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Flood-Inundation Maps for the Yellow River From River Drive to Centerville Highway, Gwinnett County, Georgia

Scientific Investigations Report 2019–5009

U.S. Department of the Interior
U.S. Geological Survey

Front cover: Photograph of U.S. Geological Survey personnel at the streamgage Yellow River at Georgia 124, near Lithonia, Georgia (02207120). Photograph by Karen Stull, U.S. Geological Survey, September 2009.

Back cover: Photograph of the streamgage Yellow River near Snellville, Georgia (02206500). Photograph by Jonathan Musser, U.S. Geological Survey, February 2018.

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DAVID BERNHARDT, Acting Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

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Suggested citation:
Musser, J.W., 2019, Flood-inundation maps for the Yellow River from River Drive to Centerville Highway, Gwinnett County, Georgia: U.S. Geological Survey Scientific Investigations Report 2019–5009, 15 p., https://doi.org/10.3133/sir20195009.

ISSN 2328-0328 (online)

Acknowledgments

The author wishes to thank Gwinnett County, Georgia, for funding the operation and maintenance of the two streamgages used for this study, for sharing information used in this report, and for its continued involvement in the U.S. Geological Survey Cooperative Water Program. Thank you to Tony Gotvald and Jeff Morris for their technical reviews of this report. Special thanks to the National Weather Service for their continued support to the U.S. Geological Survey flood-inundation mapping initiative.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to the distance above the vertical datum.

Stage, as used in this report, is the height of water surface above an arbitrary datum established at the gage (gage datum).

Abbreviations

AHPS	Advanced Hydrologic Prediction Service
DEM	digital elevation model
DFIRM	Digital Flood Insurance Rate Map
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HEC–RAS	Hydrologic Engineering Center's River Analysis System
HWM	high-water mark
lidar	light detection and ranging
NWISWeb	National Water Information System Web Interface
NWS	National Weather Service
USGS	U.S. Geological Survey

Flood-Inundation Maps for the Yellow River From River Drive to Centerville Highway, Gwinnett County, Georgia

By Jonathan W. Musser

Abstract

Digital flood-inundation maps for a 16.4-mile reach of the Yellow River in Gwinnett County, Georgia, from 0.5 mile upstream from River Drive to Centerville Highway (Georgia State Route 124) were developed to depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at two U.S. Geological Survey (USGS) streamgages in the mapped area. The maps for the 9.0-mile reach from 0.5 mile upstream from River Drive to Stone Mountain Highway (U.S. Route 78) are referenced to the streamgage Yellow River near Snellville, Ga. (station 02206500), and the maps for the 7.4-mile reach from Stone Mountain Highway to Centerville Highway are referenced to the streamgage Yellow River at Ga. 124, near Lithonia, Ga. (02207120). Real-time stage information from these streamgages can be used with these maps to estimate near real-time areas of inundation. The forecasted peak-stage information for the USGS streamgages Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120), can be used in conjunction with the maps developed for this study to show predicted areas of flood inundation.

A one-dimensional step-backwater model was developed using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC–RAS) software for the Yellow River and was used to compute flood profiles for a 16.4-mile reach of the Yellow River. The hydraulic model was then used to simulate 16 water-surface profiles at 1.0-foot (ft) intervals at the Yellow River near Snellville streamgage and 17 water-surface profiles at 1.0-ft intervals at the Yellow River near Lithonia streamgage. At the Yellow River near Snellville streamgage, the profiles ranged from a stage of 18.0 ft, which is 819.1 ft above the North American Vertical Datum of 1988 (NAVD 88), to a stage of 33.0 ft, which is 834.1 ft above NAVD 88. At the Yellow River near Lithonia streamgage, the profiles ranged from the National Weather Service action stage of 13.0 ft, which is 732.5 ft above NAVD 88, to a stage of 29.0 ft, which is 748.5 ft above NAVD 88. The simulated water-surface profiles were then combined with a geographic information system digital elevation model—derived from light detection and ranging (lidar) data having a 5.0-ft horizontal resolution—to delineate the area flooded at each 1.0-ft interval of stream stage for both streamgages.

Introduction

Gwinnett County is a suburban county in northern Georgia with the cities of Lilburn and Snellville located in the southern part of the county (fig. 1). The estimated population of Gwinnett County was 920,260 in 2017 (U.S. Census Bureau, 2018). Within the study area, the Yellow River flood plain is primarily forest with some areas of woody wetlands. The Yellow River Basin in Gwinnett County is 74.4 percent developed land, 20.4 percent forest, 1.6 percent wetlands, 0.8 percent open water, and 2.8 percent other land, which includes barren, pasture, and shrub/scrub (Homer and others, 2015). The Yellow River generally flows southward through Gwinnett County (fig. 1). Peak flood flows of greater than 7,000 cubic feet per second (ft^3/s) were recorded at the U.S. Geological Survey (USGS) streamgage Yellow River near Snellville, Georgia (station 02206500), in 1948, 1956, 1961, 1990, 1995, and 1998 (the streamgage was not in operation from 2002 to 2017 [table 1]); the largest peak flow was recorded on October 5, 1995, at 12,800 ft^3/s. Peak flood flows of greater than 7,000 ft^3/s were recorded at the USGS streamgage Yellow River at Ga. 124, near Lithonia, Ga. (station 02207120), in 2005, 2009, and 2015; the largest peak flow was recorded on September 22, 2009, at 16,500 ft^3/s (U.S. Geological Survey, 2018).

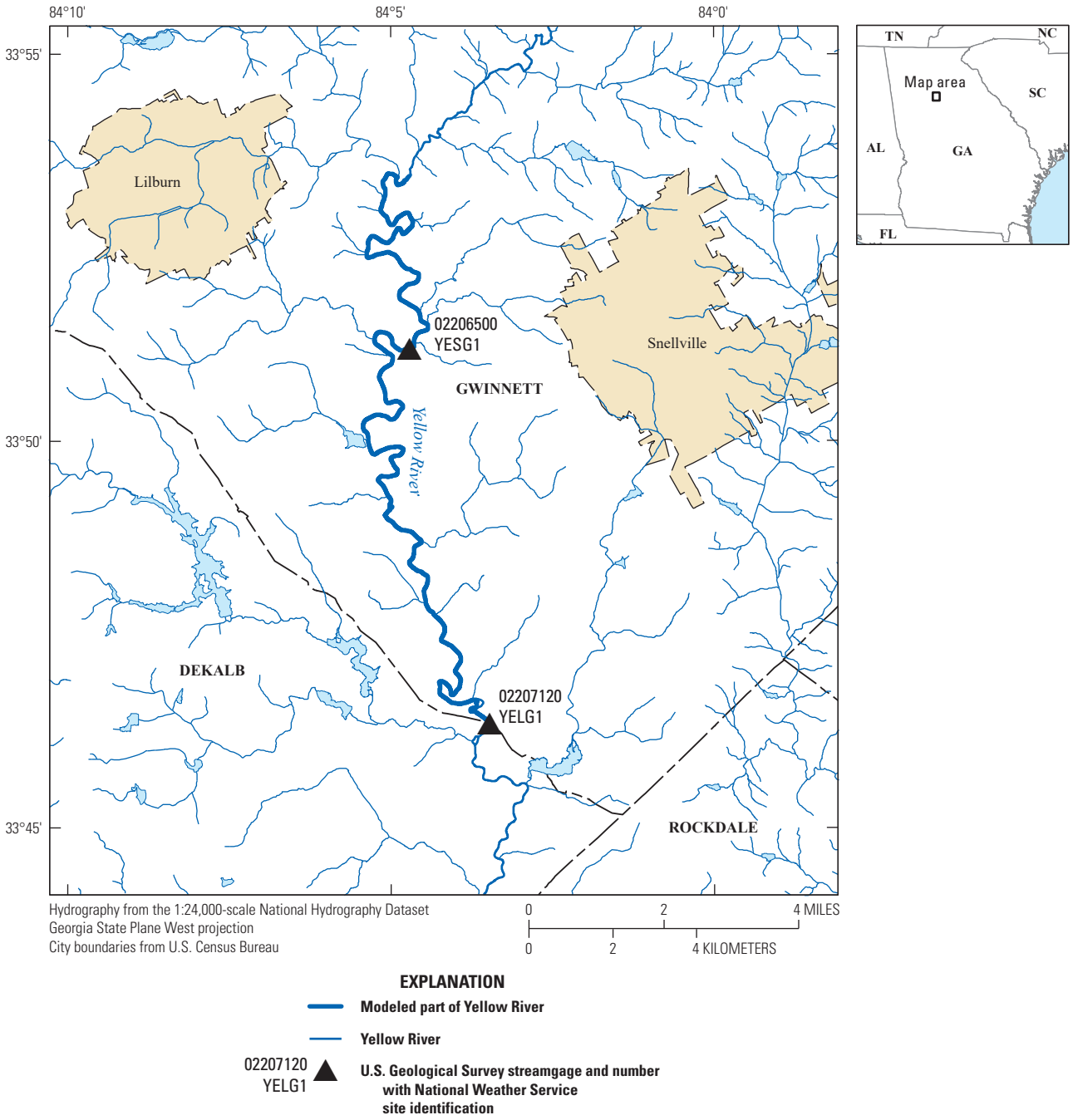


Figure 1. Location of study reach for the Yellow River and locations of U.S. Geological Survey streamgages and National Weather Service forecast sites, Gwinnett County, Georgia.

Gwinnett County officials have historically relied on several information sources to decide how to alert the public and mitigate flood damages along the Yellow River. One source was the Federal Emergency Management Agency (FEMA) Digital Flood Insurance Rate Map (DFIRM) (Federal Emergency Management Agency, 2017). A second source was the USGS streamgages (table 1) Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120). From these sites, current and historical water levels (stage) can be obtained through the USGS National Water Information System Web Interface (NWISWeb; https://doi.org/10.5066/F7P55KJN). Stage is the height of the water surface above an arbitrary datum established at the gage (gage datum). A third source of usable information was the National Weather Service (NWS) Yellow River near Northeast Lithonia streamgage (NWS YELG1; colocated with USGS 02207120) and the NWS Yellow River near Snellville streamgage (NWS YESG1; colocated with USGS 02206500), available through the Advanced Hydrologic Prediction Service (AHPS) web page (https://water.weather.gov/ahps/).

Although USGS real-time stages are useful for residents in the immediate vicinity of a streamgage, the data are of limited use to residents upstream or downstream from the gage because water-surface elevation is not constant along an entire stream channel. Likewise, depth varies locally along stream channels, and FEMA and State emergency management mitigation teams or property owners typically lack information on water depth in areas not near USGS streamgages or NWS flood-forecast points. To help the general public take individual safety precautions and give local officials a tool to help manage emergency flood operations and mitigation efforts, two series of digital flood-inundation maps for a 16.4-mile (mi) reach of the Yellow River were developed by the USGS in cooperation with Gwinnett County, Ga.

Purpose and Scope

This report describes the development of estimated flood-inundation maps for the Yellow River in Gwinnett County, Ga. Inundation maps and other flood-related data are available on the USGS Flood Inundation Mapping Science web page (https://water.usgs.gov/osw/flood_inundation/). Users can select estimated inundation maps at or near (1) the current stage at the USGS streamgage near Snellville, Ga. (02206500), or the USGS streamgage near Lithonia, Ga. (02207120), (2) the NWS forecasted peak stage, or (3) other desired stages at either USGS streamgage.

The study covers a 16.4-mi reach of the Yellow River from 0.5 mi upstream from River Drive to Centerville Highway (Georgia State Route 124) (fig. 2). Two sets of inundation maps were created on the basis of data from the two USGS streamgages within the reach. The first set of inundation maps is for a 9.0-mi reach of the Yellow River from 0.5 mi upstream from River Drive to Stone Mountain Highway (U.S. Route 78) and is based on the streamgage Yellow River near Snellville, Ga. (02206500). The second set of inundation maps is for a 7.4-mi reach of the Yellow River from Stone Mountain Highway to Centerville Highway and is based on the streamgage Yellow River at Ga. 124, near Lithonia, Ga. (02207120).

Development of the flood-inundation maps included (1) analysis of the flow and stage data collected at the two USGS streamgages (table 1); (2) collection of topographic and geometric data for flood plains and bridges; (3) determination of energy-loss factors (roughness coefficients) in the stream channel and flood plain; (4) computation of water-surface profiles using the Hydrologic Engineering Center's River Analysis System (HEC–RAS) computer program, created by the Hydrologic Engineering Center at the U.S. Army Corps of Engineers Institute for Water Resources (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2018); (5) production of two sets of estimated flood-inundation maps based on simulated stream stages at the Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgages, using the geographic information system (GIS) program ArcGIS Desktop (Esri, 2018a); and (6) development of a web interface that links to USGS real-time streamgage information.

Methods

Most methods used here are cited from published reports (Bales and others, 2007; Whitehead and Ostheimer, 2009). If techniques varied substantially because of local hydrologic conditions or available data, the variances are described in detail within this report. Inundation maps for 16 water-surface profiles referenced to the stage and water-surface elevation at the streamgage Yellow River near Snellville, Ga. (02206500), and 17 water-surface profiles referenced to the stage and water-surface elevation at the streamgage Yellow River at Ga. 124, near Lithonia, Ga. (02207120), were produced. The profiles for the Yellow River near Snellville streamgage ranged from a stage of 18.0 feet (ft), which is 819.1 ft above the North American Vertical Datum of 1988 (NAVD 88), to a stage of 33.0 ft, which is 834.1 ft above NAVD 88. The profiles for the Yellow River at Ga. 124, near Lithonia streamgage ranged from the NWS action stage of 13.0 ft, which is 732.5 ft above NAVD 88, to a stage of 29.0 ft, which is 748.5 ft above NAVD 88 and 5.0 ft above major flood stage (National Weather Service, 2018).

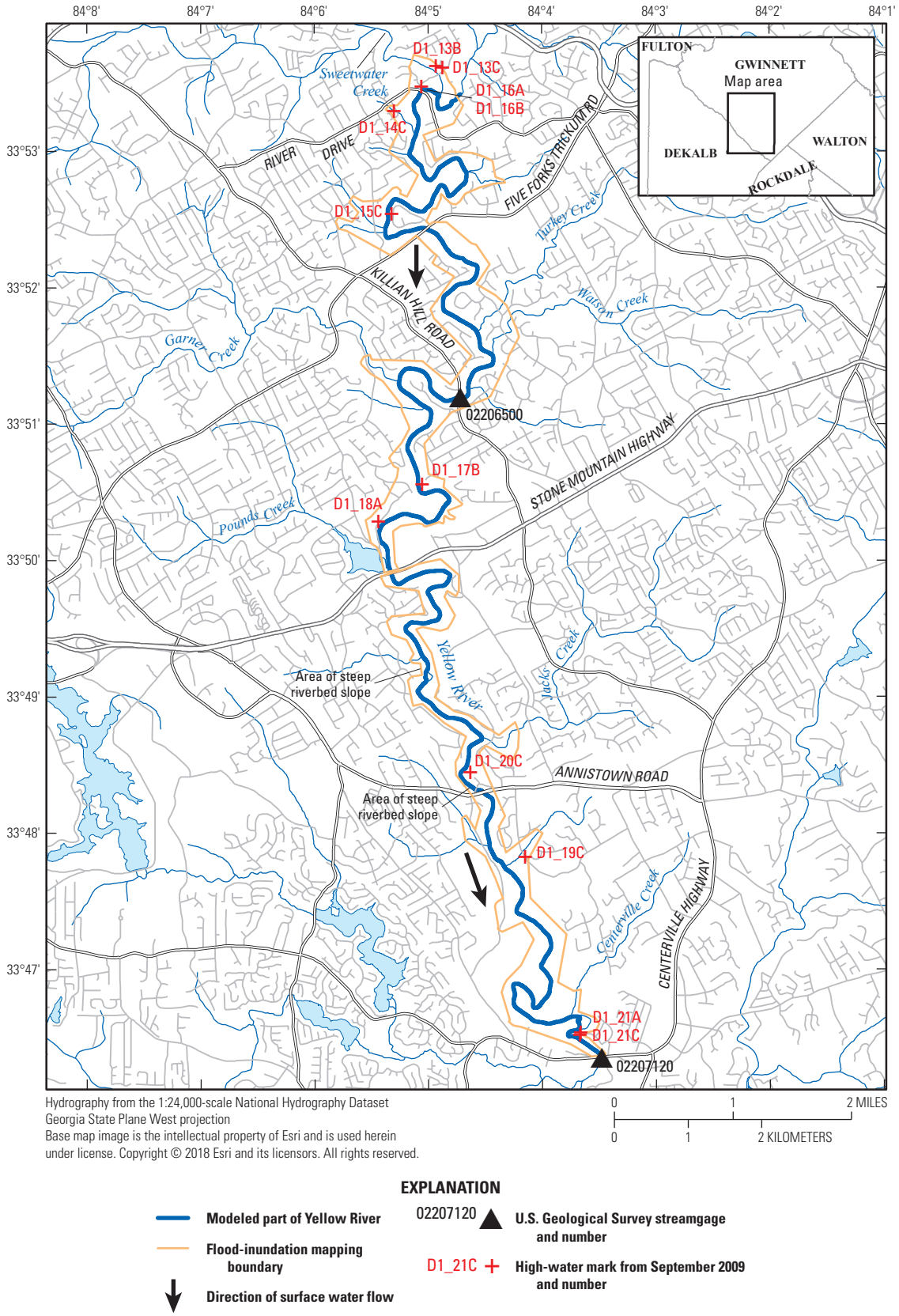


Figure 2. Yellow River bridge crossings, mapped river extent, flood-inundation mapping boundary, high-water marks from September 2009, and direction of surface-water flow, Gwinnett County, Georgia.

Table 1. Site information for selected U.S. Geological Survey streamgages on the Yellow River in Gwinnett County, Georgia.

[Data for this table were compiled from U.S. Geological Survey (2018). USGS, U.S. Geological Survey; ft, foot; ft^3/s, cubic foot per second]

USGS station number (fig. 1)	Station name	Drainage area (square miles)	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Period of record	Maximum recorded stage and corresponding flow at streamgage and date
02206500	Yellow River near Snellville, Ga.	136	33°51'11"	84°04'42"	1943 to 2002 and 2017 to current year (2019)	19.75 ft* 12,800 ft^3/s Oct. 5, 1995
02207120	Yellow River at Ga. 124, near Lithonia, Ga.	161	33°46'20"	84°03'28"	2002 to current year (2019)	27.47 ft 16,500 ft^3/s Sept. 22, 2009

*Stage at a previous gage datum.

Study Area Description

The Yellow River is located in northern Georgia in the Piedmont physiographic province (Clark and Zisa, 1976). The drainage area of the Yellow River is 55.1 square miles (mi^2) at the upstream end of the study reach, upstream from where Sweetwater Creek joins with the Yellow River. The drainage area of Sweetwater Creek where it joins the Yellow River is 70.7 mi^2. The drainage area of the Yellow River is 136 mi^2 at the Yellow River near Snellville, Ga. (02206500), streamgage, 148 mi^2 at Stone Mountain Highway, and 161 mi^2 at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage, which is at the downstream end of the study reach (fig. 2). The study reach of the Yellow River is located entirely in Gwinnett County, Ga. (fig. 1). The Yellow River generally flows south through Gwinnett County between the cities of Lilburn and Snellville and flows into DeKalb County near the lower end of the study reach. The major tributaries flowing into the Yellow River along the study reach are Sweetwater Creek, Turkey Creek, Watson Creek, Garner Creek, Pounds Creek, Jacks Creek, and Centerville Creek. The Yellow River Basin terrain is gently rolling with stream valleys that are fairly deep and narrow and lie 100 to 200 ft below the narrow, rounded stream divides (Clark and Zisa, 1976). The Yellow River study reach is about 16.4 mi long and is fairly consistent in slope and width, except for two areas of steep riverbed slope downstream from Stone Mountain Highway. The average channel slope over the entire reach is about 6.6 feet per mile. The land contiguous to the study reach is classified as a mix of developed and forest, with the immediate flood plain area being mostly forest. Between Annistown Road and Centerville Highway, the land is mostly classified as forest (Homer and others, 2015). Within the study reach, six road bridges cross the main channel and the adjacent flood plain (fig. 2).

Previous Studies

Similar studies that provide flood-inundation maps for a range of stream stages in Georgia were completed by the USGS in Albany, Ga., for the Flint River (Musser and Dyar, 2007); Atlanta, Ga., for Peachtree Creek (Musser, 2012a); Gwinnett County, Ga., for Suwanee Creek (Musser, 2012b); Cobb County, Ga., for Sweetwater Creek (Musser, 2012c); Alpharetta and Roswell, Ga., for Big Creek (Musser, 2015a); DeKalb County, Ga., for South Fork Peachtree Creek (Musser, 2015b); and Lowndes County, Ga., for the Withlacoochee River (Musser, 2018). The methods for the Flint River model used a finite-element, two-dimensional model, which differed from those used to develop the Yellow River model. The methods used for the Peachtree Creek, Suwanee Creek, Sweetwater Creek, Big Creek, South Fork Peachtree Creek, and the Withlacoochee River models were similar to those used to develop the Yellow River model. Additionally, the current—as of 2019—DFIRM for Gwinnett County, Ga., was published on June 4, 2017 (Federal Emergency Management Agency, 2017), but it was not used in this study, other than to define a general area of the flood plain for modeling purposes.

Constructing Water-Surface Profiles

The water-surface profiles used to produce the 33 flood-inundation maps in this study were computed using HEC–RAS, version 5.0.3 (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2018). HEC–RAS is a one-dimensional, step-backwater model used for simulation of water-surface profiles with gradually varied, steady-state, or unsteady-state flow computation options. Inputs into the HEC–RAS model include cross sections representing the land surface, bridge geometry, roughness coefficients, and multiple flow values. For this study, the HEC–RAS analysis was completed by using the steady-state flow computation option.

Hydrologic and Steady-Flow Data

The hydrologic network in the study area consists of two USGS streamgages operated within the study reach (fig. 1; table 1). Water level (stage) is measured continuously at each site, and continuous records of streamflow are computed. Stage is the height of the water surface above an arbitrary datum established at the gage (gage datum). All water-surface elevations are referenced to NAVD 88. The streamgages are equipped with satellite radio transmitters that allow data to be transmitted routinely and made available online within 1 hour of collection. The streamgages are also equipped with recording rain gages. Steady-flow data for the study reach were calibrated in the model using the rating curve (stage-streamflow or stage-discharge relation) at the streamgages Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120). Downstream boundary conditions in the model were set using the rating curve at the Yellow River near Lithonia streamgage.

The flows at Yellow River near Snellville, Ga. (02206500), were used for the reach from 0.5 mi upstream from River Drive to Stone Mountain Highway. The flows at Yellow River at Ga. 124, near Lithonia, Ga. (02207120), were used for the reach from Stone Mountain Highway to Centerville Highway. Flow-change points were added into the HEC–RAS model at stream tributaries in each reach where the drainage area increased abruptly. The ratio of the drainage area at these points, with the drainage area at each streamgage raised to the power of 0.54 multiplied by the flow at the streamgage, is the model flow at these points (Gotvald and Knaak, 2011). Tables 2 and 3 show model flow values for selected locations. The Yellow River near Snellville, Ga. (02206500), streamgage was operational and at a different datum from 1943 to 2002. In 2017, the current streamgage (as of 2019) was installed on a new bridge with a different structure, which changed the out-of-bank topography in the flood plain.

Table 2. Stages (and water-surface elevations) with corresponding streamflow estimates for selected simulated water-surface profiles at selected locations for the Yellow River near Snellville, Georgia (02206500), streamgage.

Location of streamflow estimate for the Yellow River	Stage, in feet above gage datum (Water-surface elevation, in feet above North American Vertical Datum of 1988)								
	18.0 (819.1)	20.0 (821.1)	22.0 (823.1)	24.0 (825.1)	26.0 (827.1)	28.0 (829.1)	30.0 (831.1)	32.0 (833.1)	33.0 (834.1)
	Streamflow, in cubic feet per second								
0.5 miles above River Drive	2,800	3,610	4,430	5,320	6,270	7,280	8,360	9,520	10,100
Below Sweetwater Creek	4,380	5,640	6,930	8,310	9,800	11,400	13,100	14,900	15,700
Below Turkey Creek	4,490	5,780	7,100	8,520	10,000	11,700	13,400	15,300	16,100
Near Snellville streamgage (02206500)	4,580	5,890	7,230	8,680	10,200	11,900	13,700	15,600	16,400
Below Garner Creek	4,690	6,030	7,410	8,890	10,500	12,200	14,000	15,900	16,800

Table 3. Stages (and water-surface elevations) with corresponding streamflow estimates for selected simulated water-surface profiles at selected locations for the Yellow River at Georgia 124, near Lithonia, Georgia (02207120), streamgage.

Location of streamflow estimate for the Yellow River	Stage, in feet above gage datum (Water-surface elevation, in feet above North American Vertical Datum of 1988)								
	13.0 (732.5)	15.0 (734.5)	17.0 (736.5)	19.0 (738.5)	21.0 (740.5)	23.0 (742.5)	25.0 (744.5)	27.0 (746.5)	29.0 (748.5)
	Streamflow, in cubic feet per second								
Below Pounds Creek	5,070	6,410	7,770	9,230	10,800	12,400	14,100	15,900	17,700
Below Jacks Creek	5,220	6,590	8,000	9,500	11,100	12,800	14,500	16,400	18,200
Near Lithonia streamgage (02207120)	5,320	6,720	8,150	9,680	11,300	13,000	14,800	16,700	18,600

Topographic-Bathymetric Data

Two HEC–RAS models for the Yellow River were obtained from Gwinnett County. Parts of the models were combined to create one model for the study reach. Additional cross sections were added to the USGS model where the distance between two cross sections was more than 500 ft in the original model and where the original cross sections were not long enough to extend across the entire flood plain. The in-channel elevations of these new cross sections were calculated by extracting the in-channel part of an original cross section and lowering or raising it on the basis of the channel slope between two adjacent original cross sections. The overbank elevations of the new cross sections were calculated from a raster elevation dataset. The source for the raster elevation was a 5.0-ft by 5.0-ft cell raster digital elevation model (DEM) derived from light detection and ranging (lidar) data collected by Gwinnett County in 2015. The additional cross sections for HEC–RAS were created from the DEM using the HEC–GeoRAS software (Esri, 2018b) within ArcGIS. HEC–GeoRAS is a set of tools developed for ArcGIS to translate data to and from HEC–RAS. The HEC–RAS model covers a 16.4-mi reach of the Yellow River from 0.5-mi upstream from River Drive to Centerville Highway. Downstream stream lengths were computed within HEC–GeoRAS.

Various drainage modifying structures (bridges, culverts, roadway embankments, levees, and dams) in and along the stream can affect water-surface elevations during floods. To account for these structural features, the structural dimensions of six bridges were included in the model. From upstream to downstream on the Yellow River, the bridges are River Drive, Five Forks Trickum Road, Killian Hill Road, Stone Mountain Highway, Annistown Road, and Centerville Highway (fig. 2). The geometries of these bridges were already present in the HEC–RAS model; however, the bridges on Five Forks Trickum Road and Killian Hill Road had changed since the model was created. To account for the changes, the structural dimensions of these two bridges were measured and surveyed in the field. Using data obtained from the surveys, the bridges were replaced in the HEC–RAS model. A footbridge is located just upstream from the Stone Mountain Highway bridge, but on the basis of visual inspection, it was determined that the bottom of the footbridge is higher than the bottom of the Stone Mountain Highway bridge and there are no piers in the river to impede flow. The footbridge was not included in the model except to adjust the ineffective flow areas to account for the change in topography on the ends of the footbridge. A detailed description of the methods used to acquire and process the topographic and bathymetric data is provided in Bales and others (2007).

Energy-Loss Factors

Field observations and land-cover data were used to select initial (precalibration) Manning's roughness coefficients (*n* values) for energy (friction) loss calculations (Coon, 1998). The final Manning's *n* values ranged from 0.04 to 0.11 for the main channel. The Manning's *n* values ranged from 0.06 to 0.17 for the overbank areas modeled in the reach.

Model Calibration and Performance

The hydraulic model was calibrated using the most current (2018) stage-discharge relations at the Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgages in conjunction with adjusting the Manning's *n* value for the channel and overbank areas until the results of the hydraulic computations closely agreed with the expected water-surface elevations at the Yellow River near Snellville, Ga. (02206500), streamgage and high-water marks (HWMs) from September 2009, which were obtained from Gwinnett County (fig. 2).

The initial calibration of the model was to the HWMs from September 2009. The Manning's *n* values were adjusted until the water-surface elevations closely matched the elevations from the HWMs. Many of the HWMs were collected within 300 ft of other HWMs, and some recorded elevations were not consistent with nearby HWMs. When inconsistencies were found, the description and quality of the HWMs were evaluated to determine which HWMs would be used for calibration. Of the 23 HWMs along the study reach, 12 were used for the model calibration.

The initial calibration of the upstream end of the model to the three HWMs near River Drive resulted in model elevations between 0.9 and 1.4 ft lower than the HWMs for the same Manning's *n* values used in other parts of the model. Table 4 shows the differences between the HWM elevations and the modeled water-surface elevations. Because the Yellow River near Snellville, Ga. (02206500), streamgage was not operating during August 2009, the flows used in the model for this calibration are based on the August 2009 peak flow at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage. The rainfall radar estimate downloaded from the NWS on September 23, 2009, for September 18–22, 2009 (fig. 3), shows higher rainfall totals in the Yellow River Basin upstream from the Yellow River near Snellville, Ga. (02206500), streamgage than downstream from the streamgage. Because of this rainfall distribution, the actual flow in the Yellow River near River Drive during the September 2009 flood event is likely higher than what would be predicted using the drainage area ratio from Gotvald and Knaak (2011). To test the calibration, a constant flow of 17,100 ft^3/s was used in the model. This flow corresponds to the peak gage height at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage in September 2009 based on the current rating. This flow value is larger than the 16,500 ft^3/s peak that was recorded in 2009 because the streamgage rating changed between 2009 and 2019 and the current rating is used in the model (established September 30, 2013). With this constant flow, the modeled water-surface

elevations at the HWMs near River Drive ranged from 0.3 to 0.7 ft higher than the elevation of the HWMs. Thus, the actual streamflow in the Yellow River near River Drive during the September 2009 flood event was likely between the 15,300 ft^3/s determined by the drainage area ratio method and the 17,100 ft^3/s peak at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage.

On the basis of the calibration of the model to the September 2009 HWMs, the simulated flow in the model at the Yellow River near Snellville, Ga. (02206500), streamgage was 15,600 ft^3/s and the water-surface elevation was 833.2 ft, which corresponds to a streamgage height of 32.1 ft. This flow is higher than any flow previously recorded at the streamgage, so the rating curve was adjusted to this simulated streamgage height and flow and extended with a straight-line extension to a streamgage height of 33.0 ft.

After the model was calibrated to the September 2009 HWMs, the model was further calibrated to various stages and flows by adjusting the Manning's *n* values for the channel. For the 9.0-mi reach from 0.5 mi upstream from River Drive to Stone Mountain Highway, the flow values in the model were based on the Yellow River near Snellville, Ga. (02206500), streamgage and calibrated to the rating curve at that streamgage. Table 5 shows the modeled water-surface elevations and the water-surface elevations from the rating curve at the Yellow River near Snellville, Ga. (02206500), streamgage for this section of the model. For the 7.4-mi reach between Stone Mountain Highway and Centerville Highway, the flow values in the model were based on flows at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage. These flow values were extended upstream, using the drainage area ratio method, to the Yellow River near Snellville, Ga. (02206500), streamgage, where they were used for calibration to the water-surface elevations corresponding to the flows in the model. Table 6 shows the modeled water-surface elevations and the water-surface elevations from the rating curve at the Yellow River near Snellville, Ga. (02206500), streamgage.

Development of Water-Surface Profiles

Profiles were developed for 16 stages at 1.0-ft intervals between 18.0 and 33.0 ft referenced to the Yellow River near Snellville, Ga. (02206500), streamgage. Streamflows corresponding to profiles at water-surface elevations were obtained from the most current (2018) rating curve in use at the streamgage (rating no. 14.0, effective December 20, 2017; U.S. Geological Survey, 2018) for the Yellow River between 0.5 mi upstream from River Drive to Stone Mountain Highway. Profiles were developed for 17 stages at 1.0-ft intervals between 13.0 and 29.0 ft referenced to the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage. Streamflows corresponding to profiles at water-surface elevations were obtained from the most current (2018) rating curve in use at the streamgage (rating no. 8.0, effective December 14, 2016; U.S. Geological Survey, 2018). The streamflow values for all profiles were adjusted along the Yellow River, primarily at junctions with smaller tributaries.

Simulated stage and streamflow estimates for selected locations and profiles are provided in tables 2 and 3. The downstream boundary conditions were set as the water-surface elevation based on the stage at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage. All streamflow and water-elevation data used for the model are available in U.S. Geological Survey (2018).

Flood-Inundation Mapping

Flood-inundation GIS layers were created on the basis of simulated water-surface elevations at the Yellow River near Snellville, Ga. (02206500; NWS designation YESG1), streamgage for each 1.0-ft interval in stage from 18.0 ft to 33.0 ft and the Yellow River at Ga. 124, near Lithonia, Ga. (02207120; NWS designation YELG1), streamgage for each 1.0-ft interval in stage from 13.0 ft to 29.0 ft. A polygon layer showing the inundated area and a raster showing the depth of inundation were created. Additionally, boundary polygon layers showing the extent of the inundation area were created for both streamgages. The layers were created in ArcGIS by exporting a 5.0-ft by 5.0-ft cell depth raster from HEC–RAS and selecting all cells with a depth greater than 0.05 ft. The resulting polygon inundated area was cleaned up by deleting all polygons smaller than 400 square feet (ft^2) and filling all holes (non-inundated areas) in the inundated layer smaller than 400 ft^2. Any polygon pieces not directly connected to the river were deleted, except where there was a documented culvert or bridge. Although these inundated areas separated by a culvert or bridge were included in the inundation maps, there is a large amount of uncertainty in these areas because of the interaction of the flow through the culvert or bridge and backwater from the Yellow River. Thus, these areas are marked as "Area of uncertainty" on the online Flood Inundation Mapper. Also, the tributaries of the Yellow River, which are shown as inundated, are a result of backwater effects from the Yellow River. At the lower flow values of the Yellow River, the tributaries may not be shown as inundated, but it is likely water is still flowing in them. Boundary layers were created to limit the extent of the inundation polygons and depth rasters to the Yellow River from 0.5-mi upstream from River Drive to Stone Mountain Highway and from Stone Mountain Highway to Centerville Highway. Though the depth rasters are rounded to the nearest 0.1 ft, the resulting inundation maps have a vertical accuracy of about 0.5 ft.

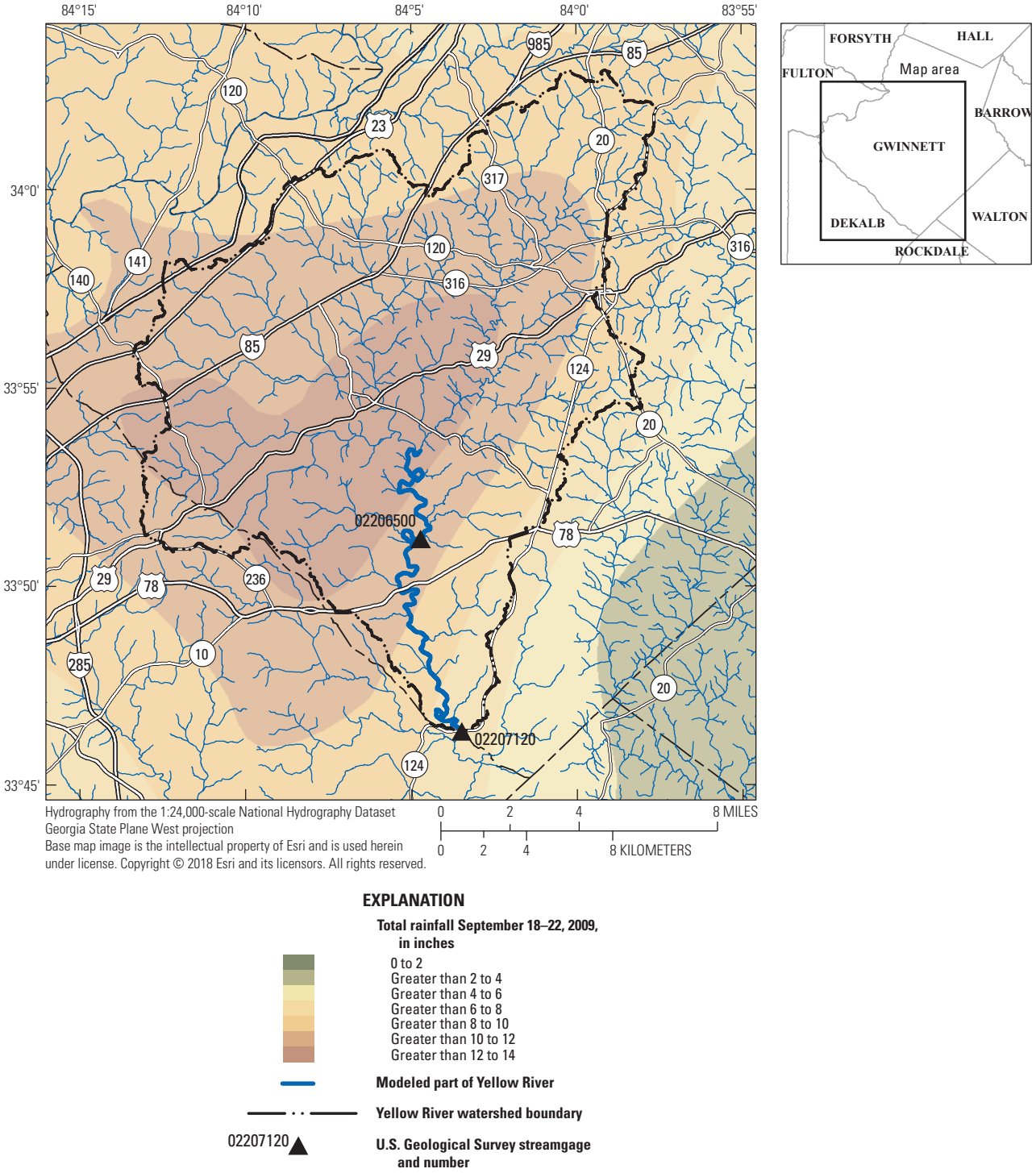


Figure 3. National Weather Service radar rainfall estimates for September 18–22, 2009, for the Yellow River Basin, Gwinnett County, Georgia.

Table 4. Comparison of high-water mark (HWM) elevations and modeled water-surface elevations on the Yellow River, Gwinnett County, Georgia, for simulated and constant flow.

[Elevation is listed in feet above the North American Vertical Datum of 1988. ft, foot; —, no value]

Gwinnett County HWM identification	HWM type	HWM quality[1]	HWM elevation (ft)	Modeled water-surface elevation for simulated flow (ft)	Elevation difference (ft)	Modeled water-surface elevation for constant flow (ft)	Elevation difference (ft)
D1_21C	Debris	Moderate	748.5	748.6	0.1	—	—
D1_21A	Debris line	Good	748.9	748.7	−0.2	—	—
D1_19C	Mud line	Good	762.2	762.0	−0.2	—	—
D1_20C	Debris line	Moderate	781.6	781.9	0.3	—	—
D1_18A	Mud line	Good	818.3	818.3	0.0	—	—
D1_17B	Mud line	Moderate	823.4	823.1	−0.3	—	—
D1_15C	Debris	Good	846.2	845.9	−0.3	—	—
D1_14C	Mud line	Moderate	854.4	853.5	−0.9	855.1	0.7
D1_16A and D1_16B	Water line	Good	856.5	855.1	−1.4	856.8	0.3
D1_13B and D1_13C	Debris	Good	856.6	855.3	−1.3	857.0	0.4

[1]High-water mark quality is from Gwinnett County and is not representative of U.S. Geological Survey quality standards.

Table 5. Comparison of modeled water-surface elevations and rating curve water-surface elevations at the Yellow River near Snellville, Georgia (02206500), streamgage, for the 9.0-mile reach of the Yellow River from 0.5-mile upstream from River Drive to Stone Mountain Highway, Gwinnett County, Ga.

[Stage is listed in feet above the gage datum. Elevation is listed in feet above the North American Vertical Datum of 1988. ft, foot]

Stage at Yellow River near Snellville, Ga. (02206500) (ft)	Modeled water-surface elevation at Yellow River near Snellville, Ga. (02206500) (ft)	Rating curve water-surface elevation at Yellow River near Snellville, Ga. (02206500) (ft)	Elevation difference (ft)
18.0	819.1	819.6	0.5
19.0	820.1	820.5	0.4
20.0	821.1	821.3	0.2
21.0	822.1	822.1	0.0
22.0	823.1	822.8	−0.3
23.0	824.1	824.5	0.4
24.0	825.1	825.1	0.0
25.0	826.1	825.8	−0.3
26.0	827.1	827.3	0.2
27.0	828.1	828	−0.1
28.0	829.1	829.4	0.3
29.0	830.1	830.0	−0.1
30.0	831.1	831.3	0.2
31.0	832.1	831.9	−0.2
32.0	833.1	833.2	0.1
33.0	834.1	833.7	−0.4

Table 6. Comparison of modeled water-surface elevations and rating curve water-surface elevations at the Yellow River near Snellville, Georgia (02206500), streamgage, based on stage and flows at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage for the 7.4-mile reach of the Yellow River from Stone Mountain Highway to Centerville Highway, Gwinnett County, Ga.

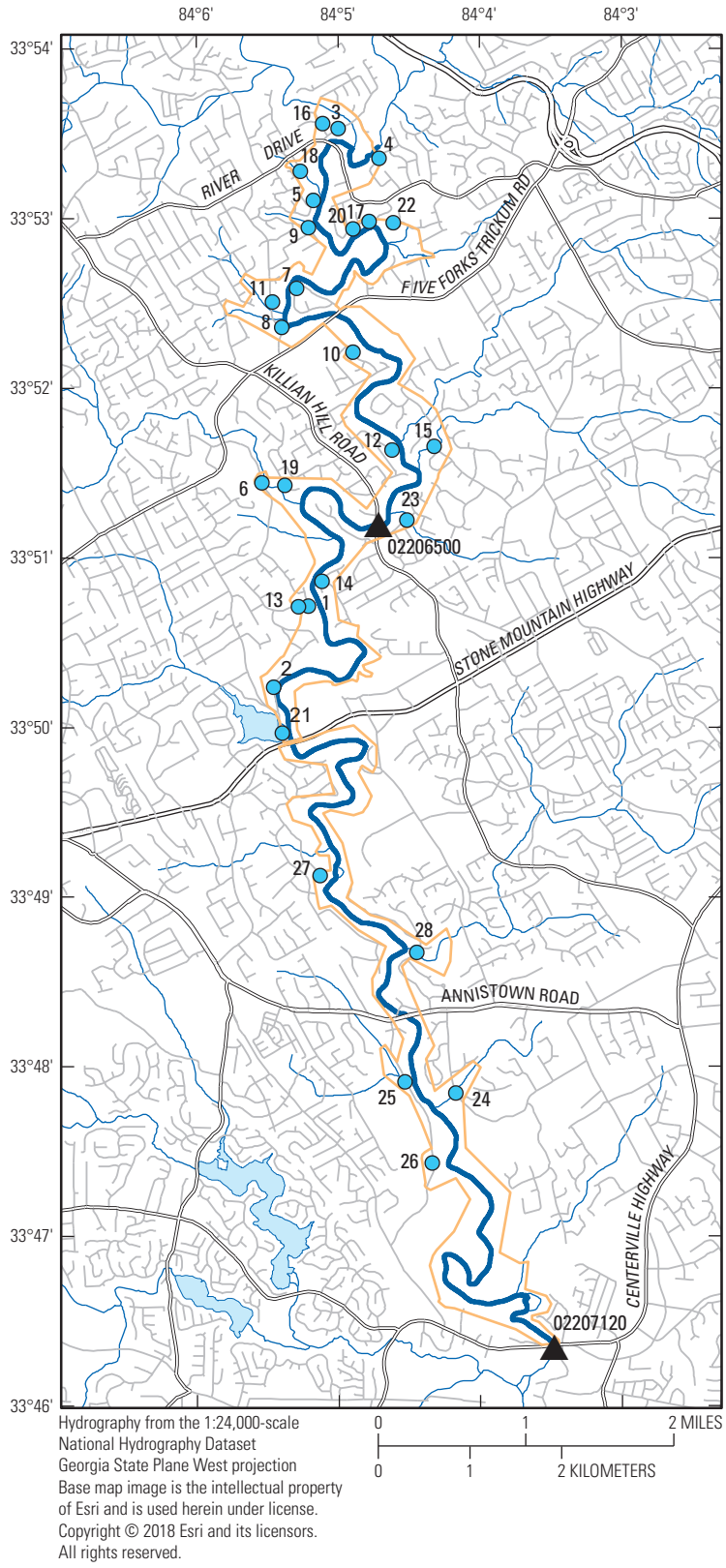
[Stage is listed in feet above the gage datum. Elevation is listed in feet above the North American Vertical Datum of 1988. ft, foot]

Stage at Yellow River at Ga. 124, near Lithonia, Ga. (02207120) (ft)	Modeled water-surface elevation at Yellow River near Snellville, Ga. (02206500) (ft)	Rating curve water-surface elevation at Yellow River near Snellville, Ga. (02206500) (ft)	Elevation difference (ft)
13.0	819.6	819.9	0.3
14.0	820.5	820.8	0.3
15.0	821.5	821.6	0.1
16.0	821.7	822.3	0.6
17.0	822.4	823	0.6
18.0	824.3	824.6	0.3
19.0	825.3	825.3	0.0
20.0	826.3	825.9	−0.4
21.0	827.2	827.4	0.2
22.0	828.2	828	−0.2
23.0	829.1	829.4	0.3
24.0	830	830.0	0.0
25.0	830.9	831.2	0.3
26.0	831.8	831.7	−0.1
27.0	832.8	832.9	0.1
28.0	833.6	833.5	−0.1
29.0	834.7	834.1	−0.6

The final step in the creation of the inundation polygons was to remove the area of the non-inundated bridges from the inundation polygon. None of the simulated stages inundated the six major roads crossing the Yellow River: River Drive, Five Forks Trickum Road, Killian Hill Road, Stone Mountain Highway, Annistown Road, and Centerville Highway, but some of the flows did reach the low part of the bridge deck at three bridges. For the Yellow River near Snellville, Ga. (02206500), streamgage, the River Drive bridge was reached at a stage of 30 ft, and the Five Forks Trickum Drive bridge was reached at a stage of 31 ft. For the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage, the Stone Mountain Highway bridge was reached at a stage of 23 ft and was nearly overtopped at 29 ft. Numerous small streets were inundated at various simulated stages. The locations of these streets are shown in figure 4 along with the stage at which the streets would be inundated according to the model. The 33 inundation polygons, 33 depth rasters, 2 boundary polygons, and all associated metadata are available for download in Musser (2019).

Yellow River, Georgia, Flood-Inundation Maps on the Internet

The USGS Flood Inundation Mapping Program website (https://water.usgs.gov/osw/flood_inundation/) was established by the USGS to provide estimated flood-inundation information to the public. The GIS layers from this study are viewable on the Flood Inundation Mapper (available from the above link) over selected base maps linked from the website. The GIS layers can also be downloaded in commonly used electronic file formats. Each stream reach displayed on the website contains links to the NWISWeb graphs of the current stage and streamflow at the streamgages Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120), to which the inundation maps are referenced. A link is also provided for the NWS AHPS web page (https://water.weather.gov/ahps/). The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding concerning individual structures so preparations for flooding and decisions about emergency responses can be completed efficiently.

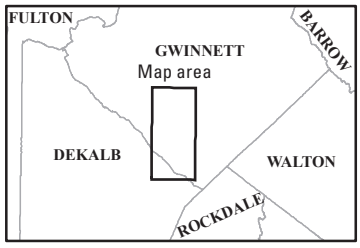


Streets inundated by the hydraulic model based on the Yellow River near Snellvile, Georgia (02206500), streamgage

Map identification number	Street name	Stage of first inundation, in feet above gage datum
1	Rolling River Drive	18
2	Riverside Drive	20
3	Connemara Trace	22
4	Rae Place	23
5	Tamer Lane	23
6	Oleander Drive	24
7	East River Bend Drive	25
8	Tom Smith Road	25
9	Finger Creek	27
10	Gwens Trail	27
11	Yellow River Water Reclamation Driveway	27
12	Larkview Drive	28
13	Rangewood Drive	28
14	River Club Drive	28
15	Rivermist Drive	28
16	Silver Creek Run	28
17	Vinyard Way	29
18	Gavenwood Drive	31
19	Timber Glen Court	31
20	Vinyard Way	31
21	Lake Lucerne Road	32
22	Sean Way	32
23	Yellowstone Way	32

Streets inundated by the hydraulic model based on the Yellow River near Georgia 124, near Lithonia Georgia (02207120), streamgage

24	Spain Road	18
25	Juhan Road	21
26	Juhan Road	22
27	Carlene Way	24
28	Moorings Parkway	27



EXPLANATION

- Modeled part of Yellow River
- Flood-inundation mapping boundary
- 02207120 — U.S. Geological Survey streamgage and number
- 26 — Location of inundated street and map identification number

Figure 4. Locations of streets inundated by the hydraulic model of the Yellow River, Gwinnett County, Georgia.

Disclaimer For Flood-Inundation Maps

Inundated areas shown should not be used for navigation, regulatory, permitting, or other legal purposes. The USGS provides these maps "as-is" for use as quick-reference emergency planning tools but assumes no legal liability or responsibility resulting from the use of this information.

Uncertainties and Limitations Regarding Use of Flood-Inundation Maps

The flood boundaries shown were estimated on the basis of water stages and streamflows at the USGS streamflow gaging stations (Yellow River near Snellville, Ga. [02206500], or Yellow River at Ga. 124, near Lithonia, Ga. [02207120]), steady-state hydraulic modeling (assuming unobstructed flow), and a DEM. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing in March 2018. Unique meteorological factors (timing and distribution of storms) could cause actual streamflows along the modeled reach to vary from those assumed during a flood, which may lead to deviations from the water-surface elevations and inundation boundaries shown. Additional areas could be flooded due to unanticipated backwater from major tributaries along the main stem or localized debris- or ice-jams. Inundated areas shown should not be used for navigation, regulatory, permitting, or other legal purposes. Although the USGS intends to make this server available 24 hours a day, 7 days a week, timely delivery of data and products from this server through the internet is not guaranteed. The USGS provides these maps "as-is" for use as quick-reference emergency planning tools but assumes no legal liability or responsibility resulting from the use of this information.

If this series of flood-inundation maps is to be used in conjunction with NWS river forecasts, the user should be aware that additional uncertainties may be inherent or factored into NWS forecast procedures. The NWS uses river forecast models to estimate the quantity and timing of water flowing through selected river reaches in the United States. These forecast models (1) estimate the amount of runoff generated by a precipitation event, (2) compute how the water moves downstream, and (3) predict the flow and stage (water-surface elevation) for the river at a given location (AHPS forecast point) throughout the forecast period (3 to 5 days, at 6-hour intervals in many locations). For information on AHPS forecasts, please visit the NWS Precipitation and River Forecasting overview web page (https://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf).

Summary

A series of estimated geographic information system (GIS) flood-inundation layers was developed by the U.S. Geological Survey (USGS), in cooperation with Gwinnett County, Georgia, for a 16.4-mile (mi) reach of the Yellow River, which includes a 9.0-mi reach from 0.5 mi upstream from River Drive to Stone Mountain Highway (U.S. Route 78) and a 7.4-mi reach from Stone Mountain Highway to Centerville Highway (Georgia State Route 124). These GIS flood-inundation layers, available at the USGS Flood Inundation Mapping Program website, in conjunction with the real-time stage data from the USGS streamgages Yellow River near Snellville, Ga. (02206500), and Yellow River at Ga. 124, near Lithonia, Ga. (02207120), and National Weather Service flood-stage forecasts, can help the general public take individual safety precautions and provide local officials with a tool for managing emergency flood operations and flood-mitigation efforts.

The GIS flood-inundation layers were developed using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC–RAS) computer program to compute water-surface profiles and delineate estimated flood-inundation areas for selected stream stages. The layers show estimated flood-inundation areas overlain on selected base maps of the upper 9.0-mi reach of the study area for 1.0-foot (ft) increments of stage between 18.0 and 33.0 ft (water-surface elevation of 819.1 to 834.1 ft above the North American Vertical Datum of 1988 [NAVD 88]) at the Yellow River near Snellville, Ga. (02206500), streamgage and the lower 7.4-mi reach for 1.0-ft increments of stage between 13.0 and 29.0 ft (water-surface elevation of 732.5 to 748.5 ft above NAVD 88) at the Yellow River at Ga. 124, near Lithonia, Ga. (02207120), streamgage.

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Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Reston and Sacramento Publishing
Service Centers

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20195009