USGS
science for a changing world

Prepared in cooperation with Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Missouri

Flood-Inundation Maps for Dardenne Creek in St. Charles County, Missouri, 2019

Scientific Investigations Report 2020–5060

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

Cover. Inundated areas along Dardenne Creek in St. Louis County, Missouri. Photograph from the U.S. Geological Survey Flood Inundation Mapper.

Flood-Inundation Maps for Dardenne Creek in St. Charles County, Missouri, 2019

By David C. Heimann, Jonathon D. Voss, and Paul H. Rydlund, Jr.

Prepared in cooperation with Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Missouri

Scientific Investigations Report 2020–5060

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

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:
Heimann, D.C., Voss, J.D., and Rydlund, P.H., Jr., 2020, Flood-inundation maps for Dardenne Creek in St. Charles County, Missouri, 2019: U.S. Geological Survey Scientific Investigations Report 2020–5060, 14 p., https://doi.org/10.3133/sir20205060.

Associated data for this publication:
Heimann, D.C., Voss, J.D., and Rydlund, P.H., Jr., 2020, Geospatial datasets for the flood-inundation study of Dardenne Creek, St. Charles County, Missouri, 2019: U.S. Geological Survey data release, https://doi.org/10.5066/P9QPY9MI.

ISSN 2328-0328 (online)

Acknowledgments

The authors wish to thank the Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Missouri, for support in the development of flood-inundation maps and the operation and maintenance of the streamgages used for this study. The authors acknowledge Wood Environment and Infrastructure Solutions, Inc., for providing the original hydraulic model used in 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)
acre	4,047	square meter (m^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) unless otherwise stated.

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

Abbreviations

AEP	annual exceedance probability
AHPS	Advanced Hydrologic Prediction Service
DEM	digital elevation model
FEMA	Federal Emergency Management Agency
FIS	flood insurance study
GIS	geographic information system
HEC–GeoRAS	Hydrologic Engineering Center's Geospatial River Analysis System
HEC–RAS	Hydrologic Engineering Center's River Analysis System
lidar	light detection and ranging
n	Manning's roughness coefficient
NGVD 29	National Geodetic Vertical Datum of 1929
NWIS	National Water Information System
NWS	National Weather Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Flood-Inundation Maps for Dardenne Creek in St. Charles County, Missouri, 2019

By David C. Heimann, Jonathon D. Voss, and Paul H. Rydlund, Jr.

Abstract

Digital flood-inundation maps for a 9.9-mile reach of Dardenne Creek, St. Charles County, Missouri, were created by the U.S. Geological Survey (USGS), in cooperation with the Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Mo. The flood-inundation maps, which can be accessed through the USGS Flood Inundation Mapping Program 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 the USGS streamgages 05514860 Dardenne Creek at Old Town St. Peters, Mo., and 05587450 Mississippi River at Grafton, Illinois. Near-real-time stages at these streamgages may be obtained 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/ahps2/hydrograph.php?wfo=lsx&gage=drcm7 and https://water.weather.gov/ahps2/hydrograph.php?wfo=lsx&gage=grfi2, which also forecasts flood hydrographs at these sites (sites DRCM7 and GRFI2).

Flood profiles were computed for the Dardenne Creek stream reach by means of a one-dimensional model for simulating water-surface profiles with steady-state flow computations. The model was calibrated by using the current stage-streamflow relation at the USGS streamgages 05514840 Dardenne Creek at O'Fallon, Mo., and 05514860 Dardenne Creek at Old Town St. Peters, Mo., and the documented high-water marks from the flood of December 2015.

The hydraulic model was then used to compute 17 water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the streamgage datum and ranging from 16 ft, or near bankfull, to 32 ft at the reference streamgage 05514860. Stages in the lower Dardenne Creek can be affected by backwater from the Mississippi River; therefore, several sets of water-surface profiles were developed representing the extent of varying levels of backwater as referenced to the USGS streamgage 05587450 on the Mississippi River at Grafton, Ill. The upper stage for each map library exceeds the stage corresponding to the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval flood) at the streamgage location. 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 0.26-ft vertical accuracy and 0.71-ft horizontal resolution) to delineate the area flooded at each water level.

The availability of these maps, along with real-time 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 mitigation, preparedness and planning, flood-response activities such as evacuations and road closures, and postflood recovery efforts.

Introduction

During September 2008, December 2015–January 2016, and May 2017, the major flood stage, as defined by the National Weather Service (NWS), was exceeded along Dardenne Creek in St. Charles County, Missouri. Flooding along lower Dardenne Creek and downstream Mississippi River contributed to St. Charles County being included in a Federal Major Disaster Declaration in January 2016 (Federal Emergency Management Agency [FEMA], 2020). The residents of O'Fallon, St. Peters, and unincorporated areas of St. Charles County lacked the resources needed to fully determine the status and consequences of water levels (stages) and streamflows along Dardenne Creek to mitigate and prepare for flood conditions that threaten lives and property and maximize response and recovery efforts.

Before this study, emergency responders in O'Fallon and St. Peters relied on several information sources (all of which are available on the internet) to make decisions on how to best alert the public and mitigate flood damages along Dardenne Creek. One source is the FEMA flood insurance study (FIS) for St. Charles County, dated June 2018 (FEMA, 2018). A second source of information is the U.S. Geological Survey (USGS) streamgages 05514840, Dardenne Creek at O'Fallon, Mo., and 05514860, Dardenne Creek at Old Town St. Peters, Mo., from which current (USGS, 2020a, b) and historical (since 1999) water levels and streamflows, including annual peak flows, can be obtained. A third source of

flood-related information is the NWS Advanced Hydrologic Prediction Service (AHPS), which displays the USGS stage data from the O'Fallon and St. Peters streamgages and also issues forecasts of stage for the St. Peters streamgage (NWS, 2019a).

Although the current stage at a USGS streamgage is particularly useful for residents near a streamgage, it is of limited use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream reach. 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 the stages recorded at the USGS streamgage. By referring to the appropriate map, emergency responders can discern the severity of flooding (depth of water and areal extent), identify roads that are or will soon be flooded, and make plans for notification or evacuation of residents 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 shown to motivate residents to take precautions and heed warnings that they previously might have disregarded. In 2019, the USGS, in cooperation with the Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Mo., conducted a project to produce a library of flood-inundation maps for a reach of Dardenne Creek extending through O'Fallon, St. Peters, and unincorporated St. Charles County, Mo.

Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for Dardenne Creek, St. Charles County, Mo., and identifies where on the internet the maps can be found and ancillary data (geographic information system [GIS] flood polygons and depth grids) can be downloaded. The study extent includes a 9.9-mile (mi) reach from 0.12 mi upstream from the USGS streamgage in O'Fallon, Mo., to about 0.82 mi downstream from the USGS streamgage in St. Peters, Mo. (fig. 1). The maps were produced for flood levels using hydrologic data from four USGS streamgages (05514840, 05514860, 05587450, and 05587498; fig. 1; table 1) including two gages in the Dardenne Creek study reach (05514840 and 05514860) and two streamgages on the Mississippi River (05587450 and 05597498). Flood levels were referenced to the stage recorded at streamgage 05514860, Dardenne Creek at Old Town St. Peters, Mo., near the downstream extent of the study reach; and maps indicating the potential extent of Mississippi River backwater in the study reach were referenced to streamgage 05587450, Mississippi River at Grafton, Illinois.

The flood-inundation maps of Dardenne Creek cover stages ranging from 16.0 to 32.0 feet (ft), referenced to the Old Town St. Peters streamgage local datum. The 16-ft stage is approximately bankfull and is defined by the NWS (2019b) as the "action stage" or that stage which, when reached by a rising stream, requires the NWS or a partner to take some type of mitigation action in preparation for possible

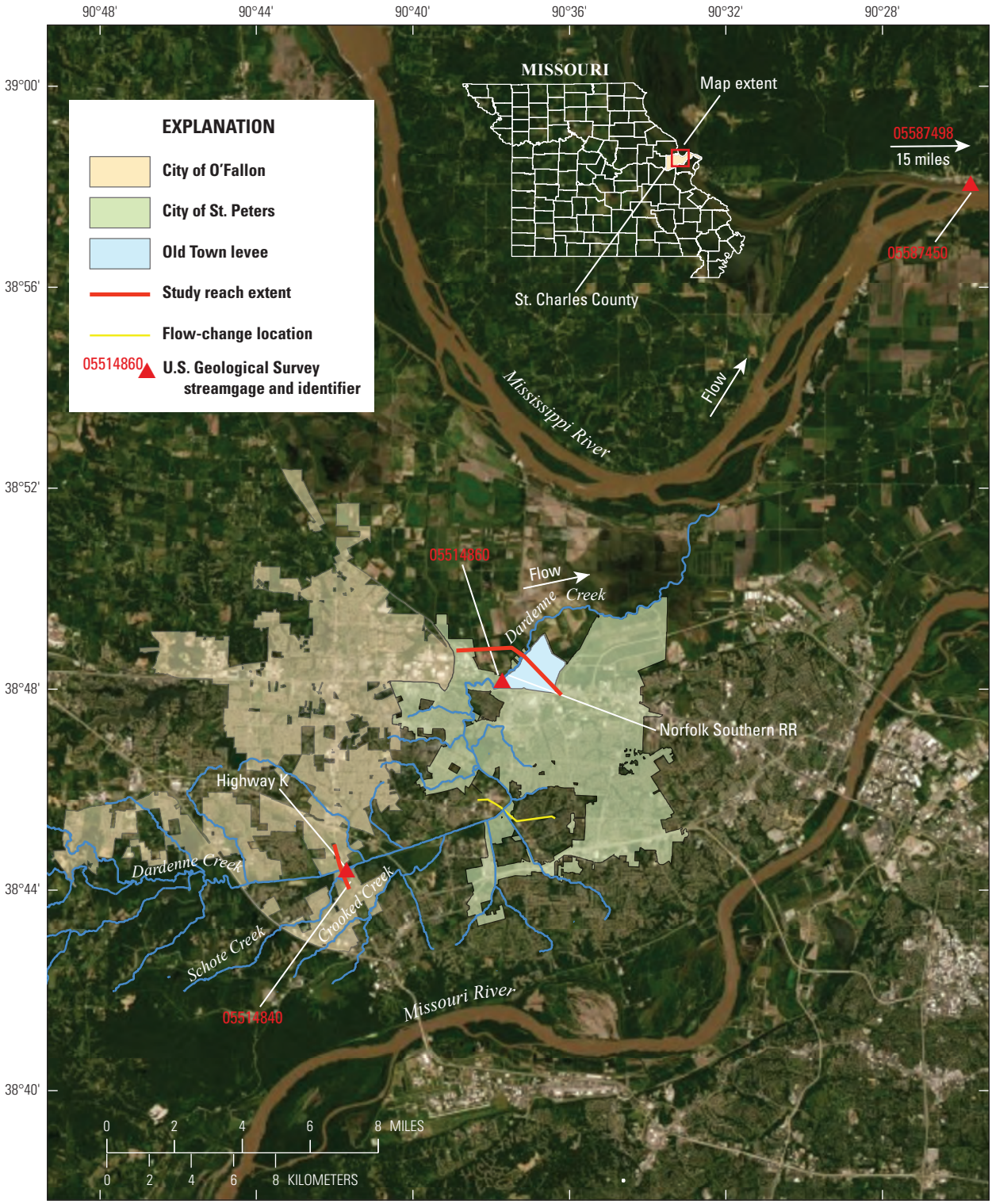
Table 1. U.S. Geological Survey streamgages for Dardenne Creek at St. Peters, Missouri, and vicinity.

[Station location is shown in figure 1. Latitude and longitude are given in degrees (°), minutes (′), and seconds (″). mi², square mile; NAD 83, North American Datum of 1983; ft, foot; NAVD 88, North American Vertical Datum of 1988; ft³/s, cubic foot per second; --, no data]

Station name	Station number	Drainage area (mi²)	Latitude (NAD 83)	Longitude (NAD 83)	Period of peak-flow record (water year[1])	Maximum recorded stage (ft), corresponding gage datum elevation (ft, NAVD 88), and date	Maximum streamflow (ft³/s) and date
Dardenne Creek at O'Fallon, Missouri	05514840	61	38°44′25.3″	90°41′42.2″	2000–20	19.85 (481.83) December 27, 2015	8,620 December 27, 2015
Dardenne Creek at Old Town St. Peters, Missouri	05514860	102	38°48′10.95″	90°37′42.54″	2000–20	24.03 (449.42) December 27, 2015	10,600 December 27, 2015
Mississippi River at Grafton, Illinois	05587450	171,300	38°58′04.7″	90°25′44.4″	1933–2020	38.17(441.96) August 1, 1993	[2]598,000 August 1, 1993
Mississippi River Pool at Lock and Dam 26 at Alton, Illinois	05587498	--	38°53′11.2″	90°10′57.17″	1987–2020	39.12 (439.20) August 1, 1993	--

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

[2]Maximum streamflow affected to unknown degree by regulation or diversion.



World Geodetic System 1984 Web Mercator (Auxillary Sphere) projection
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)

Figure 1. Location of study reach for Dardenne Creek at St. Peters, Missouri, and vicinity.

significant hydrologic activity. The 32-ft stage exceeds the stage that corresponds to the estimated 0.2-percent annual exceedance probability (AEP) flood (500-year recurrence interval flood). The maps depicting the extent of backwater from the Mississippi River in the Dardenne Creek study reach cover a range from 18 to 40 ft referenced to USGS streamgage 05587450, Mississippi River at Grafton, Ill. The 18-ft stage is approximately the NWS flood stage at the Grafton streamgage, and the 40-ft stage exceeds the estimated 0.2-percent AEP flood at the Mississippi River at Grafton as determined by the U.S. Army Corps of Engineers (USACE; USACE, 2004).

Study Area Description

Dardenne Creek is in east-central Missouri in St. Charles County, and the study reach includes, but is not limited to, the cities of O'Fallon and St. Peters (fig. 1). The drainage area upstream from the USGS streamgage 05514840 in O'Fallon is 61 square miles (mi^2), and the drainage area upstream from USGS streamgage 05514860 at Old Town St. Peters is 102 mi^2. Minor tributaries that join Dardenne Creek within the study reach, and between the two streamgages, include Schote Creek (drainage area=5.0 mi^2) and Crooked Creek (drainage area=7.2 mi^2; fig. 1). The Dardenne Creek Basin falls within the Interior River Valley and Hills ecoregion characterized by smooth to moderately dissected, forested river side-slopes and bluffs. The region, which lies along the Mississippi and Missouri Rivers, is a transition zone between the loess- and till-covered plains to the north and the interior Ozark Highlands to the south (U.S. Environmental Protection Agency, 2020). The primary land cover of the study basin upstream from the St. Peters streamgage is developed lands (41 percent) followed by forest (32 percent) and agriculture (24 percent) based on 2016 National Land Cover Data (Yang and others, 2018). The population of the cities of O'Fallon and St. Peters increased 11 and 7.5 percent, respectively, between 2010 and 2018 (U.S. Census Bureau, 2020). The study reach is 9.9 mi with a mean top-of-bank width of 110 ft and mean slope of 3.8 feet per mile based on cross-section data obtained from a hydraulic model of Dardenne Creek (Alecia Williams, Wood Environment and infrastructure Solutions, Inc., written commun., 2019) developed for the 2018 FIS for St. Charles County, Mo. (FEMA, 2018). Flood impacts near the Dardenne Creek at St. Peters streamgage over the range of stages from the NWS-defined "flood stage" to the "major flood" conditions are documented at NWS (2020).

A total of 12 bridges are represented in the Dardenne Creek hydraulic model reach and have the potential to affect water-surface elevations during flooding along the stream. These 12 bridges are 2 major four-lane highway bridges, 7 two-lane highways and county road bridges, 1 railroad bridge, and 2 pedestrian trail bridges. The downstream section of the study reach includes a segment of the St. Peters Old Town Levee System constructed after flooding in 1993 (fig. 1). This section of the levee spans about 4.8 mi, protects about 668 acres, and is included in the National Levee Database (USACE, 2020; https://levees.sec.usace.army.mil/#/).

Previous Studies

The latest FIS for Dardenne Creek in St. Charles County (FEMA, 2018) was completed by Wood Environment and Infrastructure Solutions, Inc. in 2018. A hydraulic model developed in 2010 (Alecia Williams, Wood Environment and Infrastructure Solutions, Inc., written commun., 2019) was used in the current FIS. The FIS uses estimates of the peak streamflows with 10-, 2-, 1-, and 0.2-percent AEPs (table 2) and their associated water-surface elevations for Dardenne Creek. These peak streamflow estimates originally were developed by the USACE in a previously published watershed study of Dardenne Creek (USACE, 2007).

Table 2. Peak streamflows for selected annual exceedance probabilities for Dardenne Creek in St. Charles County, Missouri.

[Data from Federal Emergency Management Agency (2018) and U.S. Army Corps of Engineers (2007). mi^2, square mile; ft^3/s, cubic foot per second; RR, railroad]

Location on Dardenne Creek (fig. 1)	Drainage area (mi^2)	Estimated streamflows (ft^3/s) for indicated annual exceedance probability (percent)			
		10	2	1	0.2
At State Highway K	61.2	9,960	16,830	19,910	30,550
At Norfolk Southern RR	102.8	10,370	17,170	19,400	29,460
At mouth	154.2	10,310	14,230	17,440	25,960

Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (USGS, 2020c) so that the process followed and products produced are similar regardless of which USGS office is responsible for the work. Tasks specific to the development of the flood-inundation maps for this study included (1) acquiring the hydraulic model that is used in the current FIS for Dardenne Creek in O'Fallon and St. Peters, Mo. (Alicia Williams, Wood Environment and Infrastructure Solutions, Inc., written commun., 2019), (2) surveying bridge cross-sections at all bridges within the study reach, (3) calibrating energy-loss factors (roughness coefficients) in the stream channel and floodplain and determining steady-state flow data, (4) computing water-surface profiles using the USACE Hydrologic Engineering Center's River Analysis System (HEC–RAS) computer program (USACE, HEC, 2019), (5) producing estimated flood-inundation maps for selected stream stages using HEC–RAS and a GIS, and (6) preparing the maps as shapefile polygons that depict the areal extent of flood inundation at various stages, 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 hydraulic model used in this study was developed in 2010 by Wood Environment and Infrastructure Solutions, Inc. for an update of the FIS for O'Fallon and St. Peters, Mo. (Alecia Williams, Wood Environment and Infrastructure Solutions, Inc., written commun., 2019). This model, developed using HEC–RAS version 5.0.7 (USACE, HEC, 2019), was calibrated by the USGS and used to produce the flood-inundation maps in this study. HEC–RAS is a one-dimensional model for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options.

Hydrologic Data

This study uses hydrologic data from four USGS streamgages (05514840, 05514860, 05587450, and 05587498; fig. 1; table 1); two of these streamgages (05514840 and 05514860) are located in the Dardenne Creek study reach at which stage is measured every 15 minutes. Stage is measured at the Mississippi River streamgages (05587450 and 05597498) every 30 minutes. The stages are transmitted hourly by a satellite radio at each streamgage and are made available on the internet through the USGS National Water Information System (NWIS) database (USGS, 2020d). Stage data from these streamgages are referenced to a local datum but can be converted to water-surface elevations referenced to the North American Vertical Datum of 1988 (NAVD 88) or National Geodetic Vertical Datum of 1929 by adding the corresponding vertical datum (table 3). Continuous records of streamflow for the Dardenne Creek streamgages are computed from a stage-streamflow relation (Turnipseed and Sauer, 2010). The streamflow records are available through the USGS NWIS database.

The estimated streamflows for specific stages used in the model simulations (table 4) were obtained from a stage-streamflow rating (rating 10.0) at the Dardenne Creek at Old Town St. Peters streamgage that was generated from discrete streamflow measurements. Several minor tributaries join Dardenne Creek within the 9.9-mile study reach between the O'Fallon and St. Peters streamgages, and a flow-change location was included at reach mile 5.9 in the model at a location downstream from several tributaries (fig. 1; table 4). The mean ratio (0.89) of peak streamflows from concurrent peaks at the O'Fallon and St. Peters streamgages over the range of recorded conditions and overall period of record was used to determine the corresponding upstream model boundary flows (table 4).

Topographic and Bathymetric Data

All topographic data used in this study are referenced vertically to NAVD 88, unless otherwise stated, and horizontally to the North American Datum of 1983. Cross-section

Table 3. Vertical datums of U.S. Geological Survey streamgages used in this study.

[NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

Station name	Station number	Vertical datum, in feet above NAVD 88 (or NGVD 29)
Dardenne Creek at O'Fallon, Missouri	05514840	461.98
Dardenne Creek at Old Town St. Peters, Missouri	05514860	425.39
Mississippi River at Grafton, Illinois	05587450	(403.79)
Mississippi River at Lock and Dam 26 at Alton, Illinois	05587498	(400.00)

[1]Streamgage vertical datum established or checked using a Level II survey with accuracy within 0.26 foot as defined in Rydlund and Densmore (2012).

Table 4. Estimated streamflows for corresponding stages and water-surface elevations at selected locations, used in the hydraulic model of Dardenne Creek at Old Town St. Peters, Missouri.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; ft³/s, cubic foot per second]

Stage of water-surface profile (ft)[1]	Water-surface elevation (ft, NAVD 88)	Estimated streamflow at indicated location (ft³/s)	
		At upstream end of study reach (reach mile 9.9)[2]	At reach mile 5.9 in study reach[2]
16	441.39	2,380	2,680
17	442.39	2,890	3,250
18	443.39	3,520	3,950
19	444.39	4,270	4,800
20	445.39	5,070	5,700
21	446.39	6,010	6,750
22	447.39	7,030	7,900
23	448.39	8,230	9,250
[3]24	449.39	9,430	10,600
25	450.39	10,600	11,900
26	451.39	11,800	13,300
27	452.39	13,000	14,600
28	453.39	13,400	15,100
29	454.39	16,400	18,400
30	455.39	17,100	19,200
31	456.39	22,100	24,800
32	457.39	26,700	30,000

[1]Water-surface profiles are 1-ft increments of stage, referenced to the local gage datum of the U.S. Geological Survey streamgage 05514860, Dardenne Creek at Old Town St. Peters, Missouri.

[2]The downstream extent of Hydrologic Engineering Center's River Analysis System model (fig.1) is reach mile 0.0.

[3]Highest streamflow measurement corresponds to stage of 24.05 ft.

elevation data from the 2010 model obtained from Wood Environment and Infrastructure, Inc (Alecia Williams, Wood Environment and Infrastructure Solutions, Inc., written commun., 2019) were updated to a digital elevation model (DEM) that was derived from light detection and ranging (lidar) data collected in February 2017 by Merrick-Surdex Joint Venture, Greenwood Village, Missouri, through a contract with the Metropolitan St. Louis Sewer District and available through the USGS National Map Viewer (USGS, 2019). Postprocessing of these data was completed by Surdex Corporation on August 17, 2017. The bare-earth lidar data were processed using USGS Base Lidar Specifications version 1.3 (Heidemann, 2018) that met or exceeded the National Map Accuracy standards for vertical and horizontal accuracy guidelines for 2-ft contours (American Society for Photogrammetry and Remote Sensing, 1990, 2004). The lidar data have a horizontal accuracy of 1.97 ft (60 centimeters) root mean square error and vertical accuracy of 0.607 ft (18.5 centimeters) root mean square error. The final DEM, which has a 3.28-ft grid-cell size, has a vertical accuracy of plus or minus 1 ft.

By using the USACE Hydrologic Engineering Center's Geospatial River Analysis System (HEC–GeoRAS; Ackerman, 2009), a set of procedures, tools, and utilities for processing geospatial data in ArcGIS, elevation data were extracted from the DEM for the model cross sections (fig. 1) and subsequently input to the HEC–RAS model. Because lidar data cannot provide ground elevations below a stream's water surface, channel cross sections in the HEC–RAS model were surveyed by Wood Environment and Infrastructure Solutions during 2010 (Alicia Williams, Wood Environment and Infrastructure Solutions, written commun., 2019) and verified at bridge openings by USGS field crews in September 2019 to account for any fluvial changes since the original surveys. The Old Town levee surface also was surveyed by a USGS field crew in September 2019 for verification of model data. Cross-sectional depths were measured by taping down from a known bridge elevation at all surveyed locations. A differential global positioning system with real-time kinematic technology was used to derive vertical reference elevations at tape down locations and to collect levee topographic elevation points. A

Level IV survey (Rydlund and Densmore, 2012) procedure was used in acquiring reference elevations with a resulting vertical accuracy of reference points within 0.32 ft. The bathymetric data were incorporated into the HEC–RAS model, and the "RAS Mapper" feature in HEC–RAS was used to generate a DEM of channel bathymetry and to merge the bathymetry DEM with the terrain DEM. Additional information from as-built bridge plans (Dale Henderson, Missouri Department of Transportation, written commun., 2019) were used to revise cross sections at bridges that were constructed after the original model was developed (2010).

Hydraulic Structures

A total of 12 bridges are represented in the Dardenne Creek hydraulic model and have the potential to affect water-surface elevations during flooding along the stream. These 12 bridges are 2 major four-lane highway bridges, 7 two-lane highways and county road bridges, 1 railroad bridge, and 2 pedestrian trail bridges. Initial bridge-geometry data were obtained from a HEC–RAS model developed by Wood Environment and Infrastructure Solutions (Alicia Williams, Wood Environment and Infrastructure Solutions, written commun., 2019), and updated and verified through field surveys and from as-built bridge plans by personnel from the USGS Central Midwest Water Science Center. The Old Town levee along the downstream east bank of the study reach was included in the HEC–RAS model of the study reach as a levee (fig. 1). As such, the landward side of the levee remained dry until the estimated Dardenne Creek water surface exceeded the levee height. Although the levee is overtopped at Dardenne Creek at St. Peters at stages of approximately 28 ft and greater, the water depths in the leveed area cannot be estimated with certainty using a steady-state simulation, and, therefore, the leveed area is shown as an area of uncertainty throughout the range of simulated stages.

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, high-resolution aerial photographs collected through the U.S. Department of Agriculture's National Agriculture Imagery Program and available through the Missouri Spatial Data Information Service (2019), and tabulated estimates of *n* values (Chow, 1959).

As part of the calibration process, the initial *n* values were varied by flow and adjusted until the differences between simulated and observed water-surface elevations at the streamgage and elsewhere along the study reach were minimized. The final *n* values ranged from 0.04 to 0.048 for the main channel and from 0.03 to 0.12 for the overbank areas simulated in this analysis. The lowest channel coefficients were placed in straight, upstream sections of the model reach, and the highest were placed in sinuous, low-gradient, fine-material substrate reaches with vegetated banks in the downstream sections of the model reach. The lowest roughness coefficients on the floodplain were placed in open water bodies (lakes) and the highest in densely forested areas.

Hydraulic Model

The HEC–RAS analysis for this study was performed using the steady-state flow computation option. A one-dimensional model with steady-state flow option was used as the flow direction was primarily in the streamwise direction without substantial floodplain storage. The areas behind the levees at the downstream end of the model reach in which storage could be substantial are indicated as "areas of uncertainty" in the flood-inundation map products. Steady-state flow data consisted of flow regimes, boundary conditions, and peak flows that produced water-surface elevations at the streamgage cross sections that matched target water-surface elevations. These target elevations coincided with 1-ft increments of stage, referenced to the local gage datum. Subcritical (tranquil) flow regime was assumed for the simulations. Normal depth, based on an estimated mean water-surface slope of 0.0008, was used as the reach's downstream boundary condition. The normal depth condition accurately represented the range of peak streamflow conditions that were documented during the 20-years of gage operations at the Dardenne Creek at St. Peters streamgage. The flood profiles generated using the normal depth boundary condition, however, do not represent any substantial influences from backwater from the Mississippi River. The peak flows used in the model were discussed in the "Hydrologic Data" section.

The HEC–RAS model was calibrated to a developed stage-streamflow relation (rating 5.0) at streamgage 05514840 on Dardenne Creek at O'Fallon, Mo., a developed stage-streamflow relation (rating 10.0) at streamgage 05514860 on Dardenne Creek at Old Town St. Peters, Mo., and to documented high-water marks from the flood of December 27, 2015. Model calibration was accomplished by adjusting Manning's *n* values and ineffective flow characteristics until the results of the hydraulic computations closely agreed with the observed water-surface elevations for given flows. Differences between target and simulated water-surface elevations for simulated flows at the USGS streamgage 05514840 were equal to or less than 0.66 ft (table 5) and were equal to or less than 0.55 ft at USGS streamgage 05514860 (table 6). Differences between surveyed and simulated elevations of 10 high-water marks in the study reach for the flood of December 27, 2015, were less than or equal to 0.72 ft (table 7). The results demonstrate that the model is capable of simulating accurate water levels throughout the reach over a large range of stages and flows.

Table 5. Calibration of model to target water-surface elevations at U.S. Geological Survey streamgage 05514840 on Dardenne Creek at O'Fallon, Missouri.

[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)
12.02	474.00	474.26	−0.26
13.02	475.00	475.41	−0.41
14.02	476.00	476.52	−0.52
15.02	477.00	477.64	−0.64
16.02	478.00	478.66	−0.66
17.02	479.00	479.54	−0.54
18.02	480.00	480.32	−0.32
19.02	481.00	481.05	−0.05
20.02	482.00	481.74	0.26
21.02	483.00	482.33	0.66

Table 6. Calibration of model to target water-surface elevations at U.S. Geological Survey streamgage 05514860 on Dardenne Creek at St. Peters, Missouri.

[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)
14.61	440.00	439.92	−0.08
15.61	441.00	440.79	−0.21
16.61	442.00	441.66	−0.34
17.61	443.00	442.56	−0.43
18.61	444.00	443.46	−0.53
19.61	445.00	444.54	−0.46
20.61	446.00	445.59	−0.41
21.61	447.00	446.66	−0.34
22.61	448.00	447.77	−0.23
23.61	449.00	448.85	−0.15
24.61	450.00	450.05	0.05
25.61	451.00	451.55	0.55
26.61	452.00	452.14	0.14

Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for a total of 17 stages at 1-ft intervals between 16 and 32 ft as referenced to the local datum of the Dardenne Creek at Old Town St. Peters, Mo., streamgage. These stages correspond to elevations of 441.39 and 457.39 ft NAVD 88, respectively. Streamflows corresponding to the various stages were obtained from the current (2020) stage-streamflow relation (rating 10.0) for the Dardenne Creek at Old Town St. Peters, Mo., streamgage. Streamflows through the study reach were adjusted for tributary inflows by including a flow change location (fig. 1; table 4) in the model to represent the cumulative addition of primary tributary inflows.

Development of Flood-Inundation Maps

Flood-inundation maps were created for the Dardenne Creek study reach and referenced to the USGS streamgage 05514860 on Dardenne Creek at Old Town St. Peters, Mo., a designated NWS flood-forecast point (site DRCM7; NWS, 2019a). The DEM data were derived from the same

Table 7. Calibration of model to water-surface elevations at selected high-water mark locations from the December 27, 2015, flood along Dardenne Creek.

[ID, identifier; ft, foot; NAVD 88, North American Vertical Datum of 1988; D, downstream; USGS, U.S. Geological Survey; U, upstream]

Cross-section ID (ft)[1] and location	Surveyed water-surface elevation (ft, NAVD 88)	Modeled water-surface elevation (ft, NAVD 88)	Difference in elevation (ft)
92,027.5 Highway K	482.00	481.88	−0.12
91,933.7 D (at USGS streamgage 05514840)	481.83	481.63	−0.20
86,727 D Highway 364	476.60	476.41	−0.19
7,9092.7 U Highway N	472.40	471.68	−0.72
78,824 Highway N	472.21	471.57	−0.64
74,125.5 Mid Rivers Mall Road	468.54	467.96	−0.58
51,287 U Interstate 70	455.20	455.18	−0.02
48,743.1 Downstream from Interstate 70	452.60	453.00	0.41
45,558.2 Downstream from Interstate 70	450.60	450.81	0.21
44,594.5 D (at USGS streamgage 05514860)	449.42	449.33	−0.09

[1]Cross-section identification numbers are referenced to the longitudinal baseline used in the hydraulic model. The downstream model boundary cross-section ID corresponds to a value of 40,257 ft and is 40,257 ft from the confluence with the Mississippi River. The upstream boundary of 92,590.8 is 92,590.8 ft upstream from the Dardenne Creek-Mississippi River confluence.

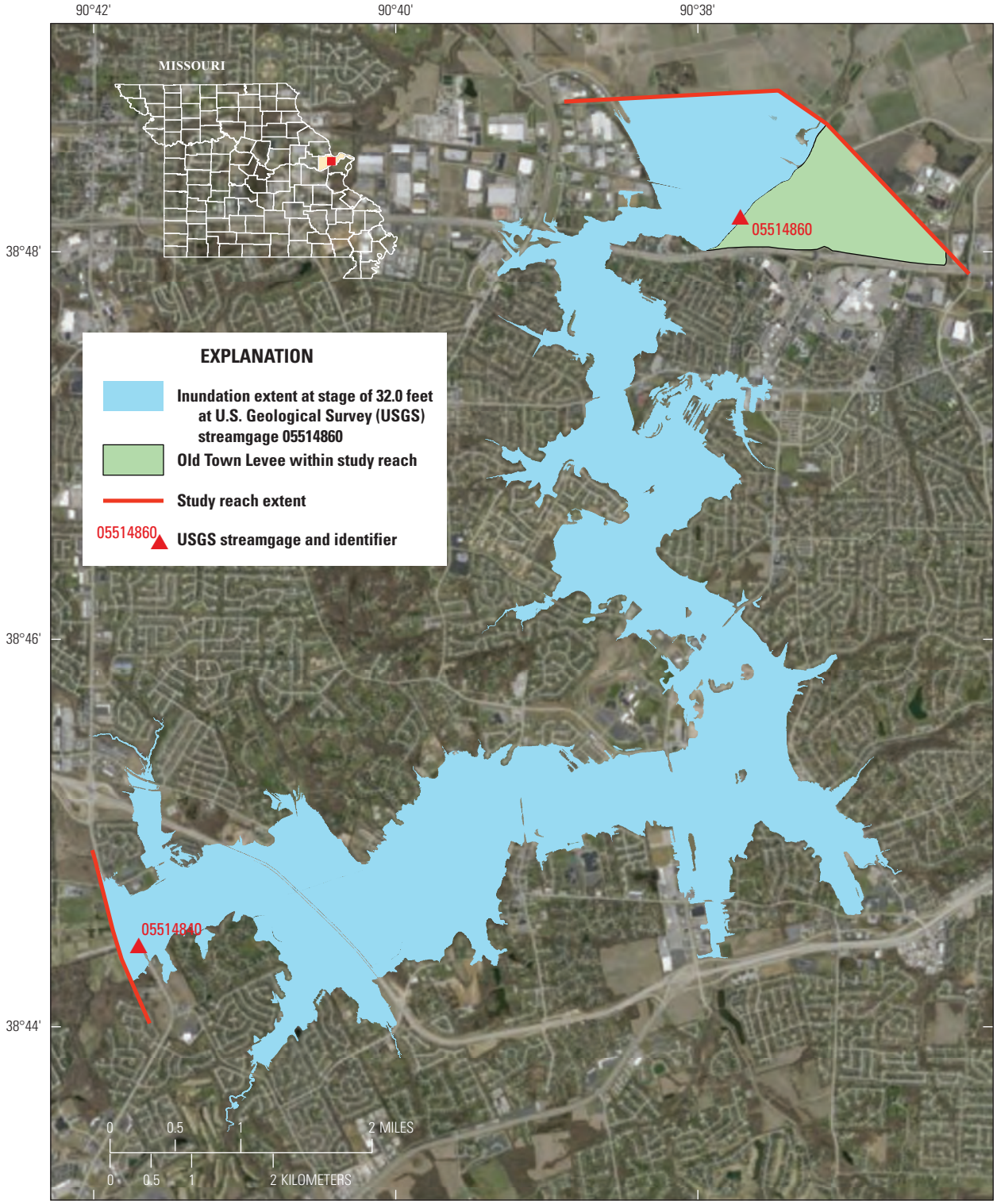
lidar data described previously in the "Topographic and Bathymetric Data" section and therefore have an estimated vertical accuracy of 2 ft (that is, plus or minus 1 ft). Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (Ackerman, 2009), which allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (USACE, HEC, 2010). Shapefile polygons and depth grids of the inundated areas for each profile were modified, as required, in the ArcMap application of ArcGIS (Esri, 2020) 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 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 are shown as not inundated until the lowest flood stage that either exceeds the bridge deck or completely inundates both approaches to the bridge. In these latter circumstances, the bridge surface is depicted as being inundated. Estimates of water depth can be obtained from the depth-grid data (Heimann and others, 2020) 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." The flood map corresponding to the highest simulated water-surface profile, a stage of 32.0 ft, is presented in figure 2.

Inundation maps of the estimated extent of backwater from the Mississippi River on the Dardenne Creek study reach were generated using GIS software. A linear-regression model was developed (fig. 3) between the water-surface elevation at the USGS streamgage 05587450 on the Mississippi River at Grafton, Ill., and the corresponding water-surface slope between the Mississippi River at Grafton and the USGS streamgage 05587498 on the Mississippi River at Lock and Dam 26 at Alton, Ill., based on observed peak data and estimated flood-frequency stage values from the USACE (2004). The estimated water-surface slopes at 1-ft stage increments at the Grafton streamgage, for stages ranging from 50- to 0.2-percent AEP flow conditions, were used to extrapolate water-surface elevations to the mouth of Dardenne Creek. A planar digital surface was assigned a value corresponding to the Mississippi River water-surface elevation at the mouth of Dardenne Creek, and the surface was overlain on the basin terrain model to generate inundation polygons and depth grids in the Dardenne Creek study reach. This methodology is similar to that used in the development of backwater profiles for tributaries as outlined in the FEMA guidelines for the development of flood profiles in FIS reports (FEMA, 2016). In total, 23 maps depicting Mississippi River backwater conditions were developed for Grafton stages of 18 to 40 ft corresponding to water-surface elevations at the mouth of Dardenne Creek of 425.38 to 445.98 ft.

Flood-Inundation Map Delivery

The current study documentation is available online at the USGS Publications Warehouse https://doi.org/10.3133/sir20205060). Also, a Flood Inundation Mapping Program



World Geodetic System 1984 Web Mercator (Auxillary Sphere) projection
Horizontal coordinate information referenced to the North American Datum of 1983 (NAD 83)

Figure 2. Flood-inundation map for Dardenne Creek in St. Charles County, Missouri, corresponding to a stage of 32.0 feet at the U.S. Geological Survey streamgage 05514860.

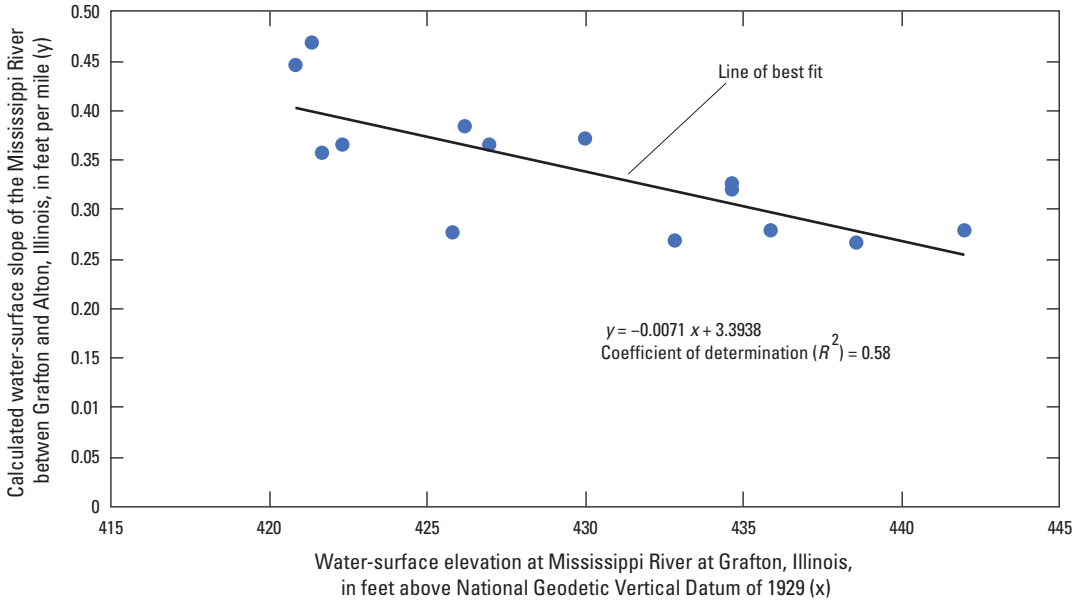


Figure 3. Relation between the water-surface elevation at the Mississippi River at Grafton, Illinois, and the calculated water-surface slope between the Grafton and Mississippi River at Alton, Illinois, streamgages.

website (https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program?qt-science_center_objects=0#qt-science_center_objects; USGS, 2020c) has been established to make USGS flood-inundation study information available to the public. The website 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 libraries for Dardenne Creek (Heimann and others, 2020). A link on the mapping application website connects to the USGS NWIS (USGS, 2020d), which presents the current stage and streamflow at the USGS streamgages 05514860 on Dardenne Creek at St. Peters, Mo., and 05587450 on the Mississippi River at Grafton, Ill., to which the inundation maps are referenced. A second link connects to the NWS AHPS site (NWS, 2019a) so that the user can obtain applicable information on forecasted peak stages at the two reference locations. Additionally, a link is provided on the mapping application to the USGS WaterAlert application (USGS, 2020e), which notifies the user when a specified stage threshold is reached. The estimated flood-inundation maps are displayed in sufficient detail so that preparations for flooding and decisions for emergency response can be performed efficiently. Depending on the flood magnitude, roadways are shown as shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use. Bridges are shaded—that is, shown as inundated—when the flood stage exceeds the elevation of the bridge deck. 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 holding 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, 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 2019. Unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the modeled reach to vary from those assumed during a flood, which may lead to deviations in the water-surface elevations and inundation boundaries shown.

Additional areas may be flooded due to unanticipated conditions such as changes in the streambed elevation or roughness, backwater into major tributaries along a main-stem river, or backwater from localized debris or ice jams. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the DEM used to simulate the land surface. An additional source of uncertainty in the prediction of water-surface elevations at the Dardenne Creek confluence with the Mississippi River, and corresponding backwater extents, is the potential variability resulting from changing slope conditions of the Mississippi River.

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.

Eight model scenarios exceed the highest streamflow measurement made at the Dardenne Creek at St. Peters streamgage corresponding to a stage of approximately 24 ft, therefore, there is additional uncertainty for flood-inundation maps at stages greater than 24 ft. Incremental changes in inundation area and water depths are not displayed on the USGS Flood Inundation Program web site for the Old Town levee area within the Dardenne Creek study reach (fig. 2). The leveed area is displayed on the web mapper as a designated area of uncertainty.

Summary

A series of digital flood-inundation maps were developed by the U.S. Geological Survey (USGS) in cooperation with the Missouri Department of Transportation, St. Charles County, and the Cities of O'Fallon and St. Peters, Missouri, for Dardenne Creek, in St. Charles County, Missouri. The maps cover a reach about 9.9 miles long corresponding to the approximate limits of Dardenne Creek within the O'Fallon and St. Peters city limits. The maps were developed by using the U.S. Army Corps of Engineers' Hydrologic Engineering Center's River Analysis System (HEC–RAS) and Hydrologic Engineering Center's Geospatial River Analysis System (HEC–GeoRAS) programs 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 stage-streamflow relation at the USGS streamgage 05514840 Dardenne Creek at O'Fallon, USGS streamgage 05514860 Dardenne Creek at St. Peters, and to observed high-water marks from the December 2015 flood. The model was used to compute 17 water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the local streamgage datum and ranging from 16.0 ft, or near bankfull, to 32.0 ft, which exceeds the stage corresponding to the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval). In total, 23 maps also were developed showing inundation area within the study reach displaying the extent of backwater from the Mississippi River in the study reach that were referenced to the USGS streamgage 05587450 Mississippi River at Grafton, Illinois.

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 Program website (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 are used in conjunction with the real-time stage data from the U.S. Geological Survey reference streamgages (05514860 on Dardenne Creek at St. Peters, Mo., and 05587450 on the Mississippi River at Grafton, Ill.) and forecasted flood stage data from the National Weather Service Advanced Hydrologic Prediction Service. The joint products can help guide the general public in taking individual safety precautions and provides emergency management personnel with a tool to mitigate and prepare for flood-related emergencies, efficiently manage emergency flood operations, and effectively conduct postflood recovery efforts.

References Cited

Ackerman, C.T., 2009, HEC–GeoRAS—GIS tools for support of HEC–RAS using ArcGIS—User's manual (ver. 4.2): U.S. Army Corps of Engineers, CPD–83, [variously paged], accessed May 6, 2019, at https://www.hec.usace.army.mil/software/hec-georas/downloads.aspx.

American Society for Photogrammetry and Remote Sensing, 1990, ASPRS accuracy standards for large-scale maps: American Society for Photogrammetry and Remote Sensing, accessed December 11, 2019, at http://www.asprs.org/a/society/committees/standards/1990_jul_1068-1070.pdf.

American Society for Photogrammetry and Remote Sensing, 2004, ASPRS guidelines—Vertical accuracy reporting for lidar data: American Society for Photogrammetry and Remote Sensing, accessed December 17, 2018, at https://www.asprs.org/a/society/committees/standards/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Esri, 2020, ArcGIS (ver. 10.7.1): Esri software, accessed January 12, 2020, at https://www.esri.com/software/arcgis/.

Federal Emergency Management Agency [FEMA], 2016, Guidance for flood risk analysis and mapping—Flood profiles: Federal Emergency Management Agency, Guidance Document 85, 8 p. [Also available at https://www.fema.gov/media-library-data/1485269649213-8f3f5dd54ab7c3ded7d5bcecaff61eab/Flood_Profiles_Guidance_Nov_2016.pdf.]

Federal Emergency Management Agency [FEMA], 2018, Flood insurance study, St. Charles County, Missouri, and incorporated areas: Washington D.C., Federal Emergency Management Agency, v. 1, 106 p. [Also available at https://www.stcharlescitymo.gov/DocumentCenter/View/7136/Flood-Insurance-Study-Report.]

Federal Emergency Management Agency [FEMA], 2020, Missouri severe storms, tornadoes, straight-line winds, and flooding (DR–4250): Federal Emergency Management Agency, Major Disaster Declaration, accessed January 14, 2020, at https://www.fema.gov/disaster/4250.

Heidemann, H.K., 2018, Lidar base specification (ver. 1.3, February 2018): U.S. Geological Survey Techniques and Methods, book 11, chap. B4, 101 p., accessed February 7, 2020, at https://doi.org/10.3133/tm11b4.

Heimann, D.C., Voss, J.D., and Rydlund, P.H., Jr., 2020, Geospatial datasets for the flood-inundation study of Dardenne Creek, St. Charles, Missouri, 2019: U.S. Geological Survey data release, https://doi.org/10.5066/P9QPY9MI.

Missouri Spatial Data Information Service, 2019, Missouri imagery data: Missouri Spatial Data Information Service digital data, accessed September 14, 2019, at http://www.msdis.missouri.edu/data/imagery/index.html. [NAIP 2018 data directly accessible at http://msdis-archive.missouri.edu/archive/Missouri_Imagery/naip2018/.]

National Weather Service [NWS], 2019a, Advanced Hydrologic Prediction Service river forecasts: National Weather Service digital data, accessed October 17, 2019, at https://water.weather.gov/ahps/forecasts.php.

National Weather Service [NWS], 2019b, National Weather Service glossary—Action stage: National Weather Service web page, accessed November 17, 2019, at https://w1.weather.gov/glossary/index.php?word=action+stage.

National Weather Service [NWS], 2020, Advanced Hydrologic Prediction Service river forecasts—Dardenne Creek at St. Peters: National Weather Service digital data, accessed April 20, 2020, at https://water.weather.gov/ahps2/hydrograph.php?wfo=lsx&gage=drcm7.

Rydlund, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes, accessed March 2, 2020, at https://doi.org/10.3133/tm11D1.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p. [Also available at https://doi.org/10.3133/tm3A8.]

U.S. Army Corps of Engineers [USACE], 2004, Upper Mississippi River System flow frequency study—Appendix D: U.S. Army Corps of Engineers, [variously paged].

U.S. Army Corps of Engineers [USACE], 2007, Dardenne Creek watershed study—A comprehensive hydraulic study of Dardenne Creek and its tributaries: U.S. Army Corps of Engineers, 64 p.

U.S. Army Corps of Engineers [USACE], Hydrologic Engineering Center [HEC], 2010, HEC–RAS—River analysis system—Hydraulic reference manual (ver. 4.1, January 2010): U.S. Army Corps of Engineers, [variously paged], accessed May 15, 2018, at https://www.hec.usace.army.mil/software/hec-ras/download.aspx.

U.S. Army Corps of Engineers [USACE], Hydrologic Engineering Center [HEC], 2019, HEC–RAS—River analysis system—Hydraulic reference manual (ver. 5.0.7, March 2019): U.S. Army Corps of Engineers, [variously paged], accessed May 15, 2019, at https://www.hec.usace.army.mil/software/hec-ras/download.aspx.

U.S. Army Corps of Engineers [USACE], 2020, National Levee database: U.S. Army Corps of Engineers digital data, accessed February 2, 2020, at https://levees.sec.usace.army.mil/#/.

U.S. Census Bureau, 2020, QuickFacts—United States population estimates: U.S. Census Bureau, accessed January 18, 2020, at https://www.census.gov/quickfacts/fact/table/US/PST045219.

U.S. Environmental Protection Agency, 2020, Ecoregion download riles by State—Region 7—Level IV Ecoregions of Iowa and Missouri: U.S. Environmental Protection Agency digital data, accessed January 14, 2020, at https://www.epa.gov/eco-research/ecoregion-download-files-state-region-7.

U.S. Geological Survey [USGS], 2019, The National Map viewer: U.S. Geological Survey web-based application, accessed May 15, 2019, at https://viewer.nationalmap.gov/advanced-viewer/.

U.S. Geological Survey [USGS], 2020a, USGS 05514840 Dardenne Creek at O'Fallon, Missouri, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 4, 2020, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://waterdata.usgs.gov/nwis/uv?site_no=05514840.]

U.S. Geological Survey [USGS], 2020b, USGS 05514860 Dardenne Creek at Old Town St. Peters, Missouri, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 4, 2020, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://waterdata.usgs.gov/nwis/uv?site_no=05514860.]

U.S. Geological Survey [USGS], 2020c, Flood Inundation Mapping (FIM) Program: U.S. Geological Survey web page, accessed January 7, 2020, at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program?qt-science_center_objects=0#qt-science_center_objects.

U.S. Geological Survey [USGS], 2020d, USGS surface-water data for the Nation, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 3, 2020, at https://doi.org/10.5066/F7P55KJN. [Surface-water data directly accessible at https://waterdata.usgs.gov/nwis/sw.]

U.S. Geological Survey [USGS], 2020e, WaterAlert: U.S. Geological Survey web-based application, accessed March 20, 2020, at https://maps.waterdata.usgs.gov/mapper/wateralert/.

Yang, L., Jin, S., Danielson, P., Homer, C., Gass, L., Bender, S.M., Case, A., Costello, C., Dewitz, J., Fry, J., Funk, M., Granneman, B., Kiknes, G.C., Rigge, M., and Xian, G., 2018, A new generation of the United States National Land Cover Database—Requirements, research priorities, design, and implementation strategies: ISPRS Journal of Photogrammetry and Remote Sensing, v. 146, p. 108–123. [Also available at https://doi.org/10.1016/j.isprsjprs.2018.09.006.]

For more information about this publication, contact:
Director, USGS Central Midwest Water Science Center
1400 Independence Road
Rolla, MO 65401
573–308–3667

For additional information, visit: https://www.usgs.gov/centers/cm-water

Publishing support provided by the
Rolla Publishing Service Center

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20205060