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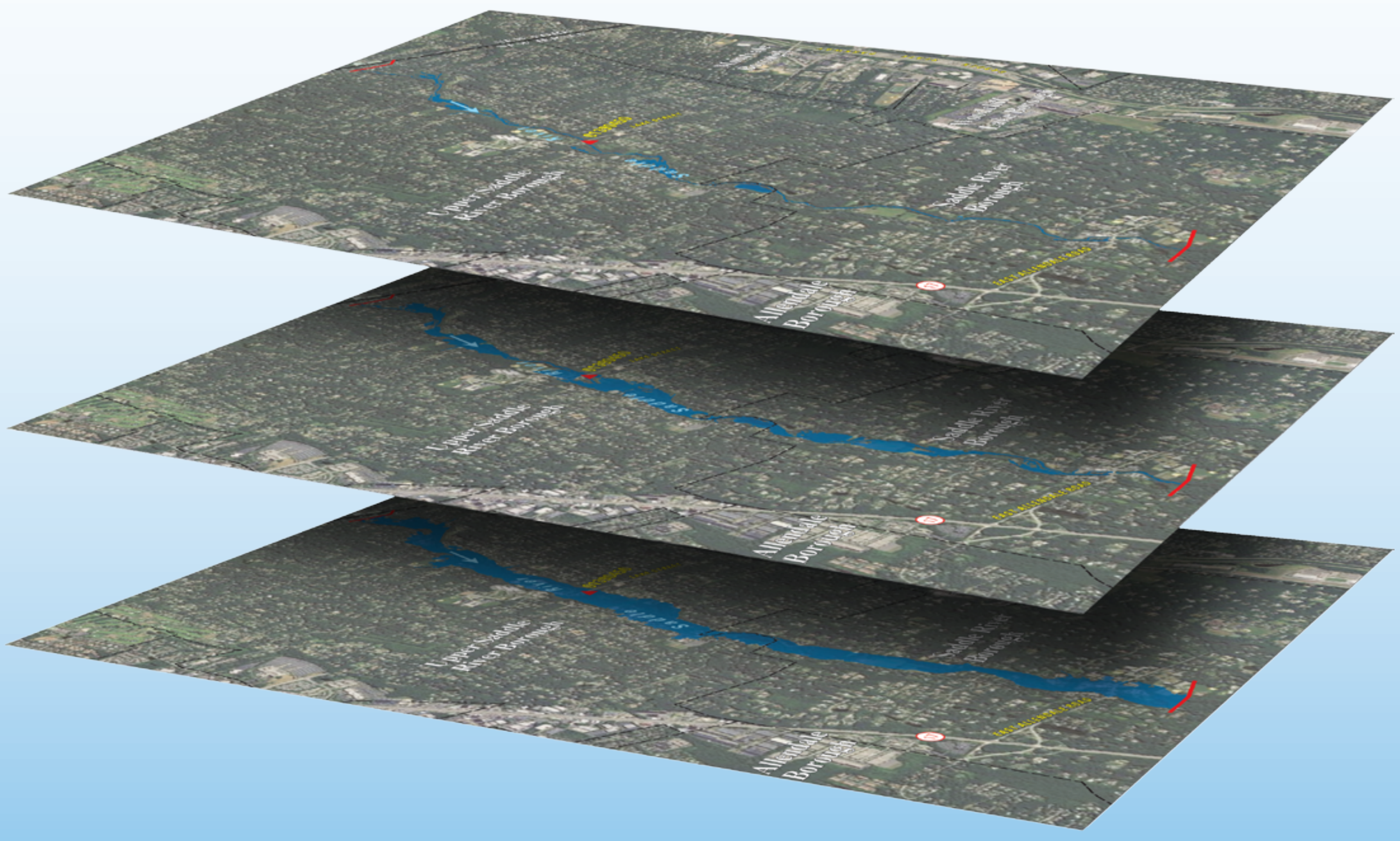
Flood-Inundation Maps for the Saddle River from Upper Saddle River Borough to Saddle River Brorough, New Jersey, 2013



Pamphlet to accompany

Scientific Investigations Map 3262

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

Cover. Illustration showing simulated floods corresponding to a gage height of 3.0, 4.5, and 6.5 feet at the U.S. Geological Survey streamgage 01390450 Saddle River at Upper Saddle River, New Jersey.

Flood-Inundation Maps for the Saddle River from Upper Saddle River Borough to Saddle River Borough, New Jersey, 2013

By Kara M. Watson and Heidi L. Hoppe

Prepared in cooperation with the
New Jersey Department of Environmental Protection

Pamphlet to accompany
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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Acknowledgments

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(Each sheet is available for download in PDF. For links, see http://pubs.usgs.gov/sim/3262/.)

Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
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)

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).

Flood-Inundation Maps for the Saddle River from Upper Saddle River Borough to Saddle River Borough, New Jersey, 2013

By Kara M. Watson and Heidi L. Hoppe

Abstract

Digital flood-inundation maps for a 4.1-mile reach of the Saddle River from 0.6 miles downstream from the New Jersey-New York State boundary in Upper Saddle River Borough to 0.2 miles downstream from the East Allendale Road bridge in Saddle River Borough, New Jersey, were created by the U.S. Geological Survey (USGS) in cooperation with the New Jersey Department of Environmental Protection (NJDEP). The inundation maps, which can be accessed through the USGS Flood Inundation Mapping Science Web site at http://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding corresponding to select water levels (stages) at the USGS streamgage 01390450, Saddle River at Upper Saddle River, New Jersey. Current conditions for estimating near real-time areas of inundation using USGS streamgage information may be obtained on the Internet at http://waterdata.usgs.gov/nwis/uv?site_no=01390450. The National Weather Service (NWS) forecasts flood hydrographs at many places that are often collocated with USGS streamgages. NWS-forecasted peak-stage information may be used in conjunction with the maps developed in this study to show predicted areas of flood inundation.

In this study, flood profiles were computed for the stream reach by means of a one-dimensional step-backwater model. The model was calibrated by using the most current stage-discharge relations (in effect March 2013) at USGS streamgage 01390450, Saddle River at Upper Saddle River, New Jersey, and documented high-water marks from recent floods. The hydraulic model was then used to determine eight water-surface profiles for flood stages at 0.5-foot (ft) intervals referenced to the streamgage datum, North American Vertical Datum of 1988 (NAVD 88), and ranging from bankfull, 0.5 ft below NWS Action Stage, to the upper extent of the stage-discharge rating which is approximately 1 ft higher than the highest recorded water level at the streamgage. Action Stage is the stage which when reached by a rising stream the NWS or a partner needs to take some type of mitigation action in preparation for possible significant hydrologic activity. The simulated water-surface profiles were then combined with a geographic information system 3-meter (9.84 ft) digital elevation model (derived from Light Detection and Ranging (LiDAR) data) in order to delineate the area flooded at each water level.

The availability of these maps along with real-time streamflow data and information regarding current stage from USGS streamgages and forecasted stream stages from the NWS provide emergency management personnel and residents with information that is critical for flood response activities, such as evacuations and road closures, as well as for post-flood recovery efforts.

Introduction

The Boroughs of Upper Saddle River and Saddle River are urban communities with estimated populations of 8,200 and 3,150, respectively, and population densities of 1,560 and 640 persons per square mile (U.S. Bureau of Census, 2010). These boroughs have experienced severe flooding numerous times, most notably in June and August 2011, Tropical Storm Floyd in 1999, and 1977. Damage costs for these floods (not adjusted for inflation) were reported to be $174,800 in 2011, $44,000 in 1999, and $22,380 in 1977 (New Jersey Department of Environmental Protection, State National Flood Insurance Program Coordinators Office, written commun., 2012). Most of the flood damages have occurred along the Saddle River, which flows through the Boroughs of Upper Saddle River and Saddle River. Floodplains within Upper Saddle River and Saddle River Boroughs are highly developed and contain a mix of residential and commercial structures.

Prior to this study, borough officials from Upper Saddle River and Saddle River have relied on several information sources (all of which are available on the Internet) to make decisions on how to best alert the public and mitigate flood damages. One source is the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Bergen County dated September 30, 2005 (Federal Emergency Management Agency, 2005). A second source of information is the USGS streamgage 01390450, Saddle River at Upper Saddle River, New Jersey, from which current or historical water levels (stage) can be obtained. A third source is the National Weather Service (NWS) forecast of peak stage at the USGS streamgage through the Advanced Hydrologic Prediction

Service (AHPS) Web site. Although information on USGS current stage and NWS forecast stage is particularly useful for residents in the immediate vicinity of a streamgage, it is of limited use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream channel. Also, FEMA and State emergency management mitigation teams or property owners typically lack information related to how deep the water is at locations other than near USGS streamgage or NWS flood-forecast points.

Purpose and Scope

The purpose of this report is to describe the development of a series of estimated flood-inundation maps for the Saddle River from Upper Saddle River Borough to Saddle River Borough, New Jersey. The maps and other useful flood information are available on the USGS Flood Inundation Mapping Science Web site at http://water.usgs.gov/osw/flood_inundation/. Internet users can select estimated inundation maps that correspond to (1) current stages at the USGS streamgage; (2) the NWS forecasted peak stage, or (3) other desired stream stages.

The scope of the study was limited to a 4.1-mile reach of the Saddle River from 0.6 miles downstream from the New Jersey-New York State boundary in Upper Saddle River Borough to 0.2 miles downstream from the East Allendale Road bridge in Saddle River Borough, New Jersey. Tasks specific to development of the maps were (1) analysis of peak streamflow data from station 01390450 (table 1), (2) collection of topographic data and geometric data (for structures/bridges) throughout the study reach, (3) verification of energy-loss factors (roughness coefficients) in the stream channel and floodplain, and steady-flow data from previous studies, (4) computation of water-surface profiles by use of the U.S. Army Corps of Engineer's HEC–RAS computer program (U.S. Army Corps of Engineers, 2010) and a geographic information system (GIS), and (5) development of a Web interface that links to USGS real-time streamgage information and NWS forecasted peak stage to facilitate the display of user-selected flood-inundation maps on the Internet.

Methods used are generally cited from previously published reports. If techniques varied significantly from previously documented methods due to local hydrologic conditions or available data, they are described in detail in this report. Maps were produced for water levels referenced to the stage at USGS streamgage 01390450 and ranging from approximately bankfull, 0.5 ft below NWS Action Stage, to the upper extent of the stage-discharge rating, approximately 1 ft higher than the maximum observed water level at the streamgage. Action Stage is the stage which when reached by a rising stream, lake, or reservoir represents the level where the NWS or a partner/user needs to take some type of mitigation action in preparation for possible significant hydrologic activity (National Weather Service, 2010).

Study Area Description

The Saddle River is in northeast New Jersey in the Piedmont physiographic province. The drainage area ranges from 10.9 square miles (mi^2) at USGS streamgage 01390450 to 16.0 mi^2 at the downstream extent of the study reach (fig. 1). The headwaters originate in Rockland County, in southern New York State, and the stream generally flows southward before entering the borough limits of Upper Saddle River in Bergen County, New Jersey. There are three major tributaries that flow into the Saddle River within the extent of the study reach. Pine Brook and West Branch Saddle River join the main stem of the Saddle River upstream from USGS streamgage 01390450 as it flows through Upper Saddle River Borough (fig. 2). The third tributary, Pleasant Brook, joins the main stem of the Saddle River downstream from USGS streamgage 01390450 as it flows through Upper Saddle River Borough. The headwaters of the Saddle River are 4.9 miles upstream from USGS streamgage 01390450. The Saddle River drains into the Passaic River 22.8 miles downstream from USGS streamgage 01390450. The basin terrain is moderately hilly. The study reach is approximately 4.1 miles long, has an average top-of-bank channel width of about 79 ft and an average channel slope of 52.1 feet per mile (ft/mi). About 81.1 percent of the land contiguous to the study reach is classified as urban or developed, 11.5 percent as forest, and 1.5 percent as wetland (New Jersey Department of Environmental Protection, 2010). The basin is still under redevelopment, and population has increased 3.82 percent from 10,900 to 11,400 between 2000 and 2010 [U.S. Census Bureau, 2012]. Six major road crossings or other structures are located within the channel of the study reach or the adjacent flood plain (fig. 2).

Previous Studies

The current FIS for Upper Saddle River (Federal Emergency Management Agency, 2005) was completed by Natural and Technological Hazards Management Consulting, Inc.

Table 1. U.S. Geological Survey streamgage and miscellaneous site information for study basin, Saddle River, New Jersey.

Station name	Station number	Drainage area (square miles)	Latitude	Longitude	Period of record	Maximum recorded stage at gage (feet) and date
Saddle River at Upper Saddle River, NJ	01390450	10.9	41°03′31″	74°05′44″	Sept. 1966 to current year	5.64 Sep 16, 1999

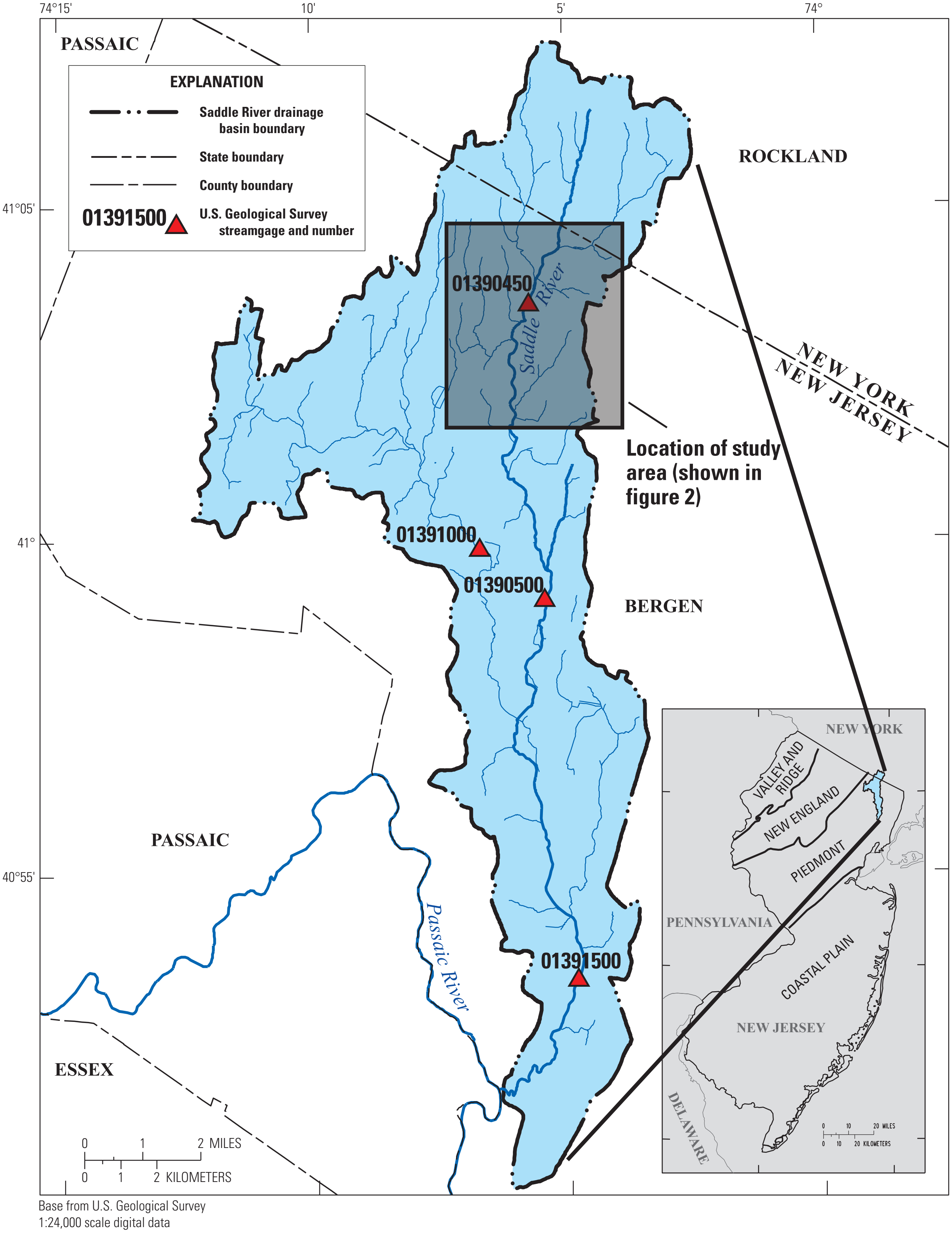

Figure 1. Location of study reach for the Saddle River in New Jersey.

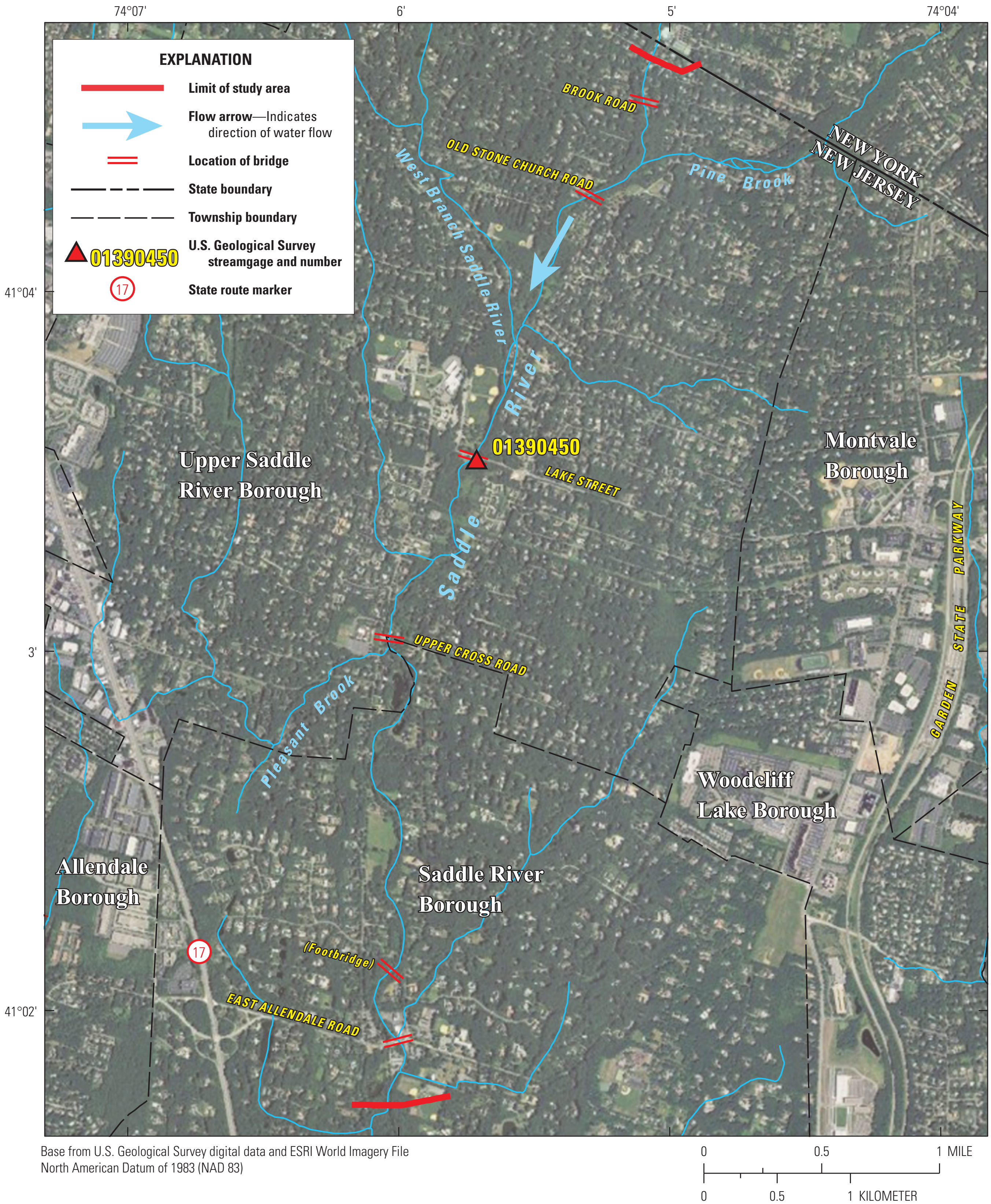

Figure 2. Location of model extent and direction of surface-water flow at streamgage 01390450, Saddle River at Upper Saddle River, New Jersey.

(NTHMC) in 2004. That study provided information on the 1- and 0.2-percent annual exceedance probability water-surface profiles and associated flood plain maps for the Saddle River. Estimates of the peak discharges for the 1-percent annual exceedance probability flood along the Saddle River, as shown in table 2 below for the study reach, were described in FEMA (2005).

Constructing Water-Surface Profiles

The water-surface profiles used to produce the eight flood-inundation maps in this study were computed by using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). HEC–RAS is a one-dimensional step-backwater model for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. The HEC–RAS analysis for this study was done by using the steady-state flow computation option. An unsteady-state model would be more appropriate if the river had dynamic streamflow conditions such as backwater or tidal flow.

Hydrologic and Steady Flow Data

The study area hydrologic network consists of USGS streamgage 01390450 with a period of record from 1966 to the current water year (fig. 1; table 1). Water level (stage) is measured in real-time through a satellite radio transmitter continuously and continuous records of streamflow are computed at this site. All water-surface elevations are referenced to North American Vertical Datum of 1988 (NAVD 88) and displayed in the National Water Information System (NWIS).

Steady-flow data consisted of flow regime, boundary conditions (normal depth, or the streamgage stage-discharge relation value), and peak-discharge information. The peak-discharge data for the study reach were obtained from field measurements and the stage-discharge relation (rating no. 7.0) that was developed by the USGS at streamgage 01390450.

Topographic/Bathymetric Data

Channel cross sections were developed from NTHMC field surveys that were conducted in 2004; these cross sections provide detailed channel elevation data below the water surface and were collected using hydroacoustic instrumentation to measure depth and Differential Global Positioning System (DGPS) instrumentation to determine horizontal position. Light Detection and Ranging (LiDAR) data were used to provide 3-meter (9.84 ft) digital elevation data for the portions of the cross sections that were above the water surface at the time of the surveys. The LiDAR data were collected in 2006–07, and post-processing of these data was completed by U.S. National Geospatial-Intelligence Agency (NGA) in 2007.

Various manmade drainage structures (bridges, culverts, roadway embankments, levees, and dams) in and along the stream affect or have the potential to affect water-surface elevations during floods along the stream. To properly account for six bridges (fig. 2) in the model, structural dimensions were measured and surveyed in the field concurrently with the stream-channel surveys. A detailed description of the methods used to acquire and process the topographic and bathymetric data can be found in Bales and others (2007).

Energy Loss Factors

Field observations and high-resolution aerial photographs were used to select initial (pre-calibration) Manning's roughness coefficients (n values) for energy (friction) loss calculations. The final Manning's n values used ranged from 0.025 to 0.035 for the main channel and 0.020 to 0.10 for the overbank areas modeled in this analysis.

Model Calibration and Performance

The hydraulic model was calibrated to the most current stage-discharge relation at station 01390450. During the June 2011 flood event, the measured peak discharge and associated stage were 3,790 cubic feet per second (ft^3/s) and 5.41 ft, respectively. The measured peak discharge and stage for the 1999 flood were 6,290 ft^3/s and 5.64 ft. Model calibration was accomplished by adjusting Manning's n values and, in some cases, changing the channel cross section or slope until the results of the hydraulic computations closely agreed with the known flood discharge and stage values. Differences between measured and simulated water levels for measured or rated flows at USGS streamgage 01390450 were equal to or less than 0.22 ft. The results demonstrate that the model is capable of simulating accurate water levels over a wide range of flows in the basin. Details on techniques used in model development and calibration can be found in Bales and others (2007).

Table 2. 1-percent annual exceedance probability peak-discharge estimates, drainage areas, and percentage of total discharge for selected locations on the Saddle River, New Jersey. (from Federal Emergency Management Agency, 2005)

Location on Saddle River	Drainage area (square miles)	Discharge estimate (cubic feet per second)	Percentage of total discharge
At Lake Street, Saddle River at Upper Saddle River, NJ streamgage	10.9	5,920	100

Development of Water-Surface Profiles

Profiles were developed for a total of eight stages at 0.5-ft intervals between 3.0 ft and 6.5 ft as referenced to USGS streamgage 01390450. Discharges corresponding to the various stages were obtained from the most current stage-discharge relation (rating no. 7.0) for station 01390450.

Discharges for all profiles on the Saddle River (table 3) at locations upstream and downstream from USGS streamgage 01390450 were selected with the assumption that the percentage contribution to the total flow was the same as that assumed for the 2005 FIS (table 2).

Inundation Mapping

Flood-inundation maps were created based on USGS streamgage 01390450, Saddle River at Upper Saddle River. The maps were created in a geographic information system by combining the water-surface profiles and digital elevation model data. The 3-meter (9.84-ft) digital elevation model data were derived from LiDAR data obtained from NGA (National Geospatial-Intelligence Agency, 2007).

Each digitized cross-section line used for the study area was attributed with a HEC-RAS calculated water-surface elevation for each of the eight profiles (table 3). The flood surfaces were generated by using an iterative finite-difference interpolation technique found in the ArcGIS, TopoToRaster tool. This tool is unique because it is the only ArcGIS interpolation routine designed to work intelligently with contour data, and it combines locally efficient interpolation methods with global surface-continuity routines (Environmental Systems Research Institute, Inc., 2009). Inputs into the tool are contour data using the digital cross sections attributed with the NAVD 88 elevation, in feet, and boundary data using the study-area polygon. Depth of water grids were generated by subtracting the flood water-surface elevation from the study-area digital elevation model (DEM) (Roland and Hoffman, 2011). The map products show estimated flood-inundated areas overlaid on high-resolution, geo-referenced, aerial photographs of the study area for each of the water-surface profiles that were generated by the hydraulic model.

Table 3. Stages and water-surface elevations for the Saddle River at Upper Saddle River, New Jersey streamgage (U.S. Geological Survey streamgage 01390450) with corresponding discharge estimates at Lake Street along the Saddle River, New Jersey, for selected simulated water-surface profiles.

Profile number	Stage (feet above gage datum)	Elevation (feet above NAVD 88)	Discharge (cubic feet per second)
2	3.50	187.7	330
4	4.50	188.7	1,250
6	5.50	189.7	4,110
8	6.50	190.7	9,290

Saddle River, New Jersey, Flood-Inundation Maps on the Internet

The flood-inundation maps and current study documentation are available online at the U.S. Geological Survey Publications Warehouse (http://pubs.usgs.gov/sim/2013/3262). Also, the Flood Inundation Mapping Science website has been established to provide a portal for USGS flood-inundation study information to the public at http://water.usgs.gov/osw/flood_inundation/. The web portal has a link (http://wim.usgs.gov/FIMI/FloodInundationMapper.html) to interactive online map libraries that can be downloaded in several commonly used electronic file formats. In the latter link, each stream reach displayed contains further links to the USGS National Water Information System (NWISWeb) graphs of the current stage and streamflow at USGS streamgage 01390450 to which the inundation maps are referenced. The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding with respect to individual structures so that preparations for flooding and decisions for emergency response can be performed efficiently. Roadways and bridges were closely reviewed and are shown shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use. Bridge surfaces that have a simulated water level surface at the low chord of the bridge deck or higher are depicted to be inundated (table 4). However, buildings which are shaded do not reflect inundation but denote that bare earth surfaces in the vicinity of the buildings are inundated. When the water depth (as indicated in the Web Mapping Application by holding the cursor over an inundated area) in the vicinity of the building of interest exceeds that building's height, the structure can be considered fully submerged.

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 a quick reference, emergency planning tool but assumes no legal liability or responsibility resulting from the use of this information.

Table 4. Occurrence of bridge inundation determined from simulated water-surface profiles corresponding to a stage level for the study area extent for the Saddle River at Upper Saddle River, New Jersey, streamgage (U.S. Geological Survey streamgage 01390450).

Stage (feet)	Bridge inundated
3.5	None
4.5	Upper Cross Road and Lake Street
5.5	East Allendale Road, Upper Cross Road, Lake Street, Stone Church Road, and Brook Road
6.5	East Allendale Road, footbridge, Upper Cross Road, Lake Street, Stone Church Road, and Brook Road

Uncertainties and Limitations Regarding Use of Flood-Inundation Maps

Although the flood-inundation maps represent the boundaries of inundated areas with a distinct line, some uncertainty is associated with these maps. The flood boundaries shown were estimated on the basis of water stages and streamflow at the USGS streamgage 01390450. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, assuming unobstructed flow, and using streamflows and hydrologic conditions anticipated at the USGS streamgage. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of September 2004. Unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the modeled reach to vary from those assumed during a flood, which may lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded due to unanticipated conditions, such as changes in the streambed elevation or roughness, backwater into major tributaries along a main stem river, or backwater from localized debris or ice jams. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the digital elevation model used to simulate the land surface. Additional uncertainties and limitations pertinent to this study may be described elsewhere in this report.

If this series of flood-inundation maps will be used in conjunction with National Weather Service (NWS) river forecasts, the user should be aware of additional uncertainties that may be inherent or factored into NWS forecast procedures. The NWS uses forecast models to estimate the quantity and timing of water flowing through selected stream reaches in the United States. These forecast models (1) estimate the amount of runoff generated by precipitation and snowmelt, (2) simulate the movement of floodwater as it proceeds downstream, and (3) predict the flow and stage (and water-surface elevation) for the stream at a given location (AHPS forecast point) throughout the forecast period (every 6 hours and 3 to 5 days out in many locations). For more information on AHPS forecasts, please see: http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

Summary

A series of estimated flood-inundation maps were developed in cooperation with the New Jersey Department of Environmental Protection for the Saddle River between the Borough of Upper Saddle River and the Borough of Saddle River, New Jersey. These maps, available at a U.S Geological Survey Web portal, in conjunction with the real-time stage data from the USGS streamgage 01390450, Saddle River at Upper Saddle River, New Jersey, will help to guide the general public in taking individual safety precautions and will provide municipal officials with a tool to efficiently manage emergency flood operations and flood mitigation efforts.

The maps were developed by using the U.S. Army Corps of Engineers' HEC–RAS and HEC–GeoRAS programs to compute water-surface profiles and to delineate estimated flood-inundation areas for selected stream stages. The maps show estimated (shaded) flood-inundation areas overlaid on high-resolution, geo-referenced, aerial photographs of the study area for stream stages between 3.0 ft and 6.5 ft at the USGS streamgage 01390450. Interactive use of the maps by using the mouse cursor to click within the shaded areas can give users a general indication of depth of water at any point. These maps can be accessed through the USGS Flood Inundation Mapping Science Web site at http://water.usgs.gov/osw/flood_inundation/.

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