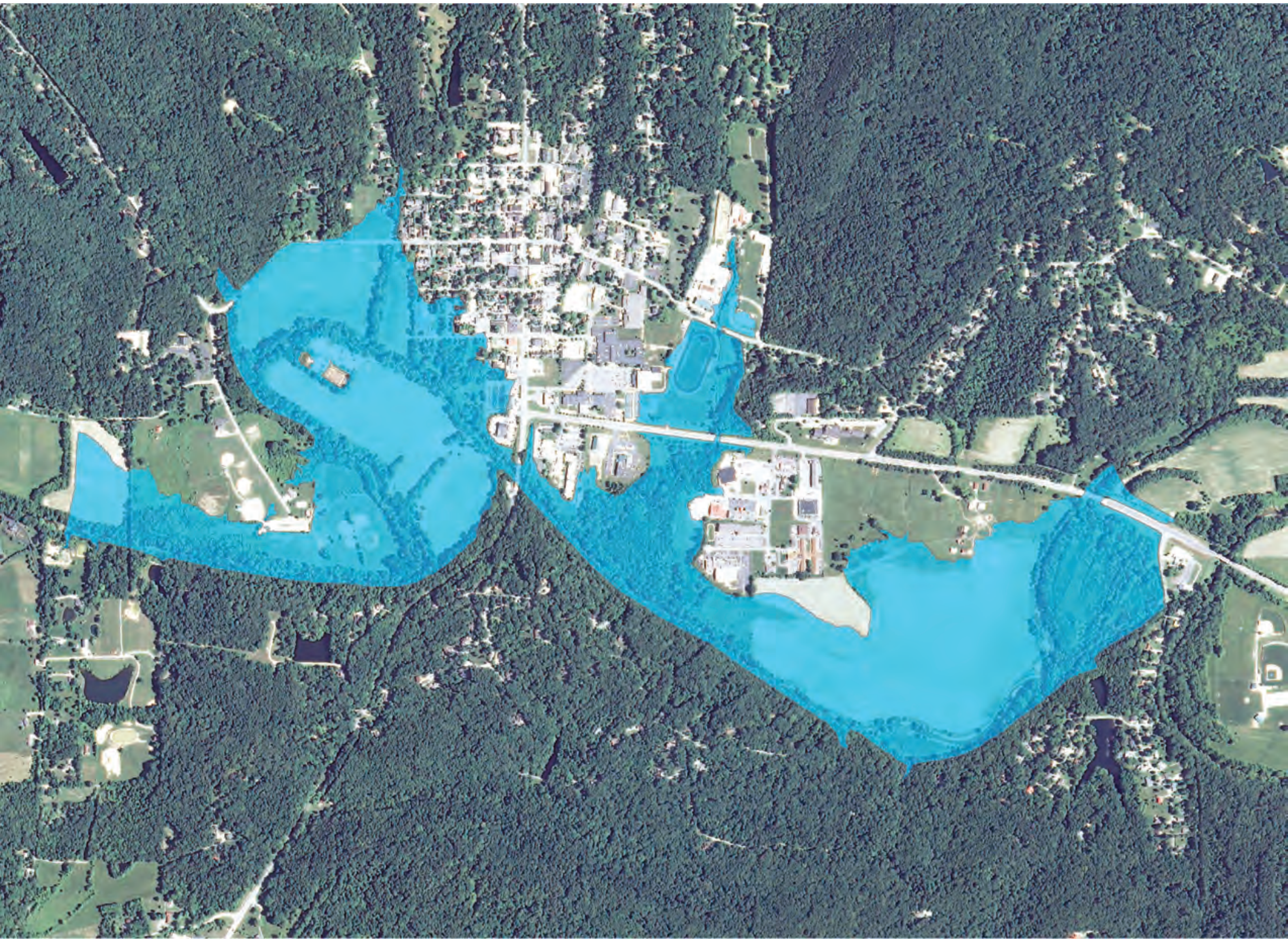
USGS
science for a changing world

Prepared in cooperation with the Indiana Department of Transportation

Flood-Inundation Maps for North Fork Salt Creek at Nashville, Indiana



Scientific Investigations Report 2017–5127

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

Cover. Flood–inundation map for North Fork Salt Creek at Nashville, Indiana, corresponding to a stage of 22.9 feet at the U.S. Geological Survey streamgage 03371650.

Flood-Inundation Maps for North Fork Salt Creek at Nashville, Indiana

By Zachary W. Martin

Prepared in cooperation with the Indiana Department of Transportation

Scientific Investigations Report 2017–5127

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

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Martin, Z.W., 2017, Flood-inundation maps for North Fork Salt Creek at Nashville, Indiana: U.S. Geological Survey Scientific Investigations Report 2017–5127, 10 p., https://doi.org/10.3133/sir20175127.

ISSN 2328-0328 (online)

Acknowledgments

The author wishes to thank the Indiana Department of Transportation for cooperation in funding the operation and maintenance of the streamgage used for this study. Special thanks are given to the National Weather Service for their continued support of the U.S. Geological Survey flood-inundation mapping program.

Contents

Figures

Tables

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 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 distance above the vertical datum.

Flood-Inundation Maps for North Fork Salt Creek at Nashville, Indiana

By Zachary W. Martin

Abstract

Digital flood-inundation maps for a 3.2-mile reach of North Fork Salt Creek at Nashville, Indiana, were created by the U.S. Geological Survey (USGS) in cooperation with the Indiana Department of Transportation. The flood-inundation maps, which can be accessed through the USGS Flood Inundation Mapping Science website at http://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding that correspond to selected water levels (stages) at the North Fork Salt Creek at Nashville, Ind., streamgage (USGS station number 03371650). Real-time stages at this streamgage may be obtained from the USGS National Water Information System at http://waterdata.usgs.gov/nwis or the National Weather Service (NWS) Advanced Hydrologic Prediction Service at http:/water.weather.gov/ahps/, which also shows observed USGS stages at the same site as the USGS streamgage (NWS site NFSI3).

Flood profiles were computed for the stream reach by means of a one-dimensional, step-backwater hydraulic modeling software developed by the U.S. Army Corps of Engineers. The hydraulic model was calibrated using the current (2015) stage-discharge rating at the USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. The hydraulic model was then used to compute 12 water-surface profiles for flood stages at 1-foot (ft) intervals, except for the highest profile of 22.9 ft, referenced to the streamgage datum ranging from 12.0 ft (the NWS “action stage”) to 22.9 ft, which is the highest stage of the current (2015) USGS stage-discharge rating curve and 1.9 ft higher than the NWS “major flood stage.” The simulated water-surface profiles were then combined with a geographic information system digital elevation model (derived from light detection and ranging data having a 0.98-ft vertical accuracy and 4.9-ft horizontal resolution) to delineate the area flooded at each stage.

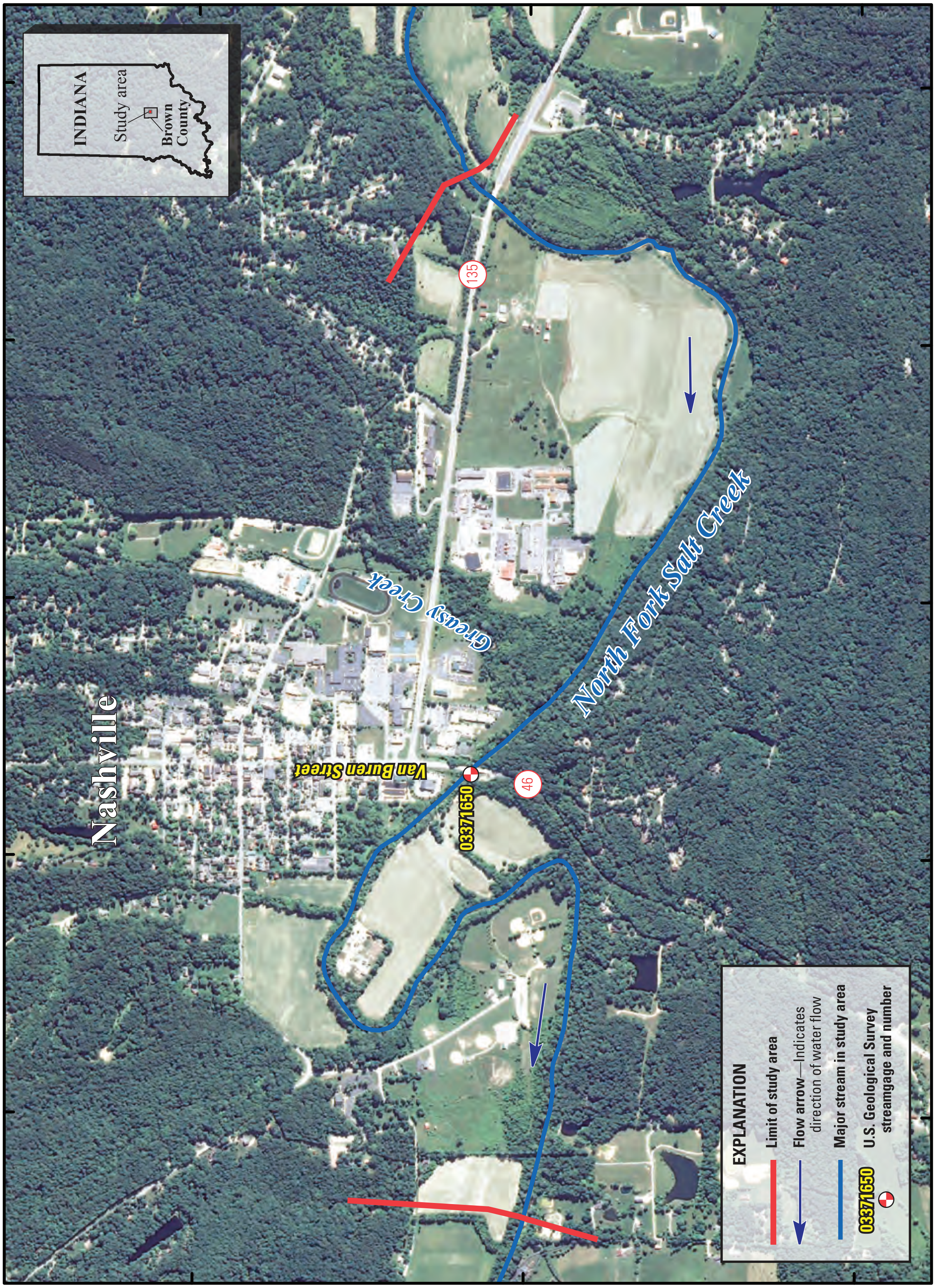
The availability of these maps, along with information regarding current stage from the USGS streamgage, will provide emergency management personnel and residents with information that is critical for flood response activities, such as evacuations and road closures, as well as for postflood recovery efforts.

Introduction

The town of Nashville, Indiana, in central Brown County along the banks of North Fork Salt Creek (fig. 1), has an estimated population of 803 (U.S. Census Bureau, 2010). Nashville has experienced flood stages numerous times, most recently in 2015 and 2016 (National Weather Service, 2017a). The highest recorded flood on North Fork Salt Creek at Nashville was in July 2015 with a recorded peak stage value of 20.01 feet (ft) (U.S. Geological Survey, 2017d). North Fork Salt Creek flows through central Brown County from the northeast to the southwest. The land around North Fork Salt Creek corridor near Nashville has been developed primarily for agricultural and recreational uses with some residential and commercial development. At various stages and National Weather Service (NWS) Flood Categories, residential, commercial, recreational, and agricultural areas are affected by the floodwaters of North Fork Salt Creek (National Weather Service, 2017a).

Before this study, emergency responders in Nashville relied on a few information sources to make decisions on how to best alert the public and mitigate flood damages. An example of an information source is the Federal Emergency Management Agency flood insurance study (FIS) for Brown County, dated December 8, 2016 (Federal Emergency Management Agency, 2016). A second example of an information source is the U.S. Geological Survey (USGS) streamgage 03371650, North Fork Salt Creek at Nashville, Ind., from which current (2017; U.S. Geological Survey, 2017d) and historic (since 1962; U.S. Geological Survey, 2017c) stages and discharges, including annual peak flows, can be obtained (https://nwis.waterdata.usgs.gov/in/nwis/uv/?site_no=03371650&agency_cd=USGS). A third example of an information source is the NWS Advanced Hydrologic Prediction Service (AHPS), which displays the current USGS stage data for USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. (National Weather Service, 2017a).

Although the current stage at a USGS streamgage is particularly useful for residents near a streamgage, the stage is of little use to residents farther upstream or downstream because the water-surface elevation is not constant along the stream reach. Additionally, knowledge of the water level at a



Projection: Indiana State Plane Eastern Zone
Horizontal coordinate information is referenced to the North American Datum of 1983
Orthophotography from Indiana Spatial Data Portal,
National Agricultural Imagery Program, 2012, available at http://gis.iu.edu/

Figure 1. Location of study reach for North Fork Salt Creek at Nashville, Indiana, and location of U.S. Geological Survey streamgage 03371650.

streamgage is difficult to translate into depth and areal extent of flooding at points distant from the streamgage. A way to address these informational gaps is to produce a library of flood-inundation maps that are referenced to 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 may be flooded, and make plans for notification or evacuation of residents in harm's way for some distance upstream and downstream from the streamgage. In addition, the capability to visualize the potential extent of flooding has motivated residents to take precautions and heed warnings that previously might have been disregarded. In 2017, the USGS, in cooperation with the Indiana Department of Transportation, led a project to produce a library of flood-inundation maps for North Fork Salt Creek at Nashville, Ind.

Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for North Fork Salt Creek at Nashville, Ind., and identifies where on the internet the maps can be viewed and ancillary data (geographic information system [GIS] flood polygons and depth grids) can be downloaded. The flood-inundation maps correspond to stages at the USGS streamgage. This study covers a 3.2-mile (mi) reach along North Fork Salt Creek, 0.1 mi upstream from the State Road 135 bridge to 1.7 mi downstream from the State Road 46 or Van Buren Street bridge (fig. 1).

The maps were produced for flood levels referenced to the stage recorded at USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. (table 1); the streamgage is on the downstream side of State Road 46 (fig. 1). The maps range in stage from 12.0 to 22.9 ft above the streamgage datum. The 12.0-ft stage is near bankfull and is defined by the National Weather Service (2017b) as the "action stage" or the stage that, when reached by a rising stream, represents the level where the NWS or a partner needs to take some type of mitigation action in preparation for possible substantial hydrologic activity. The 22.9-ft stage is the highest stage on the current USGS stage-discharge rating curve (USGS rating number 1.0, effective July 7, 2015). A stage of 21.0 ft is the "major flood stage," as determined by the National Weather Service (2017b).

Study Area Description

The North Fork Salt Creek study reach is in the city of Nashville, which is in central Indiana and has the third highest population of Brown County. The stream is in the Norman Upland physiographic section of the Southern Hills and Lowlands Region (Gray, 2000). The headwaters of North Fork Salt Creek originate in Brown County, Ind. The drainage area is 69.9 square miles (mi^2) at the upstream end of the study reach and 77.5 mi^2 at the downstream end of the study reach (U.S. Geological Survey, 2017a). The study reach is about 3.2 mi long and has a channel slope of about 0.0006 (3.2 feet per mile). Land use along the study reach is residential, commercial, recreational, and agricultural. The study reach is traversed by two State road bridges.

Previous Studies

The current FIS for Brown County contains hydrologic and hydraulic analyses from previous and new studies effective December 8, 2016 (Federal Emergency Management Agency, 2016). The new FIS studies were completed by the Schneider Corporation, on behalf of the Indiana Department of Natural Resources in 2007 (Federal Emergency Management Agency, 2016). The previous FIS analysis for Brown County was done by the Indiana Department of Natural Resources in 1984 (Federal Emergency Management Agency, 2016). Values of the 10, 2, and 1 percent annual exceedance probabilities for North Fork Salt Creek at Nashville, Ind., based on streamgage peak flow data are shown in table 2 (Knipe, 2004).

Table 1. U.S. Geological Survey streamgage information for North Fork Salt Creek at Nashville, Indiana.

[Station location is shown in figure 1. mi^2, square mile; ft, foot; NAVD 88, North American Vertical Datum of 1988; ft^3/s, cubic foot per second; °, degree; ′, minute; ″, second]

Station name	Station number	Drainage area (mi^2)	Latitude	Longitude	Datum of gage (ft, NAVD 88)	Period of record	Maximum documented stage (ft) and date	Maximum documented discharge (ft^3/s) and date
North Fork Salt Creek at Nashville, Indiana	03371650	76.1	39°12′ 05.1″	86° 14′ 49.6″	576.14	1962 to 1976 and 2015 to current year (2017)	20.01, July 14, 2015	7,200, May 24, 1968

Table 2. Estimated discharges for selected annual exceedance probabilities for North Fork Salt Creek at Nashville, Indiana.

[mi^2, square mile; ft^3/s, cubic foot per second; USGS, U.S. Geological Survey. Data from Knipe, 2004]

Location on North Fork Salt Creek	Drainage area (mi^2)	Estimated discharges (ft^3/s) for indicated annual exceedance probabilities in percent		
		10	2	1
USGS Streamgage 03371650	76.1	6,700	8,440	9,120

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, 2017b) so that the process and products are consistent regardless of which USGS office is responsible for the work. Tasks specific to developing the flood maps for Nashville, Ind., were as follows: (1) operation of the Nashville streamgage and collection of streamflow data on North Fork Salt Creek (table 1); (2) collection of topographic and bathymetric data for selected cross sections and geometric data for structures and bridges along the study reach; (3) estimation of energy-loss factors (roughness coefficients) in the stream channel and flood plain and determination of steady-flow data; (4) computation of water-surface profiles using the U.S. Army Corps of Engineers' Hydrologic Engineering Centers River Analysis System (HEC–RAS) computer program (Brunner, 2016a, 2016b, 2016c); (5) production of estimated flood-inundation maps at various stream stages using the U.S. Army Corps of Engineers' Hydrologic Engineering Centers Geospatial River Analysis System (HEC–GeoRAS) computer program (Brunner, 2012) and GIS; and (6) preparation of the maps, as shapefile polygons that depict the areal extent of flood inundation and as depth grids that provide the depth of floodwaters, for display on a USGS flood-inundation mapping application.

Computation of Water-Surface Profiles

The water-surface profiles used to produce the 12 flood-inundation maps in this study were computed with HEC–RAS, version 5.0.3 (Brunner, 2016a, 2016c). The HEC–RAS model is a one-dimensional step-backwater model that simulates water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options.

Hydrologic Data

The study reach includes USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. (fig. 1; table 1), which was in operation from August 1962 to September 1976 and has been in operation continuously since July 2015. Water level (stage) is measured every 15 minutes, transmitted hourly by a satellite antenna at the streamgage, and made available on the internet through the USGS National Water Information System (U.S. Geological Survey, 2017c). Stage data from this streamgage 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 576.14 ft. Continuous records of streamflow are computed from a stage-discharge relation, which has been developed for the streamgage, and are available through the USGS National Water Information System website (U.S. Geological Survey, 2017c).

The flows used in the model simulations (table 3) were taken from the current stage-discharge relation for streamgage 03371650 (number 1.0, effective July 7, 2015) and corresponded to the target stages. One major tributary, Greasy Creek, joins North Fork Salt Creek within the 3.2-mi study reach. The streamgage-derived discharges were adjusted to account for tributary inflows (table 3). These adjustments were calculated based on the average percent difference in discharge estimates from the peak-flow statistics flow report at the two locations in table 3, using a web-based application named StreamStats (U.S. Geological Survey, 2017a). The discharges upstream from the confluence of Greasy Creek were decreased 3.5 percent from the streamgage-rated discharges.

Topographic and Bathymetric Data

All topographic data used in this study are referenced vertically to NAVD 88 and horizontally to the North American Datum of 1983. Cross section elevation data were obtained from a digital elevation model (DEM) that was derived from light detection and ranging (lidar) data that were collected as part of a statewide project during 2011–13 by Woolpert, Inc., Geospatial Services, Dayton, Ohio (Woolpert, Inc., 2011). The lidar data for Brown County were collected in 2011. The DEM was obtained from the Indiana Spatial Data Portal (Indiana University, 2013). The original lidar data have a horizontal resolution of 4.9 ft and vertical accuracy of 0.98 ft at a 95-percent confidence level based on a root mean squared error of 0.49 ft for the "open terrain" land-cover category. By these criteria, the lidar data support production of 2-ft contours (Dewberry, 2012); the final DEM has a grid-cell size of 5 ft by 5 ft and a vertical accuracy of plus or minus 1 foot.

Table 3. Estimated discharges for corresponding stages and water-surface elevations used in the hydraulic model of U.S. Geological Survey streamgage 03371650, North Fork Salt Creek at Nashville, Indiana.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; ft^3/s, cubic foot per second; mi^2, square miles; USGS, U.S. Geological Survey]

Stage of water-surface profile (ft)[1]	Water-surface elevation (ft, NAVD 88)	Estimated discharge at indicated location, ft^3/s	
		Upstream of Greasy Creek, drainage area = 70.7 mi^2	USGS streamgage 03371650 (downstream of Greasy Creek), drainage area = 76.1 mi^2
12.0	588.14	1,590	1,650
13.0	589.14	2,010	2,080
14.0	590.14	2,470	2,560
15.0	591.14	2,980	3,090
16.0	592.14	3,560	3,680
17.0	593.14	4,170	4,320
18.0	594.14	4,850	5,020
19.0	595.14	5,580	5,780
20.0	596.14	6,370	6,590
21.0	597.14	7,220	7,490
22.0	598.14	8,100	8,390
22.9	599.04	8,960	9,280

[1]Water-surface profiles are 1-foot increments of stage referenced to the streamgage datum of the U.S. Geological Survey streamgage, North Fork Salt Creek at Nashville, Ind. (station number 03371650).

Because lidar data cannot provide ground elevations below the water surface of a stream, channel cross sections were surveyed by USGS personnel during November 2016 to supplement the in-channel geometries. Cross sectional depths and elevations were measured using hydroacoustic instrumentation or a real-time kinematic global positioning system at 21 locations. A differential global positioning system with real-time kinematic technology was used to derive horizontal locations and the elevation of the water surface at each surveyed cross section. Georeferenced cross sections were made to coincide with the locations of the within-channel field-surveyed cross sections using the HEC–GeoRAS program, version 10.2 (Brunner, 2012). The HEC–GeoRAS program is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS and was used to extract elevation data from the DEM for 21 cross sections. For these 21 cross sections, within-channel field data were directly merged with the DEM data.

The DEM-generated cross section data were used in conjunction with the RAS Mapper tool in HEC–RAS 5.0.3 to interpolate below-water ground elevations through the study reach (Brunner, 2016b). The RAS Mapper creates an interpolation surface between each cross section. The interpolated surface is then used with the DEM-generated cross section data to create a grid of elevation data between two cross sections. In this study, a grid of 5 ft by 5 ft was created for the in-channel DEM. The merged DEM, consisting of the lidar and in-channel data, was used to create an additional 42 DEM-generated cross sections in HEC–GeoRAS, for input to the HEC–RAS model. The 63 cross-section lines were drawn to best represent flow vectors in the channel and flood plain and were spaced longitudinally every 300 ft on average. Instructions for creating a terrain model of the channel data are presented in chapter 2 of the U.S. Army Corps of Engineers 2D Modeling User's Manual, Version 5.0 (Brunner, 2016b).

Hydraulic Structures

Two structures, the State Road 46 (Van Buren Street) and State Road 135 bridge, have the potential to affect water-surface elevations during floods along the stream reach. Bridge-geometry data were obtained from field surveys led by personnel from the USGS in November 2016. Levees were not present in this modeled reach of North Fork Salt Creek.

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 are quantified by the Manning's roughness coefficient ("*n*" value) (Phillips and Tadayon, 2006). Initial (precalibration) *n* values were selected based on field observations, high-resolution aerial photographs, and the FIS hydraulic model (Federal Emergency Management Agency, 2016). Initially, an *n* value of 0.039 was selected for sand and gravel bed material with minor to moderate channel vegetation and debris. The overbank areas in the effective flow zones consisted of tree cover and open recreational or agricultural spaces, so an *n* value range of 0.050 to 0.100 was selected.

As part of the calibration process, the initial *n* values were adjusted until the differences between simulated and observed water-surface elevations at the USGS streamgage were minimized. The final *n* values were 0.044–0.048 for the main channel and 0.06–0.108 for the overbank areas modeled in this analysis.

Hydraulic Model

The HEC–RAS analysis for this study was done using the steady-state flow computation option. Steady-state flow data consisted of flow regime, boundary conditions, and flow rates that produced water-surface elevations at the streamgage that matched target water-surface elevations. These target elevations coincided with even 1-ft increments of stage, except for the highest profile of 22.9 ft, referenced to the local streamgage datum (U.S. Geological Survey, 2017d). Subcritical (tranquil) flow regime was assumed for the simulations. Normal depth, based on an estimated average water-surface slope of 0.0004 from survey data collected by USGS personnel, was used as the downstream boundary condition of the reach. The flows that were used in the model are included in the “Hydrologic Data” section.

The HEC–RAS hydraulic model was calibrated to the current stage-discharge relation (USGS rating no. 1.0, July 7, 2015) at USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. The model was calibrated by adjusting Manning’s *n* values and channel cross section ineffective flow areas until the results of the hydraulic computations closely agreed with the observed water-surface elevations for given flows. Ineffective flow areas were determined based on heavy vegetation, hydraulic connectivity to the channel, and proximity to the channel. Most of the overbank portion of the cross sections were assigned as ineffective in order to calibrate the hydraulic model. Differences between simulated and observed water-surface elevations for the 12 simulated flows at the USGS streamgage were equal to or less than 0.14 ft (table 4). The simulated water-surface elevations indicate that the model is capable of computing accurate water levels for a wide range of flows in the study reach. The datasets and model input used in this study are available through a data release at https://doi.org/10.5066/F7VQ316V (Martin, 2017).

Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for 12 stages at 1.0-ft intervals, except for the highest profile of 22.9 ft, between 12 and 22.9 ft as referenced to the local datum of USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. These stages correspond to elevations of 588.14 and 599.04 ft, NAVD 88, respectively. Discharges corresponding to the various stages were obtained from the current stage-discharge relation (USGS rating no. 1.0, July 7, 2015) (table 3) for USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind.

Table 4. Calibration of hydraulic model to target water-surface elevations at U.S. Geological Survey streamgage 03371650, North Fork Salt Creek at Nashville, Indiana.

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

Stage of water-surface profile (ft)	Target water-surface elevation (ft, NAVD 88)	Modeled water-surface elevation (ft, NAVD 88)	Difference in elevation (ft)
12.0	588.14	588.00	–0.14
13.0	589.14	589.05	–0.09
14.0	590.14	590.10	–0.04
15.0	591.14	591.15	0.01
16.0	592.14	592.18	0.04
17.0	593.14	593.19	0.05
18.0	594.14	594.11	–0.03
19.0	595.14	595.08	–0.06
20.0	596.14	596.04	–0.10
21.0	597.14	597.05	–0.09
22.0	598.14	598.11	–0.03
22.9	599.04	599.08	0.04

Development of Flood-Inundation Maps

Flood-inundation maps were created for a reach of North Fork Salt Creek at Nashville, Ind. The maps were created in a GIS by combining the 12 water-surface profiles and DEM data. The DEM data were derived from the same lidar data described in the “Topographic and Bathymetric Data” section and, therefore, have an estimated vertical accuracy of plus or minus 1 ft. In addition, the in-channel elevation data were merged with the lidar DEM data to provide a reasonable estimate of the stream bathymetry. Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (Brunner, 2012), which allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (Brunner, 2016a, 2016c). Shapefile polygons and depth grids of the inundated areas for each profile were modified, as required, in the ArcMap application of ArcGIS (Esri, 2017) to ensure a hydraulically reasonable transition of the flood boundaries between modeled cross sections.

Any inundated areas that were detached from the main channel were examined to identify subsurface hydraulic connections with the main river, such as through culverts under roadways. Where such connections existed, the mapped inundated areas were retained in their respective flood maps; otherwise, the erroneously delineated parts of the flood extent were deleted. The flood-inundation areas are overlaid on high-resolution, georeferenced, aerial photographs of the study area. Bridge surfaces for North Fork Salt Creek are displayed as inundated regardless of the actual water-surface elevation in relation to the bridge deck elevation. Estimates of water depth can be obtained from the depth-grid data that are included with the presentation of the flood maps on an interactive USGS mapping application described in the “Flood-Inundation Map Delivery” section. The flood map corresponding to the highest simulated water-surface profile, a stage of 22.9 ft, is shown in figure 2.

Flood-Inundation Map Delivery

A Flood Inundation Mapping Science website has been established to make USGS flood-inundation study information available to the public (U.S. Geological Survey, 2017b). The website (https://fim.wim.usgs.gov/fim/) links to a mapping application that presents map libraries and provides detailed information on flood extents and depths for modeled sites. The mapping application enables the production of customized flood-inundation maps from the map library for North Fork Salt Creek at Nashville, Ind. A link on this website connects to the USGS National Water Information System (U.S. Geological Survey, 2017d), which presents the current stage and streamflow at USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind., to which the inundation maps are referenced. A second link connects to the NWS AHPS site (National Weather Service, 2017a) so that the user can obtain applicable information on flood categories. The estimated flood-inundation maps are displayed in sufficient detail so that preparations for flooding and decisions for emergency response can be made 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. Bridges are shaded—that is, shown as inundated—regardless of the flood magnitude. A shaded building should not be interpreted to mean that the structure is completely submerged but that bare earth surfaces near the building are inundated. The water depth (as indicated in the mapping application by clicking the cursor over an inundated area) near the building would be an estimate of the water level inside the structure, unless flood-proofing measures had been implemented.

Disclaimer for Flood-Inundation Maps

The flood-inundation maps should not be used for navigation or 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 based on water stages and streamflows at the selected USGS streamgage. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, by assuming unobstructed flow, and by 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 November 2016. 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 because of unanticipated conditions such as changes in the streambed elevation or roughness, backwater into major tributaries along a main stem river, backwater from localized debris or ice jams, or backwater into storm sewers and detention basins. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the DEM 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 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

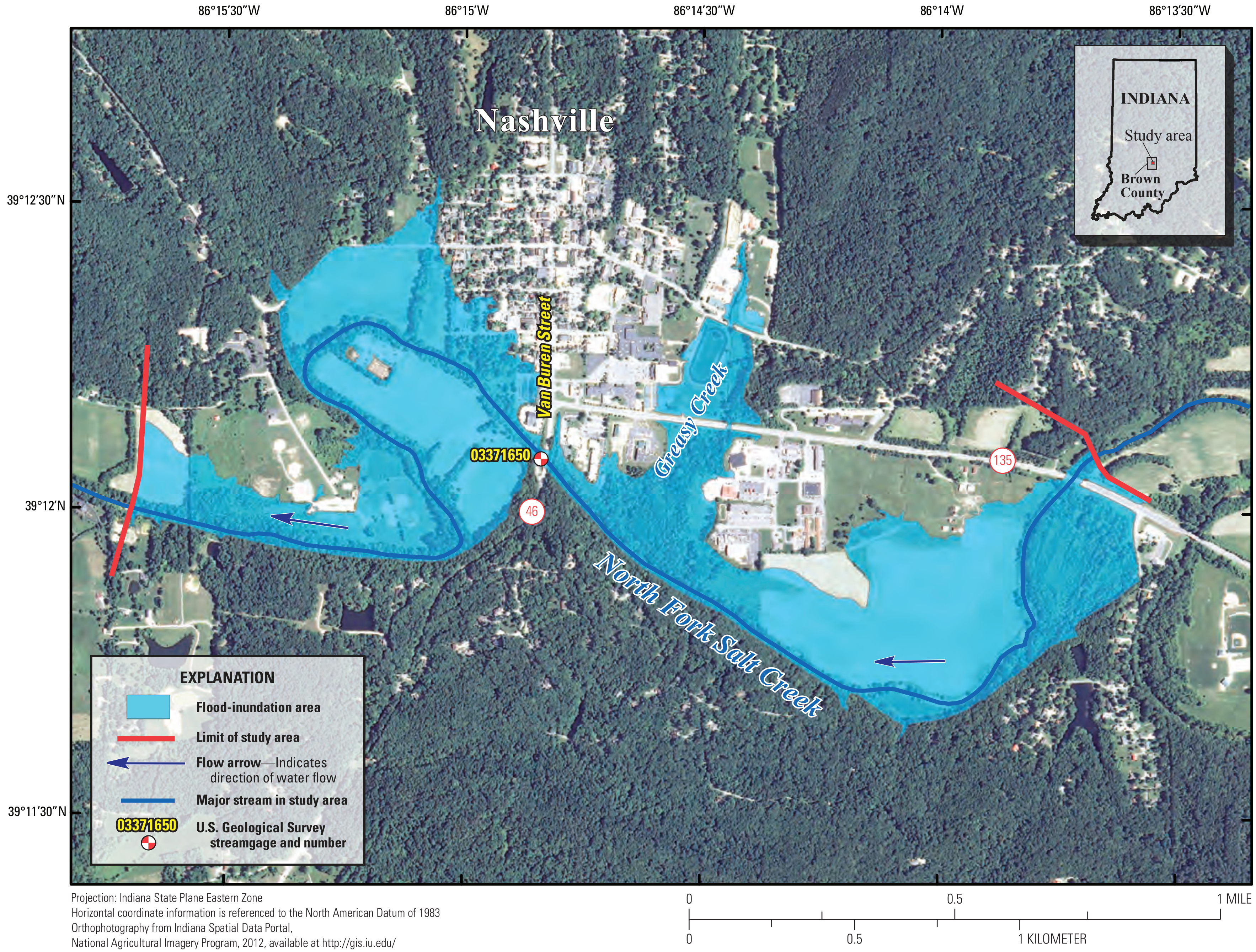


Figure 2. Flood-inundation map for North Fork Salt Creek at Nashville, Indiana, corresponding to a stage of 22.9 feet at the U.S. Geological Survey streamgage 03371650.

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 flows 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, see http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

Summary

A series of 12 digital flood-inundation maps was developed in cooperation with the Indiana Department of Transportation for U.S. Geological Survey (USGS) streamgage 03371650, North Fork Salt Creek at Nashville, Indiana. The maps cover a reach about 3.2 miles long, 0.1 mile upstream from the State Road 135 bridge to 1.7 miles downstream from the State Road 46 or Van Buren Street bridge. The maps were developed using the U.S. Army Corps of Engineers' Hydrologic Engineering Centers River Analysis System and Hydrologic Engineering Centers Geospatial River Analysis System 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 calibrated to the current (2015) stage-discharge relation at USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind. The model was used to compute 12 water-surface profiles for flood stages at 1-foot (ft) intervals, except for the highest profile of 22.9 ft, referenced to the streamgage datum and ranging from 12.0 ft or the National Weather Service "action stage" to 22.9 ft, which is the highest stage of the current (2015) USGS stage-discharge rating curve and 1.9 ft higher than the National Weather Service "major flood stage." The simulated water-surface profiles were then combined with a geographic information system digital elevation model derived from light detection and ranging 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 through a mapping application that can be accessed on the USGS Flood Inundation Mapping Science website (https://water.usgs.gov/osw/flood_inundation).

The interactive maps on this mapping application can give users a general indication of depth of water at any point by clicking within the shaded areas using the mouse cursor. These maps, in conjunction with the real-time stage data from USGS streamgage 03371650, North Fork Salt Creek at Nashville, Ind., 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 postflood recovery efforts.

References Cited

Brunner, G.W., 2012, HEC–GeoRAS, GIS tools for support of HEC–RAS using ArcGIS 10—User's manual, version 10: U.S. Army Corps of Engineers, Hydrologic Engineering Center [variously paged].

Brunner, G.W., 2016a, HEC–RAS, River Analysis System hydraulic reference manual, version 5: U.S. Army Corps of Engineers, Hydrologic Engineering Center, [variously paged].

Brunner, G.W., 2016b, HEC–RAS, River Analysis System, 2D modeling user's manual, version 5: U.S. Army Corps of Engineers, Hydrologic Engineering Center, [variously paged].

Brunner, G.W., 2016c, HEC–RAS River Analysis System user's manual, version 5: U.S. Army Corps of Engineers, Hydrologic Engineering Center, [variously paged].

Dewberry, 2012, National enhanced elevation assessment: Fairfax, Va., Dewberry, 84 p., accessed May 16, 2017, at http://www.dewberry.com/docs/default-source/documents/neea_final-report_revised-3-29-12.pdf?sfvrsn=0.

Esri, 2017, ArcGIS: accessed May 16, 2017, at http://www.esri.com/software/arcgis/.

Federal Emergency Management Agency, 2016, Flood insurance study, Brown County, Indiana and incorporated areas: Washington D.C., 86 p.

Gray, H.H., 2000, Physiographic divisions of Indiana: Indiana Geological Survey Special Report 61, 15 p., 2 fig., 1 pl.

Indiana University, 2013, Indiana spatial data portal: Indiana University web page, accessed May 16, 2017, at http://gis.iu.edu/.

Knipe, David, 2004, Estimation of peak discharges of Indiana streams by using log Pearson (III) distribution: Purdue University, accessed June 20, 2017, at http://www.indiana.gov/dnr/water/files/Estimation_of_Peak_Discharges_of_Indiana_Streams.pdf.

Martin, Z.W., 2017, North Fork Salt Creek at Nashville, Indiana, flood-inundation model and GIS data: U.S. Geological Survey data release, accessed November 2017, at https://doi.org/10.5066/F7VQ316V.

National Weather Service, 2017a, Advanced hydrologic prediction service, North Fork Salt Creek (MI/IN) at Nashville: National Weather Service web page, accessed May 19, 2017, at http://water.weather.gov/ahps2/hydrograph.php?wfo=ind&gage=NFSI3.

National Weather Service, 2017b, National Weather Service glossary: National Weather Service web page, accessed May 16, 2017, at http://w1.weather.gov/glossary/.

Phillips, J.V. and Tadayon, Saeid, 2006, Selection of Manning's roughness coefficient for natural and constructed vegetated and non-vegetated channels and vegetation maintenance plan guidelines for vegetated channels in central Arizona: U.S. Geological Survey Scientific Investigations Report 2006–5108, 41 p.

U.S. Census Bureau, 2010, 2010 Census interactive population search IN–Nashville city: U.S. Census Bureau web page, accessed May 19, 2017, at https://www.census.gov/2010census/popmap/ipmtext.php?fl=18.

U.S. Geological Survey, 2017a, The StreamStats Program—Indiana: U.S. Geological Survey web page, accessed May 19, 2017, at https://water.usgs.gov/osw/streamstats/indiana.html.

U.S. Geological Survey, 2017b, USGS flood inundation mapping science: U.S. Geological Survey web page, accessed May 19, 2017, at http://water.usgs.gov/osw/flood_inundation.

U.S. Geological Survey, 2017c, USGS surface-water data for the Nation: U.S. Geological Survey National Water Information System—Web interface, accessed May 19, 2017, at https://doi.org/10.5066/F7P55KJN.

U.S. Geological Survey, 2017d, USGS 03371650, North Fork Salt Creek at Nashville, Indiana: U.S. Geological Survey National Water Information System—Web interface, accessed May 19, 2017, at https://waterdata.usgs.gov/in/nwis/uv?site_no=03371650.

Woolpert, Inc., 2011, Woolpert Order No. 71177, Indiana Statewide Imagery and Lidar Program, remote sensing image: Dayton, Ohio, Woolpert, Inc., metadata available at http://gis.iu.edu/files/documents/in2011_ortho.txt.

For more information about this publication, contact:
Director, Ohio-Kentucky-Indiana Water Science Center
U.S. Geological Survey
5957 Lakeside Boulevard,
Indianapolis, IN 46278-1996

For additional information, visit https://in.water.usgs.gov/

Publishing support provided by the
Madison and Rolla Publishing Service Centers

Martin—**Flood-Inundation Maps for North Fork Salt Creek at Nashville, Indiana**—Scientific Investigations Report 2017–5127

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20175127