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Flood-Inundation Maps for Nimishillen Creek near North Industry, Ohio, 2019

Scientific Investigations Report 2019–5083

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

Cover: View looking north (upstream) of Nimishillen Creek near the U.S. Geological Survey streamgage, Nimishillen Creek at North Industry, Ohio (03118500). Photograph by U.S. Geological Survey, June 2016.

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

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square 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)

Datum

Vertical coordinate information is referenced to (1) stage, the height above an arbitrary datum established at a streamgage, and (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).

Flood-Inundation Maps for Nimishillen Creek near North Industry, Ohio, 2019

By Matthew T. Whitehead

Abstract

Digital flood-inundation maps for a 4-mile reach of Nimishillen Creek near North Industry, Ohio, were created by the U.S. Geological Survey (USGS) in cooperation with the Muskingum Watershed Conservancy District, Ohio, and the Stark County Board of Commissioners. The flood-inundation maps, which can be accessed through the USGS Flood Inundation Mapping (FIM) Program website at https://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgage on Nimishillen Creek at North Industry, Ohio (station number 03118500). Near-real-time stages at this streamgage can be obtained on the internet from the USGS National Water Information System at https://waterdata.usgs.gov/ or the National Weather Service Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/, which also forecasts flood hydrographs at this site.

Flood profiles were computed for the stream reach by means of a one-dimensional step-backwater model. The model was calibrated to the current stage-discharge relation at the streamgage on Nimishillen Creek at North Industry and documented high-water marks from the flood of January 12, 2017.

The hydraulic model was then used to compute seven water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the streamgage datum and ranging from 8 to 14 ft, which is from “action stage” to above “major flood stage” as reported by the National Weather Service. The simulated water-surface profiles were then used in combination with a geographic information system (GIS) digital elevation model derived from light detection and ranging data to delineate the areas flooded at each water level.

The availability of these maps, along with internet information regarding current stage from the USGS streamgage and forecasted high-flow stages from the National Weather Service, 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. Forecasts for the USGS streamgage on Nimishillen Creek at North Industry, Ohio are issued as needed during times of high water, but are not routinely available (National Weather Service, 2017).

Introduction

Before this study, emergency responders in North Industry relied on several information sources (all 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 flood insurance study for Stark County (fig. 1) (Federal Emergency Management Agency, 2018). A second source of information is the U.S. Geological Survey (USGS) streamgage, Nimishillen Creek at North Industry, Ohio (03118500) (fig. 1), for which current and historical (since 1921) water levels and discharges, including annual peak flows, can be obtained (U.S. Geological Survey, 2017a). A third source of flood-related information is the National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS), which displays the stage data from the USGS streamgage on Nimishillen Creek at North Industry and issues forecasts of stages for the streamgage (National Weather Service, 2017).

Although the current stage at a USGS streamgage is particularly useful for residents near a streamgage, the stage is of limited use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream reach. Knowledge of a water level 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 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 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 been demonstrated to motivate residents to take precautions and heed warnings that they previously might have disregarded. In 2018, the USGS, in cooperation with the Stark County board of Commissioners and the Muskingum Watershed Conservancy District, led a project to produce a library of flood-inundation maps for Nimishillen Creek at North Industry, Ohio.

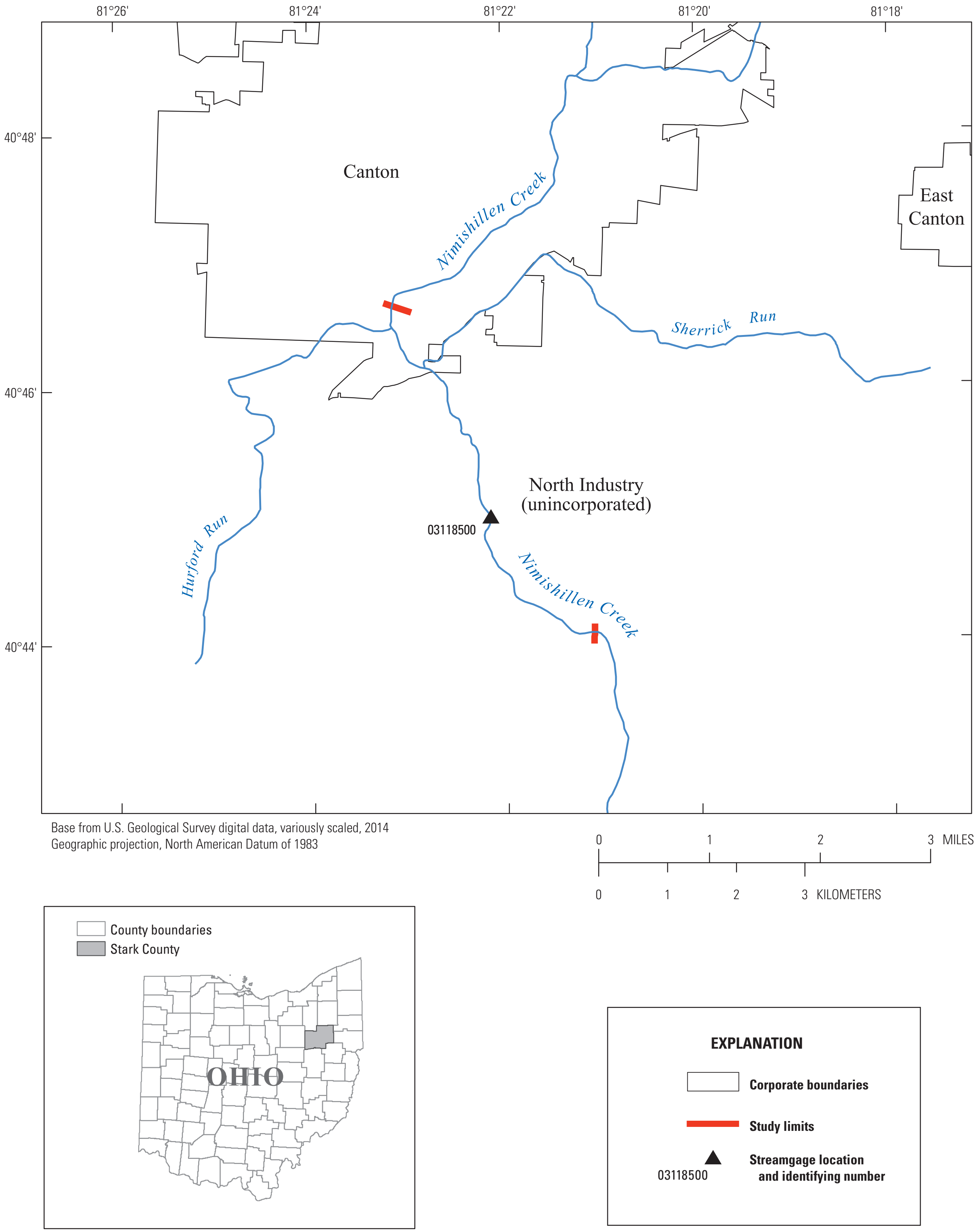

Figure 1. The location of the U.S. Geological Survey streamgage on Nimishillen Creek at North Industry, Ohio (station number 03118500), and selected tributaries.

Purpose and Scope

The purpose of this report is to describe the development of a series of estimated flood-inundation maps near the Nimishillen Creek at North Industry, Ohio, streamgage and to identify where on the internet the maps can be found and ancillary data (geographic-information-system flood polygons and depth grids) can be downloaded.

The area known as North Industry (fig. 1) is unincorporated, and south of the city of Canton, Ohio. The maps were produced for flood levels referenced to the stage recorded at the USGS streamgage Nimishillen Creek at North Industry, Ohio (table 1). The maps cover a range in stage from 8 to 14 ft streamgage datum (table 2). The 8-ft stage is about bank full and is defined by the National Weather Service (2017) as the “action stage” or that stage, when reached by a rising stream, requires the NWS or a partner to take some type of mitigation action in preparation for possible significant hydrologic activity. The 14-ft stage exceeds the “major flood stage” as defined by NWS and is nearly the historic crest of 14.18 ft from July 28, 2003 (U.S. Geological Survey, 2017a).

Study Area Description

The unincorporated area known as North Industry is in south-central Stark County, Ohio, about 100 miles northeast of Columbus (not shown), and 60 miles south of Cleveland (not shown). North Industry is south of the largest city in Stark County, Canton, and is in Canton Township. The primary creek in North Industry is Nimishillen Creek. The contributing drainage area of the streamgage on Nimishillen Creek is 172 square miles and includes rural and urban areas. The streamgage has been in three different locations. The streamgage was established in 1923 at a site 0.9 mile downstream from the current location. In 1990, the site was moved 0.67 miles downstream from the current location. The streamgage was moved to its current location (near the intersection of Faircrest Street Southeast (not shown) and Central Avenue Southeast (not shown) in April of 2013. Within the study limits of this project, the drainage area is primarily rural. This study includes a 4-mile reach of Nimishillen Creek, extending approximately 1.7 miles downstream from the streamgage and 2.3 miles upstream from the streamgage (fig. 1). A total of six hydraulic structures will affect the water-surface profiles: 1 major highway, 1 active railroad, and 4 other two-lane county roads.

Table 1. U.S. Geological Survey streamgage information for Nimishillen Creek at North Industry, Ohio.

[Station location is shown in figure 1. mi², square mile; NAVD 88, North American Vertical Datum of 1988; ft³/s, cubic foot per second; °, degree; ′, minute; ″, second; present, 2018]

Station name	Station number	Drainage area (mi²)	Latitude	Longitude	Period of peak flow record (water years[1])	Maximum recorded stage (ft), gage datum and elevation (ft, NAVD 88), and date	Maximum discharge (ft³/s) and date
Nimishillen Creek at North Industry, Ohio	03118500	172	40°44′59″	-81°22′10″	1922 to present	14.18 (994.68) July 28, 2003	9,310 July 28, 2003

[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.

Table 2. Minimum and maximum target water-surface stages and National Weather Service designated stages for U.S. Geological Survey streamgage Nimishillen Creek at North Industry, Ohio (station number 03118500).

[ft, feet]

Stream name	Minimum stage included in this report (ft)	Maximum stage included in this report (ft)	Action stage (ft)	Major flood stage (ft)
Nimishillen Creek	8.0	14.0	8.0	13.0

Previous Studies

The current flood insurance study for Stark County, Ohio was published in 2018 (Federal Emergency Management Agency, 2018). Areas prone to major floods, corresponding to 10-, 2-, 1-, and 0.2-percent annual chances of flooding (table 3) were redelineated as part of the revision of the flood insurance study in 2018. The redelineations were based on topographic information developed using light detection and ranging (lidar) data collected in 2004, which is the same topographic data used for this 2019 study. There is a slight difference in the drainage areas reported in Table 1 and Table 3 for the location of the streamgage because of the location and relocation of the streamgage (see Study Area Description section).

Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities so that the process followed and products produced are similar regardless of which USGS office is responsible for the work (U.S. Geological Survey, 2017c). Tasks specific to development of the flood maps for North Industry, Ohio were (1) collection of topographic and bathymetric data for selected cross sections and geometric data for structures and bridges along the study reach, (2) estimation of energy-loss factors (roughness coefficients) in the stream channel and flood plain, (3) determination of steady flow data, (4) computation of water-surface profiles using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC–RAS) computer program (U.S. Army Corps of Engineers, 2010), (5) production of estimated flood-inundation maps at several stream stages using the U.S. Army Corps of Engineers' HEC–GeoRAS computer program (U.S. Army Corps of Engineers, 2009) and a geographic information system (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 seven flood-inundation maps in this study were computed by using HEC–RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). The HEC–RAS is a one-dimensional step-backwater model used for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. The steady-state option was used for this report.

Hydrologic Data

The study reach includes one streamgage that has been in operation since October 1921 (fig. 1; table 1). Stage is measured every 15 minutes, transmitted hourly by a satellite radio in the streamgage, and made available on the internet through the USGS National Water Information System (U.S. Geological Survey, 2017b). Stage data from this streamgage are referenced to a local datum but can be converted to water-surface elevations referenced to the NAVD 88 by adding 980.05 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 web site.

The streamflows used in the model simulations (table 4) were taken from the current stage-discharge relation (number 25, effective March 2018) and corresponded to the target stages. There are two small tributaries, Sherrick Run and Hurford Run, within the reach studied, both are located upstream of the streamgage (fig. 1). The drainage area for Nimishillen Creek above Sherrick Run and Hurford Run is nearly the same (about 84 percent) as at the streamgage (table 5). Drainage areas at selected locations along Nimishillen Creek were calculated using StreamStats (U. S. Geological Survey, 2019). Because of the uncertainty of peak flow timing between Nimishillen Creek and the tributaries, the streamflows from the stage-discharge relation for the streamgage were not altered throughout the reach.

Table 3. Peak discharges for selected annual exceedance probabilities for Nimishillen Creek at North Industry, Ohio.

[Data from Federal Emergency Management Agency, 2012. mi^2, square mile; ft^3/s, cubic foot per second; USGS, U.S. Geological Survey]

Location on Nimishillen Creek	Drainage area (mi^2)	Estimated discharges (ft^3/s) for indicated annual exceedance probabilities (percent)			
		10	2	1	0.2
At USGS streamgage 03118500 in North Industry, Ohio	175.0	5,210	7,320	8,260	10,500

Table 4. Selected stages and associated streamflows for respective stage-discharge relations for the Nimishillen Creek at North Industry, Ohio, streamgage.

[ft, feet; ft^3/s, cubic feet per second]

Stage (ft)	Streamflow (ft^3/s)
8	1,990
9	2,530
10	3,120
11	3,860
12	4,930
13	6,360
14	8,400

Table 5. Drainage areas and percentages for selected locations for Nimishillen Creek at North Industry, Ohio.

[DA, drainage area; mi^2, square mile]

Location	River station[1]	DA (mi^2)	Percent of DA
At lower limit of study	40	175	100.2
At streamgage	8,777	172	100.0
Above Sherrick Run	17,124	157	91.3
Above Hurford Run	19,876	145	84.3
At upper limit of study area	20,933	144	83.7

[1]River stations are referenced to the longitudinal baseline used in the hydraulic model, referenced to the mouth.

Topographic and Bathymetric Data

All topographic data used in this study are referenced vertically to the North American Vertical Datum of 1988 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 lidar data collected during March 2004 by Woolpert Inc. of Columbus, Ohio . The original lidar data have horizontal resolution of 1.1 ft (0.3 meter) and vertical accuracy of 0.42 ft (.15 meter) at a 95-percent confidence level for the “open terrain” land-cover category (Federal Emergency Management Agency 2018). By these criteria, the lidar data support production of 2-ft contours (Dewberry, 2012); the final DEM, which was resampled to a 10-ft grid-cell size to decrease the GIS processing time, has a vertical accuracy of plus or minus 1 ft. By using HEC–Geo-RAS, a set of procedures, tools, and utilities for processing geospatial data in ArcGIS, elevation data were extracted from the DEM for 80 cross sections and subsequently were input to the HEC–RAS model. The cross-sectional spacing is 264 ft on average, and the maximum distance between sections is 477 ft.

Because standard lidar data do not provide ground elevations below a stream’s water-surface, channel cross sections were surveyed by USGS field crews during 2016. Cross-sectional depths were measured by wading and conventional (total station) surveying techniques at 30 locations. A differential global positioning system with real-time kinematic technology was used to derive horizontal locations and the elevations of the water surface at each surveyed cross section. Elevations determined by a real-time kinematic differential global positioning system at 10 benchmark locations were within 0.10 ft of the known elevations.

Where possible, DEM-generated cross sections were made to coincide with the locations of the within-channel field-surveyed cross sections. In these cases, within-channel data were directly merged with the DEM data. For all other cross sections, the within-channel data were estimated by interpolation from the closest field-surveyed cross section. In-channel data were surveyed upstream and downstream from every hydraulic structure. Additional cross sections were surveyed as needed to ensure that no reach length between surveyed cross sections was greater than 1 mile.

Hydraulic Structures

Six structures, consisting of 5 road crossings (Cheyanne Road, Baum Road, Faircrest Road, Allen Road and Interstate 77) and 1 railroad bridge, have the potential to affect water-surface elevations during floods along the stream. Bridge-geometry data were obtained from field surveys led by personnel from the USGS, Ohio-Kentucky-Indiana Water Science Center.

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). Initial (precalibration) *n* values were selected on the basis of field observations and high-resolution aerial photographs.

As part of the calibration process, the initial *n* values were adjusted until the differences between computed and observed water-surface elevations were minimized. The final *n* values ranged from 0.034 to 0.038 for the main channel and from 0.046 to 0.060 for the overbank areas modeled in this analysis. A root mean square error was calculated among the differences between target and observed water-surface elevations (table 6 and table 7).

Hydraulic Model and Calibration

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 stream flows that produced water-surface elevations at the streamgage cross section that matched target water-surface elevations. These target elevations coincided with even 1-ft increments of stage, referenced to the local gage datum. Subcritical (tranquil) flow regime was assumed for the simulations. Normal depth, based on channel elevations of surveyed cross sections near the bottom of the study reach, was used as the reach's downstream boundary condition. The stream flows that were used in the model were discussed in the section, "Hydrologic Data."

The HEC–RAS model was calibrated to the current stage-discharge relation at the USGS streamgage on Nimishillen Creek at North Industry, Ohio, information obtained by stage sensors (pressure transducers) at two locations along the modeled reach (fig. 2), and high-water mark elevation data collected from a flood event January 12, 2017. Surveys were led to establish the vertical datum of each stage sensor relative to North American Vertical Datum of 1988. The stage sensor elevations were checked, data were downloaded, and the sensors were cleaned three or four times per year during their deployment. The stage sensors were removed in October 2018. A comparison of the modeled to target water-surface elevations at the streamgage indicated a good relation for the range of profiles included in this study (table 6).

On January 12, 2017, the peak stage recorded at the USGS streamgage on Nimishillen Creek at North Industry, Ohio was 13.41 ft. Field discharge measurements were made on January 12 at stage 12.91 ft and on January 13 at stage 8.54 ft. Both measurements were rated poor. During the week of January 30, nine high-water marks were identified and surveyed; all marks were rated as fair. A fair rating for a high-water mark indicates a value plus or minus 0.2 ft (Koenig and others, 2017).

The streamflow value used to calibrate the HEC–RAS model for the January 2017 event (7,270 cubic feet per second) was for the maximum peak streamflow at the streamgage for water year 2017 (U.S. Geological Survey, 2017a). After calibration, the modeled elevations and measured elevations (from sensors and high-water marks) had a root mean square error of 0.31 ft, with a maximum difference of 0.73 ft (table 7). Because not all high-water marks were collocated with cross sections in the HEC–RAS model, some modeled elevations listed (table 7) were calculated using linear interpolation between modeled cross-section elevations. The difference of 0.73 ft at river station 20,933 may be a result of not lowering the discharge estimate for the calibration run above Sherrick Run and Hurford Run based on drainage area.

Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for seven stages at 1-ft intervals between 8 and 14 ft as referenced to the local datum of the USGS streamgage on Nimishillen Creek at North Industry, Ohio. These stages correspond to elevations of 988.05 and 994.05 ft NAVD 88, respectively. Discharges corresponding to the various stages were obtained from the current stage-discharge relation (number 25) for the streamgage.

Table 6. Calibration of model to target water-surface elevations at U.S. Geological Survey streamgage on Nimishillen Creek at North Industry, Ohio (station number 03118500).

[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)
8	988.05	988.15	0.10
9	989.05	988.97	–0.08
10	990.05	989.77	–0.28
11	991.05	990.70	–0.35
12	992.05	991.70	–0.35
13	993.05	992.83	–0.22
14	994.05	994.31	0.26

Table 7. Calibration of model to water-surface elevations at selected locations along Nimishillen Creek for the flood of January 12, 2017.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; HWM, high-water mark]

Description	River station[1] (ft)	Surveyed water-surface elevation (ft, NAVD 88)	Modeled water-surface elevation (ft, NAVD 88)	Difference in elevation (ft)
Stage sensor 1	447	980.51	980.46	–0.05
HWM 1	1,240	983.02	983.49	0.47
HWM 2	4,689	987.19	987.26	0.07
HWM 3	7,311	991.00	991.36	0.36
03118500 streamgage	8,777	993.46	993.51	0.05
HWM 4	8,860	994.30	994.00	–0.30
HWM 5	9,555	995.20	994.77	–0.43
HWM 6	11,482	996.63	996.58	–0.05
HWM 7	14,403	998.54	998.43	–0.11
HWM 8	16,975	1,001.76	1,001.66	–0.10
HWM 9	17,082	1,002.64	1,002.68	0.04
Stage sensor 2	20,933	1,006.31	1,007.04	0.73

[1]River station numbers are referenced to the longitudinal baseline used in the hydraulic model, referenced to the lower limit of the detailed study.

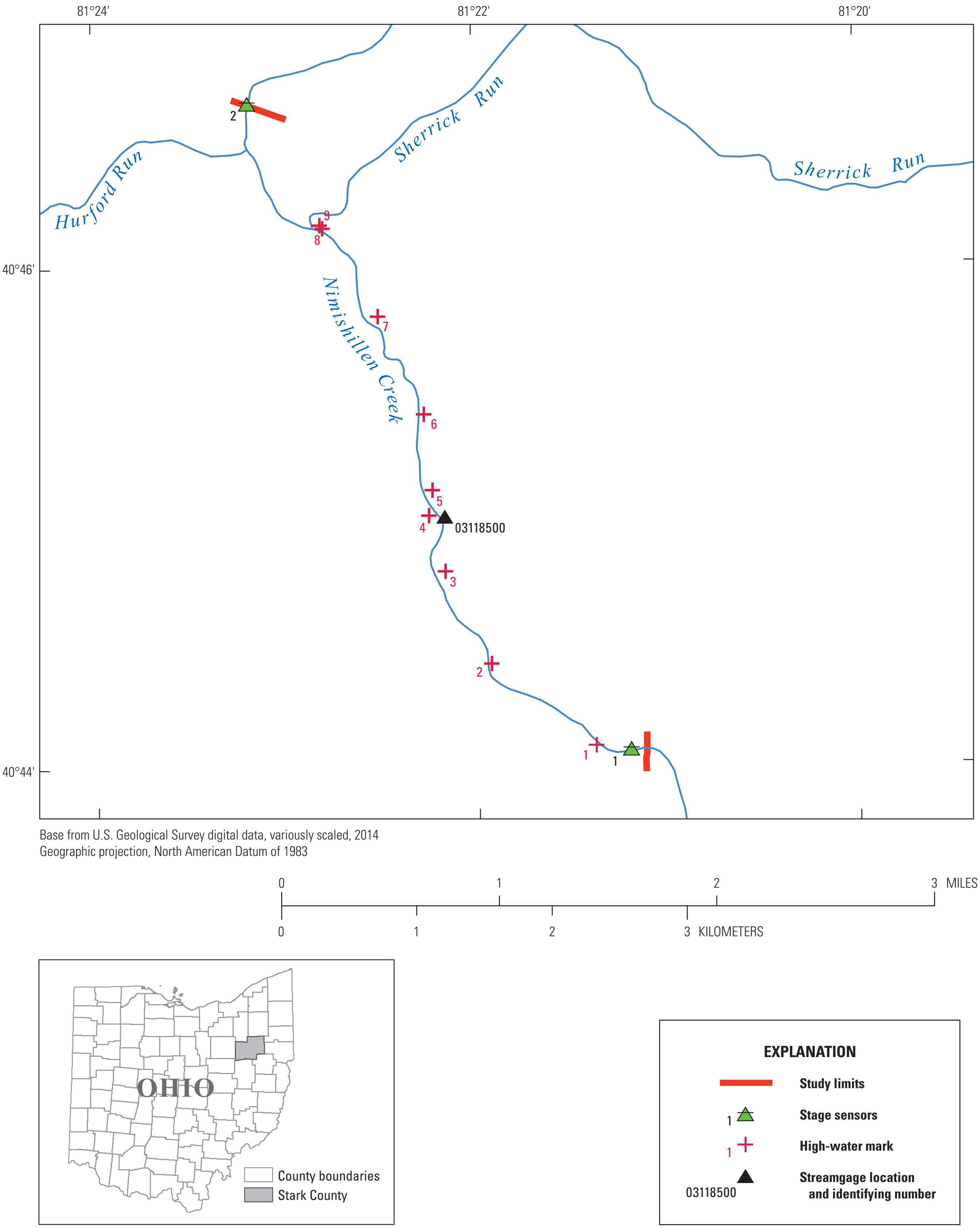

Figure 2. Locations of the USGS streamgage (station number 03118500), selected high-water marks, and stage sensors on Nimishillen Creek at North Industry, Ohio.

Development of Flood-Inundation Maps

Flood-inundation maps were created in a GIS for the seven flood profiles by combining the profiles and digital elevation model data. The DEM data were derived from the same lidar data described previously in the section “Topographic and Bathymetric Data” and, therefore, have an estimated vertical accuracy of 2 ft (that is, plus or minus 1 ft.) Estimated flood-inundation boundaries were developed for each simulated profile with HEC–GeoRas software (U.S. Army Corps of Engineers, 2009), which allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (U.S. Army Corps of Engineers, 2010). 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 among modeled cross sections. The datasets used in this study are available through a data release at https://doi.org/10.5066/P9WFOVN2 (Whitehead, 2019).

Any inundated areas that were detached from the main channel were examined to identify subsurface connections with the main creek, 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 were overlain on high-resolution, georeferenced aerial photographs of the study area. Bridge surfaces are shown as not inundated up to the lowest flood stage that completely inundates one or both approaches to the bridge. For this report, no bridges over Nimishillen Creek were inundated, even at the highest profile. There is one bridge, Cheyenne Road (not shown, at station 1,232) where the water-surface elevation for the top profile (stage 14) is within 1 ft of overtopping the road elevation, but survey data compared to model results indicate the bridge will not be inundated. Estimates of water depths can be determined from the depth-grid data that are included with the presentation of the flood maps on an interactive USGS mapping application described in the following section, “Flood-Inundation Map Delivery.”

Flood-Inundation Map Delivery

The current study documentation is available online at the U.S. Geological Survey Publications Warehouse (https://doi.org/10.5066/P9WFOVN2). Also, a Flood Inundation Mapping (FIM) Program website (U.S. Geological Survey, 2017c) has been established to make USGS flood-inundation study information available to the public (U.S. Geological Survey, 2017d). The site 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 the USGS streamgage on Nimishillen Creek at North Industry, Ohio. A link on this website connects to the USGS National Water Information System (U.S. Geological Survey, 2017b), which presents the current stage and streamflow at the USGS streamgage Nimishillen Creek at North Industry, Ohio, to which the inundation maps are referenced. A second link connects to the NWS AHPS site (National Weather Service, 2017) so that in periods of high water, the user can obtain applicable information on forecasted peak stage. The estimated flood-inundation maps are displayed in sufficient detail so that preparations for flooding and decisions for emergency response can be accomplished 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. A shaded building should not be interpreted to mean that the structure is completely submerged but rather that bare-earth surfaces near the building are inundated. In these instances, the water depth (as indicated in the mapping application by clicking the cursor on 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, 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 water stages and streamflows at selected USGS streamgages. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, assuming unobstructed flow, and used streamflows and hydrologic conditions anticipated at the USGS streamgage(s). The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of September 2018. 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, 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.

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 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 https://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

Summary

A series of seven digital flood-inundation maps were developed in cooperation with the city of Canton, Ohio, the Stark County Commissioners Office, and the Muskingum Watershed Conservancy District for Nimishillen Creek at North Industry, Ohio. The U.S. Army Corps of Engineers' HEC-RAS and HEC–GeoRAS programs were used to compute water-surface profiles and to help delineate estimated flood-inundation areas and depths of flooding for the stream stage. The HEC-RAS hydraulic model was calibrated to the current stage-discharge relation at the Nimishillen Creek at North Industry streamgage, and high-water marks surveyed after a flood event in January 2017. The model was used to compute seven water-surface profiles for flood stages from "action stage" to above "major flood stage," as reported by the National Weather Service. The computed water-surface profiles were then used in combination with a digital elevation model, derived from light detection and ranging data to delineate estimated flood-inundation areas and depth grids. These flood-inundation areas were superimposed 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 U.S. Geological Survey Flood Inundation Mapping (FIM) Program website (https://water.usgs.gov/osw/flood_inundation).

Interactive use of the maps on this mapping application can give users a general indication of depth of water at any point by using the mouse cursor to click within the shaded areas. These maps, in conjunction with the real-time stage data from the U.S. Geological Survey streamgages and forecasted flood stage data from the National Weather Service Advanced Hydrologic Prediction Service, can help emergency planners and the public make more informed decisions about flood risk.

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