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# Flood-Inundation Maps for the Peckman River in the Townships of Verona, Cedar Grove, and Little Falls, and the Borough of Woodland Park, New Jersey, 2014

Scientific Investigations Report 2016–5105

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

**Cover:**
Looking downstream from USGS gaging station number 01389534 Peckman River at Ozone Ave at Verona, NJ, January 15, 2015 (Photo by Brian Mcdowell, U.S. Geological Survey)

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By Michal J. Niemoczynski and Kara M. Watson

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**U.S. Department of the Interior**
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# Conversion Factors

Inch/Pound to SI

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| square mile ($mi^2$) | 2.59 | square kilometer ($km^2$) |
| | Flow rate | |
| cubic foot per second ($ft^3/s$) | 0.0283 | cubic meter per second ($m^3/s$) |

Vertical coordinate information is referenced to either (1) stage, the height above an arbitrary datum established at a streamgage, or (2) elevation, the height above 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 distance above the vertical datum.

# Flood-Inundation Maps for the Peckman River in the Townships of Verona, Cedar Grove, and Little Falls, and the Borough of Woodland Park, New Jersey, 2014

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## Abstract

Digital flood-inundation maps for an approximate 7.5-mile reach of the Peckman River in New Jersey, which extends from Verona Lake Dam in the Township of Verona downstream through the Township of Cedar Grove and the Township of Little Falls to the confluence with the Passaic River in the Borough of Woodland Park, were created by the U.S. Geological Survey (USGS) in cooperation with the New Jersey Department of Environmental Protection. The flood-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 probable areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534). Near-real-time stages at this streamgage may be obtained on the Internet from the USGS National Water Information System at http://waterdata.usgs.gov/.

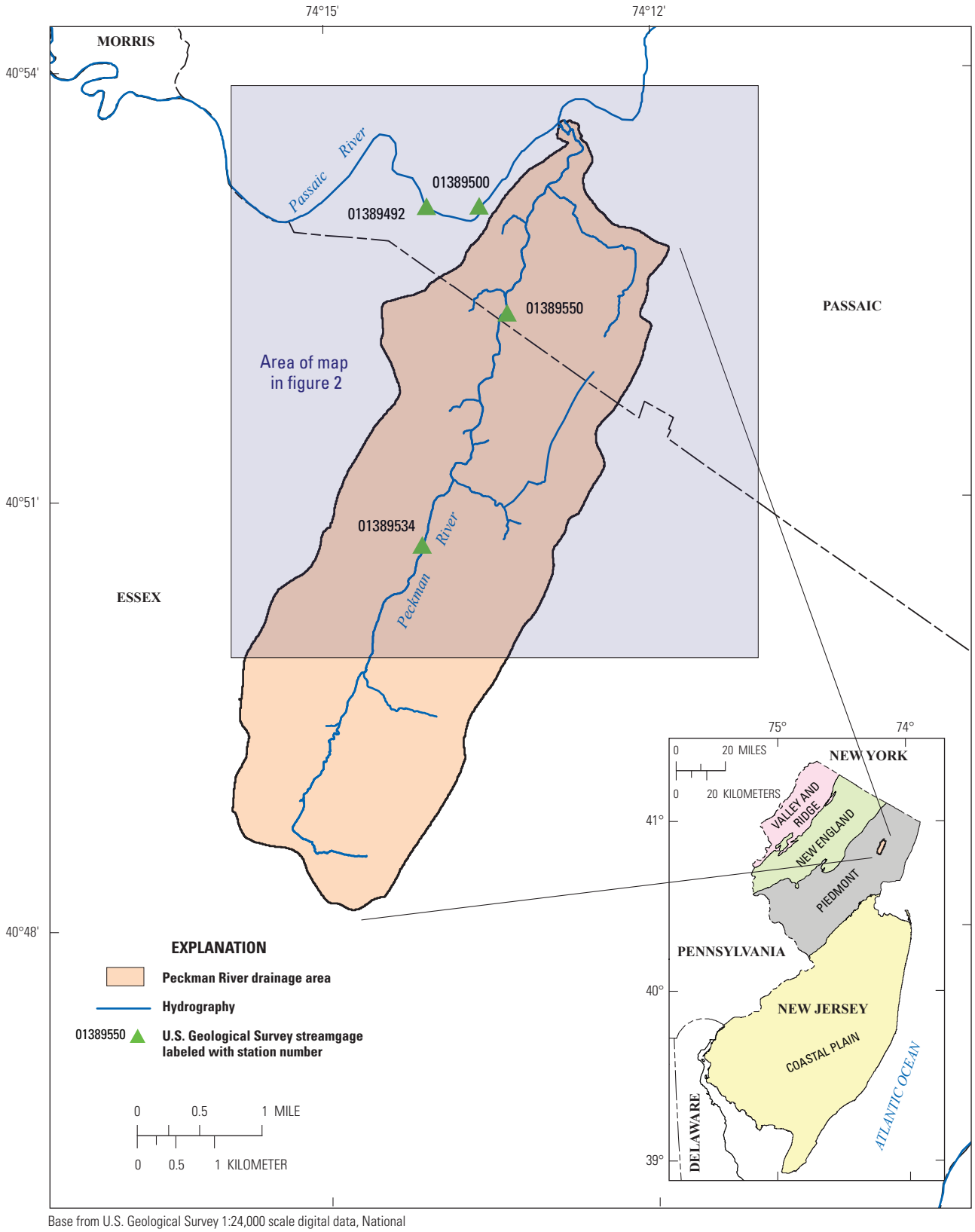
Flood profiles were simulated for the stream reach by means of a one-dimensional step-backwater model. The model was calibrated using the most current stage-discharge relations at USGS streamgages on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534) and the Peckman River at Little Falls, New Jersey (station number 01389550). The hydraulic model was then used to compute eight water-surface profiles for flood stages at 0.5-foot (ft) intervals ranging from 3.0 ft or near bankfull to 6.5 ft, which is approximately the highest recorded water level during the period of record (1979–2014) at USGS streamgage 01389534, Peckman River at Ozone Avenue at Verona, New Jersey. The simulated water-surface profiles were then combined with a geographic information system digital elevation model derived from light detection and ranging (lidar) data to delineate the area flooded at each water level.

The availability of these maps along with Internet information regarding current stage from the USGS streamgage provides emergency management personnel and residents with information, such as estimates of inundation extents, based on water stage, that is critical for flood response activities such as evacuations and road closures, as well as for post-flood recovery efforts.

## Introduction

In 2014, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection, conducted a study to produce a library of flood-inundation maps for the Peckman River at Ozone Avenue at Verona, New Jersey. This study area includes the Township of Verona (Verona), Township of Cedar Grove (Cedar Grove), Township of Little Falls (Little Falls), and the Borough of Woodland Park (Woodland Park; formerly designated as the Borough of West Paterson), which are urban communities with estimated populations of 13,332; 12,411; 14,432; and 11,819, respectively, and population densities of 4,838; 2,919; 5,276; and 3,988 persons per square mile (U.S. Bureau of Census, 2012). These communities have experienced severe flooding numerous times, most notably in 2011 (Tropical Storm Irene, flood stage 5.32 feet) and 1999 (Tropical Storm Floyd, flood stage 6.57 feet). National Flood Insurance Program flood insurance claims for these communities were reported to be $13,569,000 in 2011 and $2,506,000 in 1999 (New Jersey Department of Environmental Protection, State National Flood Insurance Program Coordinators Office, written commun., 2013). Most of the flood damages were along the lower Peckman River (fig.1) as it flows through Little Falls and Woodland Park (fig. 2). Flood plains along the Peckman River are highly developed and contain a mix of residential and commercial structures.

Prior to this study, emergency responders in Verona, Little Falls, Cedar Grove, and Woodland Park relied on two information sources (both of which are available on the Internet) to make decisions on how best to alert the public and mitigate flood damages. One source is the most recent FEMA flood insurance studies (FISs) for Essex County dated




Base from U.S. Geological Survey 1:24,000 scale digital data, National Hydrography Dataset, 2012 North American Datum fo 1983 (NAD83)

**Figure 1.** Location of study reach for Peckman River in the Piedmont Physiographic Province and U.S. Geological Survey streamgages, in New Jersey.

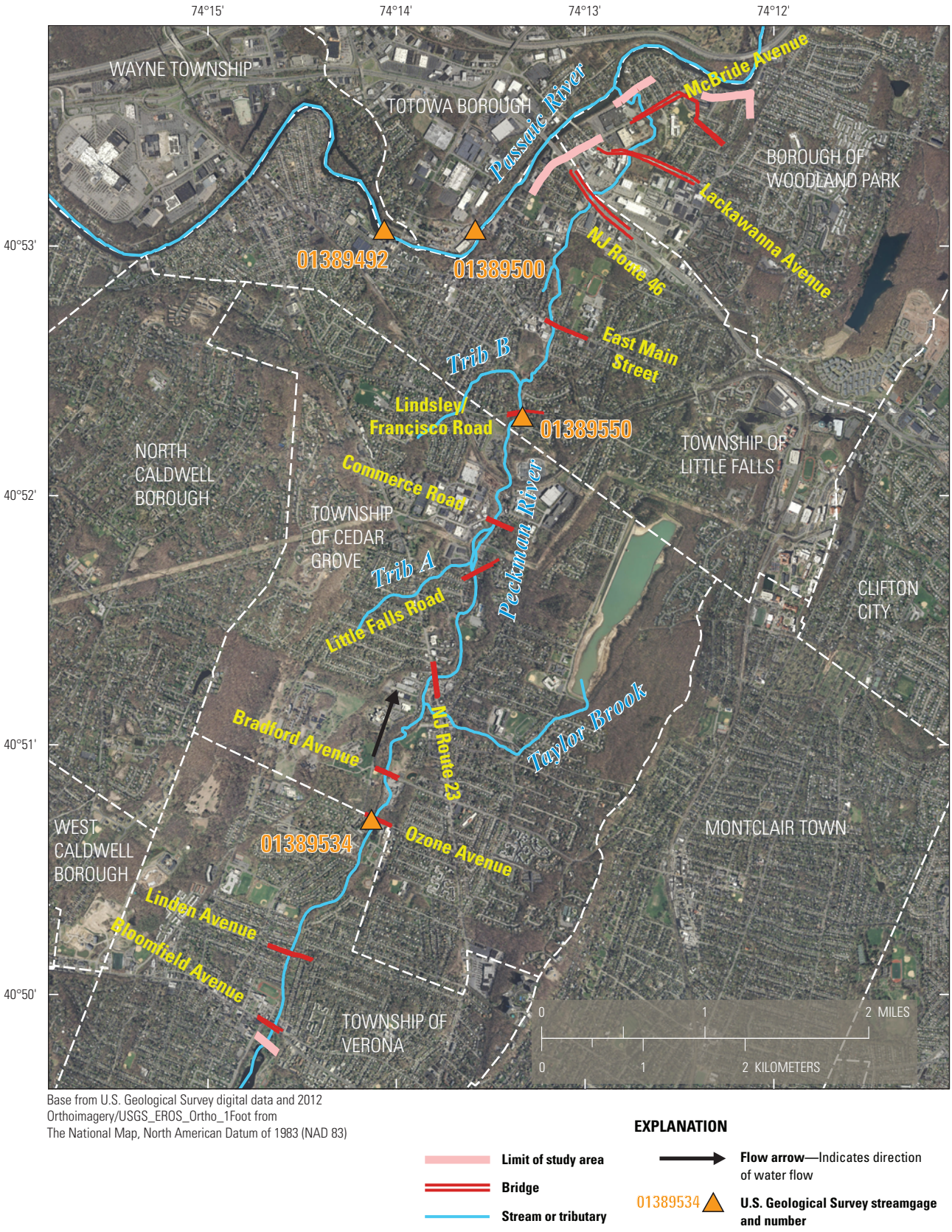



**Figure 2.** Location of study reach and direction of surface-water flow for the Peckman River at Ozone Avenue at Verona and the Peckman River at Little Falls, New Jersey.

June 4, 2007, and for Passaic County dated September 28, 2007 (Federal Emergency Management Agency, 2007a, b). A second source of information is the USGS streamgage Peckman River at Ozone Avenue at Verona, New Jersey, (station number 01389534) and the streamgage Peckman River at Little Falls, New Jersey, (station number 01389550) from which current (U.S. Geological Survey, 2014a, b) and historical water levels (stage) and flow, including annual peak flows, can be obtained.

Although the real-time stage at a USGS streamgage 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 reach. A water-level value at a streamgage is difficult to translate into depth and areal extent of flooding at points distant from the streamgage. One way to address these informational gaps is to produce a library of flood-inundation maps that are referenced to the stages recorded at the USGS streamgage. By referring to the appropriate map, emergency responders can discern the severity of flooding (depth of water and areal extent), identify roads that are or will soon be flooded, and make plans for notification or evacuation of residents for some distance upstream and downstream from the streamgage. In addition, the capability to visualize the potential extent of flooding has been shown to motivate residents to take precautions and heed warnings that they previously might have disregarded.

## Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for the USGS streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey, (station number 01389534) and identifies where on the Internet the maps can be found and ancillary data [geographic information system (GIS) flood polygons and depth grids] can be downloaded.

The flood-inundation maps cover an approximate 7.5-mile reach of the Peckman River from Verona Lake Dam in Verona, downstream through Cedar Grove and Little Falls, to just upstream from the confluence with the Passaic River in Woodland Park. Maps were produced for river levels referenced to the stage recorded at the USGS streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534; table 1); the streamgage is on the Ozone Avenue bridge on the border betweenVerona and Cedar Grove.

The maps cover a range of stages from 3.0 feet (ft) or approximately bankfull to 6.5 ft, which is approximately the maximum extent of the current stage–discharge relation at the USGS streamgage and the maximum recorded water level at the streamgage for the period of record 1979–2014. The 3.0-ft stage, approximately bankfull, is defined by the National Weather Service (NWS; 2013) as the “action stage” or the stage which when reached by a rising stream requires

**Table 1.** U.S. Geological Survey streamgage information on Peckman River at Ozone Avenue at Verona, New Jersey, and Peckman River at Little Falls, New Jersey.

[Station location is shown in figure 1; USGS, U.S. Geological Survey; $mi^2$, square miles; $ft^3/s$, cubic feet per second; NAVD 88, North American Vertical Datum of 1988]

| USGS station name | Peckman River at Ozone Avenue at Verona, New Jersey | Peckman River at Little Falls, New Jersey |
|---|---|---|
| USGS station number | 01389534 | 01389550 |
| Drainage area ($mi^2$) | 4.45 | 7.82 |
| Latitude (degrees, minutes, seconds) | 40° 50’42” | 40° 52’19” |
| Longitude (degrees, minutes, seconds) | 74°14’08” | 74°13’20” |
| Period of peak-flow record (water years[1]) | 1945, 1979–current | 2006–current |
| Maximum recorded stage, in feet, gage datum (and elevation, in feet above NAVD 88) and date | 6.57 (305.69) September 16, 1999 | 9.16 (174.85) August 28, 2011 |
| Maximum discharge, in $ft^3/s$, and date | 3,800 July 23, 1945[2] | 2,010 August 28, 2011 |

[1]Water year is the 12-month period from October 1 of one year through September 30 of the following year and is designated by the calendar year in which it ends.

[2] The maximum discharge in 1945 was a historic peak with no recorded stage.

the NWS or a partner to take some type of mitigation action in preparation for possible significant hydrologic activity. The upper limit of inundation maps is the 6.5-ft stage, which exceeds the "major flood stage" defined by the NWS as 1.5 ft.

## Study Area Description

The Peckman River is located in northeastern New Jersey in the Piedmont Physiographic Province (fig. 1). The drainage area ranges from 4.45 square miles ($mi^2$) at the USGS streamgage on the Peckman River at Ozone Avenue at Verona to 10.1 $mi^2$ at the downstream extent of the study reach. The source of the Peckman River is 5.7 miles upstream from the USGS streamgage Peckman River at Ozone Avenue at Verona in the Township of West Orange, Essex County, New Jersey. The stream flows generally northeastward before entering the Passaic River in the Borough of Woodland Park, Essex County, New Jersey. Three minor tributaries flow into the Peckman River within the study reach. Taylor Brook and an unnamed tributary, referred to in this report as "Tributary A," join the main stem of the Peckman River between USGS streamgages, Peckman River at Ozone Avenue at Verona, New Jersey, (station number 01389534) and Peckman River at Little Falls, New Jersey, (station number 01389550) as it flows through Cedar Grove (fig 2). The third unnamed tributary, referred to in this report as "Tributary B," joins the main stem of the Peckman River downstream from USGS streamgage 01389550 as it flows through Little Falls. The Peckman River drains into the Passaic River 5.9 miles downstream from the USGS streamgage Peckman River at Ozone Avenue at Verona (fig. 1). The basin terrain is moderately hilly. The study reach is approximately 7.5 miles long, has an average top-of-bank channel width of about 70 ft, and has an average channel slope of 44 feet per mile. About 72 percent of the land contiguous to the study reach is classified as urban or developed, 22 percent as forest, and 4 percent as wetland (New Jersey Department of Environmental Protection, 2010). The basin is highly developed, and the population of the municipalities encompassing the basin has increased 9.06 percent from 47,675 to 51,994 between 2000 and 2010 (U.S. Bureau of Census, 2012). Eleven 2-lane county roads and one major 6-lane state highway span the channel within the study reach (fig. 2). Additionally, one railroad bridge spans the channel within the reach. This bridge is a significantly elevated trestle that was not included in the original hydraulic model from Leonard Jackson Associates PE PLLC (Leonard Jackson Associates; Pomona, New York), presumably because it would have a negligible effect on flows through the channel at any river stage. Leonard Jackson Associates were unavailable for comments on the model; however, field observation of the bridge and review of satellite imagery confirms this assertion.

## Previous Studies

The current FISs for Verona, Cedar Grove, Little Falls, and Woodland Park in Essex and Passaic Counties (Federal Emergency Management Agency, 2007a, b) were completed in 2005 by Leonard Jackson Associates. The current FISs are revisions of the earlier studies from 1979 (Verona and Cedar Grove) and 1981 (Little Falls and Woodland Park) that were performed by NJDEP. The 2005 FISs provide information on the 10-, 2.0-, 1.0-, and 0.2-percent annual exceedance probability water-surface profiles and associated flood-plain maps for the Peckman River. Estimates of the peak flows for these annual exceedance probabilities (table 2) for the study reach were described by FEMA (2007).

**Table 2.** Peak-discharge estimates for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities and drainage areas for selected locations on the Peckman River in New Jersey (from Federal Emergency Management Agency, 2007a; Federal Emergency Management Agency, 2007b).

[$mi^2$, square miles; $ft^3/s$, cubic feet per second; USGS, U.S. Geological Survey; NJ, New Jersey; FEMA, Federal Emergency Management Agency]

| Location on Peckman River | Drainage area ($mi^2$) | Estimated peak discharges ($ft^3/s$) for indicated annual exceedance probabilities (in percent) | | | |
|---|---|---|---|---|---|
| | | 10 | 2 | 1 | 0.2 |
| Just upstream from the confluence of Tributary to Peckman River[1,2] | 2.2 | 1,165 | 1,835 | 2,185 | 3,210 |
| Just upstream from Linden Avenue[1] | 3.6 | 1,680 | 2,640 | 3,150 | 4,625 |
| Just upstream from Ozone Avenue[1] | 4.5 | 1,990 | 3,130 | 3,730 | 5,480 |
| Just upstream from the confluence of Taylor Brook in Cedar Grove[1] | 5 | 2,185 | 3,435 | 4,095 | 6,015 |
| Just upstream from the confluence of Peckman River Tributary A[1] | 6.9 | 2,765 | 4,350 | 5,185 | 7,615 |
| At downstream Little Falls corporate limits[3] | 9.55 | 1,180 | 1,780 | 2,160 | 3,350 |
| At confluence with Passaic River[3] | 9.7 | 1,220 | 1,800 | 2,200 | 3,400 |

[1]Discharges for indicated exceedance probabilities taken from the FEMA Essex County Flood Insurance Study dated June 4, 2007.

[2]Study reach begins just downstream from the confluence with this tributary.

[3]Discharges for indicated exceedance probabilities taken from the FEMA Passaic County Flood Insurance Study dated September 28, 2007.

# Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (U.S. Geological Survey, 2014c), so that the process followed and products produced are similar regardless of which USGS office is responsible for the work. Tasks specific to development of the flood maps for the USGS streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey, were (1) acquisition of the hydraulic model that was used for the most recent FEMA flood insurance studies for Verona, Cedar Grove, Little Falls, and Woodland Park (Federal Emergency Management Agency, 2007a, b), (2) computation of water-surface profiles by use of the U.S. Army Corps of Engineers' HEC-RAS computer program (U.S. Army Corps of Engineers, 2010), (3) production of estimated flood-inundation maps at various stream stages by use of a GIS, and (4) preparation of the maps, both as shapefile polygons that depict the areal extent of flood inundation and as depth grids that provide the depth of flood waters, for display on the USGS Flood Inundation Mapper Web site, http://wim.usgs.gov/FIMI/FloodInundationMapper.html (U.S. Geological Survey, 2014d).

## Computation of Water-Surface Profiles

The water-surface profiles used to produce the eight flood-inundation maps for this study were computed with the hydraulic model developed for the current FISs for Verona, Cedar Grove, Little Falls, and Woodland Park (Federal Emergency Management Agency, 2007a, b). This model, which was developed using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010), was created by Leonard Jackson Associates in 2005. 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 (U.S. Army Corps of Engineers, 2010).

### Hydrologic Data

The study reach includes two streamgages (01389534 and 01389550; fig. 1) installed in 1979 and 2006, respectively. The water level (stage) is measured every 5 minutes, transmitted hourly by a satellite radio in the streamgage, and made available on the Internet through the USGS National Water Information System (NWIS; U.S. Geological Survey, 2014b). Stage data from these streamgages are referenced to a local datum but can be converted to water-surface elevations referenced to the North American Vertical Datum of 1988 (NAVD 88) by adding 299.12 ft to stage levels at station number 01389534 and 165.69 ft to stage levels at station number 01389550. Continuous records of streamflow are computed from stage-discharge relations, developed for each streamgage, and are available through the USGS NWIS Web site (http://waterdata.usgs.gov/nj/nwis/sw). The stage-discharge relation uses continuously recorded stage measurements to obtain a continuous measurement of flow for a streamgage (http://water.usgs.gov/edu/streamflow3.html).

The peak flows used in the model simulations (table 3) were taken from the current stage-discharge relation at USGS streamgage on the Peckman River at Ozone Ave at Verona, (number 5.0, effective October 1, 2005) and correspond to the flood-inundation map stages. Three minor tributaries—Taylor Brook, Tributary A, and Tributary B—join the Peckman River within the 7.5-mi study reach. The streamgage flows were adjusted at downstream ungaged locations to account for tributary inflows and increase in drainage area through the study reach (table 3). Streamgage flows were also adjusted upstream from the gage for drainage area reduction. These adjustments were estimated by applying a drainage-area ratio to estimate ungaged streamflow, which was added to or subtracted from the main-channel flows as necessary.

### Topographic and Bathymetric Data

Channel cross-section field surveys for hydraulic analyses, conducted by Leonard Jackson Associates in 2005, provide detailed data on channel elevation below the water surface. Channel elevations were collected using traditional field surveys or hydroacoustic instrumentation to measure depth, along with Differential Global Positioning System instrumentation to determine horizontal position. Light Detection and Ranging (lidar) data were used to create 3-meter (9.84-ft) digital elevation data, from which elevations for the portions of the cross sections that were above the water surface at the time of the surveys were obtained. The lidar data were collected during 2006–07, and post-processing of these data was completed by the U.S. National Geospatial-Intelligence Agency in 2007 (National Geospatial-Intelligence Agency, 2007).

### Hydraulic Structures

Various man-made drainage structures (bridges, culverts, and roadway embankments) in and along the stream could affect water-surface elevations during flooding. To properly account for 12 bridges (fig. 2) in the model, the structural dimensions were measured and surveyed in the field concurrently with the stream-channel surveys conducted by Leonard Jackson Associates. Structures in the study reach have not been modified or altered since the completion of these surveys.

### Energy-Loss Factors

Hydraulic analyses require the estimation of energy losses that result from frictional resistance exerted by a channel on flow. These energy losses can be quantified by the Manning's roughness coefficient ("*n*" value). Manning's "*n*" values for energy (friction) loss calculations were included in the furnished hydraulic model and ranged from 0.020 to 0.045 for

the main channel and 0.020 to 0.10 for the overbank areas. Channel conditions in the study reach are typified by loose bed material, consisting of coarse gravel and cobbles, and light brush on the banks. Conditions also occasionally include concrete rubble and artificial materials. Flood-plain roughness throughout the study reach was variable. About 22 percent of the land encompassing the reach is still classified as forested, and 72 percent is classified as urban or developed (New Jersey Department of Environmental Protection, 2010). Dense vegetation, typical of a suburban forest understory and composed of trees, shrubs, and vines, and paved impervious surfaces are often present in the overbank within the same cross section. Roughness coefficients provided with the hydraulic model were considered representative of field conditions and remained unaltered.

## Hydraulic Model

The HEC-RAS analysis used the steady-state flow computation option. Steady-state flow data consist of flow regime, boundary conditions, and peak flows associated with the current USGS stage-discharge relation for the streamgage Peckman River at Ozone Avenue at Verona, New Jersey, (station 01389534) that produced water-surface elevations at the streamgage cross section, which matched target water-surface elevations. These target elevations coincided with even 0.5-ft increments of stage, referenced to the local gage datum for USGS streamgage Peckman River at Ozone Avenue at Verona, New Jersey. Subcritical flow regime was assumed for the simulations. Normal depth was used as the reach's downstream boundary condition. The energy slope used for the normal depth boundary condition was 0.0015 and was estimated by computing the slope of the channel bottom through the study reach. The flows used in the model are shown in table 3.

The hydraulic model was evaluated on the basis of the current stage-discharge relation (rating number 5.0) at the USGS streamgage 01389534 Peckman River at Ozone Avenue at Verona, New Jersey, between (and inclusive of ) stages 3.0 and 6.5 ft. The model also was evaluated on the basis of the current stage-discharge relation (rating no. 2.2) at a second USGS streamgage, 01389550 Peckman River at Little Falls, New Jersey. Target water-surface elevations at USGS streamgage Peckman River at Little Falls, New Jersey, (station number 01389550) were determined by applying the drainage area adjusted flow for the section of the reach containing the streamgage location to the stage-discharge relation at Little Falls. This was done for each stage of the water-surface profiles at the upstream streamgage. For instance, at a gage height of 5.0 ft, 1,530 cubic feet per second ($ft^3/s$) is the rated flow at station number 01389534. Station number 01389550 is located

**Table 3.** Estimated discharges for corresponding stages and water-surface elevations at selected locations, used in the hydraulic model of the U.S. Geological Survey streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534).

[ft, foot; NAVD 88, North American Vertical Datum of 1988; $ft^3/s$, cubic feet per second; NJ, New Jersey]

| Stage of water-surface profile (ft)[1] | Water-surface elevation (ft, NAVD 88) | Estimated discharge at indicated location, in $ft^3/s$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | At upstream end of study reach | Downstream from Linden Avenue | At Ozone Avenue, Peckman River at Verona, NJ, streamgage | Downstream from confluence with Taylor Brook | Downstream from confluence with Peckman River tributary A | Downstream from confluence with Peckman River tributary B | Upstream from State Route 46 at Little Falls, NJ | Downstream from State Route 46 at Woodland Park, NJ |
| **Drainage area** | | **2.68** | **3.61** | **4.48** | **6.39** | **7.31** | **8.35** | **8.86** | **9.98** |
| 3 | 302.12 | 355 | 444 | 520 | 682 | 755 | 834 | 872 | 953 |
| 3.5 | 302.62 | 495 | 619 | 724 | 950 | 1,050 | 1,160 | 1,210 | 1,330 |
| 4 | 303.12 | 654 | 817 | 956 | 1,250 | 1,390 | 1,530 | 1,600 | 1,750 |
| 4.5 | 303.62 | 834 | 1,040 | 1,220 | 1,600 | 1,770 | 1,960 | 2,040 | 2,240 |
| 5 | 304.12 | 1,050 | 1,310 | 1,530 | 2,010 | 2,220 | 2,450 | 2,560 | 2,800 |
| 5.5 | 304.62 | 1,290 | 1,610 | 1,880 | 2,470 | 2,730 | 3,010 | 3,150 | 3,450 |
| 6 | 305.12 | 1,550 | 1,940 | 2,270 | 2,980 | 3,290 | 3,640 | 3,800 | 4,160 |
| 6.5 | 305.62 | 1,850 | 2,320 | 2,710 | 3,550 | 3,930 | 4,340 | 4,540 | 4,970 |

[1]Water-surface profiles are half-foot increments of stage, referenced to the gage datum of the U.S. Geological Survey streamgage, Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534).

just downstream from the confluence with Tributary A. The drainage-area adjusted discharge for that location is 2,220 $ft^3/s$ (table 3). Using stage-discharge relation no. 2.2 at station number 01389550 with a discharge of 2,220 $ft^3/s$ returns a target stage of 9.92 ft (175.61 ft NAVD 88). Additionally, the model was assessed relative to two recent recorded peak flows and stages at the Peckman River at Ozone Avenue at Verona streamgage. Model calibration is typically accomplished by adjusting Manning's *n* values and, in some cases, changing the channel slope until the results of the hydraulic computations closely agree with the known flood flow and stage values. However, owing to the close agreement between simulated and observed flows and water-surface elevations, it was unnecessary to adjust the aforementioned parameters for this particular hydraulic model. Differences between observed and simulated water-surface elevations for the eight simulated flows at both streamgages were equal to or less than 0.02 ft (table 4). The simulated water-surface elevations at USGS streamgage 01389534 for the floods of September 16, 1999, and August 28, 2011, agreed exactly with the target water-surface elevations (table 5). The results demonstrate that the model is capable of simulating accurate water levels over a wide range of flows in the basin.

## Development of Water-Surface Profiles

Profiles were developed for eight stages at 0.5-ft intervals from 3.0 ft to 6.5 ft as referenced to the local datum of the Peckman River at Ozone Avenue at Verona, New Jersey, streamgage. These stages correspond to elevations of 302.12 ft and 305.62 ft, NAVD 88, respectively. Flows corresponding to the various stages were obtained from the most current stage-discharge relation (rating number 5.0) for the streamgage. Flows through the study reach were adjusted, as necessary, for tributary inflow(s) as shown in table 3.

## Development of Flood-Inundation Maps

Flood-inundation maps were created for a 7.5-mile reach of the Peckman River in New Jersey from Verona Lake Dam in the Township of Verona, downstream through the Township of Cedar Grove and the Township of Little Falls, and ending at the confluence with the Passaic River in the Borough of Woodland Park. The flood-inundation maps for this reach were calibrated using the flow measurements from the USGS streamgage at Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534). The maps were created in a GIS by combining the water-surface profiles and digital elevation model data derived from the combined channel surveys and lidar data. The 3-meter (9.84-ft) digital elevation model data were derived from lidar data obtained from the 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. The flood surfaces were generated using an iterative finite-difference interpolation technique (ArcMap 10.3 Topo to Raster tool). Topo to Raster is an interpolation method specifically designed for the creation of hydrologically sound digital elevation models (Environmental Systems Research Institute, Inc., 2012a). Required inputs include point data derived from the digital cross sections that had been attributed with the eight water-surface

**Table 4.** Target and simulated water-surface elevations at U.S. Geological Survey streamgages on the Peckman River at Ozone Ave at Verona, New Jersey, and Peckman River at Little Falls, New Jersey, (station numbers 01389534 and 01389550) used for evaluation of the model.

[ft, foot; NAVD 88, North American Vertical Datum of 1988]

| Stage of water-surface profile (ft) | Target (observed) water-surface elevation 01389534 (ft, NAVD 88) | Simulated water-surface elevation 01389534 (ft, NAVD 88) | Difference in elevations (ft) | Target water-surface elevation 01389550 (ft, NAVD 88) | Modeled water-surface elevation 01389550 (ft, NAVD 88) | Difference in elevation (ft) |
|---|---|---|---|---|---|---|
| 3 | 302.12 | 302.12 | 0 | 170.03 | 170.02 | 0.01 |
| 3.5 | 302.62 | 302.62 | 0 | 171.19 | 171.19 | 0 |
| 4 | 303.12 | 303.12 | 0 | 172.51 | 172.51 | 0 |
| 4.5 | 303.62 | 303.61 | 0.01 | 173.96 | 173.95 | 0.01 |
| 5 | 304.12 | 304.12 | 0 | 175.61 | 175.61 | 0 |
| 5.5 | 304.62 | 304.62 | 0 | 177.43 | 177.42 | 0.01 |
| 6 | 305.12 | 305.11 | 0.01 | 179.35 | 179.35 | 0 |
| 6.5 | 305.62 | 305.62 | 0 | 181.49 | 181.51 | -0.02 |

**Table 5.** Recorded and simulated water-surface elevations at the U.S. Geological Survey streamgage on Peckman River at Ozone Avenue at Verona, New Jersey, (station number 01389534) for the floods of September 16, 1999, and August 28, 2011, used for assessment of the model, and differences between elevations.

[ft, foot; NAVD 88, North American Vertical Datum of 1988]

| Date of flood | Recorded water-surface elevation 01389534 (ft, gage datum) | Recorded water-surface elevation 01389534 (ft, NAVD 88) | Simulated water-surface elevation 01389534 (ft, NAVD 88) | Difference in elevation (ft) |
|---|---|---|---|---|
| 16-Sep-99 | 6.57 | 305.69 | 305.69 | 0 |
| 28-Aug-11 | 5.32 | 304.44 | 304.44 | 0 |

elevations, computed by the HEC-RAS model, and a study area boundary polygon. Depth-of-water grids were generated by subtracting the flood water-surface elevation from the flood water-surface raster layer. Shapefile polygons and depth grids of the inundated areas for each of the eight profiles were edited in the ArcMap application of ArcGIS (Environmental Systems Research Institute, Inc., 2012b) to ensure a hydraulically reasonable transition of the flood boundaries between modeled cross sections. Most inundated areas that were detached from the main channel and, therefore, erroneously delineated as parts of the flood extent were removed from the mapped inundated areas. Existence of culverts hydraulically connected to the main channel was considered for several of the detached inundated areas within Little Falls. These areas were kept as part of the inundation layer. 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.

Bridge surfaces were displayed as inundated when water-surface elevations reached the lowest structural chord of the bridge or bridge deck. Estimates of water depth can be obtained from the depth-grid data that are included with the presentation of the flood maps on the interactive online map-library Web site described in the following section, "Flood-Inundation Maps on the Internet." The flood map corresponding to the highest simulated water-surface profile, a stage of 6.5 ft, is presented in figure 3.

## Flood-Inundation Maps on the Internet

The current study documentation is available online at the USGS Publications Warehouse (http://pubs.usgs.gov/sir/2016/5105) and on the Flood Inundation Mapping Science Web site (U.S. Geological Survey, 2014c), which has been established to make USGS flood-inundation study information available to the public. The Web site links to a mapping application that presents map libraries and provides detailed information on flood extents and depths for selected sites. The mapping application enables the production of customized flood-inundation maps from the map library for Peckman River at Ozone Avenue at Verona, New Jersey. Also included on the Web site is a link to the USGS National Water Information System (http://waterdata.usgs.gov/nj/nwis/uv?site_no=01389534), which presents graphs of the current stage and flow at the USGS streamgage 01389534 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. Depending on the flood magnitude, roadways are shown as shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use. Bridge surfaces are shown as shaded (inundated) when water-surface elevations reach the lowest structural chord of the bridge or bridge deck (table 6). Buildings that 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

The flood-inundation maps 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.

## 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 interpolating measured water stage and flow at two USGS streamgages. Water-surface elevations along the stream reaches were estimated using

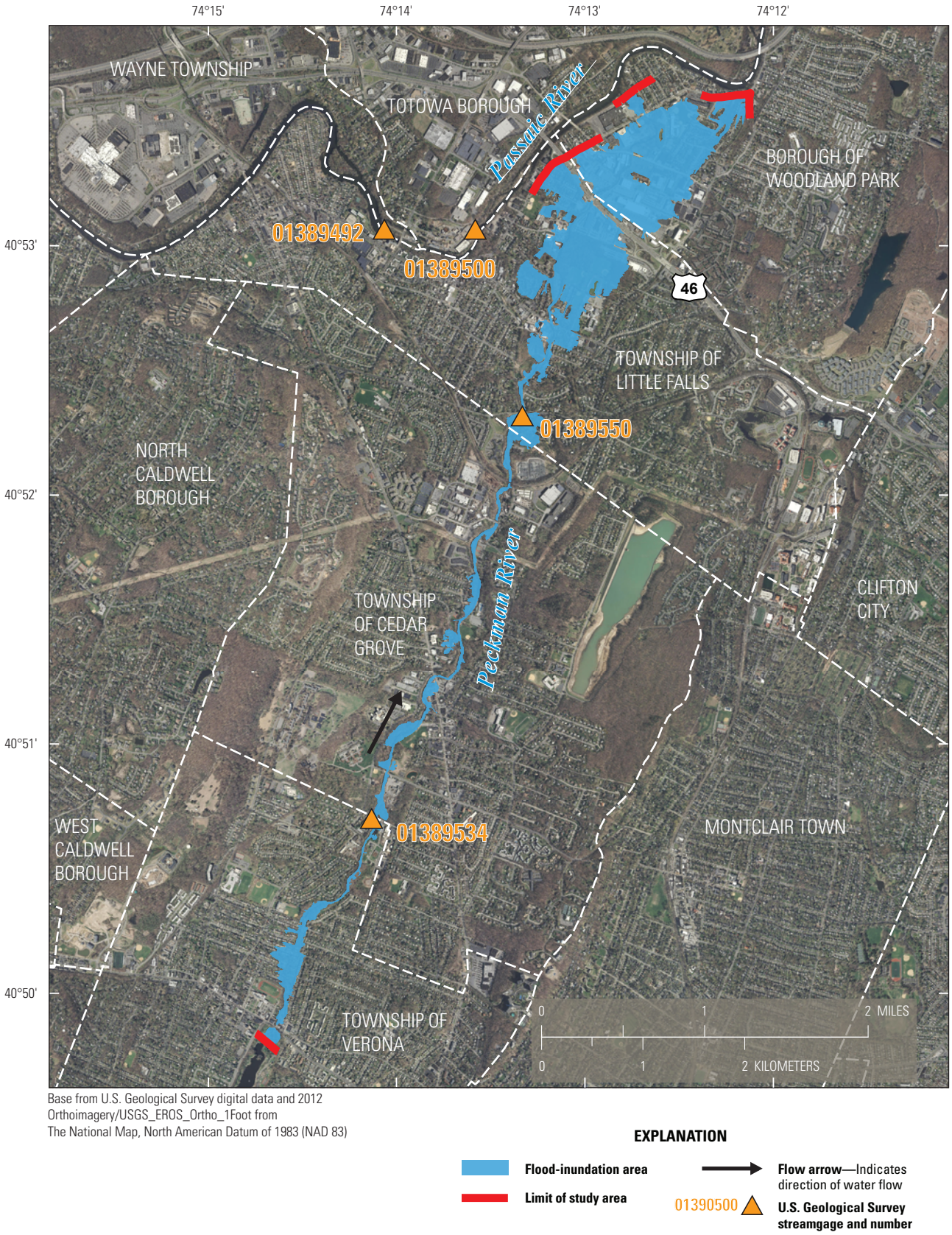



**Figure 3.** Flood-inundation map for the Peckman River at Ozone Avenue at Verona and the Peckman River at Little Falls, New Jersey (station number 01389534), corresponding to a stage of 6.5 feet at the U.S. Geological Survey streamgage.

**Table 6.** Occurrence of bridge inundation determined from simulated water-surface profiles corresponding to a stage level for the U.S. Geological Survey streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534).

[See figure 2 for location; ft, foot]

| Stage (ft) | Bridge inundated |
|---|---|
| 3 | None |
| 3.5 | None |
| 4 | None |
| 4.5 | None |
| 5 | Ozone Avenue, State Route 46, Lackawanna Avenue, McBride Avenue |
| 5.5 | Ozone Avenue, State Route 46, Lackawanna Avenue, McBride Avenue |
| 6 | Linden Ave, Ozone Avenue, Little Falls Road, Lindsley/Francisco Road, E. Main Street, State Route 46[1], Lackawanna Avenue, McBride Avenue |
| 6.5 | Linden Ave, Ozone Avenue, Bradford Avenue, State Route 23, Little Falls Road, Lindsley/Francisco Road, E. Main Street, State Route 46[1], Lackawanna Avenue, McBride Avenue |

[1]The approach to the State Route 46 bridge becomes inundated at stages of 6.0 and 6.5 ft.

steady-state hydraulic modeling, assuming unobstructed flow, and using flows and hydrologic conditions anticipated at the two USGS streamgages. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of August 2005. Unique meteorological factors (timing and distribution of precipitation) may cause actual flows along the modeled reach to vary from model results, which may lead to deviations of actual water-surface elevations and inundation boundaries from model results. Additional areas may be flooded as a result of 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 NWS river forecasts, the user needs to 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 [Advanced Hydrologic Prediction Service (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 eight digital flood-inundation maps was developed by the U.S. Geological Survey (USGS) in cooperation with the New Jersey Department of Environmental Protection for the USGS streamgage on the Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534). The maps cover a reach approximately 7.5 miles long from Verona Lake Dam in the Township of Verona, downstream through the Township of Cedar Grove and the Township of Little Falls, and ending at the confluence with the Passaic River in the Borough of Woodland Park. The maps were developed by using the U.S. Army Corps of Engineers' HEC–RAS one-dimensional hydraulic model to compute water-surface profiles and to delineate estimated flood-inundation areas and depths of flooding for selected stream stages. The HEC-RAS hydraulic model was evaluated with the most current stage-discharge relations and two recorded flood elevations at the Peckman River at Ozone Avenue streamgage. The model was used to compute eight water-surface profiles for river stages at 0.5-ft intervals referenced to the streamgage datum at the Peckman River at Ozone Avenue at Verona, New Jersey, that range from 3.0 ft or near bankfull to 6.5 ft, which is approximately the stage of the maximum recorded peak flow (1979–2014). The simulated water-surface profiles were then combined with a geographic information system (GIS) digital elevation model [derived from light detection and ranging (lidar) data] to delineate estimated flood-inundation areas as shapefile polygons and depth grids for each profile. These flood-inundation polygons were overlaid on high-resolution, georeferenced aerial photographs of the study area. The flood maps are available at the USGS flood-inundation mapping Web portal.

Interactive use of the maps at this portal can give users a general indication of the depth of water at any point by using the mouse cursor to click within the shaded areas that delineate inundated areas, including man-made structures. These maps, in conjunction with the real-time stage data from the USGS streamgage, Peckman River at Ozone Avenue at Verona, New Jersey (station number 01389534) will help to guide the general public in taking individual safety precautions and will provide emergency management personnel with a tool to efficiently manage emergency flood operations and post-flood recovery efforts.

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