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Flood-Inundation Maps for the Little Calumet River from Lansing to South Holland, Illinois, 2020

Scientific Investigations Report 2020–5074

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

Cover photo. Photographs showing flooded road and park near the U.S. Geological Survey streamgage on the Little Calumet River at South Holland, Illinois, and (inset) flooded park near the U.S. Geological Survey streamgage on the Little Calumet River at South Holland, Ill. Photographs taken May 13, 2002, by Dave Schrader, U.S. Geological Survey.

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U.S. Department of the Interior
DAVID BERNHARDT, Secretary

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

U.S. Geological Survey, Reston, Virginia: 2020

Suggested citation:
Dunn, A.P., Straub, T.D., and Manaster, A.E., 2020, Flood-inundation maps for the Little Calumet River from Lansing to South Holland, Illinois, 2020: U.S. Geological Survey Scientific Investigations Report 2020–5074, 10 p., https://doi.org/10.3133/sir20205074.

Associated data for this publication:
Dunn, A.P., Straub, T.D., and Manaster, A.E., 2020, Geospatial datasets for the flood-inundation study of Little Calumet River from Lansing to South Holland, Illinois, 2020: U.S. Geological Survey data release, https://doi. org/10.5066/P99L14DN.

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ISSN 2328-0328 (online)

Acknowledgments

The authors wish to thank the U.S. Army Corps of Engineers and the Little Calumet River Basin Development Commission for cooperating in the funding for the operation and maintenance of the streamgages used for this study. Special thanks to the U.S. Army Corps of Engineers for their cooperation in this study, the Metropolitan Water Reclamation District of Greater Chicago for furnishing the hydraulic models, and the National Weather Service for their continued support to the U.S. Geological Survey flood-inundation mapping initiative.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square 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 elevation information is referenced to either (1) stage, the height above an arbitrary datum established at a streamgage, or (2) elevation, the height above North American Vertical Datum of 1988 (NAVD 88).

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

Abbreviations

AHPS	Advanced Hydrologic Prediction Service
DEM	digital elevation model
DWP	Detailed Watershed Plan
FEMA	Federal Emergency Management Agency
HEC–GeoRAS	U.S. Army Corps of Engineers Hydrologic Engineering Centers Geospatial River Analysis System
HEC–RAS	U.S. Army Corps of Engineers Hydrologic Engineering Centers River Analysis System
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
NWS	National Weather Service
USGS	U.S. Geological Survey

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Abstract

Digital flood-inundation maps for about an 8-mile reach of the Little Calumet River, Illinois, were created by the U.S. Geological Survey (USGS) in cooperation with the U.S. Army Corps of Engineers. The flood-inundation maps, which can be accessed through the USGS Flood Inundation Mapping Science website at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at three USGS streamgages: Little Calumet River at South Holland, Ill. (USGS station 05536290); Little Calumet River at Munster, Indiana (USGS station 05536195); and Thorn Creek at Thornton, Ill. (USGS station 05536275). Near-real-time stages at these streamgages may be obtained on the internet from the USGS National Water Information System at https://doi.org/10.5066/F7P55KJN or the National Weather Service Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/, which also forecasts flood hydrographs at these sites.

Flood profiles were computed for the stream reaches using a one-dimensional unsteady flow step-backwater hydraulic model. The model performance was evaluated using historical streamflow measurements and the most current stage-discharge relations at the USGS streamgages at Little Calumet River at South Holland, Ill.; Little Calumet River at Munster, Ind.; and Thorn Creek at Thornton, Ill. The model was used to compute 24 water-surface profiles at 1-foot intervals referenced to the streamgage datum and ranging from bankfull to about the 0.2-percent annual-exceedance probability flood (500-year recurrence interval flood). 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 0.6-foot vertical accuracy and a 2-foot horizontal resolution) to delineate the area flooded at each water level.

The availability of these maps, along with internet information regarding current stage from USGS streamgages 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.

Introduction

South Holland, Lansing, and Calumet City within the Chicago metropolitan area in Cook County, Illinois, are densely developed cities with mostly flat terrain, and subject to flooding. The area was affected by major flooding in 2008. The President signed the Major Disaster Declaration, FEMA–DR–1800, on October 3, 2008, for seven counties within the State of Illinois, including Cook County, after the September 2008 flooding (Federal Emergency Management Agency [FEMA], 2008a).

Before this study, emergency responders and city officials relied on several information sources to make decisions on how to best alert the public and mitigate flood damages. One source is the FEMA Flood Map Service Center (FEMA, 2020). A second source of information is the Detailed Watershed Plan (DWP) developed by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) (Metropolitan Water Reclamation District of Greater Chicago [MWRDGC], 2008).

The U.S. Geological Survey (USGS) streamgages on the Little Calumet River (stations 05536195 and 05536290) and Thorn Creek (station 05536275) in the National Water Information System database (USGS, 2018) are another source from which current or historical water levels (stage) can be obtained. Additionally, the National Weather Service (NWS) forecast of peak stage at the USGS streamgages through the Advanced Hydrologic Prediction Service (AHPS) site at https://water.weather.gov/ahps/ is available. Although USGS current stage and NWS forecast stage information is particularly useful for residents near a streamgage, it is of slight use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream channel. Knowledge of a water level at a streamgage is not easily translated into the depth and areal extent of flooding at points distant from the streamgage. One way to address this problem is to produce a library of flood-inundation maps that

are referenced to stages recorded at the USGS streamgages. By examining the appropriate maps, emergency responders can estimate the projected severity of flooding (depth of water and areal extent), identify roads that are or may soon be flooded, and make plans for notification or evacuation.

Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for the Little Calumet River from Lansing to South Holland, Ill., and identifies where on the internet the maps can be found and ancillary data (geographic information system flood polygons and depth grids) can be downloaded. The location and extent of the study reach is about 8 miles long from 0.4 mile downstream from the Little Calumet River at Munster, Indiana (hereafter referred to as "station 05536195"), to about 0.5 mile downstream from the Little Calumet River at South Holland, Ill. (hereafter referred to as "station 05536290") (fig. 1).

The maps were produced for flood levels referenced to the stage recorded at three USGS streamgages on the Little Calumet River from Lansing to South Holland, Ill. (table 1); the gages are station 05536195, station 05536290, and Thorn Creek at Thornton, Ill. (hereafter referred to as "station 05536275"; fig. 1). The hydraulic model was then used to develop flood-inundation maps for this report that include 24 combinations of water-surface elevations at the three streamgages (table 2). The maps range from bankfull to about the 0.2-percent annual-exceedance probability flood (500-year recurrence interval flood). The flood maps are available through a mapping application that can be accessed on the U.S. Geological Survey Flood Inundation Mapping Science website (https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program). The data release associated with this report can be found on ScienceBase (https://doi.org/10.5066/P99L14DN; Dunn and others, 2020).

Study-Area Description

The Little Calumet River is in northeastern Illinois, and the drainage area ranges from 90 square miles (mi^2) at station 05536195 to 208 mi^2 near the downstream extent of the study reach at station 05536290. The headwaters originate in Indiana, and the stream generally flows westward before entering Illinois. Thorn Creek, a tributary to the Little Calumet River, joins the main stem as it flows through South Holland. The basin terrain is mostly flat. The urban study includes about an 8-mile (mi) reach of the Little Calumet River with an average channel slope of 0.72 foot per mile (ft/mi; 0.000136 foot per foot [ft/ft]). The main channel of the study reach has various structures (bridges, culverts, roadway embankments, and levees) that lie within the channel or the adjacent flood plain.

Previous Studies

The current flood-insurance study for Cook County is available at the FEMA Flood Map Service Center (FEMA, 2020). The study provided information about the 1.0- and 0.2-percent annual-exceedance probability water-surface profiles and associated flood-plain maps for the Little Calumet River and Thorn Creek within the study area. As part of the Little Calumet River DWP development by the MWRDGC (MWRDGC, 2008), inundation maps were produced to provide a comparison to the effective FEMA flood-plain mapping. The MWRDGC study used the hydraulic model HEC–RAS 4.0 (U.S. Army Corps of Engineers [USACE], 2008).

Flooded road and park near the U.S. Geological Survey streamgage on the Little Calumet River at South Holland, Illinois. Photograph taken May 13, 2002, by Dave Schrader, U.S. Geological Survey.

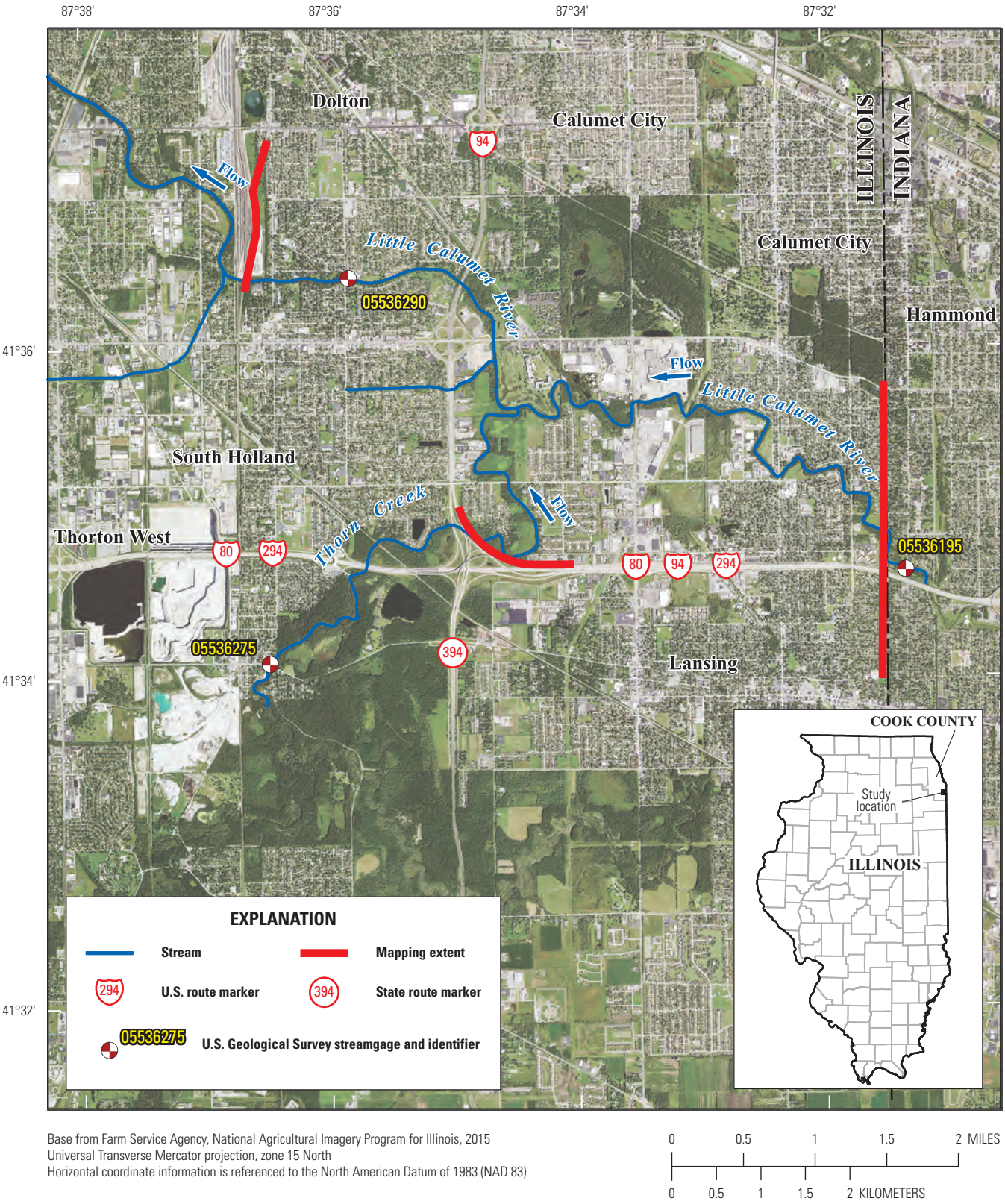

Figure 1. The study reach for the Little Calumet River and Thorn Creek, Illinois, and locations of U.S. Geological Survey streamgages.

Table 1. U.S. Geological Survey streamgage and miscellaneous site information for the study basin, Little Calumet River and Thorn Creek, Illinois.

[Vertical elevation information is referenced to the height above North American Vertical Datum of 1988; USGS, U.S. Geological Survey; NWS, National Weather Service; mi², square mile; ft, foot; °, degree; ', minute; ", second]

USGS station name	USGS station number	NWS site name[1]	Drainage area (mi²)	Latitude	Longitude	Period of record	Maximum water-surface elevation (ft) and date	Datum of streamgage (ft)
Little Calumet River at South Holland, Illinois	05536290	SHLI2	208	41°36'25"	87°35'52"	Oct. 1947–current year	595.18; 11/28/1990	574.68
Little Calumet River at Munster, Indiana	05536195	LCMI3	90.0	41°34'39"	87°31'20"	July 1958–current year	597.63; 09/14/2008	580.34
Thorn Creek at Thornton, Illinois	05536275	THNI2	104	41°34'06"	87°36'28"	April 1947–current year	603.17; 06/14/1981	586.11

[1]The NWS forecast site names are presented (forecasts are issued as needed during times of high water).

Table 2. Stages and water-surface elevations for the streamgages on the Little Calumet River (U.S. Geological Survey stations 05536290 and 05536195) and Thorn Creek (U.S. Geological Survey station 05536275) for selected simulated water-surface profiles.

[Elevations are in feet above the North American Vertical Datum of 1988; ft, foot]

	U.S. Geological Survey station 05536290		U.S. Geological Survey station 05536195		U.S. Geological Survey station 05536275	
Profile number	Elevation (ft)	Stage (ft)	Elevation (ft)	Stage (ft)	Elevation (ft)	Stage (ft)
1	585	10.32	589	8.66	592	5.89
2	586	11.32	590	9.66	594	7.89
3	587	12.32	591	10.66	595	8.89
4	587	12.32	592	11.66	593	6.89
5	588	13.32	592	11.66	597	10.89
6	589	14.32	592	11.66	597	10.89
7	589	14.32	593	12.66	599	12.89
8	589	14.32	594	13.66	599	12.89
9	590	15.32	594	13.66	599	12.89
10	590	15.32	595	14.66	599	12.89
11	591	16.32	595	14.66	599	12.89
12	591	16.32	596	15.66	600	13.89
13	592	17.32	595	14.66	597	10.89
14	592	17.32	596	15.66	600	13.89
15	592	17.32	597	16.66	600	13.89
16	593	18.32	596	15.66	598	11.89
17	593	18.32	597	16.66	601	14.89
18	594	19.32	598	17.66	602	15.89
19	595	20.32	597	16.66	602	15.89
20	595	20.32	598	17.66	603	16.89
21	596	21.32	598	17.66	607	20.89
22	597	22.32	599	18.66	607	20.89
23	598	23.32	599	18.66	607	20.89
24	599	24.32	600	19.66	604	17.89

Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (USGS, 2019) 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 were (1) retrieval of historical streamflow measurements and current rating (as of March 30, 2018) information from three streamgages on the Little Calumet River and Thorn Creek (table 1), (2) retrieval of the most recent (as of January 20, 2010) existing hydraulic model for the Little Calumet River and Thorn Creek from the MWRDGC, (3) computation of water-surface profiles by use of the USACE Hydrologic Engineering Center's River Analysis System (HEC–RAS) computer program (USACE, 2008), (4) production of estimated flood-inundation maps at various stream stages by use of the U.S. Army Corps of Engineers Hydrologic Engineering Centers Geospatial River Analysis System (HEC–GeoRAS) computer program (USACE, 2009) and a geographic information system, and (5) implementation into a web interface that links to USGS real-time streamgage information and (or) the NWS-forecasted peak stage to facilitate the display of user-selected flood-inundation maps on the internet. Maps were produced for water levels referenced to the stage at stations 05536290, 05536195, and 05536275 ranging from bankfull to about the 0.2-percent annual-exceedance probability flood (500-year recurrence interval flood).

Computation of Water-Surface Profiles

The MWRDGC hydraulic models for the Little Calumet River and Thorn Creek developed in HEC–RAS 4.0 (USACE, 2008) were updated to HEC–RAS 5.0.3 (USACE, 2016) to produce the 24 flood-inundation maps for the mapping extent in this study (fig. 1). HEC–RAS is a one-dimensional, step-backwater model for simulation of water-surface profiles with gradually varied, steady-, and unsteady-state flow computation options. The HEC–RAS analysis for this study was done using the unsteady-state flow computation option.

Hydrologic Data

The study reach includes three USGS streamgages (fig. 1; table 1). All three of the streamgages already were in operation when this project began in 2016. Water level (stage) is measured every 15 minutes and made available on the internet through the USGS National Water Information System (NWIS, USGS, 2018). 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 listed in table 1. Continuous records of streamflow were computed at all the sites from a stage-discharge relation (Turnipseed and Sauer, 2010).

A normal depth boundary condition was assumed downstream (with a friction slope estimated from the average streambed slope from the downstream mapping extent to station 05536195). To obtain the water-surface profiles for mapping, the HEC–RAS model was run in unsteady-state mode for the 50- (2-year flood), 20- (5-year flood), 10- (10-year flood), 4- (25-year flood), 2- (50-year flood), 1- (100-year flood), and 0.2- (500-year flood) percent annual-exceedance probability flood events already available in the model (MWRDGC, 2008). The model performance was evaluated using historical streamflow measurements and the most current stage-discharge relations (USGS, 2018) at the three streamgages.

Topographic/Bathymetric Data

The USGS did not do any surveying in the field to change channel cross sections in the model as documented in the DWP (MWRDGC, 2008). Also, in the DWP model, a digital elevation model (DEM) with a grid size of 2 feet (ft) and vertical accuracy of 0.6 ft was used to represent the ground surface for parts of the cross sections that were above the water surface. The DEM was created by Cook County, Ill., from a light detection and ranging dataset collected in 2003 (Cook County, 2004).

Hydraulic Structures

Various structures (bridges, culverts, roadway embankments, and levees) in and along the stream affect or have the potential to affect water-surface elevations during floods. To properly account for these features in the model, structural dimensions were included in the MWRDGC (2008) model. It was verified in 2017 from the Illinois Department of Transportation database and oral communication at a stakeholder meeting that bridges within the mapping extent were not modified since the MWRDGC (2008) model development.

Energy-Loss Factors

Manning's roughness coefficients ("*n*" values) are used in hydraulic modeling for energy- (friction) loss calculations (Arcement and Schneider, 1989). For the Little Calumet River and Thorn Creek, the Manning's *n* values used ranged from 0.043 to 0.076, and most of the values ranged from 0.04 to 0.05 for the channel modeled in this analysis. The Manning's *n* values ranged from 0.03 to 0.2 for the upper bank and overbank areas modeled in this analysis.

Hydraulic Model

The hydraulic model ratings for the 2.0-, 1.0-, and 0.2-percent annual-exceedance probability flood events for cross sections near the three USGS streamgages are shown in figure 2; figure 2*A* shows hydraulic model ratings for station 05536290, figure 2*B* shows hydraulic model ratings for station 05536195, and figure 2*C* shows hydraulic model ratings for station 05536275. USGS measurement data for the period of record (table 1) and the current streamgage rating are also shown in figure 2. The purpose of the mapping is to estimate the projected severity of flooding on a near-real-time basis. For this reason, it is important to ensure the model results encapsulate the maximum observed water-surface elevations. The simulated water-surface elevation results at each of the three streamgages are within 0.5 ft of the maximum measured water-surface elevation for a given streamflow. The model and measurements at station 05536290 (fig. 2*A*) do not indicate substantial hysteresis from unsteady-state flow conditions, but at the other two streamgages, the scatter in the measurements and hysteresis loops in the model results indicate unsteady flow conditions. However, at all three streamgages, the model results encapsulate the measured data for all conditions mapped. The results demonstrate that the model is capable of simulating accurate water levels for a range of flows in the basin.

Development of Water-Surface Profiles

The hydraulic model was used to develop flood-inundation maps for this report that include 24 combinations of water-surface elevations at the three streamgages (table 2). The maps range from bankfull to about the 0.2-percent annual-exceedance probability flood (500-year recurrence interval flood). Profiles were developed for a total of 15 elevations at 1-ft intervals between 585 and 599 ft, as referenced to station 05536290. Profiles were developed for a total of

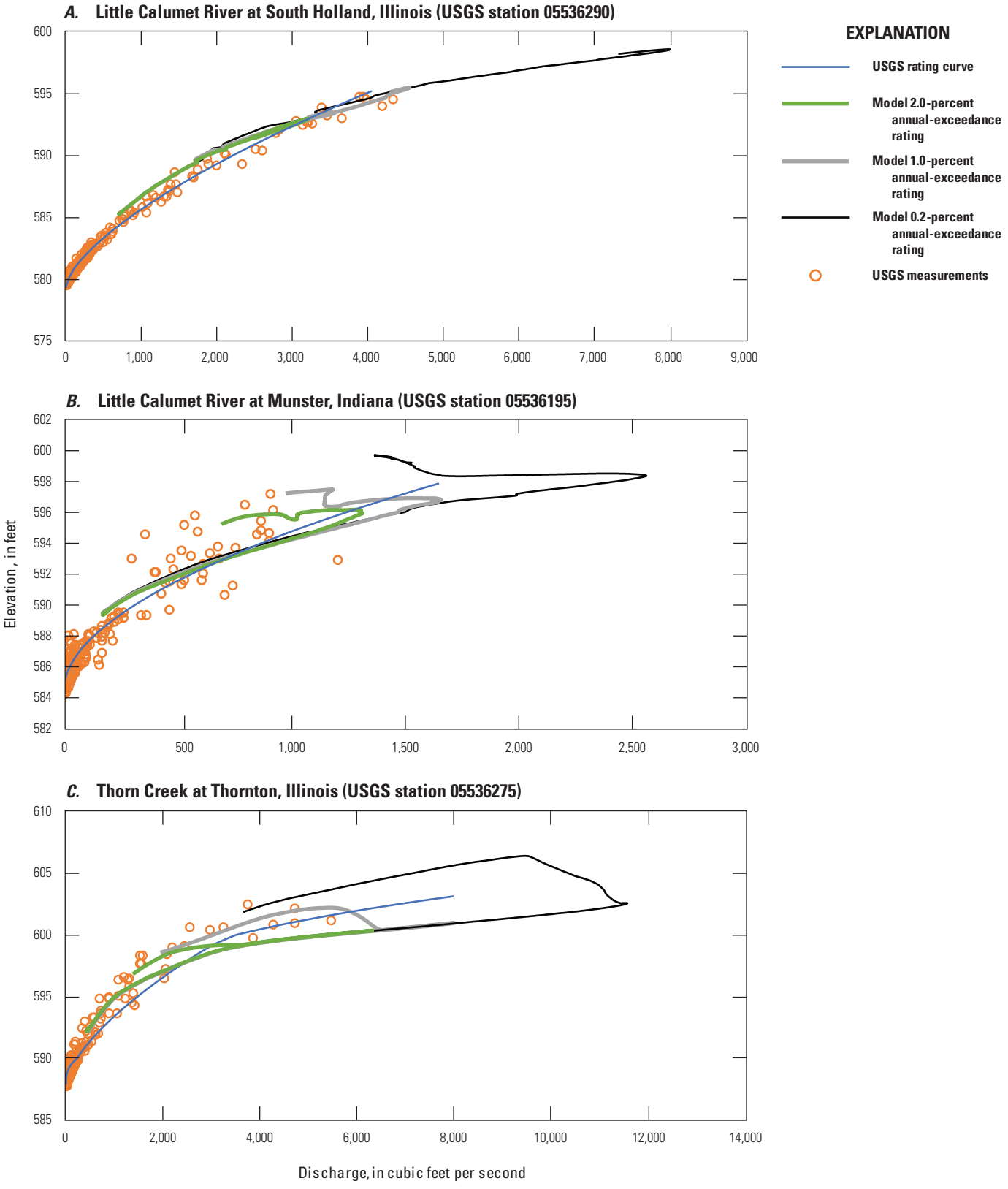

Figure 2. The hydraulic model ratings for the 2.0-, 1.0-, and 0.2-percent annual-exceedance probability flood events for cross sections near three U.S. Geological Survey (USGS) streamgages. *A*, Little Calumet River at South Holland, Illinois (USGS station 05536290); *B*, Little Calumet River at Munster, Indiana (USGS station 05536195); and *C*, Thorn Creek at Thornton, Ill. (USGS station 05536275). Measurement data for the period of record (table 1) and the current rating are shown.

12 elevations at 1-ft intervals between 589 and 600 ft, as referenced to station 05536195. Profiles were developed for a total of 13 elevations at nearly 1-ft intervals between 592 and 607 ft, as referenced to station 05536275. The unsteady model results did not take place everywhere on 1-ft intervals; however, for all 24 combinations, the difference between the 1-ft interval and the simulated result averaged 0.10, 0.18, and 0.11 ft at stations 05536290, 05536195, and 05536275, respectively.

Development of Flood-Inundation Maps

Flood-inundation maps were created for 24 combinations of water-surface elevations at the three USGS streamgages, all of which have been designated as intermittent NWS flood-forecast points where forecasts are issued as needed during times of high water (as of 2018). The maps were created using HEC–GeoRAS and a geographic information system by combining the water-surface profiles and DEM data (Cook County, 2004). DEM data were derived from 2-ft horizontal resolution light detection and ranging data with a vertical accuracy of 0.6 ft. The DEM was obtained from MWRDGC (Jack T.P. Chan, MWRDGC, written commun., 2017). Any inundated areas that were detached from the main channel were examined to identify artificial connections with the main rivers, such as through culverts under roadways. Where such connections existed, the mapped inundated areas were retained in their respective flood maps; otherwise, the disconnected inundation areas were deleted.

Flood-Inundation Map Delivery

A Flood Inundation Mapping Science website has been established at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program to provide a portal for USGS flood-inundation study information to the public. That web portal has a link (https://fim.wim.usgs.gov/fim/) to the interactive online flood inundation maps. The data release associated with this report can be found on ScienceBase (https://doi.org/10.5066/P99L14DN; Dunn and others, 2020). At the web portal, each stream reach displayed contains additional links to USGS National Water Information System web graphs of the current stage and streamflow at USGS streamgages at stations 05536290 and 05536195 to which the inundation maps are referenced. A link also is provided to the NWS AHPS website (https://water.weather.gov/ahps/) so that the user can obtain applicable information on the forecasted peak stage. The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding with respect to individual structures so that preparations for flooding and decisions for emergency response can be performed efficiently. Roadways and bridges were closely reviewed and are shown as shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use; however, buildings that are shaded do not reflect inundation but denote that bare-earth surfaces near the buildings are inundated. When the water depth (as indicated in the web mapping application by holding the cursor over an inundated area) adjacent to the building of interest exceeds the height of that building, 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 based on water stages and streamflows at selected USGS streamgages. Water-surface elevations along the stream reaches were estimated by unsteady-state hydraulic modeling, assuming unobstructed flow, and used streamflows and hydrologic conditions anticipated at the USGS streamgages. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of January 2018. Unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the simulated reach to vary from those assumed during a flood, which may lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded due to unanticipated conditions such as changes in the streambed elevation or roughness, backwater into major tributaries along a mainstem river, or backwater from localized debris or ice jams. The accuracy of the floodwater extent portrayed on these maps will differ with the accuracy of the DEM 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 3–5 days out in many locations). For more information on AHPS forecasts,

please see https://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf. Additional uncertainties and limitations pertinent to this study may be described elsewhere in this report.

Summary

A series of 24 digital flood-inundation maps were developed in cooperation with the U.S. Army Corps of Engineers for the Little Calumet River between Lansing and South Holland, Illinois. The maps cover a reach about 8 miles long from 0.4 mile downstream from the U.S. Geological Survey (USGS) streamgage Little Calumet River at Munster, Indiana (station 05536195), to about 0.5 mile downstream from the USGS streamgage Little Calumet River at South Holland, Ill. (station 05536290). The maps were developed using the U.S. Army Corps of Engineers' HEC–RAS and HEC–GeoRAS and a geographic information system program 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 stage-discharge relation at stations 05536195, 05536290, and 05536275 (USGS streamgage Thorn Creek at Thornton, Ind.). The model was used to compute 24 water-surface profiles at 1-foot (ft) intervals referenced to the streamgage datum and ranging from bankfull to the 0.2-percent annual-exceedance probability flood (500-year recurrence interval flood). 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 U.S. Geological Survey Flood Inundation Mapping Science web site (https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program).

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 two U.S. Geological Survey streamgages (stations 05536195 and 05536290), and forecasted flood stage data from the National Weather Service Advanced Hydrologic Prediction Service will help 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.

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Publishing support provided by the
Rolla and Madison Publishing Service Centers

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20205074