. Urban development is centered around the cities of Foley and Gulf Shores and traverses the watershed along Highway 59." Residential development can be found scattered throughout the watershed, however the majority of the development tends to be located in the eastern two thirds of the watershed. The remainder of the watershed consists of forest, wetlands, pasture, and shrubs. The forests and wetlands are found primarily in the southern third of the watershed.

3. Hydrologic Model

3.1. General

The hydrologic model used to evaluate the Bon Secour 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 monitoring sources.

The first source for gathering rainfall data is from weather stations that Hydro deployed throughout the watershed (Figure 3-1). On June 20, 2018, two weather stations were installed. The first weather station (MBNEP 124) was installed at Foley High School in the upper part of the watershed. The second weather station (MBNEP 126) was installed at a residence on the Bon Secour River in the lower part of the watershed.

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 rainfall data used 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 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 3-2 indicates the number of available precipitation gauges that can be used for analyzing the watershed.

The third 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. Additional points (Rain 38 – Rain 42) used for some of the calibrations using GRIB data can be found in Figure 3-3.

Figure 3-1
Watershed with Installed Weather Station Locations

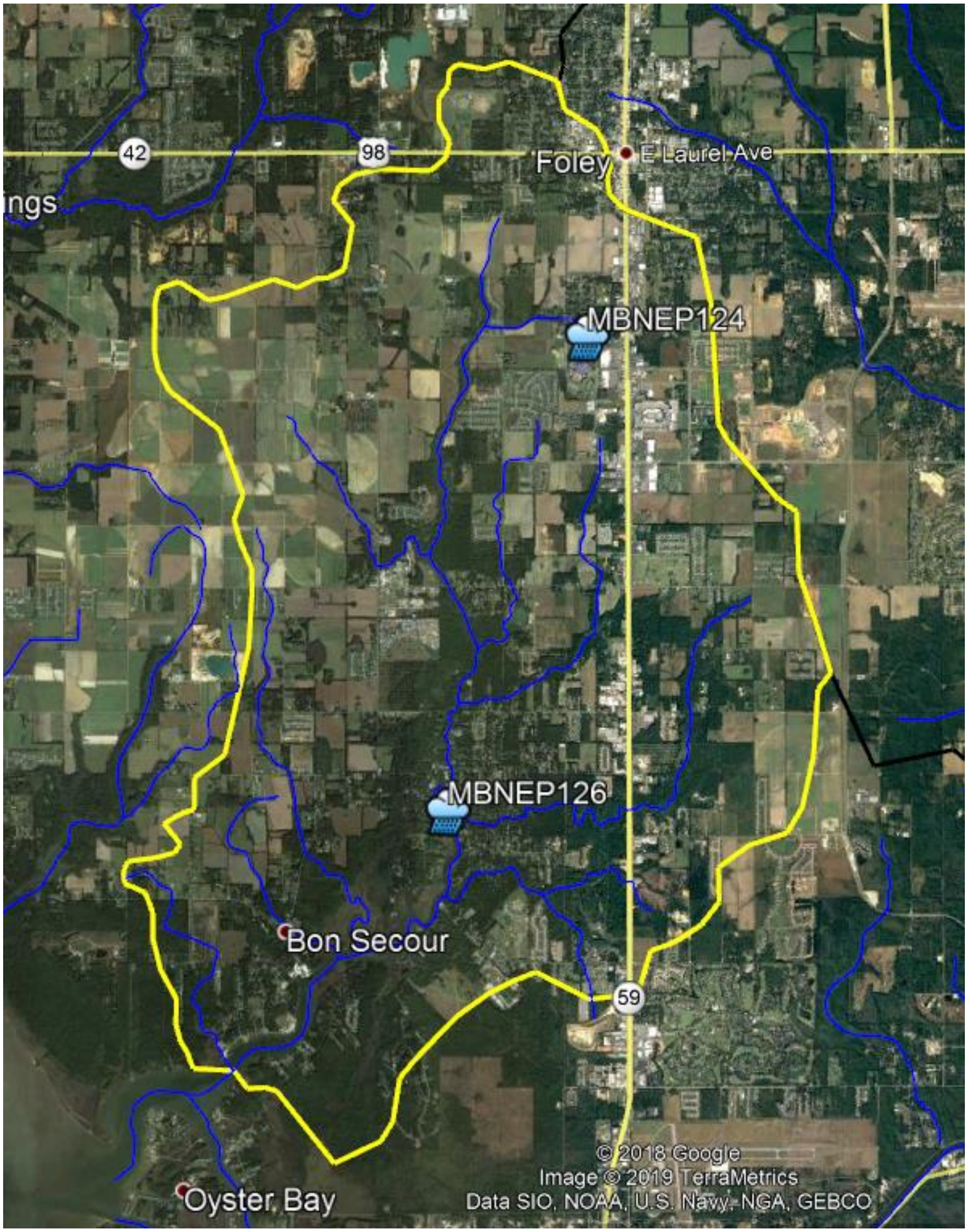
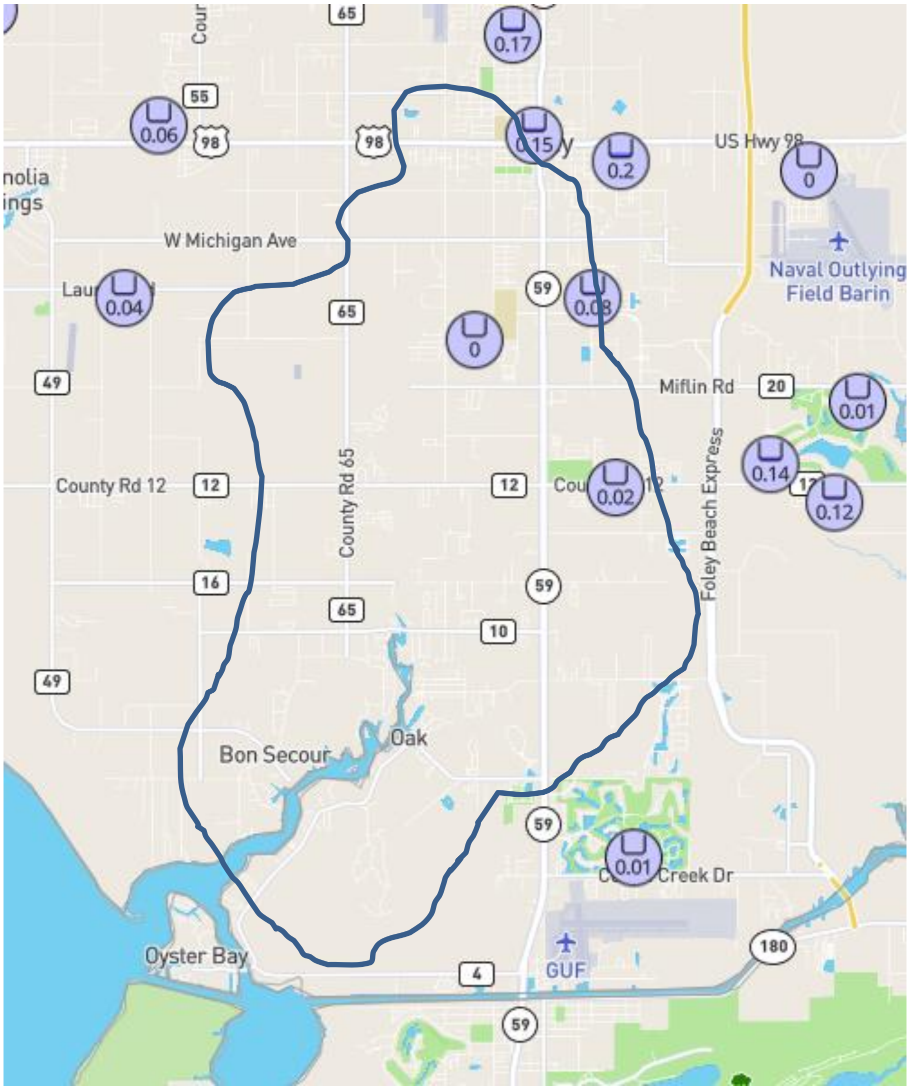
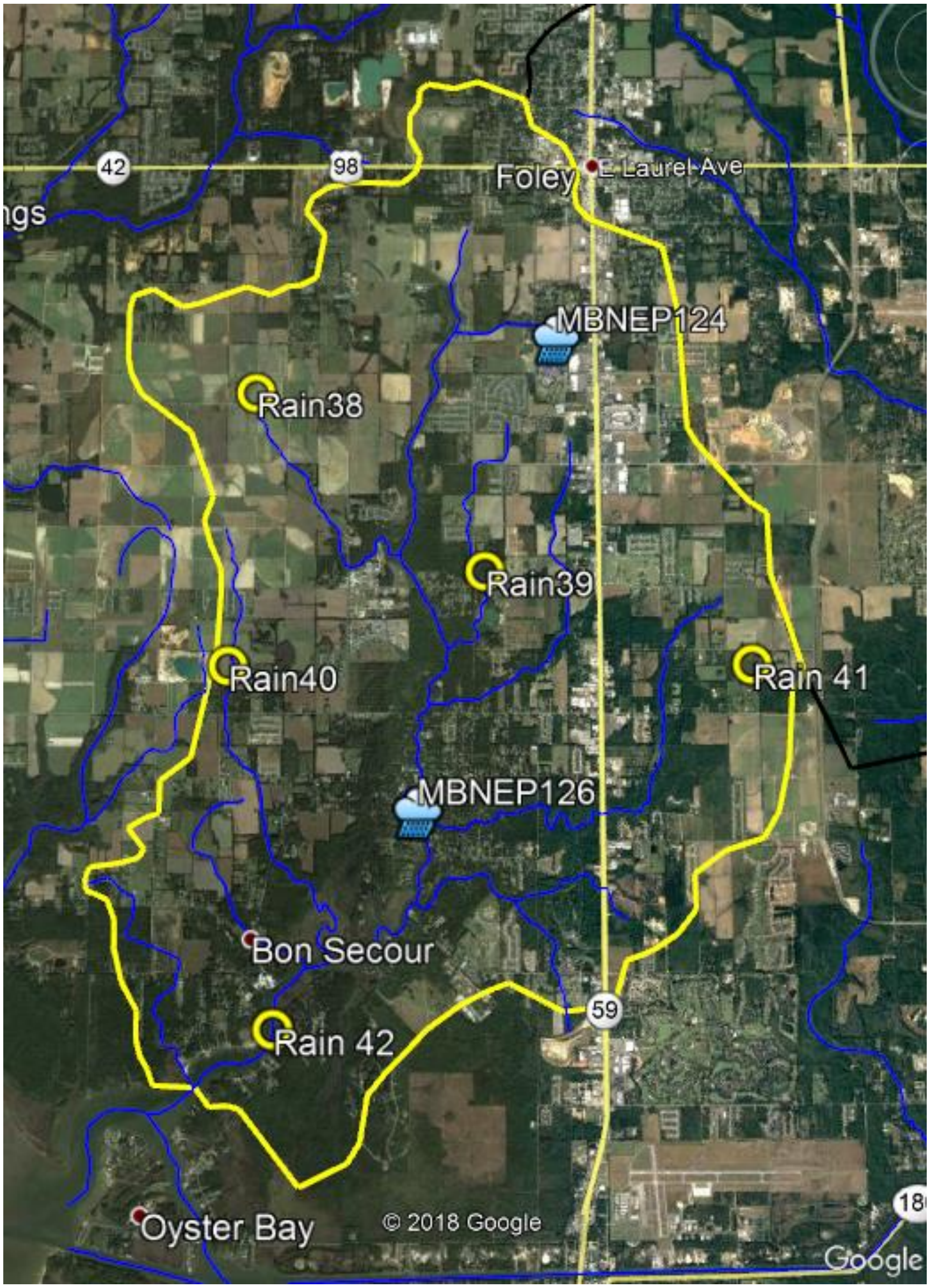


Figure 3-2
Watershed with Weather Underground Gauge Locations



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

Figure 3-3
Watershed with NOAA GRIB2 Rainfall Locations



3.3. Digital Terrain Data

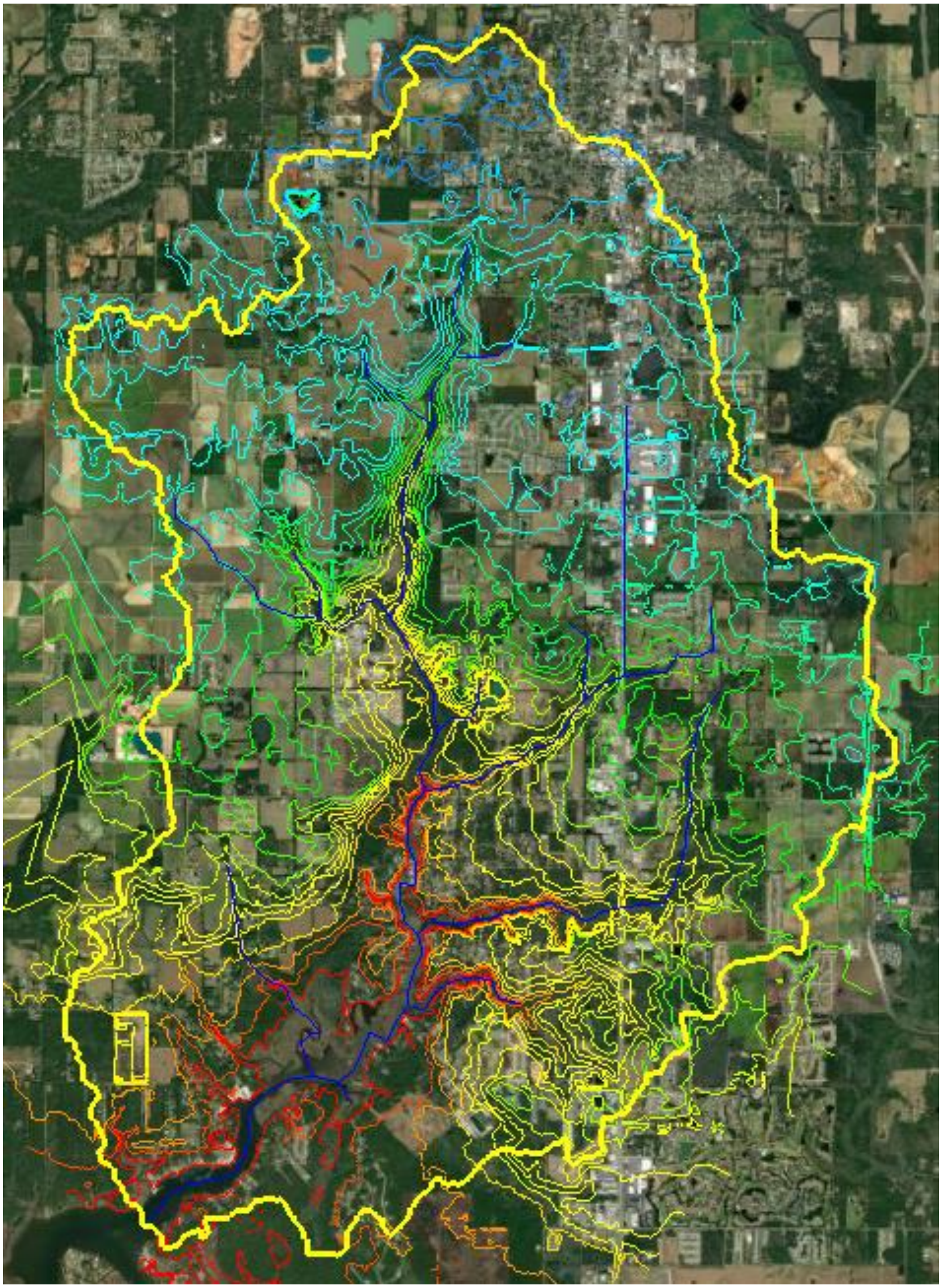
The GSSHA model uses digital terrain data to incorporate topography into the hydrologic model. For the model, elevation data was obtained from NOAA's National Centers for Environmental Information (NCEI). According to the website, "…NCEI is developing a suite of digital elevation models (DEMs) for the 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 3-4 indicates the topographic date that was utilized in the model.

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 3-4
Watershed with Topographic Data



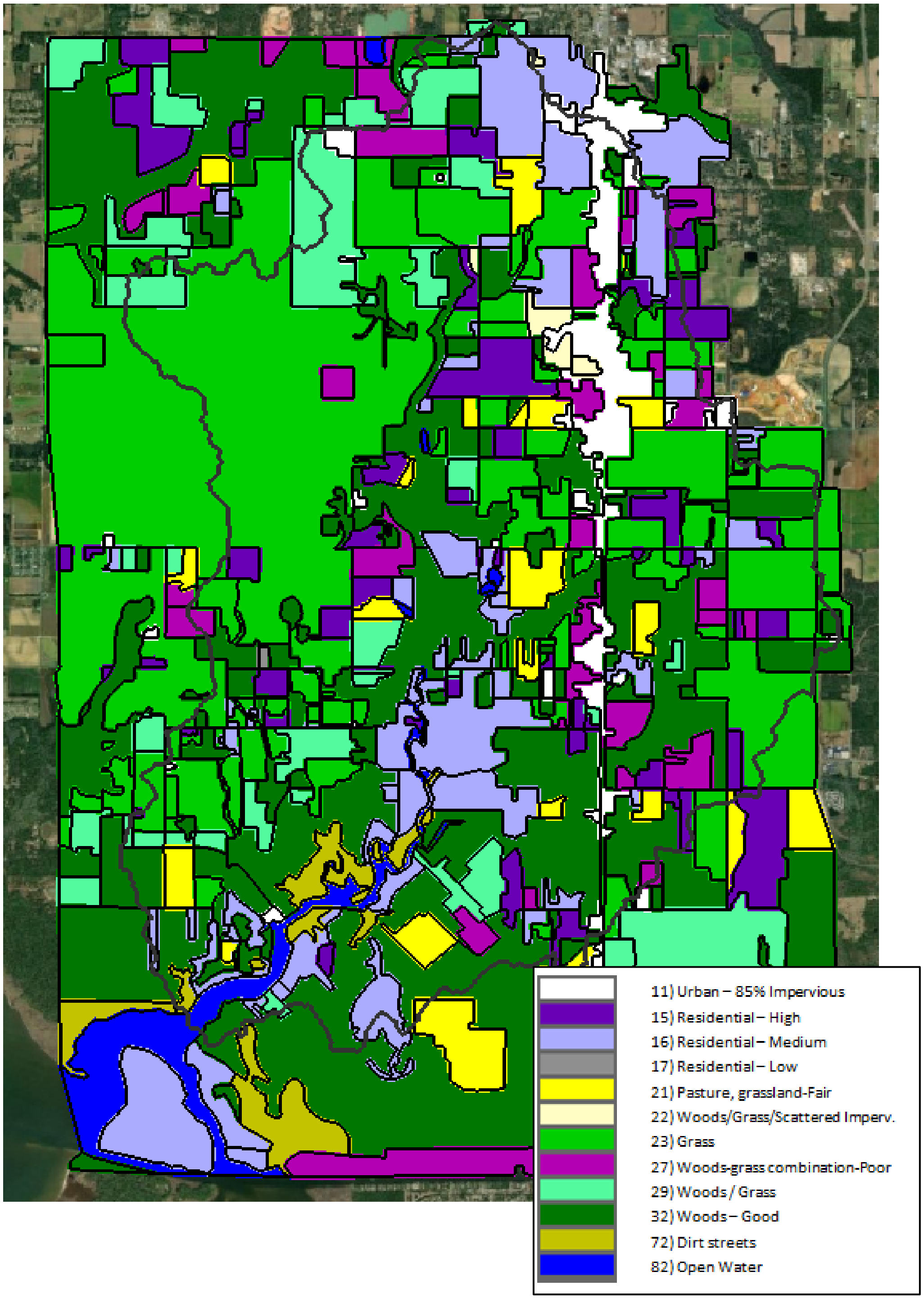
3.4. Land Use

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 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. 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 - High	0.05
16	Residential - Medium	0.06
17	Residential - Low	0.07
21	Pasture, grassland-Fair	0.20
22	Woods / Grass / Scattered Impervious	0.25
23	Grass	0.25
27	Woods-grass combination-Poor	0.30
29	Woods / Grass	0.26
32	Woods – Good	0.30
72	Dirt Streets	0.25
82	Open Water	0.011

Figure 3-5
Watershed with Digitized Land Use



3.5. Soils

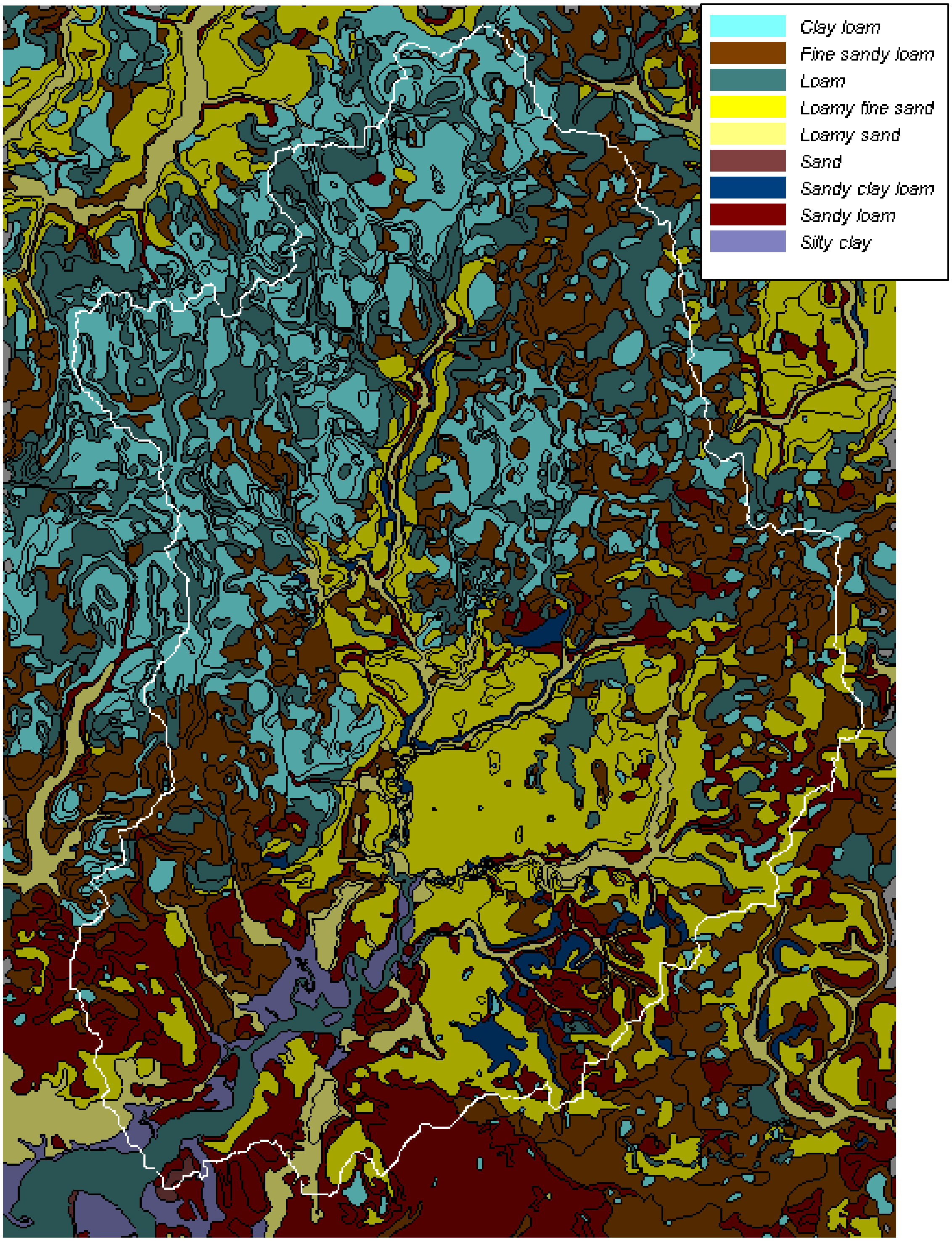
Similarly to the land use, the GSSHA model has the capability to incorporate specific characteristics of the soils located within a drainage basin. The soils coverage can be used for defining infiltration into the soil or setting the initial soil moisture. Green and Ampt (G&A) with soil moisture redistribution 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 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 3-6 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 Bon Secour 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 just above the confluence with the Intracoastal Waterway is approximately 31.7 square miles. Over the entire watershed this generates approximately 22,850 grid cells. Figures 3-7 to 3-10 indicate the gridded elevation data, gridded land use, gridded soils data, and gridded combined land use / soils layer.

Figure 3-7
Watershed with Gridded Elevation Data

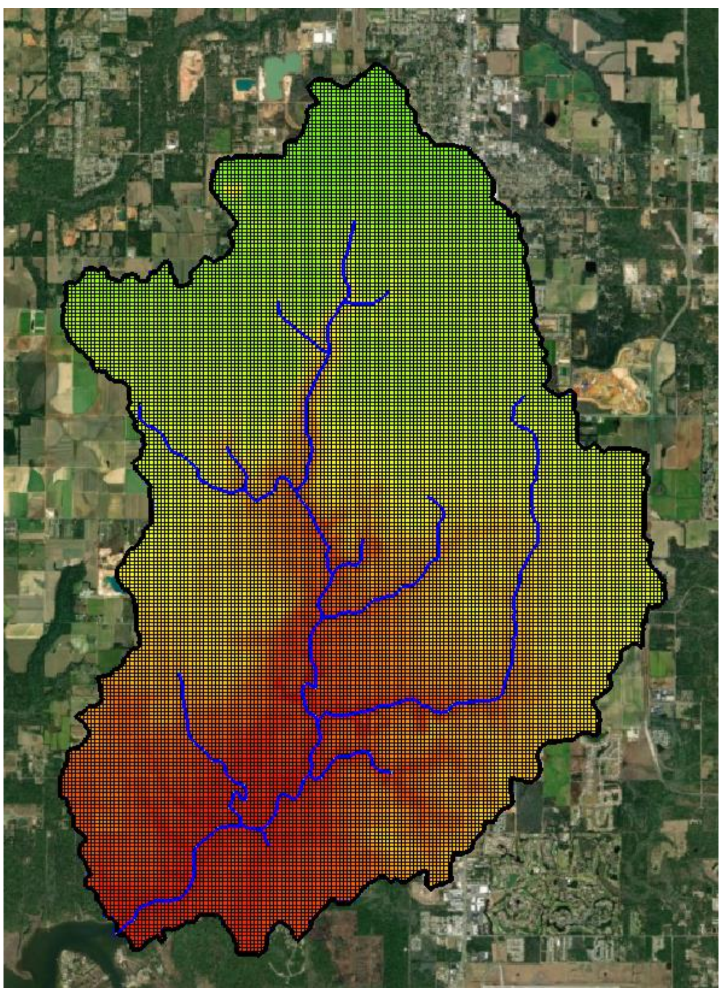


Figure 3-8
Watershed with Gridded Land Use Data

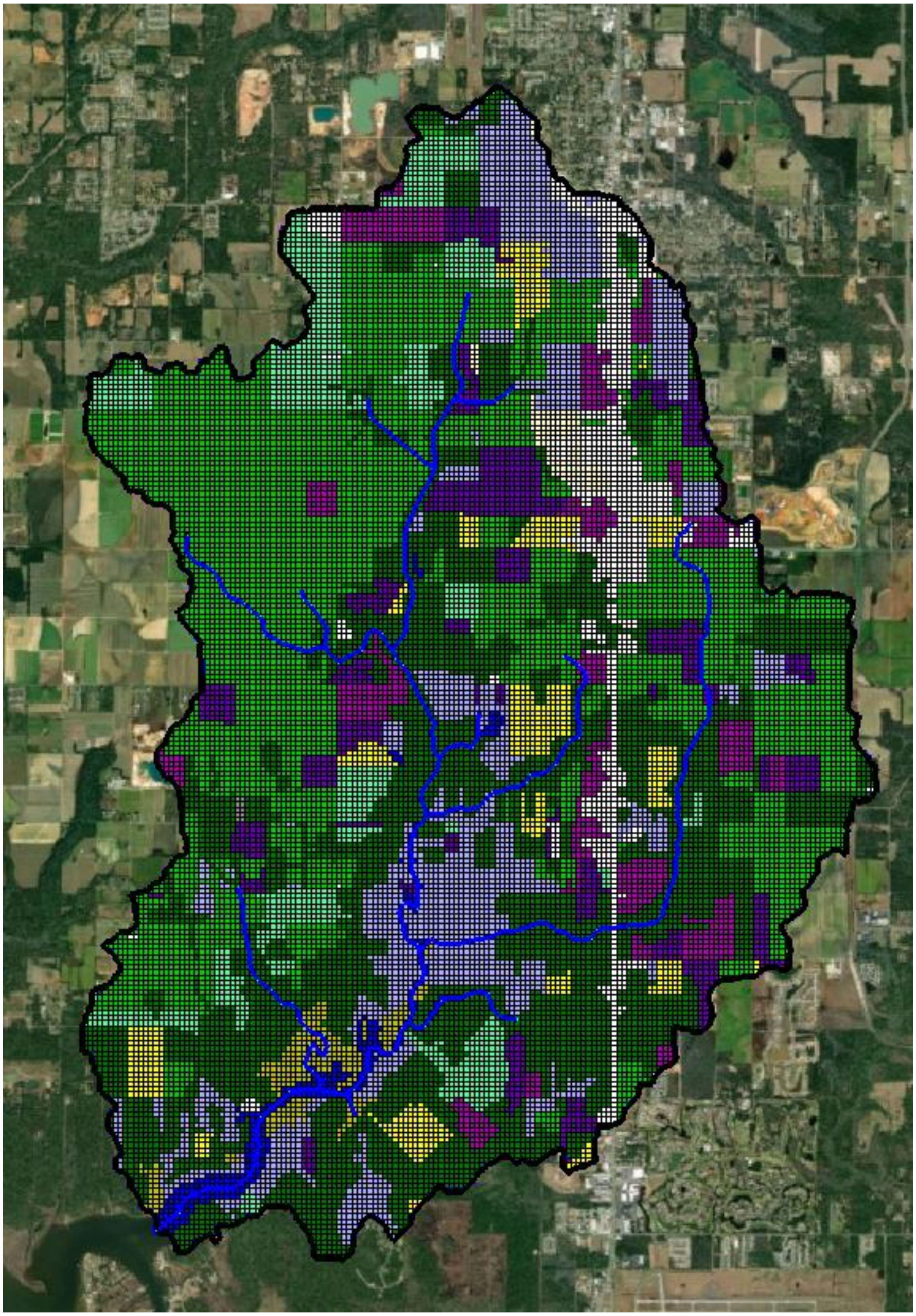


Figure 3-9
Watershed with Gridded Soils Data

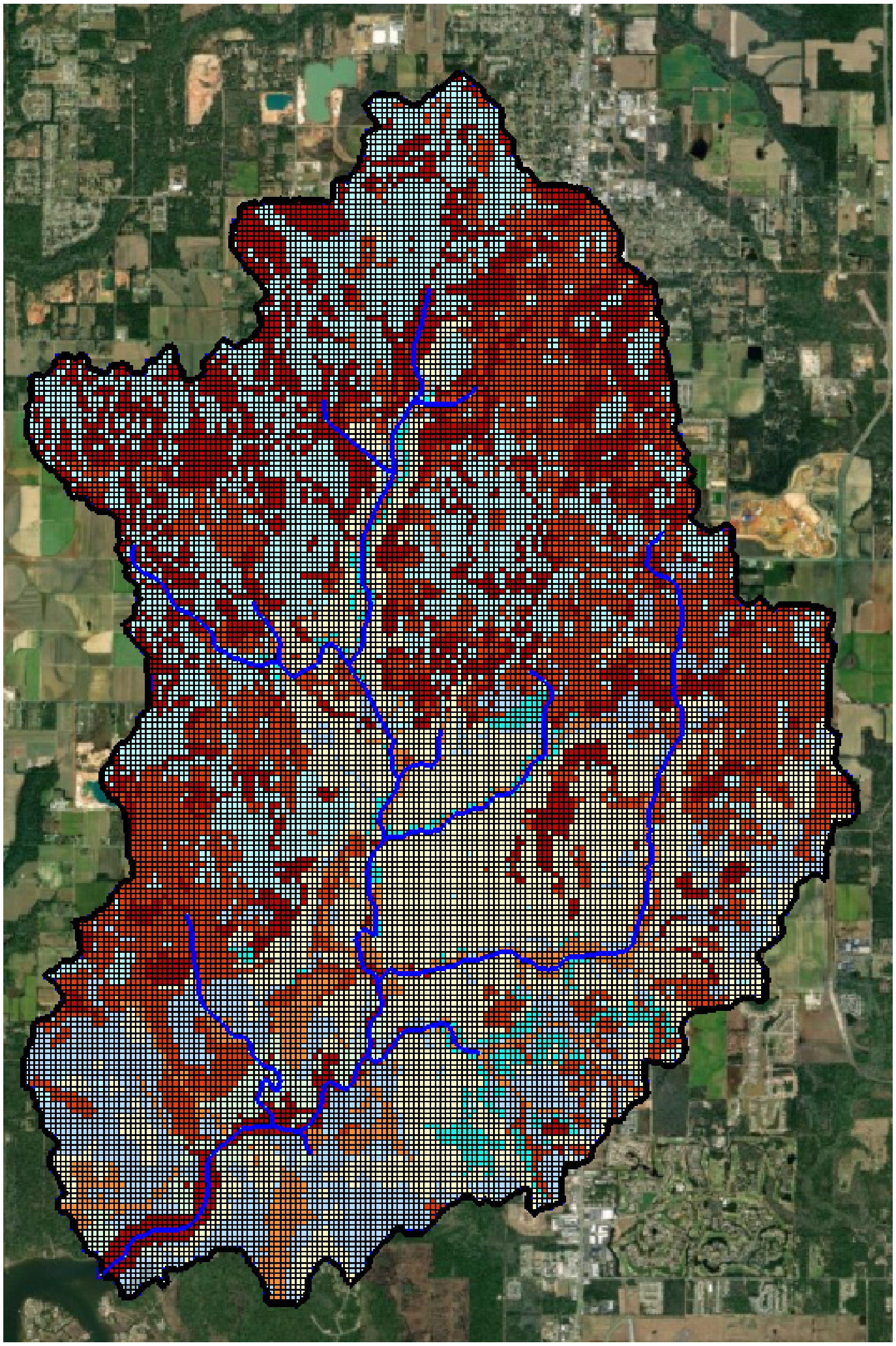
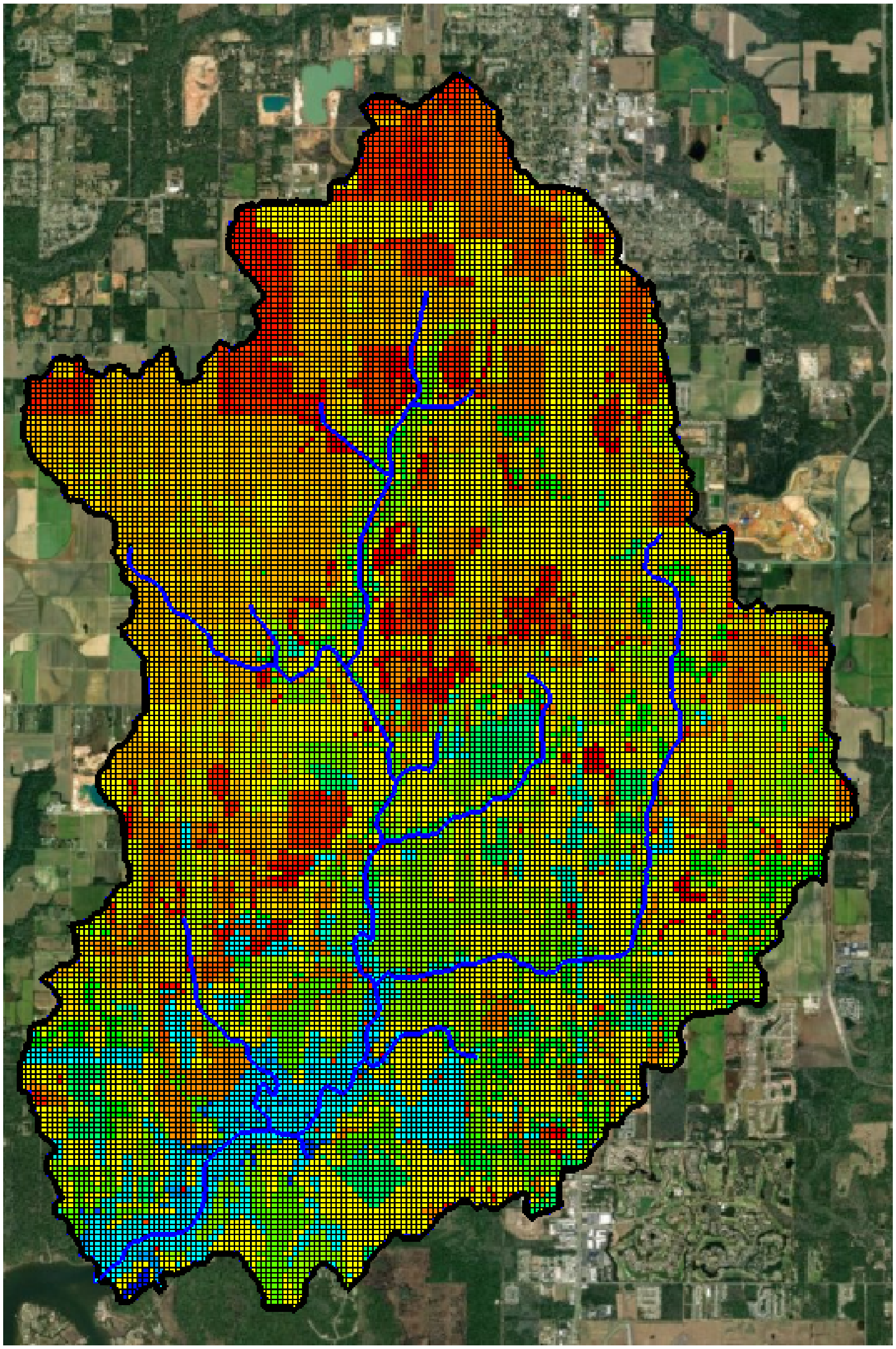


Figure 3-10
Watershed with Gridded Combined Data



4. Calibration

4.1. Bon Secour 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 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 get the water surface slope during the flood event.

There were three locations within the watershed that were deemed useful for monitoring (Figure 4-1). These locations were located near existing drainage structures for 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 three gauges were installed and started recording data on June 12, 2018. A list of gauges and locations can be found in Table 4-1.

Figure 4-1
Watershed with Stream Gauge Locations

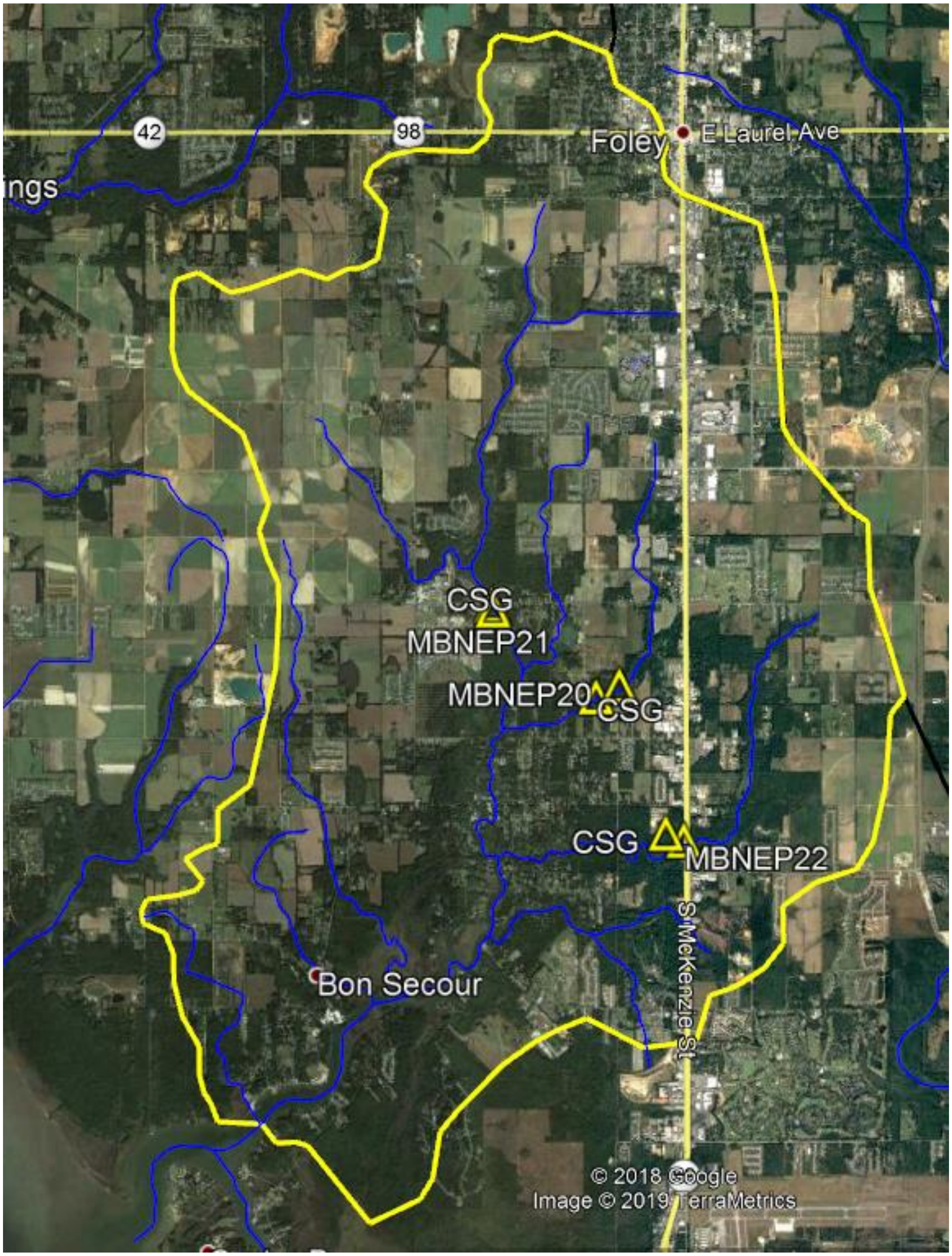


Table 4-1
Installed Stream Gauges, Stream Names, and Locations

Gauge Name	Stream	Location
MBNEP 20	Trib To Bon Secour River	55’ d.s. of CR 12 CL
Cork Gauge 20	Trib To Bon Secour River	200’ d.s. of MBNEP 21
MBNEP 21	Bon Secour River	330’ from road and power line easement intersection
Cork Gauge 21	Bon Secour River	1150’ d.s. of MBNEP 21
MBNEP 22	Boggy Branch	70’ d.s. of Hwy 59 West Lane CL
Cork Gauge 22	Boggy Branch	700’ d.s. of MBNEP 22

During the June 2018 to June 2020 time period there were very limited storm events that could be used for calibration and validation. From the Telog RU-33 stream gauge data (Figures 4-2, 4-3, and 4-4) it was determined that a fairly adequate rainfall event occurred on September 4-5, 2018 due to Tropical Storm Gordon. This event produced approximately 3.5”-4.5” of rain throughout the watershed in 24 hours. Using NOAA Atlas 14 (Figure 4-5) for this rain depth and time period, it was determined that this rain event is below 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 (10+ year). This event was used however in order to get an initial understanding of hydrograph timing throughout the basin.

The second rainfall event that was analyzed was the December 13, 2018 event. This event produced approximately 3” of rain throughout the watershed in approximately 6 hours. Using NOAA Atlas 14 (Figure 4-5) for this rain depth and time period, it was determined that this rain event is less than a 1-year storm.

The third rainfall event that was analyzed was the December 28, 2018 event. This event produced a maximum of 3.5" of rain throughout the watershed in approximately 12 hours. Using NOAA Atlas 14 (Figure 4-5) for this rain depth and time period, it was determined that this rain event is less than a 1-year storm.

The final rainfall event that was analyzed was the June 7, 2020 event. This event produced a maximum of 4.4" of rain throughout the watershed in approximately 24 hours. Using NOAA Atlas 14 (Figure 4-5) for this rain depth and time period, it was determined that this rain event is less than a 1-year storm.

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 can be considered are interception and retention.

Figure 4-2
MBNEP 20 Gauge Height Readings – June 2018-June 2020

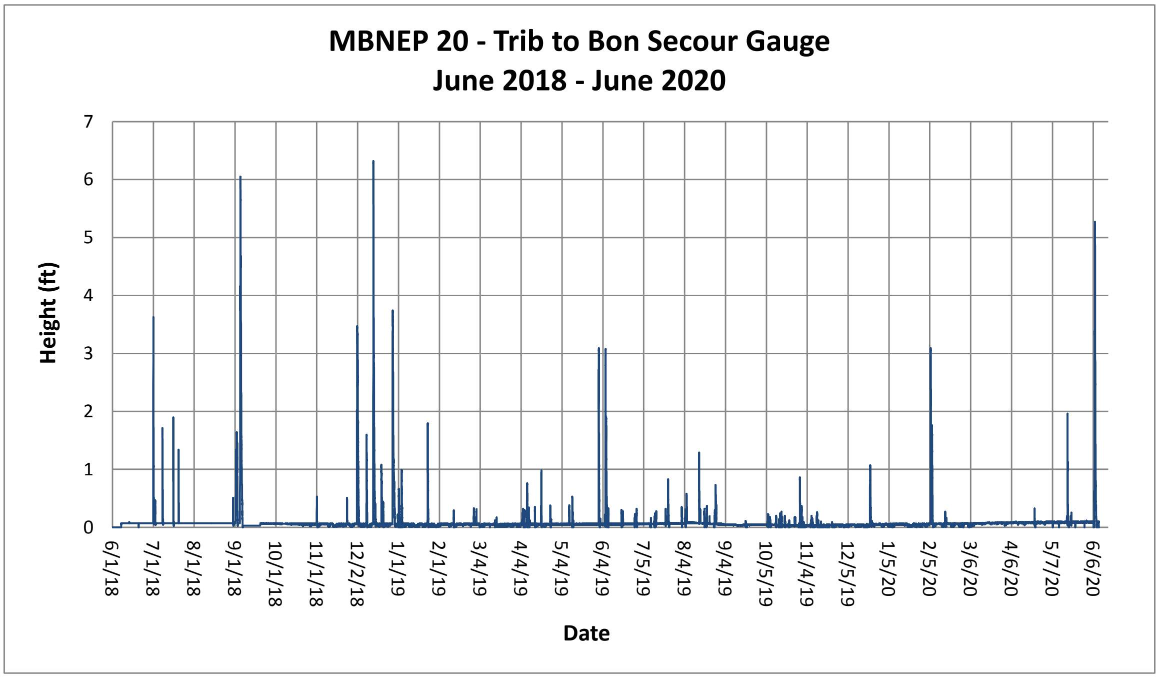


Figure 4-3
MBNEP 21 Gauge Height Readings – June 2018-June 2020

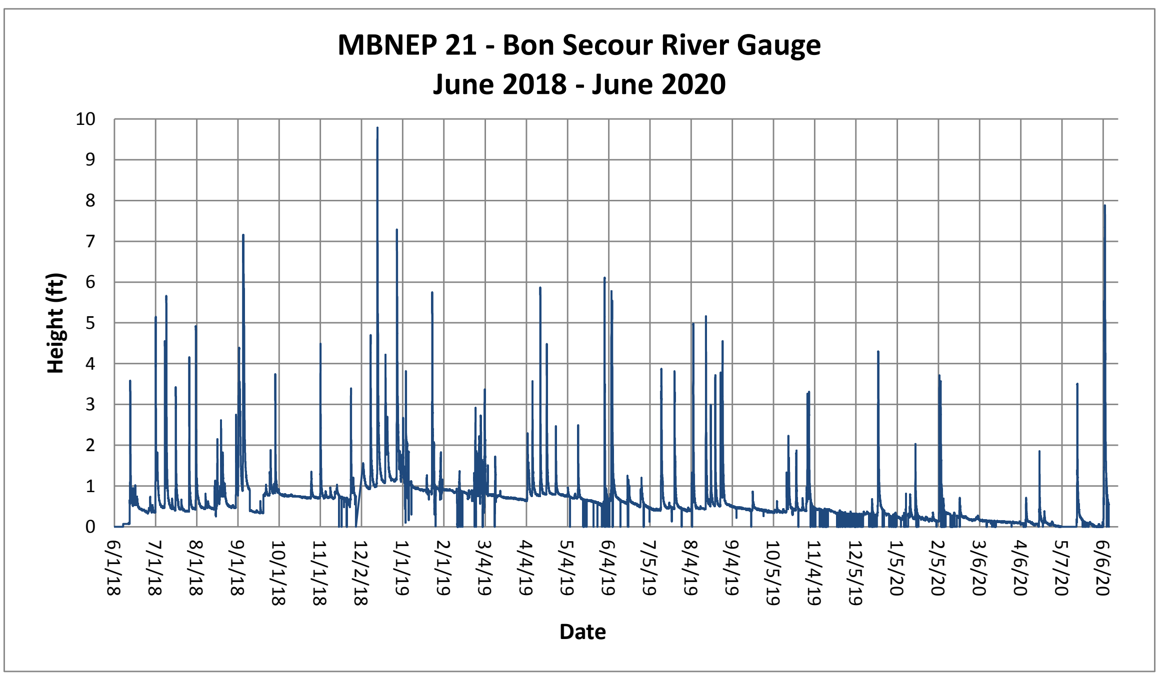


Figure 4-4
MBNEP 22 Gauge Height Readings – June 2018-June 2020

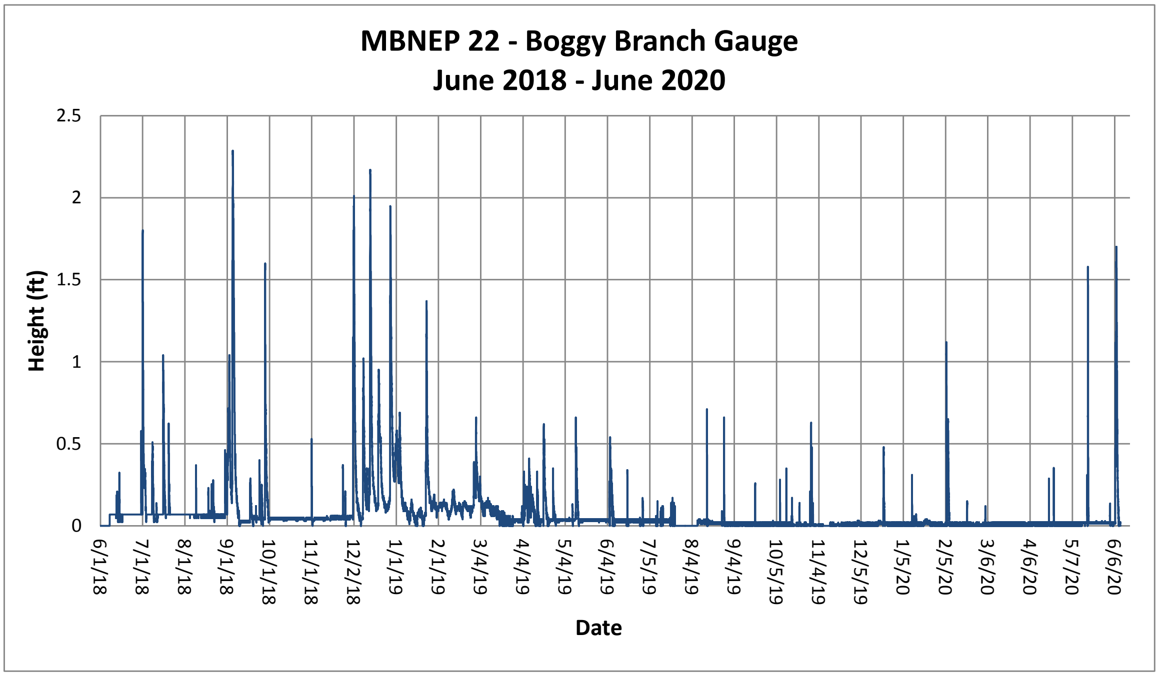


Figure 4-5
Point Precipitation Frequency Estimates

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]

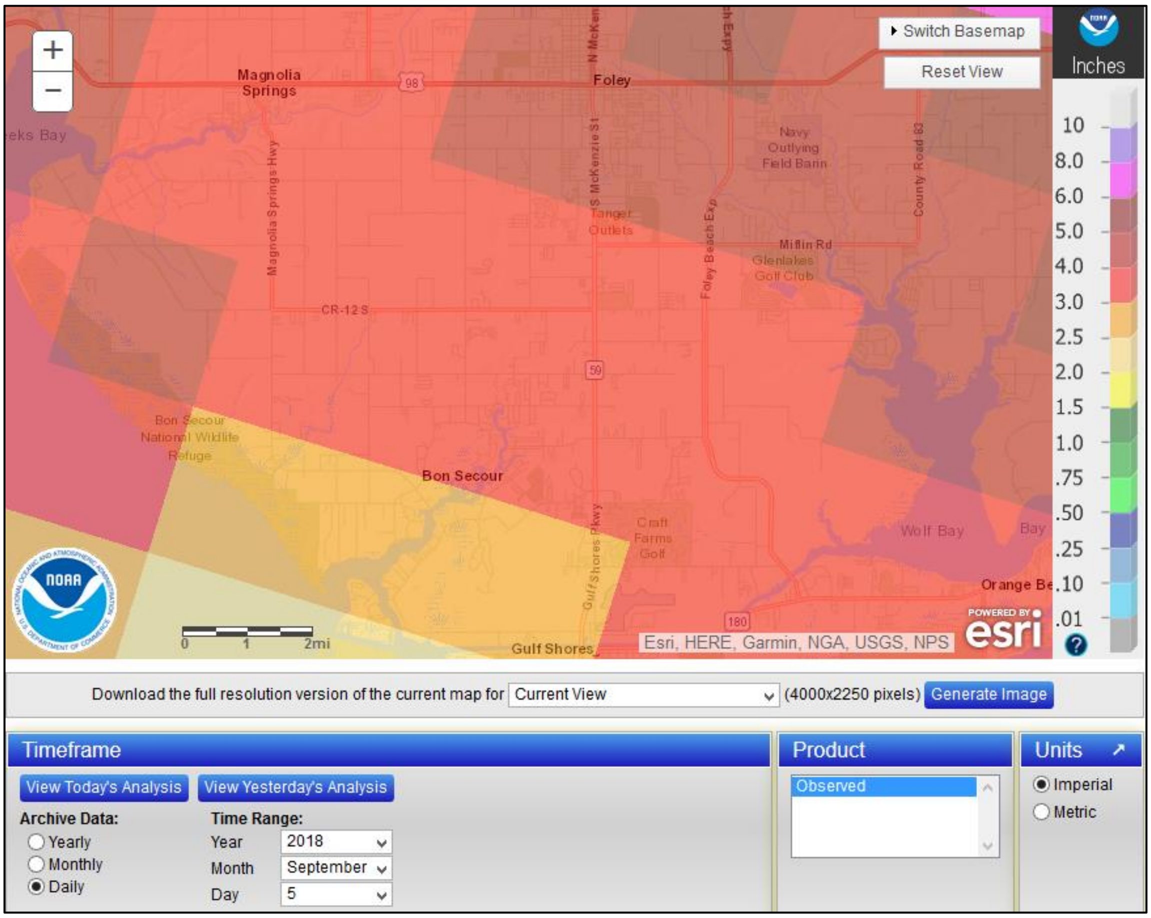
Duration	Average recurrence interval (years)								
	1	2	5	10	25	50	100	200	500
5-min	**0.591** (0.491-0.715)	**0.676** (0.561-0.819)	**0.815** (0.673-0.990)	**0.929** (0.763-1.13)	**1.09** (0.857-1.36)	**1.21** (0.928-1.53)	**1.32** (0.982-1.73)	**1.44** (1.02-1.93)	**1.60** (1.09-2.20)
10-min	**0.865** (0.718-1.05)	**0.990** (0.821-1.20)	**1.19** (0.986-1.45)	**1.36** (1.12-1.66)	**1.59** (1.25-1.99)	**1.76** (1.36-2.25)	**1.94** (1.44-2.53)	**2.11** (1.50-2.83)	**2.34** (1.59-3.23)
15-min	**1.06** (0.876-1.28)	**1.21** (1.00-1.46)	**1.46** (1.20-1.77)	**1.66** (1.36-2.02)	**1.94** (1.53-2.43)	**2.15** (1.66-2.74)	**2.36** (1.75-3.08)	**2.58** (1.83-3.45)	**2.86** (1.94-3.93)
30-min	**1.55** (1.29-1.88)	**1.78** (1.47-2.15)	**2.14** (1.77-2.60)	**2.45** (2.01-2.99)	**2.87** (2.27-3.61)	**3.21** (2.47-4.09)	**3.54** (2.63-4.63)	**3.88** (2.76-5.21)	**4.34** (2.95-5.99)
60-min	**2.13** (1.77-2.58)	**2.42** (2.01-2.93)	**2.91** (2.40-3.54)	**3.33** (2.74-4.07)	**3.94** (3.12-4.97)	**4.42** (3.42-5.66)	**4.92** (3.66-6.45)	**5.44** (3.87-7.33)	**6.16** (4.20-8.52)
2-hr	**2.71** (2.26-3.25)	**3.07** (2.56-3.69)	**3.68** (3.06-4.44)	**4.22** (3.49-5.11)	**5.00** (4.00-6.28)	**5.64** (4.39-7.17)	**6.30** (4.72-8.21)	**7.00** (5.01-9.38)	**7.98** (5.47-11.0)
3-hr	**3.10** (2.60-3.71)	**3.51** (2.95-4.21)	**4.24** (3.54-5.08)	**4.88** (4.05-5.88)	**5.83** (4.69-7.32)	**6.62** (5.18-8.41)	**7.45** (5.62-9.70)	**8.35** (6.01-11.2)	**9.60** (6.62-13.2)
6-hr	**3.76** (3.18-4.46)	**4.30** (3.63-5.11)	**5.27** (4.43-6.28)	**6.17** (5.16-7.38)	**7.53** (6.13-9.45)	**8.69** (6.86-11.0)	**9.93** (7.55-12.9)	**11.3** (8.19-15.0)	**13.2** (9.18-18.1)
12-hr	**4.36** (3.71-5.14)	**5.09** (4.32-6.00)	**6.42** (5.43-7.59)	**7.67** (6.45-9.10)	**9.60** (7.88-12.0)	**11.3** (8.97-14.2)	**13.1** (10.0-16.9)	**15.1** (11.0-20.0)	**17.9** (12.5-24.4)
24-hr	**5.01** (4.30-5.86)	**5.91** (5.06-6.92)	**7.60** (6.48-8.92)	**9.21** (7.80-10.9)	**11.7** (9.73-14.6)	**13.9** (11.2-17.5)	**16.3** (12.6-21.0)	**19.0** (14.0-25.1)	**22.8** (16.1-30.9)
2-day	**5.82** (5.02-6.75)	**6.81** (5.86-7.90)	**8.71** (7.48-10.1)	**10.6** (9.01-12.4)	**13.5** (11.3-16.8)	**16.1** (13.0-20.2)	**19.0** (14.8-24.3)	**22.2** (16.5-29.1)	**26.8** (19.1-36.1)
3-day	**6.38** (5.53-7.37)	**7.35** (6.36-8.50)	**9.27** (7.99-10.7)	**11.2** (9.56-13.0)	**14.2** (12.0-17.6)	**16.9** (13.8-21.1)	**20.0** (15.6-25.5)	**23.3** (17.4-30.6)	**28.3** (20.2-38.0)
4-day	**6.85** (5.95-7.88)	**7.81** (6.77-8.99)	**9.71** (8.39-11.2)	**11.6** (9.97-13.5)	**14.7** (12.4-18.2)	**17.4** (14.2-21.7)	**20.5** (16.1-26.1)	**24.0** (18.0-31.3)	**29.1** (20.8-38.9)
7-day	**8.02** (7.01-9.17)	**8.99** (7.85-10.3)	**10.9** (9.50-12.5)	**12.8** (11.1-14.8)	**16.0** (13.5-19.5)	**18.7** (15.4-23.1)	**21.8** (17.2-27.6)	**25.3** (19.0-32.8)	**30.4** (21.9-40.5)

* This chart was generated from the lat/long point of 30.3469, -88.7066

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

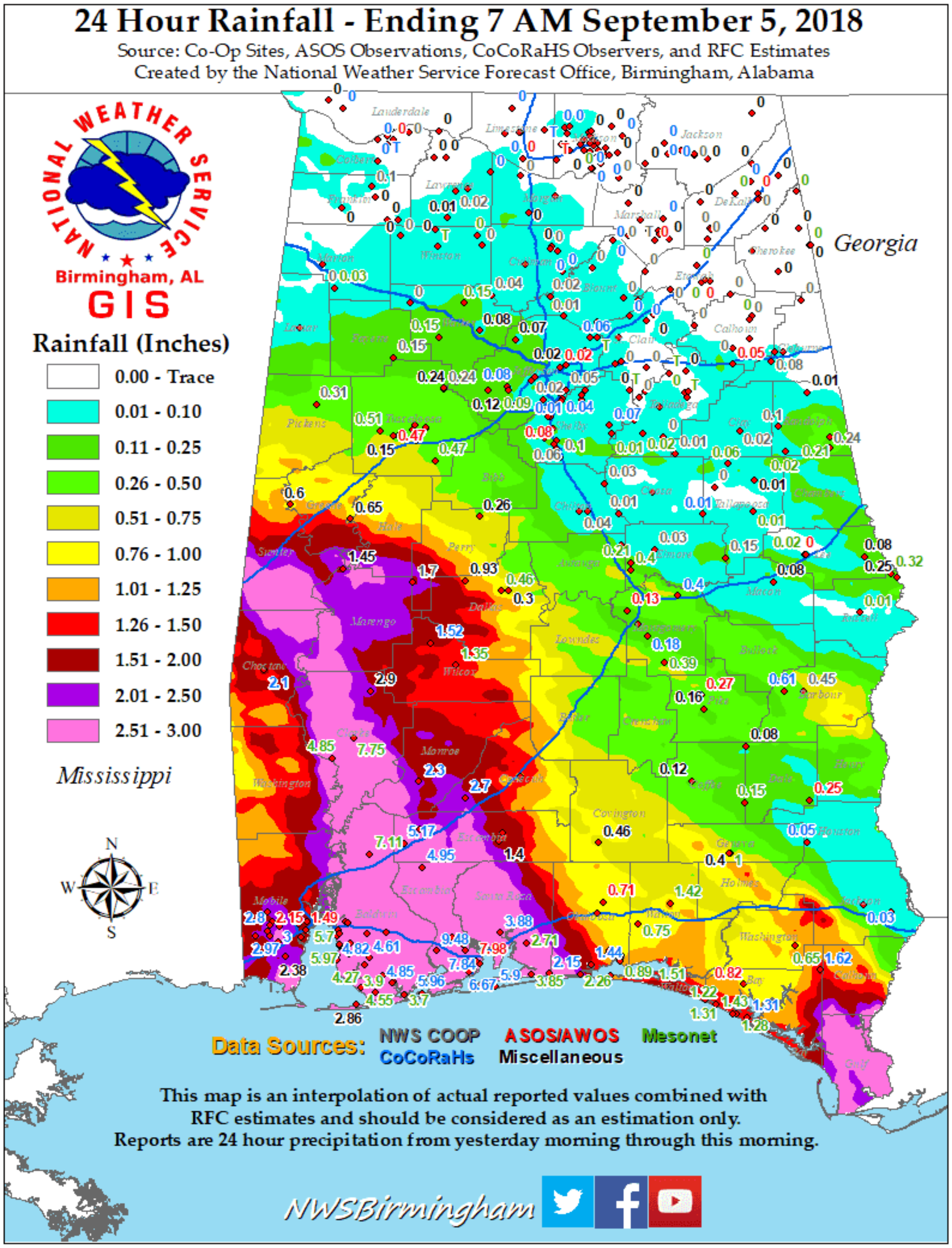
Figures 4-6 and 4-7 indicate the total rainfall maps for the September 4, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-8, 4-9, 4-10, and 4-11 indicate total rainfall distribution and the calibrated model output.

Figure 4-6
September 4-5, 2018 – AHPS Total Rainfall Map



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

Figure 4-7
September 4-5, 2018 – Total Rainfall Map



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

Figure 4-8
September 4-5, 2018 – Total Rainfall Distribution

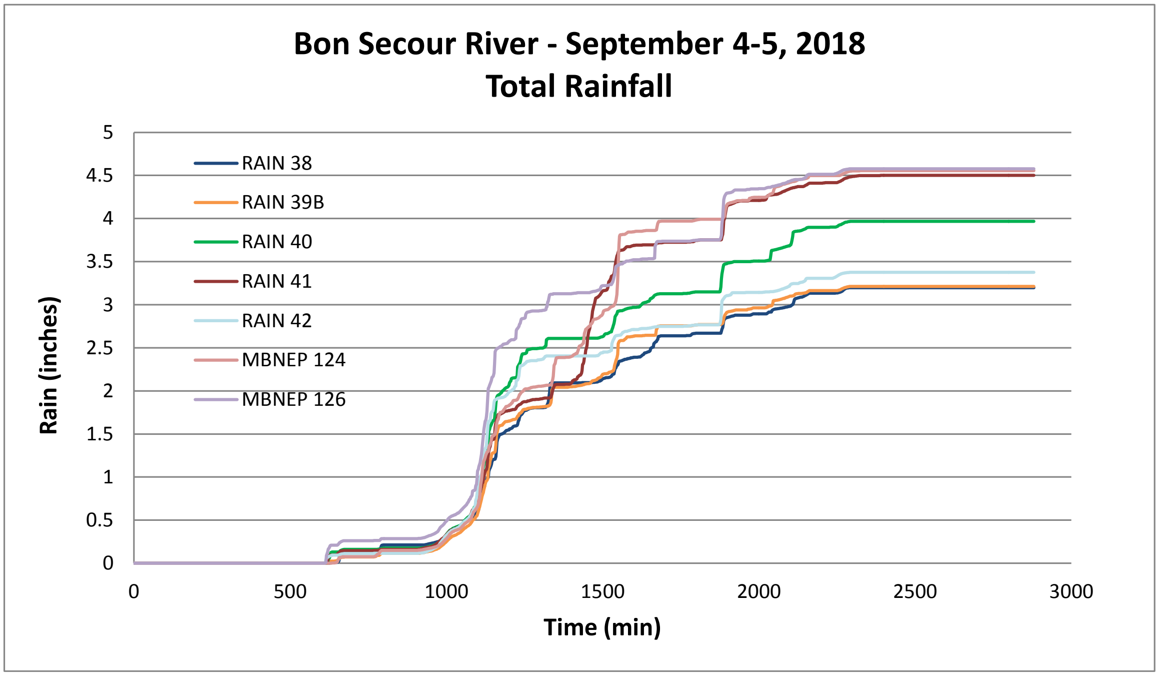


Figure 4-9
September 4-5, 2018 – Trib to Bon Secour River Calibration

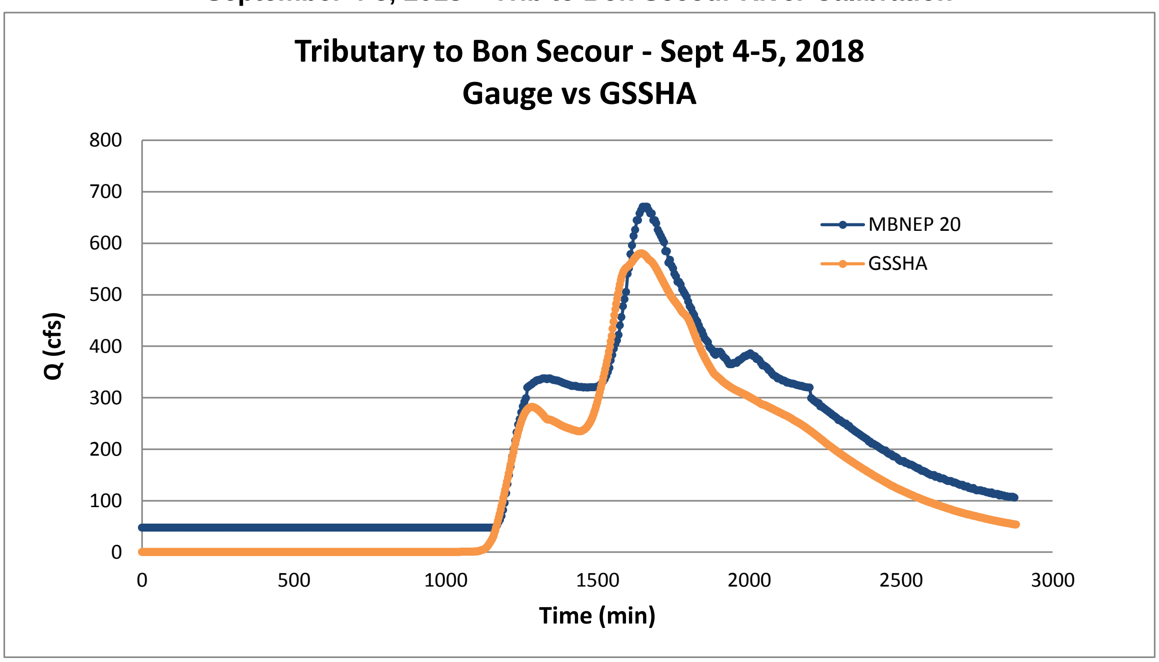


Figure 4-10
September 4-5, 2018 – Bon Secour River Calibration

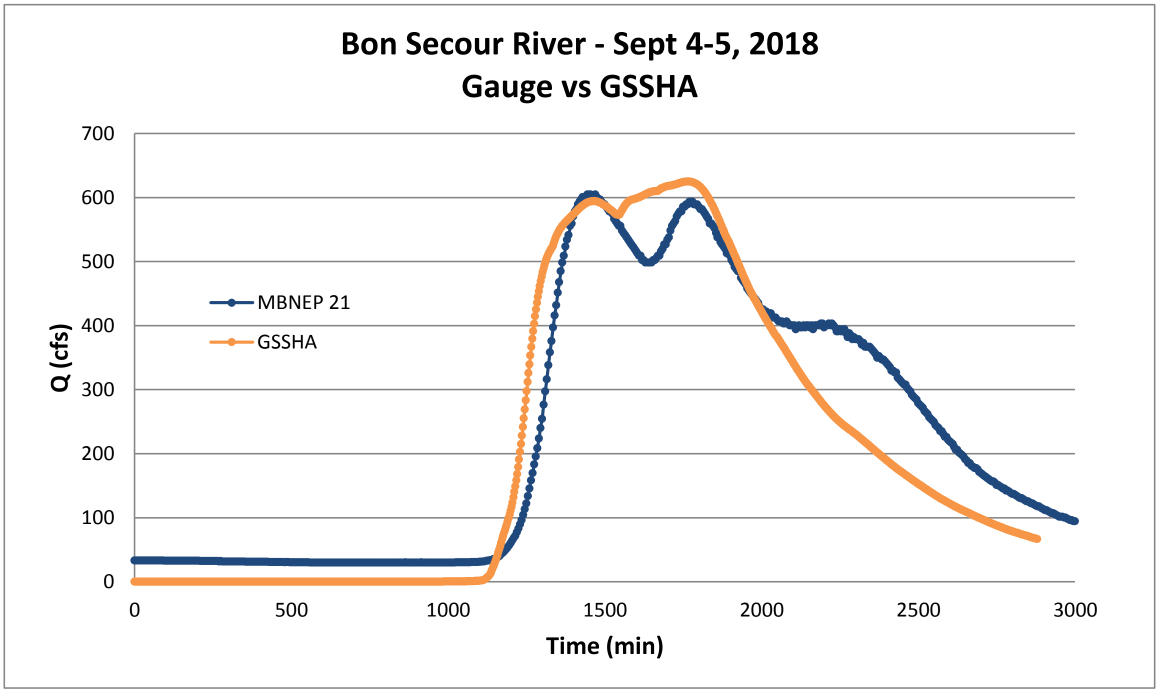
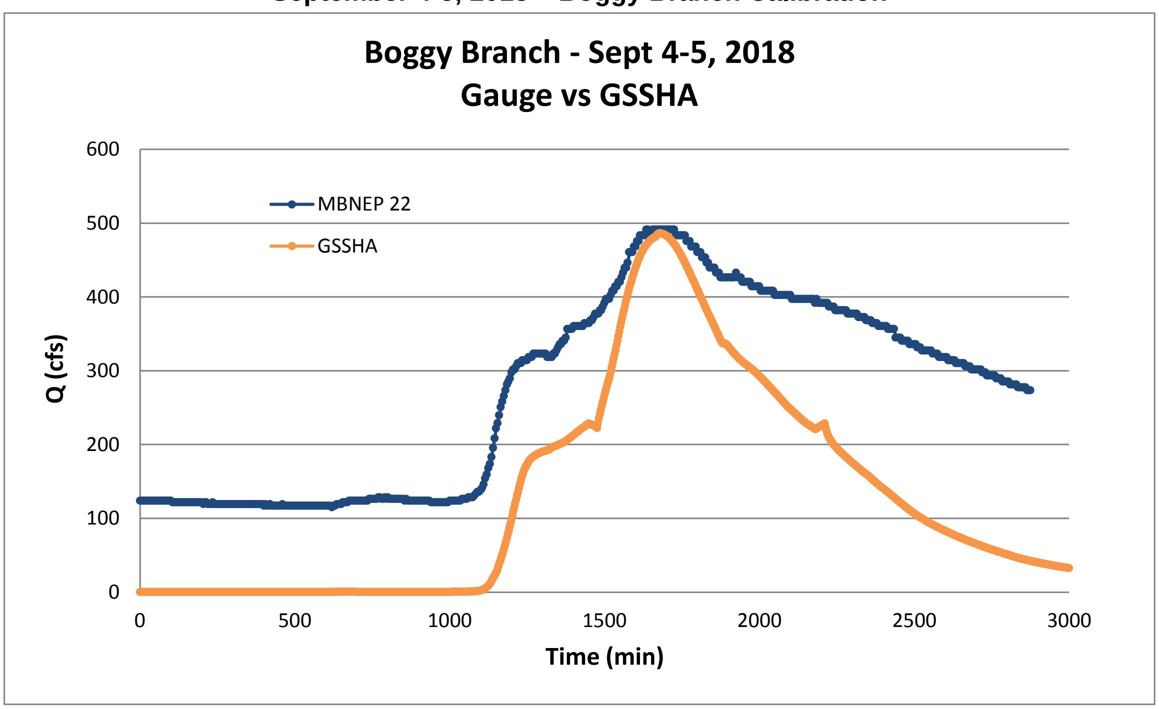


Figure 4-11
September 4-5, 2018 – Boggy Branch Calibration



Figures 4-12 and 4-13 indicate the total rainfall maps for the December 13, 2018 rain event generated by the NWS Advanced Hydrologic Prediction Service and the Birmingham NWS Forecast Office. Figures 4-14, 4-15, 4-16, and 4-17 indicate total rainfall distribution and the calibrated model output.

Figure 4-12
December 13-14, 2018 – AHPS Total Rainfall Map

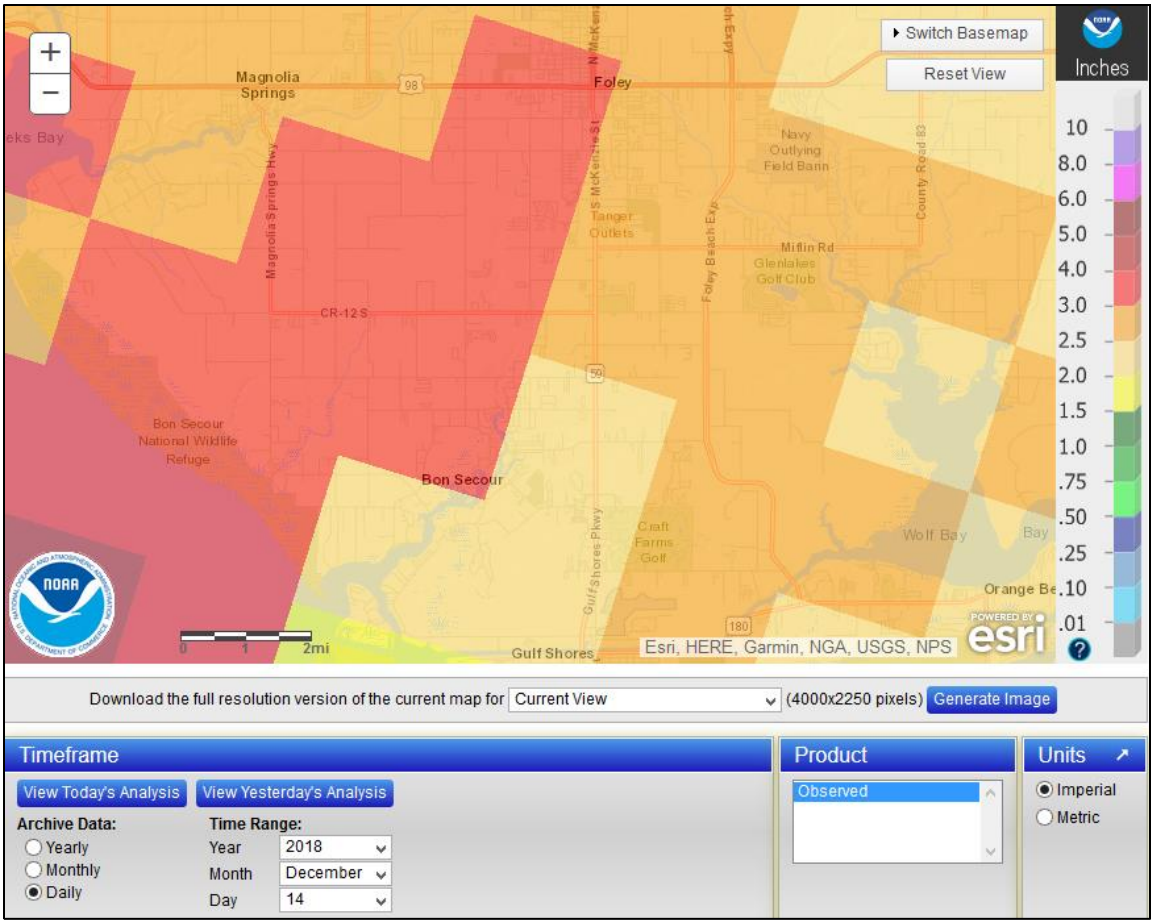


Figure 4-13
December 13-14, 2018 – Total Rainfall Map

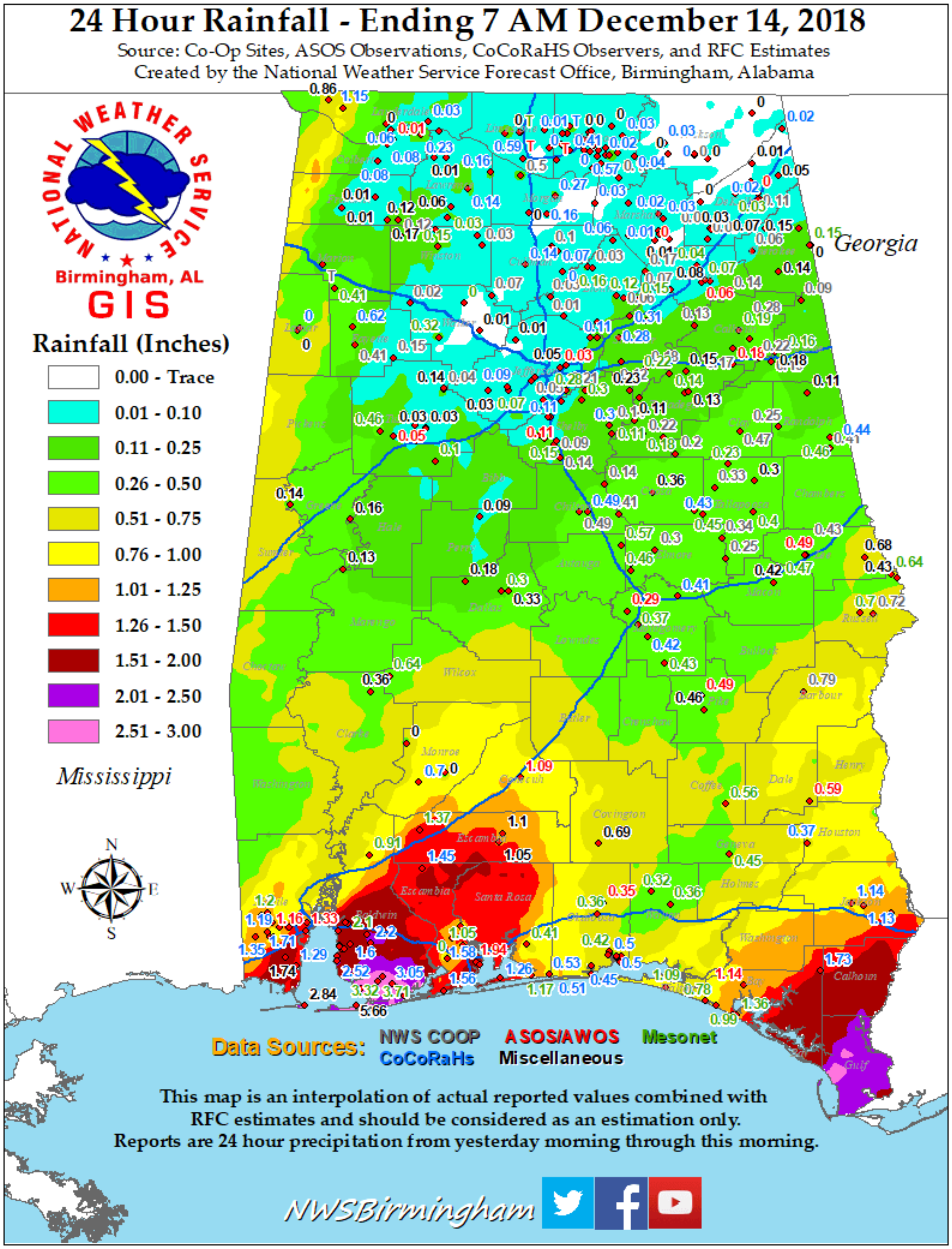


Figure 4-14
December 13, 2018 – Total Rainfall Distribution

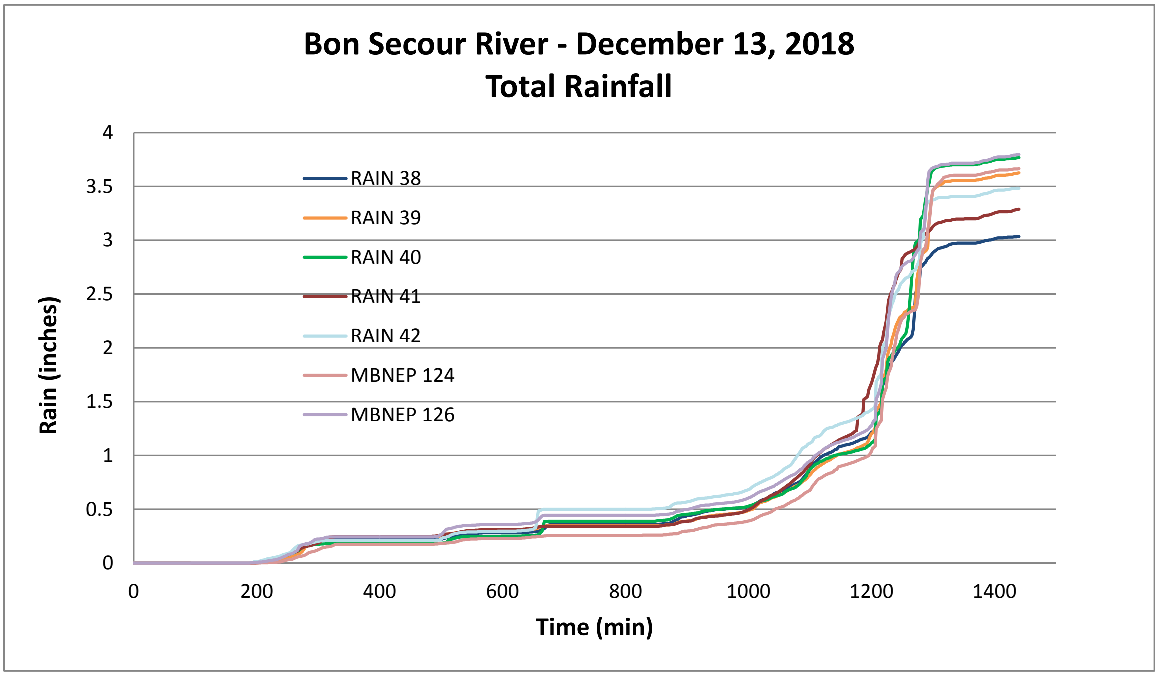


Figure 4-15
December 13, 2018 – Trib to Bon Secour River Calibration

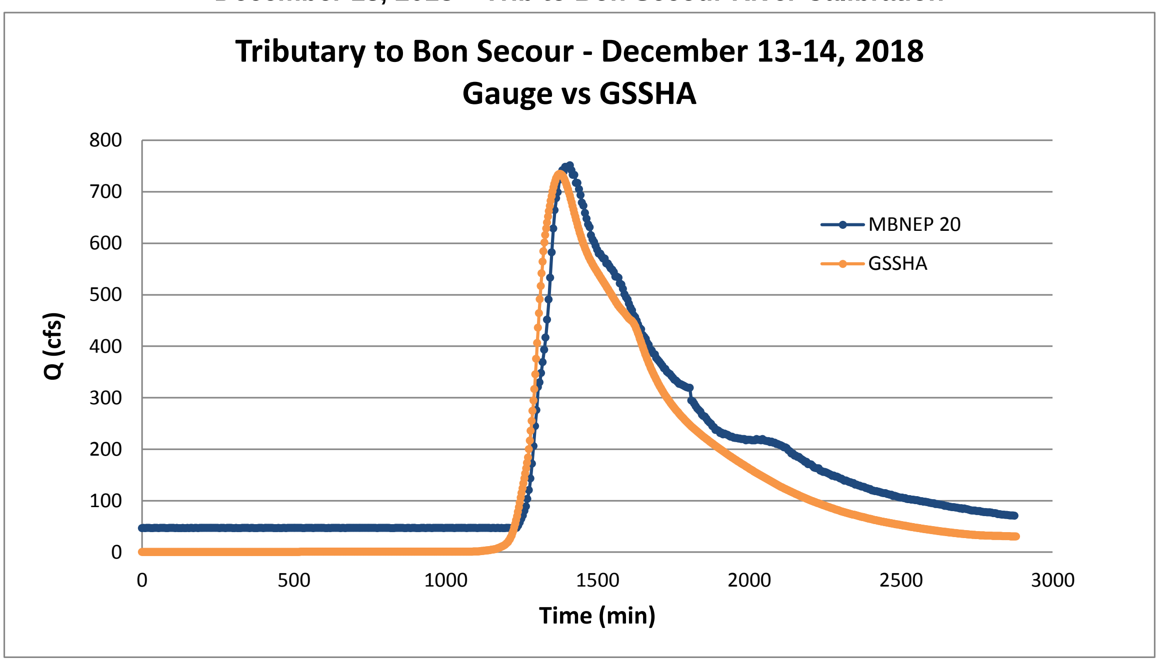


Figure 4-16
December 13-14, 2018 – Bon Secour River Calibration

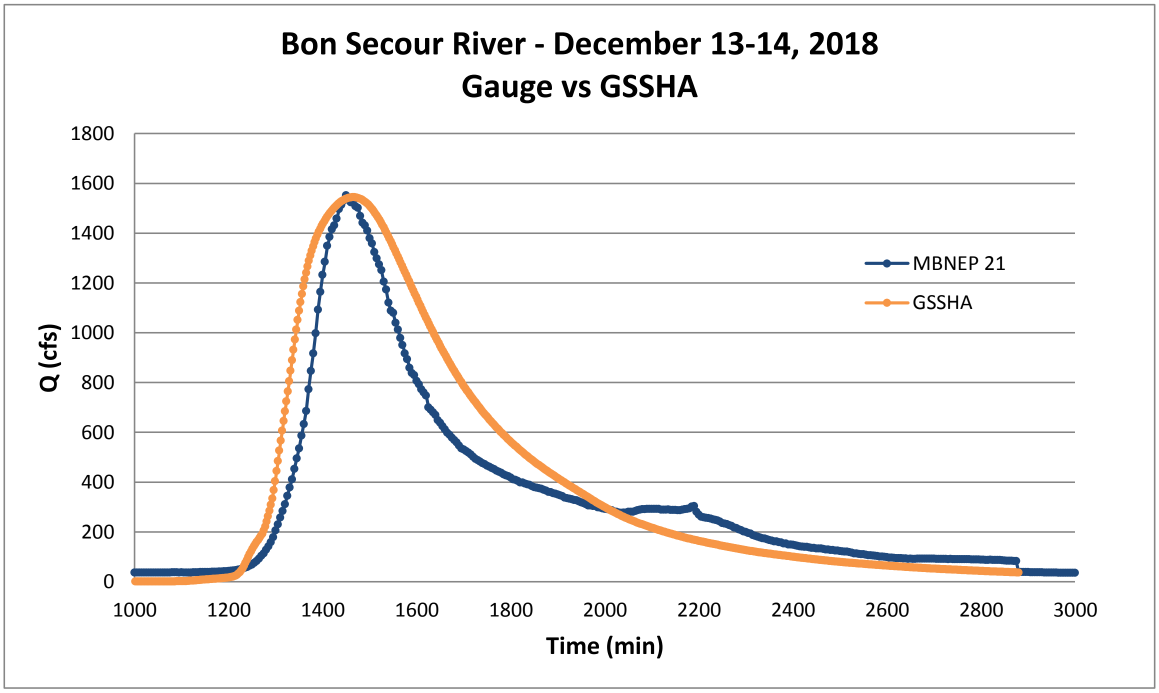
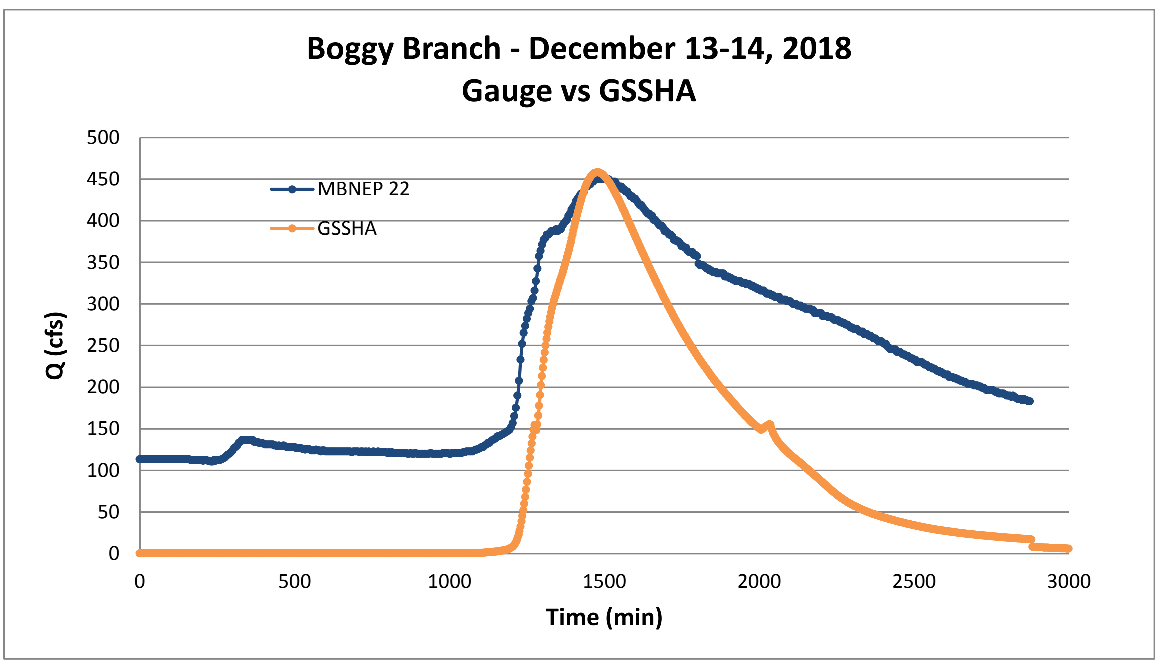


Figure 4-17
December 13-14, 2018 – Boggy Branch Calibration



Figures 4-18 and 4-19 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. Figures 4-20, 4-21, 4-22, and 4-23 indicate total rainfall distribution and the calibrated model output.

Figure 4-18
December 28-29, 2018 – AHPS Total Rainfall Map

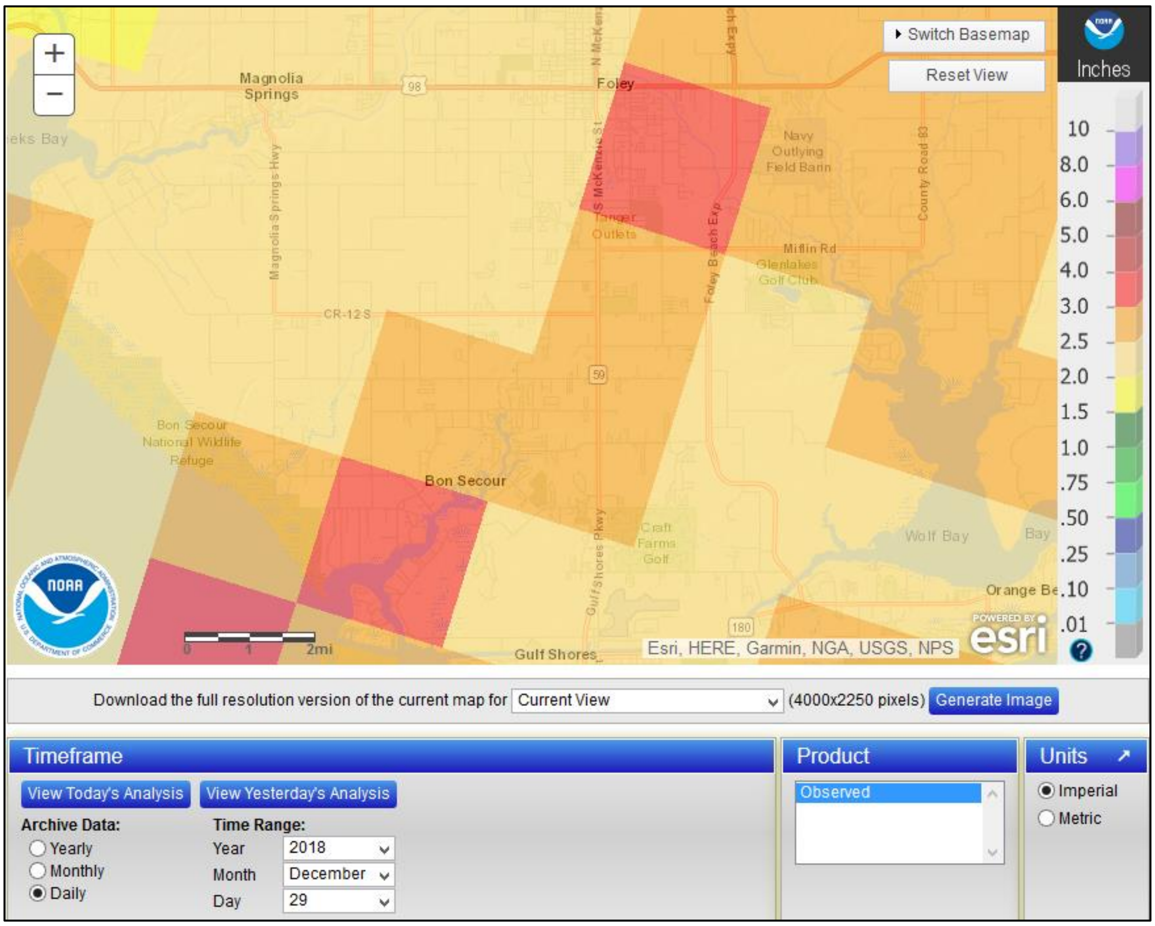


Figure 4-19
December 28-29, 2018 – Total Rainfall Map

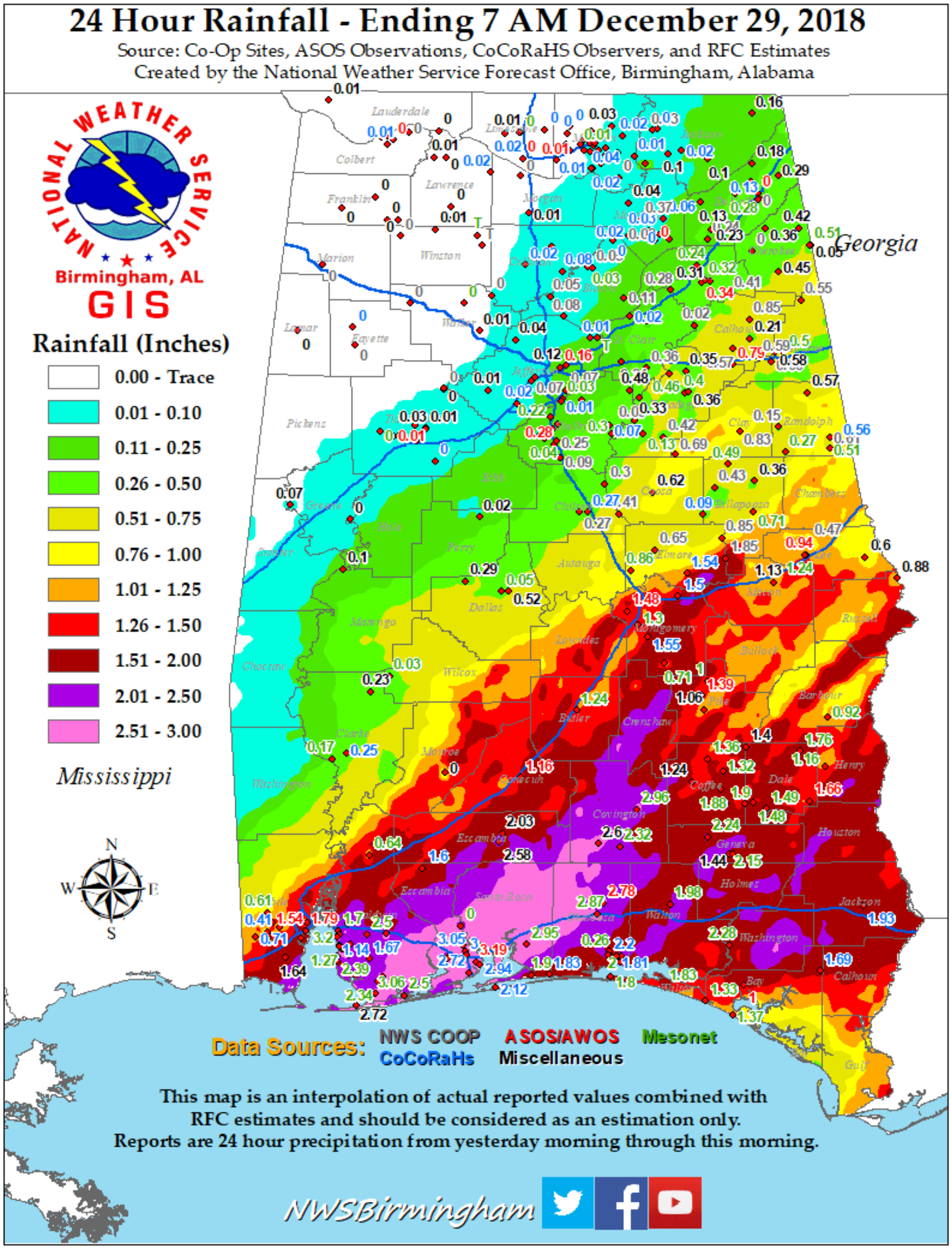


Figure 4-20
December 28, 2018 – Total Rainfall Distribution

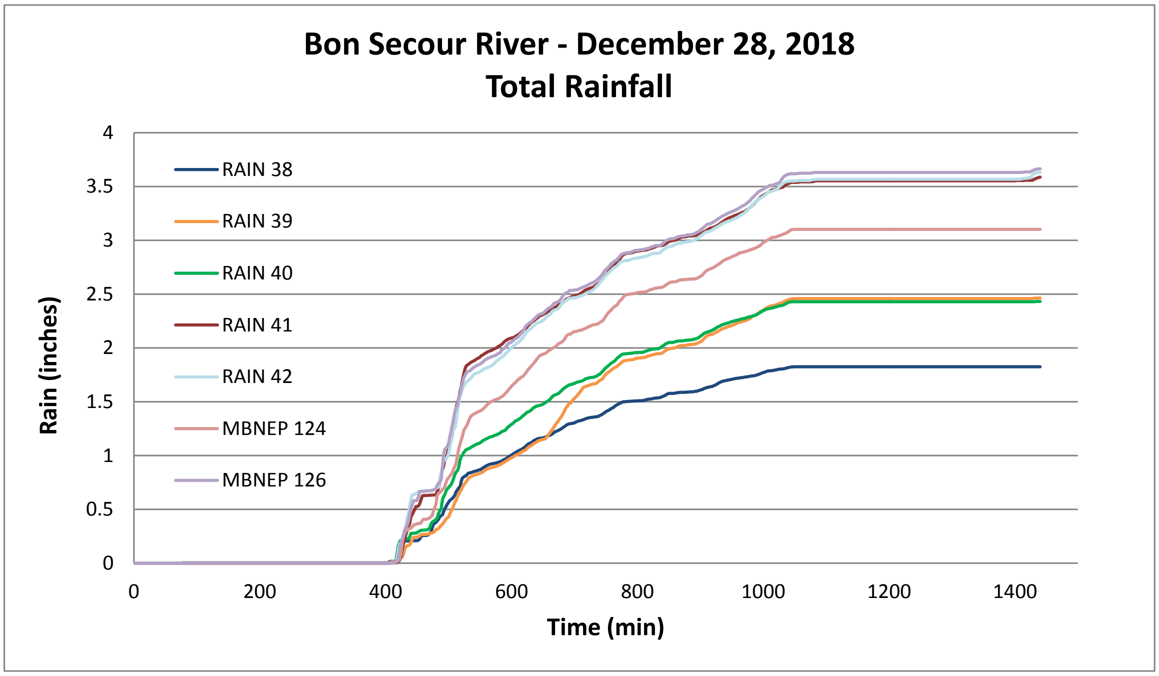


Figure 4-21
December 28, 2018 – Trib to Bon Secour River Calibration

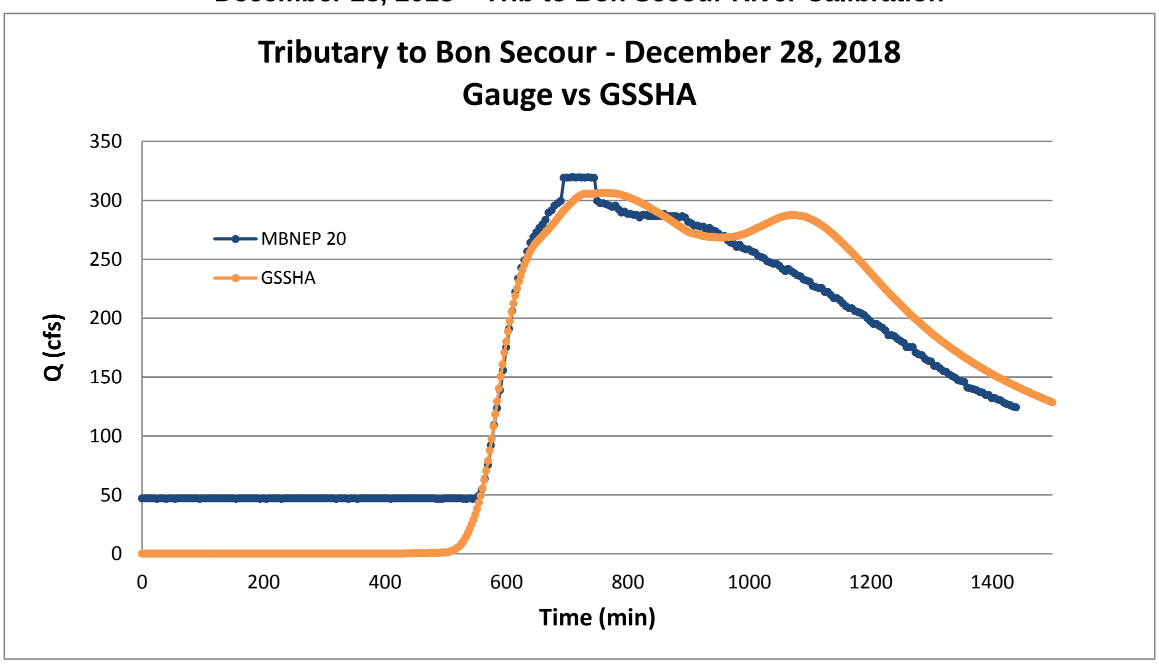


Figure 4-22
December 28, 2018 – Bon Secour River Calibration

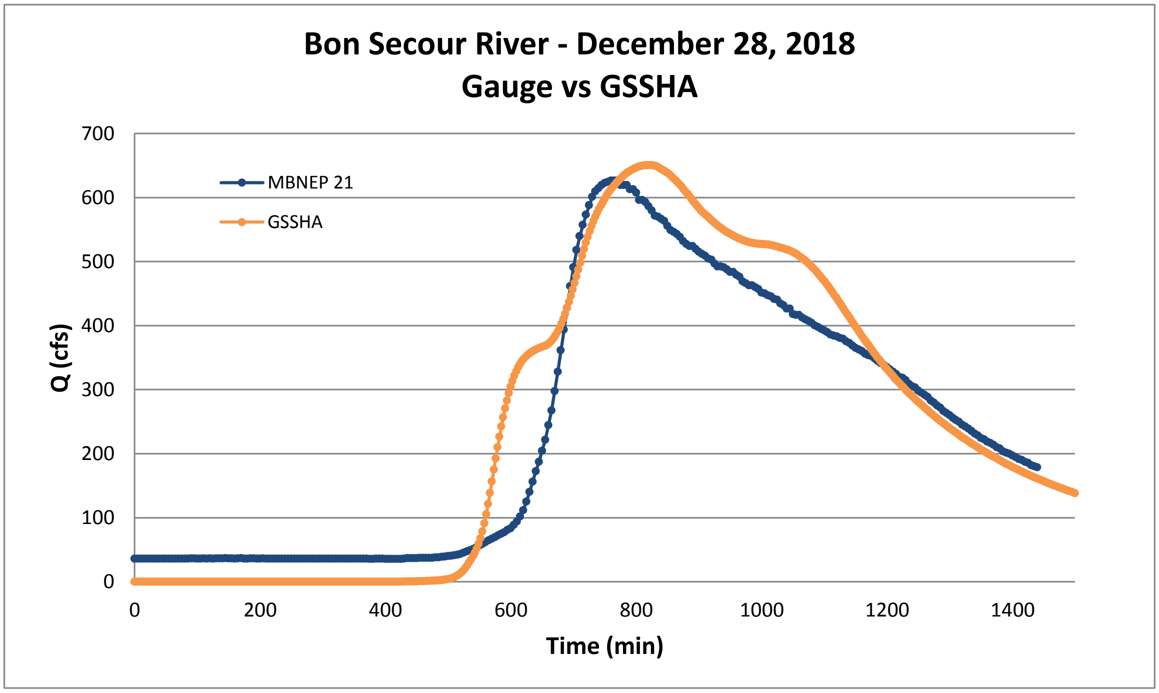
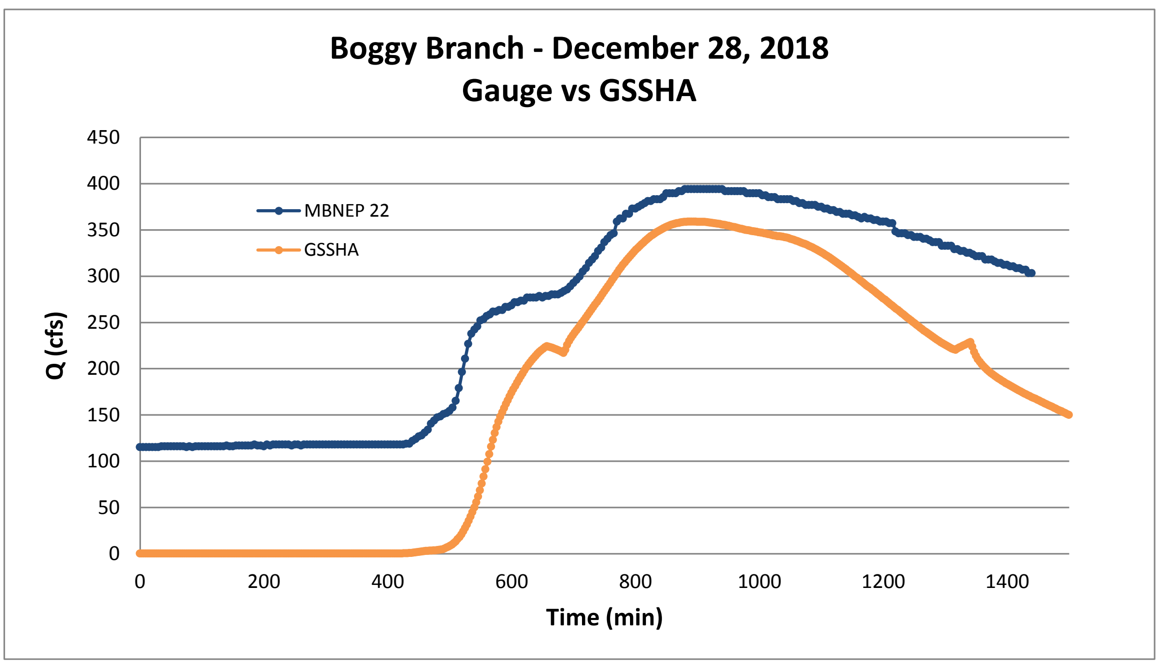


Figure 4-23
December 28, 2018 – Boggy Branch Calibration



Figures 4-24 and 4-25 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 4-26, 4-27, 4-28, and 4-29 indicate total rainfall distribution and the calibrated model output.

Figure 4-24
June 7-8, 2020 – AHPS Total Rainfall Map

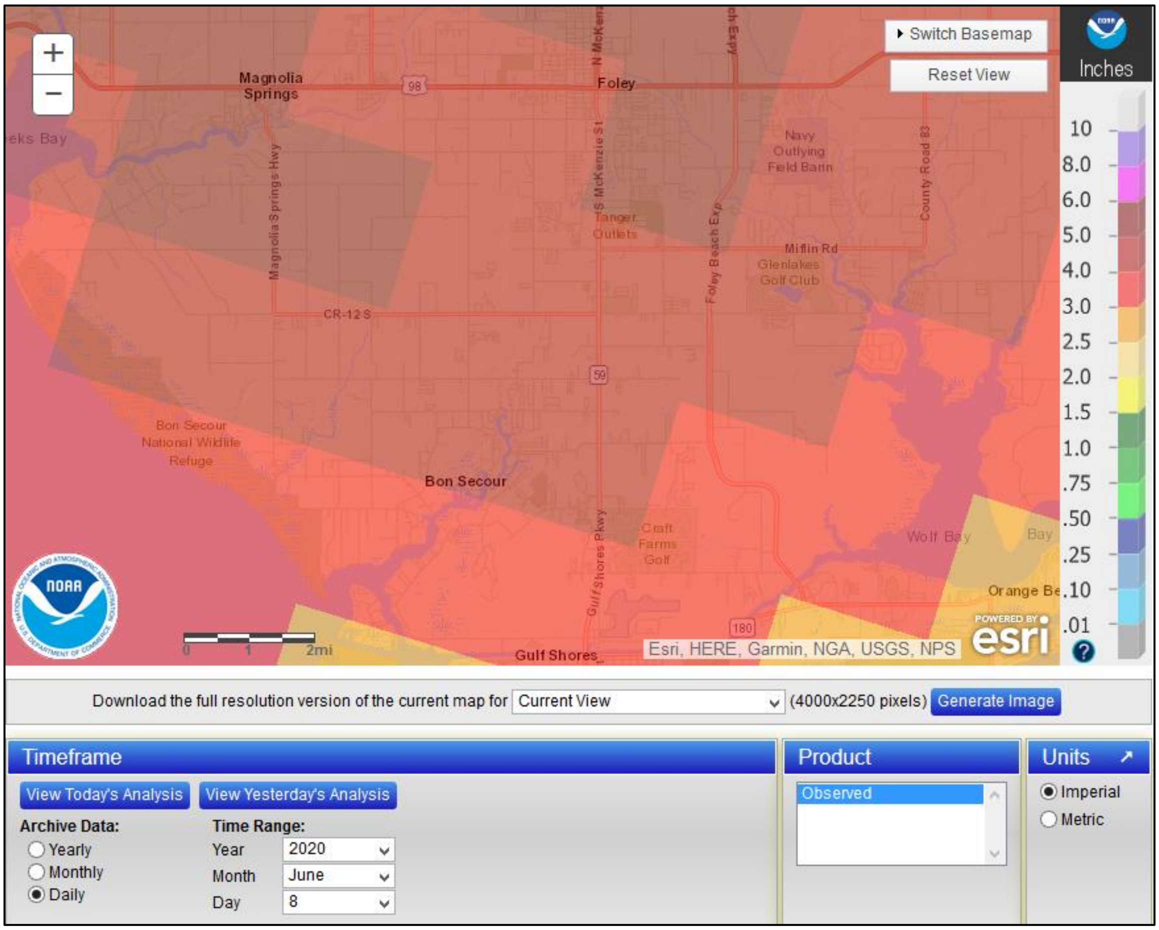


Figure 4-25
June 7-8, 2020 – Total Rainfall Map

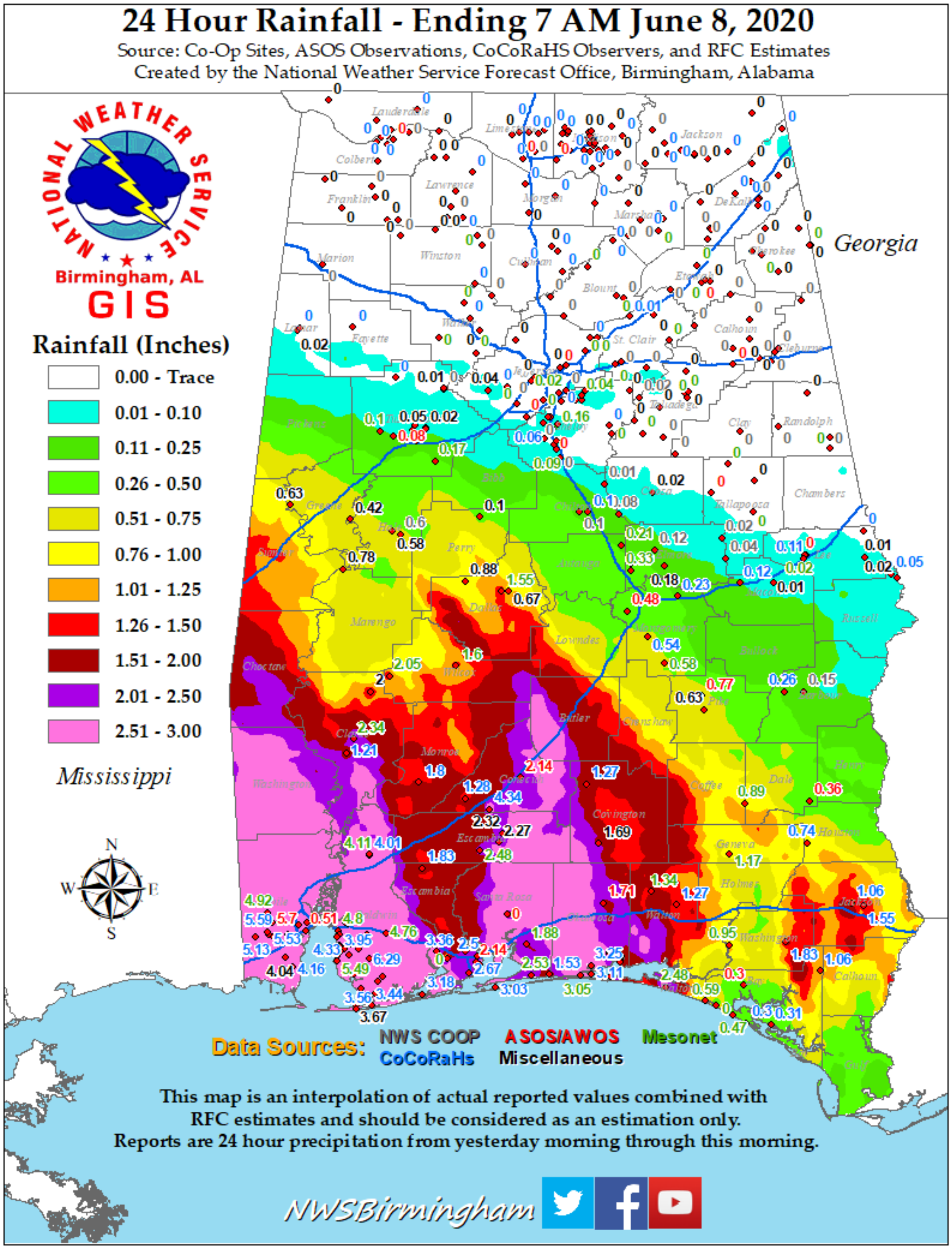


Figure 4-26
June 6-8, 2020 – Total Rainfall Distribution

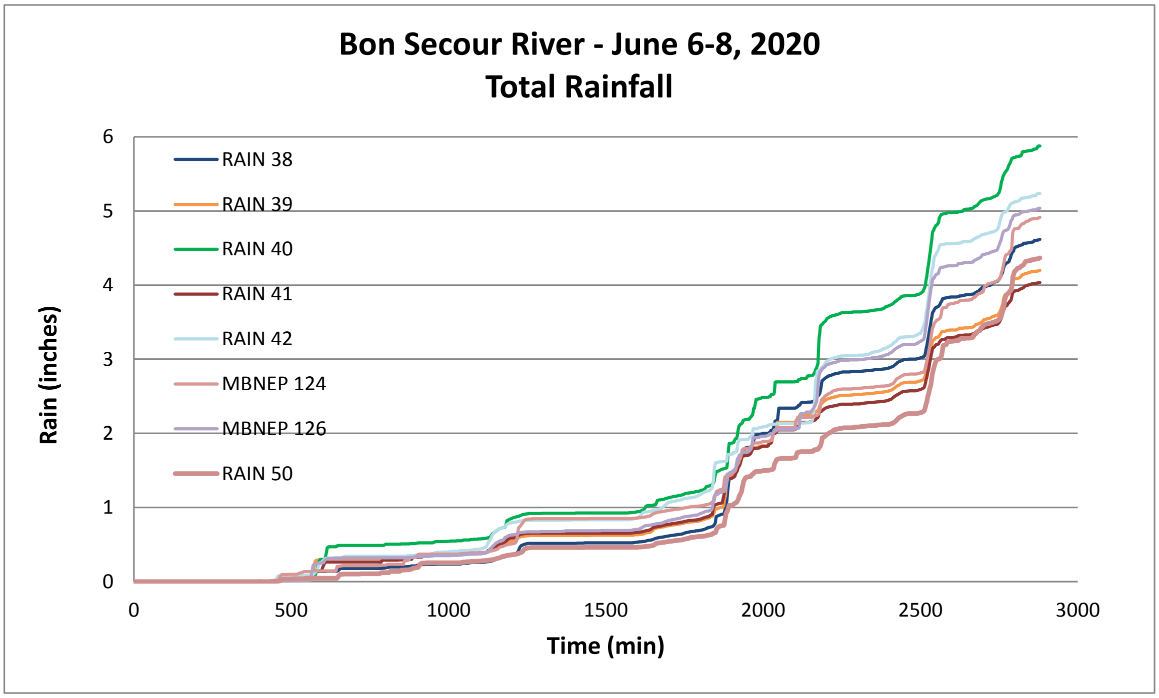


Figure 4-27
June 6-8, 2020 – Trib to Bon Secour River Calibration

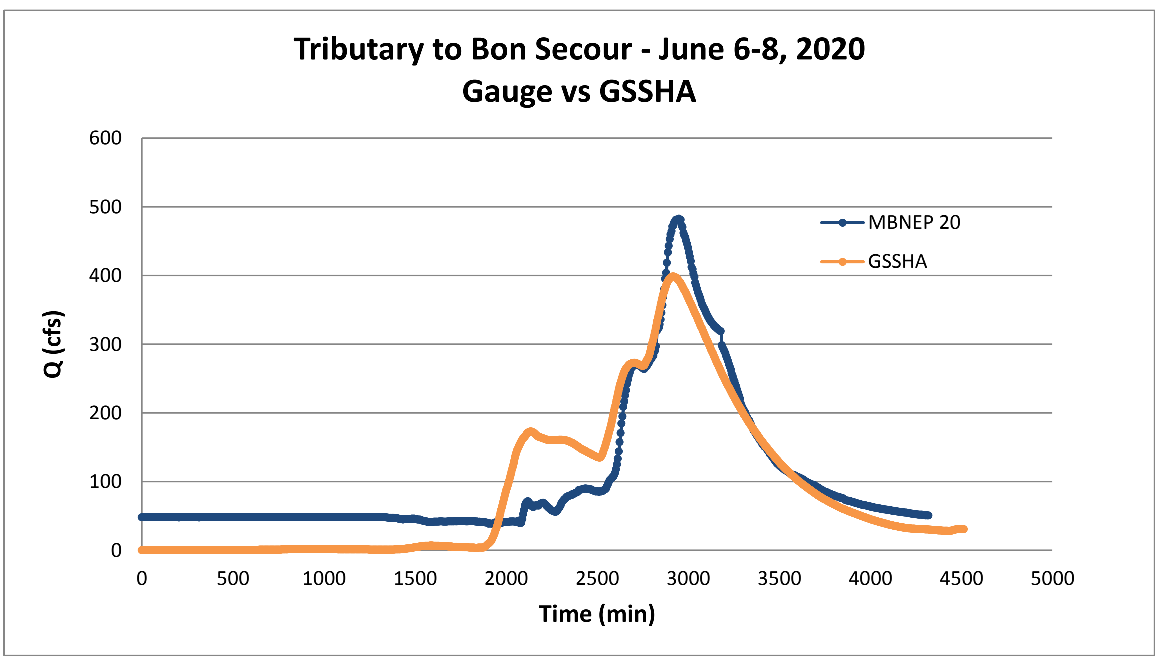


Figure 4-28
June 6-8, 2020 – Bon Secour River Calibration

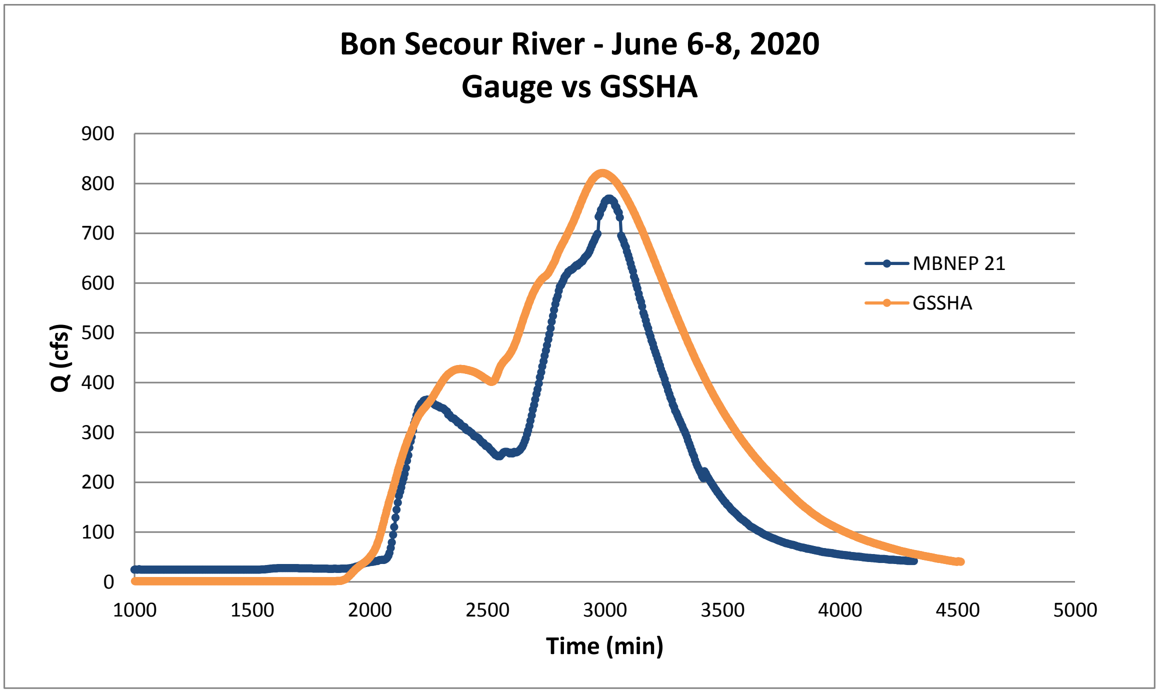
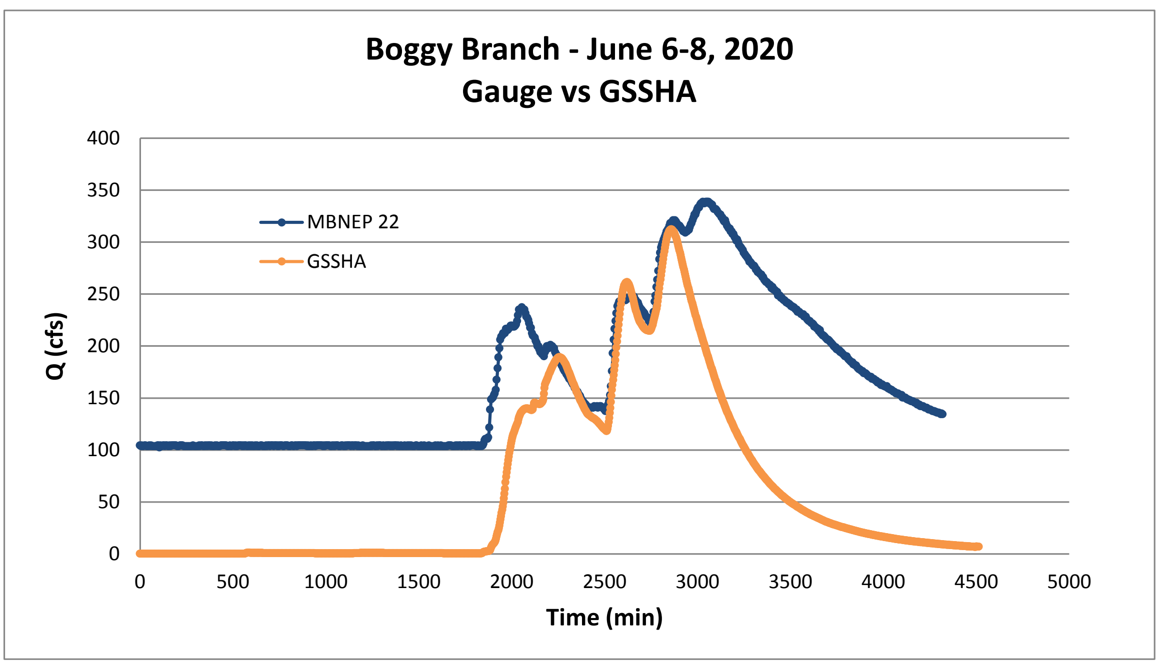


Figure 4-29
June 6-8, 2020 – Boggy Branch Calibration



5. Results and Conclusions

5.1. Results

During the evaluation period between the middle of June 2018 and June 2020 the Bon Secour River watershed experienced very few storm events that could be used for any kind of calibration. These events occurred at the end of 2018 with a maximum amount of rain of only 4.5 inches. The majority of storms occurring in 2019 and 2020 had rainfall amounts less than 2 or 3 inches. Using the stream gauge plots found in Figures 4-2, 4-3, and 4-4, the largest events were chosen for model calibration. During this study, the largest discharge event occurred on December 13, 2018. This rainfall event produced approximately 4" of rain in 12 hours. Using Figure 4-5, it was determined that this is just under a 1-year recurrence interval. Comparing the calibrated discharges to the discharges determined from rural regression equations, it can be seen that the even though the watershed experienced an event less than a 1-year recurrence interval, the discharges are between the rural regression 2-year and 5-year discharges.

The first event used for calibration was from Tropical Storm Gordon on September 4-5, 2018 in which the watershed experienced between 3" – 4.5" in 12 hours. This equates to a storm event less than a 1-year recurrence interval. The next event used for analysis occurred on December 28, 2018. For this event the watershed experienced approximately 3.5" in 10 hours. This event was also classified as being less than a 1-year storm event. The final event used for analysis occurred on June 7, 2020. For this event the watershed experienced approximately 4.4" in 24 hours from Tropical Storm Cristobal. This event was classified as being less than a 1-year storm event. As with the December 13, 2018 rain storm, the measured discharges for the three above events are higher than the rural regression discharges for the same recurrence interval.

5.2. Conclusions

After analysis of the discharges and rainfall events that occurred between June 2018 and June 2020, it has been determined that rainfall events just under a 1-year recurrence interval produce discharges closer to those calculated from the 2-year rural regression equations. The increased discharges are due to the high urban development located in the eastern portion of the watershed along SR 59. This includes business and commercial development from the City of Foley.

There is also residential development scattered throughout the watershed that impact storm water discharges.

For smaller rain events (< 1-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. Typically a model calibrated to small events like a 1-year storm does not properly translate to a large flooding event. For larger discharge events (10+ year), the model will need to be reevaluated and recalibrated to correctly determine the timing and magnitude of the peak discharges throughout the watershed.

6. References

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