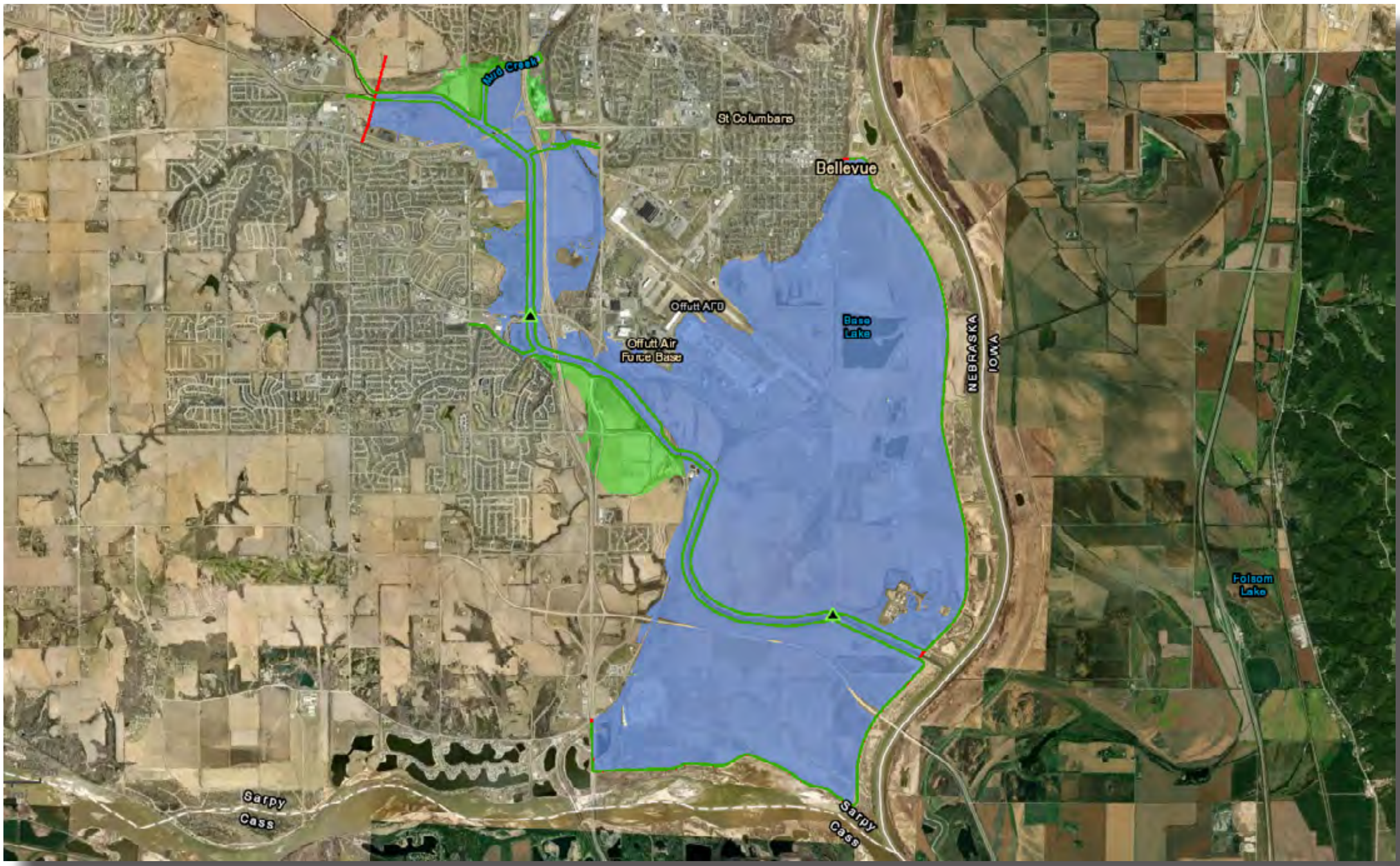
Prepared in cooperation with the U.S. Air Force, Offutt Air Force Base

Flood-Inundation Maps for an 8-Mile Reach of Papillion Creek near Offutt Air Force Base, Nebraska, 2022



Scientific Investigations Report 2023–5054

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

Cover. Image showing inundated areas along Papillion Creek near Offutt Air Force Base, Nebraska, from the U.S. Geological Survey Flood Inundation Mapper.

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By Kellan R. Strauch and Christopher M. Hobza

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U.S. Geological Survey, Reston, Virginia: 2023

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Suggested citation:
Strauch, K.R., and Hobza, C.M., 2023, Flood-inundation maps for an 8-mile reach of Papillion Creek near Offutt Air Force Base, Nebraska, 2022: U.S. Geological Survey Scientific Investigations Report 2023–5054, 12 p., https://doi.org/10.3133/sir20235054.

Associated data for this publication:
Strauch, K.R., 2023, Flood inundation geospatial datasets for Papillion Creek near Offutt Air Force Base, Nebraska: U.S. Geological Survey data release, https://doi.org/10.5066/P9XQIXMN.

U.S. Geological Survey, 2021, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, https://doi.org/10.5066/F7P55KJN.

ISSN 2328-0328 (online)

Acknowledgments

The authors would like to thank the staff at the 55th Civil Engineer Squadron Flood Recovery Office for their administrative and logistical support throughout the duration of this project. We also would like to thank Trip Spiller, emergency manager, for his assistance with data collection. We also thank Paul Woodward and the Papio-Missouri River Natural Resources District for providing additional information regarding the 2019 flood and the levee systems near and along the Missouri River and Papillion Creek. The authors also would like to thank all the men and women serving at Offutt Air Force Base.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
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)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F – 32) / 1.8.

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).

Supplemental Information

Pressure is given in millibars (mbar).

Abbreviations

AEP	annual exceedance probability
DEM	digital elevation model
FEMA	Federal Emergency Management Agency
HEC–RAS	Hydrologic Engineering Center-River Analysis System
lidar	light detection and ranging
n	Manning’s roughness coefficient
NWS	National Weather Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Flood-Inundation Maps for an 8-Mile Reach of Papillion Creek near Offutt Air Force Base, Nebraska, 2022

By Kellan R. Strauch and Christopher M. Hobza

Abstract

Digital flood-inundation maps for an 8-mile reach of Papillion Creek near Offutt Air Force Base, Nebraska, were created by the U.S. Geological Survey (USGS) in cooperation with the U.S. Air Force, Offutt Air Force Base. 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 Papillion Creek at Fort Crook, Nebr. (station 06610795), and Papillion Creek at Harlan Lewis Road near La Platte, Nebr. (station 06610798). Near-real-time stages at these streamgages may be obtained from the USGS National Water Information System database at https://doi.org/10.5066/F7P55KJN or from the National Weather Service Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/.

Flood profiles were computed for the 8-mile stream reach by means of a one-dimensional step-backwater model. The model was calibrated by adjusting roughness coefficients to best represent the current (2022) stage-streamflow relation at the Papillion Creek at Fort Crook (station 06610795) streamgage.

The hydraulic model then was used to compute water-surface profiles for 157 scenarios using a combination of stage values in 1-foot (ft) stage intervals that ranged from 27 to 39 ft at the Papillion Creek at Fort Crook (station 06610795) streamgage and from 13.9 to 30.9 ft at the Papillion Creek at Harlan Lewis Road near La Platte (station 06610798) streamgage, as referenced to the local datums. The simulated water-surface profiles then were combined by a geographic information system with a digital elevation model, which had a 3.281-ft grid to delineate the area flooded and water depths at each stage. The availability of these flood-inundation maps, along with information regarding current stage from the USGS streamgages, can provide emergency management personnel and residents with information that is critical for flood response activities and postflood recovery efforts.

Introduction

Offutt Air Force Base, south of Omaha, Nebraska, is bordered by the Missouri River to the east and Papillion Creek to the south and west (fig. 1). Because of its proximity to the confluence of Papillion Creek and other tributaries with the Missouri River, Offutt Air Force Base experienced substantial flooding during a March 2019 flooding event. Abnormally cold temperatures in February and early March resulted in frozen soils with about 6–10 inches of snow cover on the ground prior to a “bomb cyclone” (a rapidly strengthening storm in which pressure drops at least 24 millibars within 24 hours) that dropped an additional 2–3 inches of rainfall in parts of eastern Nebraska and South Dakota and western Iowa (Masters, 2019). This combination of events produced a 1-percent annual exceedance probability (AEP) flood (commonly known as a 100-year flood) on the Missouri River and produced a 0.5-percent AEP flood (commonly known as a 200-year flood) on the Platte River. The floodwaters breached levee R–616–613 (fig. 1), northeast of Offutt Air Force Base, and resulted in floodwaters that rose to at least 971.95 feet (ft) above the North American Vertical Datum of 1988 (NAVD 88; U.S. Geological Survey, 2021a), which submerged the lower half of the Offutt Air Force Base runway and inundated about 30 buildings on base (Keller, 2019). The floodwaters damaged about 130 structures (such as roads, bridges, electrical lines, and buildings), of which 60 were damaged beyond repair (Associated Press, 2019). Repair and renovation costs at Offutt Air Force Base were estimated to cost as much as $1 billion and take 5 years to complete (Liewer, 2019).

Emergency managers on and near Offutt Air Force Base have relied on several sources (all of which are available on the internet) to make decisions on how to best alert Offutt Air Force Base personnel and mitigate flood damages. One source of information is the U.S. Geological Survey (USGS) streamgages at Papillion Creek at Fort Crook, Nebr. (station 06610795; hereafter referred to as “Papillion Creek at Fort Crook”), and Papillion Creek at Harlan Lewis Road near La Platte, Nebr. (station 06610798; hereafter referred to as “Papillion Creek at Harlan Lewis Road”; table 1), from which current (2022) and historical water levels and streamflows, including annual peak flows, can be obtained (table 1; U.S. Geological Survey, 2021c). Another source of flood-related information is the National Weather Service (NWS) Advanced Hydrologic Prediction Service, which provides the USGS stage data for the two Papillion Creek streamgages (NWS identifier: FCKN1, PHRN1) and issues stage forecasts for Papillion Creek and the Missouri River (NWS identifier: OMHN1; National Weather Service, 2021a, b, c).

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 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 to notify or evacuate 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 may motivate residents to take precautions and heed warnings that they previously might have disregarded. In 2020–21, the USGS, in cooperation with Offutt Air Force Base, led a study to produce a library of flood-inundation maps for an 8-mile (mi) reach of Papillion Creek near Offutt Air Force Base in Nebraska.

Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for an 8-mi reach of Papillion Creek near Offutt Air Force Base in Nebraska and identifies where on the internet the maps can be viewed and ancillary data (geographic information system flood polygons and depth grids) can be downloaded. The flood-inundation maps cover an 8-mi reach of Papillion Creek starting 345 ft downstream from the confluence of Big Papillion Creek and continuing downstream near the confluence of Papillion Creek and the Missouri River (fig. 1). The flood-inundation maps were produced for water levels referenced to the stage recorded at two USGS streamgages on Papillion Creek; Papillion Creek at Fort Crook (station 06610795; table 1) and Papillion Creek at Harlan Lewis Road (station 06610798; table 1). The maps have a range in stage from equal to or less than the "action" stage to equal to or greater than the "major" flood stage (table 1), as designated by the NWS (National Weather Service, 2021d). The geospatial datasets used in this study are available as a USGS data release (Strauch, 2023).

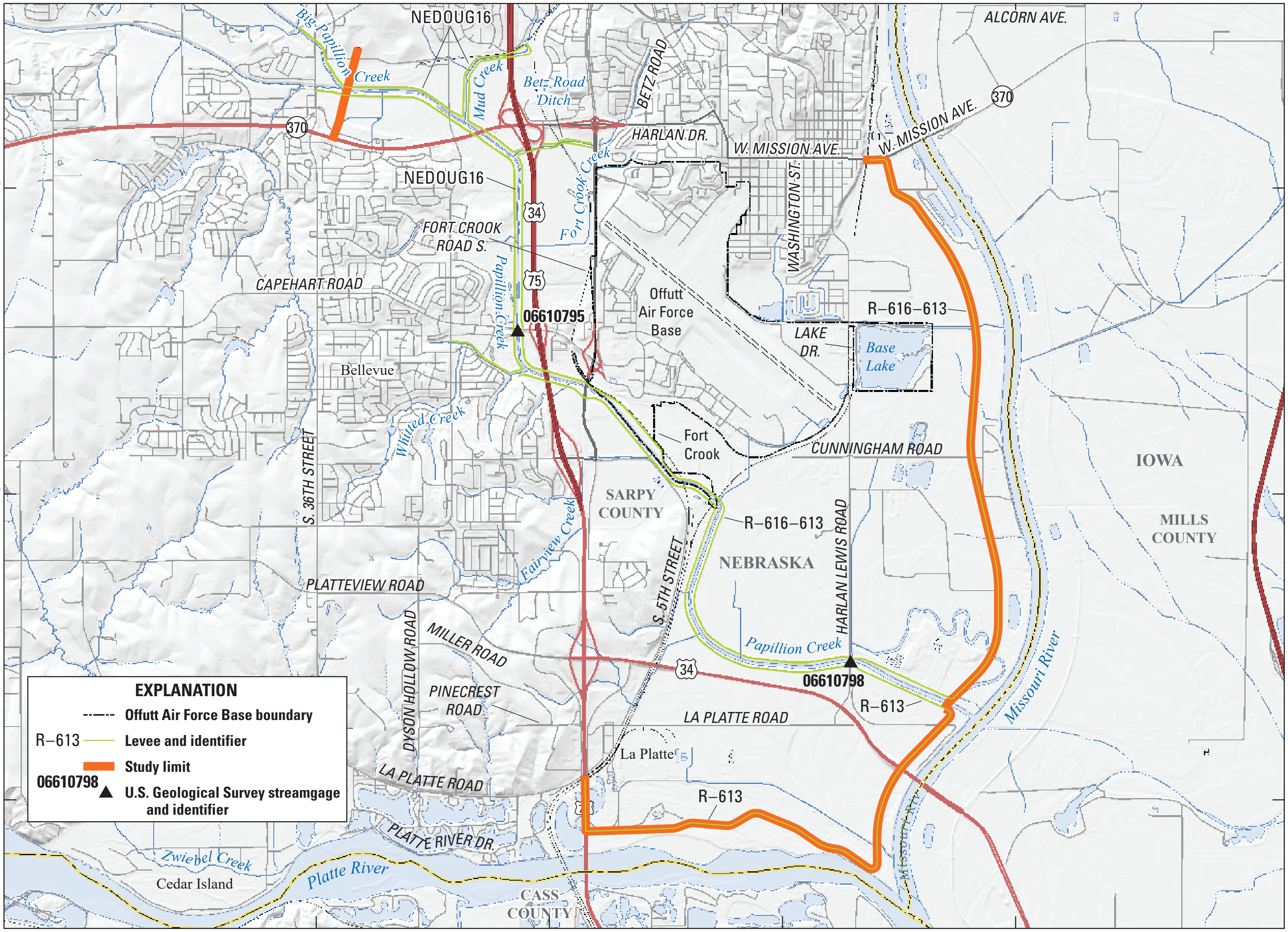
Table 1. U.S. Geological Survey streamgage information for Papillion Creek near Offutt Air Force Base.

[USGS, U.S. Geological Survey; mi^2, square mile; ft, foot; NAVD 88, North American Vertical Datum of 1988; Nebr., Nebraska; °, degree; ′, minute; ″, second; streamgage information from U.S. Geological Survey, 2021c]

USGS station name	USGS station number	Drainage area (mi^2)	Latitude	Longitude	Gage datum (ft above NAVD 88)	Period of record	Minimum stage included in this report (ft)	Maximum stage included in this report (ft)	Action stage (ft)[1]	Major flood stage (ft)[1]
Papillion Creek at Fort Crook, Nebr.	06610795	384	41°07'04.2″	95°56'15.6″	945.77	[2]Mar. 2012 to present (2021)	27	39	27	39
Papillion Creek at Harlan Lewis Road near La Platte, Nebr.	06610798	401	41°04'55.58″	95°53'23.12″	944.45	Aug. 2020 to present (2021)	13.9	30.9	17.5	27.5

[1]As reported by the National Weather Service (National Weather Service, 2021b, c).

[2]Annual peak flow values available since 2004.



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World Geodetic System of 1984 Web Mercator projection
Horizontal coordinate information is referenced to World Geodetic System of 1984 datum

0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Figure 1. Location of 8-mile study reach of Papillion Creek, near Offutt Air Force Base, Nebraska, and locations of U.S. Geological Survey streamgages.

Study Area Description

The study area is in the Dissected Till Plains section of the Central Lowland physiographic province (not shown; Fenneman, 1938). The drainage area of Papillion Creek is about 401 square miles (U.S. Geological Survey, 2020a) and includes much of the Omaha metropolitan area and parts of the cities of Bellevue (fig. 1), Elkhorn, Papillion, and Millard (not shown). In general, much of the downstream end of the basin is urbanized, and much of the upstream part of the basin is used for agricultural purposes (Center for Advanced Land Management Information Technologies, 2007). The Omaha metropolitan area has experienced a 16-percent population growth from 2010 to 2020 (U.S. Census Bureau, 2021). As a result, some areas within the basin once dominated by agricultural land use have been developed into urban and suburban land uses (Papio-Missouri River Natural Resources District, 2017). The climate is continental and temperate with large seasonal variations in temperature and precipitation. The 30-year (1991–2020) daily mean temperature in Bellevue, Nebr. (fig. 1), ranges from 26.1 to 73.9 degrees Fahrenheit in winter and summer, respectively (National Centers for Environmental Information, 2021). The average annual precipitation in Omaha (fig. 1) is 30.62 inches per year (1991–2020), of which 74 percent falls during April–September (National Centers for Environmental Information, 2021).

The 8-mi reach of Papillion Creek is south and west of Offutt Air Force Base and flows southeast through parts of the city of Bellevue, Nebr., to the Missouri River (fig. 1). The USGS streamgage Papillion Creek at Fort Crook (station 06610795) is in the approximate center of the reach, and the USGS streamgage Papillion Creek at Harlan Lewis Road (station 06610798) is near the downstream end of the reach, about 1 mi upstream from the confluence with the Missouri River. Minor tributaries to Papillion Creek within the study reach include Mud Creek, Betz Road Ditch, Fort Crook Creek, Whitted Creek, and Fairview Creek (fig. 1). The main channel of Papillion Creek within the study reach had eight road crossings or other structures (railroad, roadway, and pedestrian bridges) as of October 2021.

In response to devastating floods in 1959, 1964, and 1965, structural flood control measures such as levee construction and channel straightening were completed to increase the conveyance capacity of Papillion Creek and its major tributaries (Papio-Missouri River Natural Resources District, 2021a). Within the study reach, three major levee systems, NEDOUG16, R–613, and R–616–613, provide flood control to adjacent low-lying areas (fig. 1). NEDOUG16 is a non-Federal levee system that borders both sides of Papillion Creek and Big Papillion Creek from near their confluence, which is upstream from the study reach, to downstream at Capehart Road (fig. 1). The NEDOUG16 levee was constructed in the 1960s and is currently sponsored by the Papio-Missouri River Natural Resources District. The NEDOUG16 levee is at risk of incipient overtopping from floods with an AEP ranging from 1 to 5 percent (U.S. Army Corps of Engineers, 2021).

Downstream from Capehart Road (fig. 1), Papillion Creek is bordered by Federal levee R–613, which was completed by the U.S. Army Corps of Engineers (USACE) in 1975, along the right bank (right or left bank orientation is referenced as if one is looking in the downstream direction of the stream/river) of the stream (Papio-Missouri River Natural Resources District, 2021b), to the confluence of Papillion Creek with the Missouri River, along the right bank of the Missouri River to its confluence with the Platte River, and along the left bank of the Platte River to La Platte. Federal levee R–616–613 borders the study reach along the left bank of Papillion Creek at Capehart Road to the confluence of Papillion Creek with the Missouri River, along the right bank of the Missouri River upstream to W. Mission Avenue (fig. 1). Construction of levee R–616–613 was completed in 1986. The two-part levee system provides protection for about 1,500 people and 540 structures with an estimated property value of $278 million (U.S. Army Corps of Engineers, 2021). Levee R–616–613 was constructed with a higher design flood elevation because of the constriction of the Missouri River by the levees. As a result of this higher design flood elevation, the older R–613 levee was too low to meet the elevations and freeboard requirements (Papio-Missouri River Natural Resources District, 2021b). The R–613 and R–616–613 levees were initially designed to have an incipient overtopping AEP of 0.5 percent, which is to say they are designed to withstand a flow event with an AEP of 0.5 percent, or a 200-year flood event. At the time this report was written (2022), the R–616–613 and R–613 levees were being renovated. The renovation included raising the levee elevation as much as 3 ft in some locations to maintain an incipient overtopping AEP of 0.5 percent and providing other safety improvements. The levee-protected areas are included in the USACE National Levee Database (U.S. Army Corps of Engineers, 2021).

Previous Studies

The current flood insurance study for Sarpy County (not shown on any maps; Federal Emergency Management Agency, 2010) was completed by a study contractor for the Federal Emergency Management Agency (FEMA). In addition, updated hydrology and hydraulic analyses have been completed more recently (2014) by the USACE to provide an updated FEMA flood insurance study (U.S. Army Corps of Engineers, Hydrologic Engineering Branch, 2014). At the time this report was written (2022), the USACE report had not yet been reviewed or accepted by FEMA. Both studies provided information for the 10-, 2-, 1-, and 0.2-percent AEP peak streamflows for locations near the study reach.

Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (U.S. Geological Survey, 2021b) so that the process and products are similar regardless of which USGS office is responsible for the work. Tasks specific to development of the flood maps for Papillion Creek included (1) acquisition of the most current hydraulic model from the Papio-Missouri River Natural Resources District; (2) verification of energy-loss factors (roughness coefficients) in the stream channel and floodplain and determination of steady-flow data; (3) production of estimated flood-inundation maps at various stream stages using the USACE Hydrologic Engineering Center-River Analysis System (HEC–RAS) Mapper program (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2020); and (4) 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 specified streamgage heights, for viewing on a USGS flood-inundation-mapping application.

Computation of Water-Surface Profiles

The water-surface profiles used to produce the flood-inundation maps in this study were computed using HEC–RAS, version 6.0 (Brunner, 2021). HEC–RAS is a one-dimensional and two-dimensional hydraulic model used for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options.

Hydrologic Data

The study reach includes two streamgages (fig. 1; table 1). Stage is measured every 15 minutes, transmitted hourly by a satellite radio, and made available through the USGS National Water Information System database (U.S. Geological Survey, 2021c). Stage data from these streamgages are referenced to a local datum but can be converted to water-surface elevations referenced to NAVD 88 by adding the NAVD 88 gage datum value in table 1.

The peak flows used in the model simulations were taken from the current stage-streamflow relation (rating number 8, effective March 1, 2014) and corresponded to the target stages at the Papillion Creek at Fort Crook (station 06610795) streamgage (table 2). For peak flows that were greater than the current stage-streamflow rating (greater than 32,100 cubic feet per second), the calibrated HEC–RAS model developed for the current study was used to extend the rating. Flows ranging from 4,723 to 39,700 cubic feet per second were used as input into the hydraulic model to produce water-surface profiles. No major tributaries join Papillion Creek within the 8-mi study reach; therefore, the gage-derived streamflows were not adjusted for tributary inflows but were held constant throughout the study reach for a given profile.

Topographic and Bathymetric Data

All topographic data used in this study are referenced vertically to NAVD 88 and horizontally to the North American Datum of 1983. Cross-section elevation data were obtained from a digital elevation model (DEM) that was derived from light detection and ranging (lidar) data, which were collected during December 2016 by Woolpert, Inc., of Dayton, Ohio (U.S. Geological Survey, 2020b). The original lidar data vertical accuracy was 0.50 ft at a 95-percent confidence level based on a root mean square error of 0.26 ft for the “open terrain” land-cover category. By these criteria, the lidar data supported production of 2-ft contours (Dewberry, 2012). The final DEM had a 3.281-ft grid-cell size and a vertical accuracy of plus or minus 1 ft (U.S. Geological Survey, 2020b).

Because standard lidar data do not provide ground elevations below the water surface of a stream, and because of current levee construction in the study area, in-channel geometry and top of levee data for the models were obtained from surveyed cross sections as described in the hydraulic study done to design the levee modifications (FYRA Engineering, 2016). These additional data were used to modify the existing lidar DEM. The model-generated cross-section data were used in conjunction with the RAS Mapper tool in HEC–RAS, version 6.0.0, to interpolate ground elevations below water and levee modifications through the study reach (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2020). The RAS Mapper tool was used to interpolate the ground surface between each successive pair of cross sections. The interpolated surface then was used to create a grid of elevation data between the cross sections. In this study, a grid of 3.281-ft by 3.281-ft cells was created for the in-channel and levee modification DEM and was merged with the DEM derived from lidar. Instructions for creating a terrain model of the channel data are provided in chapter 8, “Terrain Modification,” of the USACE “HEC–RAS Mapper User’s Manual,” version 6.0 (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2020).

Hydraulic Structures

A total of 8 road crossings or other structures (1 railroad, 1 pedestrian, and 6 roadway bridges) have the potential to affect water-surface elevations during floods along the stream. Levees line both banks for the length of the study reach, as described in the “Study Area Description” section and as shown in figure 1. Because of the uncertainty as to the effectiveness of these levees, they were not simulated as a levee in the HEC–RAS model; rather, where appropriate to do so, the landward side of the levee was simulated as an ineffective flow area up to the elevation of the top of the levee.

Energy-Loss Factors

Hydraulic analyses require the estimation of energy losses that result from frictional resistance exerted by a channel on streamflow. These energy losses are quantified by the Manning's roughness coefficient (*n* value; Barnes, 1967). Initial (precalibration) *n* values were selected based on field observations and high-resolution aerial photographs. 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 Papillion Creek at Fort Crook (station 06610795) streamgage were minimized. The final *n* values were 0.028 for the main channel and ranged from 0.032 to 0.042 for the overbank areas simulated in this analysis.

Hydraulic Model

The HEC–RAS analysis for this study was done using the steady-state flow computation option. Steady-state flow data consisted of the flow regime, boundary conditions, and flows that produced water-surface elevations at the streamgage cross section that matched target water-surface elevations. These target elevations coincided with 1-ft increments of stage, referenced to the local streamgage datums. Subcritical (tranquil) flow regime was assumed for the simulations. For the initial nonbackwater condition, normal depth (depth of flow in a channel when the slope of the water surface and channel bottom is the same and the water depth remains constant), based on a water-surface slope of 0.00052, was used as the downstream boundary condition. The calculation of normal depth was estimated from the slope of the channel bottom of the three farthest downstream cross sections in the model. The flows that were used in the model for the initial water-surface elevations are listed in table 3. To accurately model possible flow scenarios that can occur because of the backwater from the Missouri River, the initial water-surface elevations were increased in 1-ft increments up to a stage of 30.9 ft (975.35 ft above NAVD 88), for the streamgage Papillion Creek at Harlan Lewis Road (station 06610798), for each streamflow modeled in table 2.

The HEC–RAS model was calibrated to the current (2022) stage-streamflow relation at the Papillion Creek at Fort Crook (station 06610795) streamgage using a normal depth boundary condition by the method described in the "Energy-Loss Factors" section. Differences between observed and simulated water-surface elevations for the 10 simulated flows at the USGS streamgage were equal to or less than 0.33 ft (table 3).

Table 2. Stages and water-surface elevations at the Papillion Creek at Fort Crook (U.S. Geological Survey station 06610795) streamgage and corresponding range of stages for the downstream boundary condition at the Papillion Creek at Harlan Lewis Road near La Platte (U.S. Geological Survey station 06610798) streamgage used in the hydraulic model of Papillion Creek near Offutt Air Force Base, Nebraska.

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

Stage (ft)[1]	Water-surface elevation (ft above NAVD 88)	Number of backwater scenarios	Range of stages for downstream boundary condition at the Papillion Creek at Harlan Lewis Road near La Platte, Nebr. (06610798), streamgage, in feet (elevation, in feet above NAVD 88)
27	972.77	15	13.9–27.9 (958.35–972.35)
28	973.77	15	14.9–28.9 (959.35–973.35)
29	974.77	15	15.9–29.9 (960.35–974.35)
30	975.77	15	16.9–30.9 (961.35–975.35)
31	976.77	14	17.9–30.9 (962.35–975.35)
32	977.77	13	18.9–30.9 (963.35–975.35)
33	978.77	12	19.9–30.9 (964.35–975.35)
34	979.77	12	19.9–30.9 (964.35–975.35)
35	980.77	11	20.9–30.9 (965.35–975.35)
36	981.77	10	21.9–30.9 (966.35–975.35)
37	982.77	9	21.9–30.9 (966.35–975.35)
38	983.77	8	22.9–30.9 (967.35–975.35)
39	984.77	8	22.9–30.9 (967.35–975.35)

[1]Stage is referenced to the gage datum of the U.S. Geological Survey streamgage Papillion Creek at Fork Crook, Nebraska (station 06610795).

Table 3. Calibration of model to target water-surface elevations at the U.S. Geological Survey streamgage Papillion Creek at Fort Crook, Nebraska (station 06610795).

[ft, foot; ft^3/s, cubic foot per second; NAVD 88, North American Vertical Datum of 1988; --, value greater than rating curve and not used for model calibration]

Stage of water-surface profile (ft)	Streamflow (ft^3/s)	Target water-surface elevation (ft, NAVD 88)	Modeled water-surface elevation (ft, NAVD 88)	Difference in elevation (ft)
27.00	11,700	972.77	972.64	−0.13
28.00	13,000	973.77	973.47	−0.30
29.00	14,700	974.77	974.44	−0.33
30.00	16,700	975.77	975.54	−0.23
31.00	18,800	976.77	976.56	−0.21
32.00	21,100	977.77	977.60	−0.17
33.00	23,600	978.77	978.75	−0.02
34.00	26,300	979.77	979.83	0.06
35.00	29,100	980.77	980.92	0.15
36.00	32,100	981.77	982.04	0.27
37.00	[1]34,100	982.77	--	--
38.00	[1]36,900	983.77	--	--
39.00	[1]39,700	984.77	--	--

[1]Streamflow for the stage of the water-surface profile was determined using the calibrated model to extend the stage-streamflow rating at the U.S. Geological Survey streamgage Papillion Creek at Fork Crook, Nebraska (station 06610795).

Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for a total of 157 flood scenarios for Papillion Creek near Offutt Air Force Base. The flood scenarios corresponded to a range of Papillion Creek inflows combined with a range in backwater created by the confluence with the Missouri River. Papillion Creek inflows were represented by stage values in 1-ft stage intervals that ranged from 27 to 39 ft, as referenced to the local datum of the Papillion Creek at Fort Crook (station 06610795) streamgage. The range in the Missouri River backwater boundary condition was represented in 1-ft stage intervals from 13.9 to 30.9 ft, as referenced to the local datum of the Papillion Creek at Harlan Lewis Road (station 06610798) streamgage. For some profiles, the minimum and maximum ranges vary (table 2) because the combination of inflow value and the backwater condition created an invalid or impossible water-surface elevation. A trial-and-error process was used to determine the proper model inputs to simulate water-surface profiles relating to each 1-ft mapped stage at the Papillion Creek at Fort Crook (station 06610795) streamgage to relate the boundary condition to the target stages at the streamgages. Because downstream constant stage varied at the Papillion Creek at Harlan Lewis Road (station 06610798) streamgage, the maximum upstream boundary condition flows resulted in variable maximum stages for each set of water-surface profiles (table 2).

Development of Flood-Inundation Maps

Flood-inundation maps for the 8-mi reach of Papillion Creek near Offutt Air Force Base were created in a geographic information system by combining the water-surface profiles and DEM data. The DEM data were derived from the same 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 water-surface profile were developed with HEC–RAS Mapper software (U.S. Army Corps of Engineers, Hydrologic Engineering Center, 2020). Shapefile polygons and depth grids of the inundated areas for each profile were modified, as needed, in the ArcMap application of ArcGIS (Esri, 2021) 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 stream, 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 overlaid on high-resolution, georeferenced, aerial photographs of the study area. Bridge surfaces are shown as noninundated up to the lowest flood stage that intersects the lowest structural chord of 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 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 datasets (depth grids and shapefiles) used in this study are available as a USGS data release (Strauch, 2023). The flood map corresponding to the highest simulated water-surface profile, a stage of 39 ft at the Papillion Creek at Fort Crook (station 06610795) streamgage and 30.9 ft at the Papillion Creek at Harlan Lewis Road (station 06610798) streamgage, is presented in figure 2.

Flood-Inundation-Map Delivery

A Flood Inundation Mapping Program website (U.S. Geological Survey, 2021b) has been established at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program to make USGS flood-inundation study information available to the public. The website links to a mapping application that provides map libraries and 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 Papillion Creek near Offutt Air Force Base. A link on this website connects to the USGS National Water Information System database (U.S. Geological Survey, 2021c), which provides the current stage and streamflow at the Papillion Creek at Fort Crook (station 06610795) and Papillion Creek at Harlan Lewis Road (station 06610798) streamgages, to which the inundation maps are referenced. The estimated flood-inundation maps are shown in sufficient detail so that preparations for flooding and decisions for emergency response can be completed efficiently. Depending on the flood magnitude, roadways are shown as shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use. Bridge surfaces are shown as noninundated up to the lowest flood stage that intersects the lowest structural chord of the bridge. A shaded building should not be interpreted to mean that the structure is completely submerged; rather, 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 based on 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 using 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 December 2021. Unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the model 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 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 (Advanced Hydrologic Prediction Service forecast point) throughout the forecast period (every 6 hours and 3–5 days out in many locations). For more information on Advanced Hydrologic Prediction Service forecasts, please see https://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf. Another source of uncertainty relevant to the study reach is the NEDOUG16, R–613, and R–616–613 levee system, which, if breached, can produce variable flood extents and water depths on the landward side of the levee. These areas of uncertainty are shown as a shaded green color on the flood-inundation-mapping web application (example shown in fig. 2). Additional uncertainties and limitations pertinent to this study may be described elsewhere in this report.

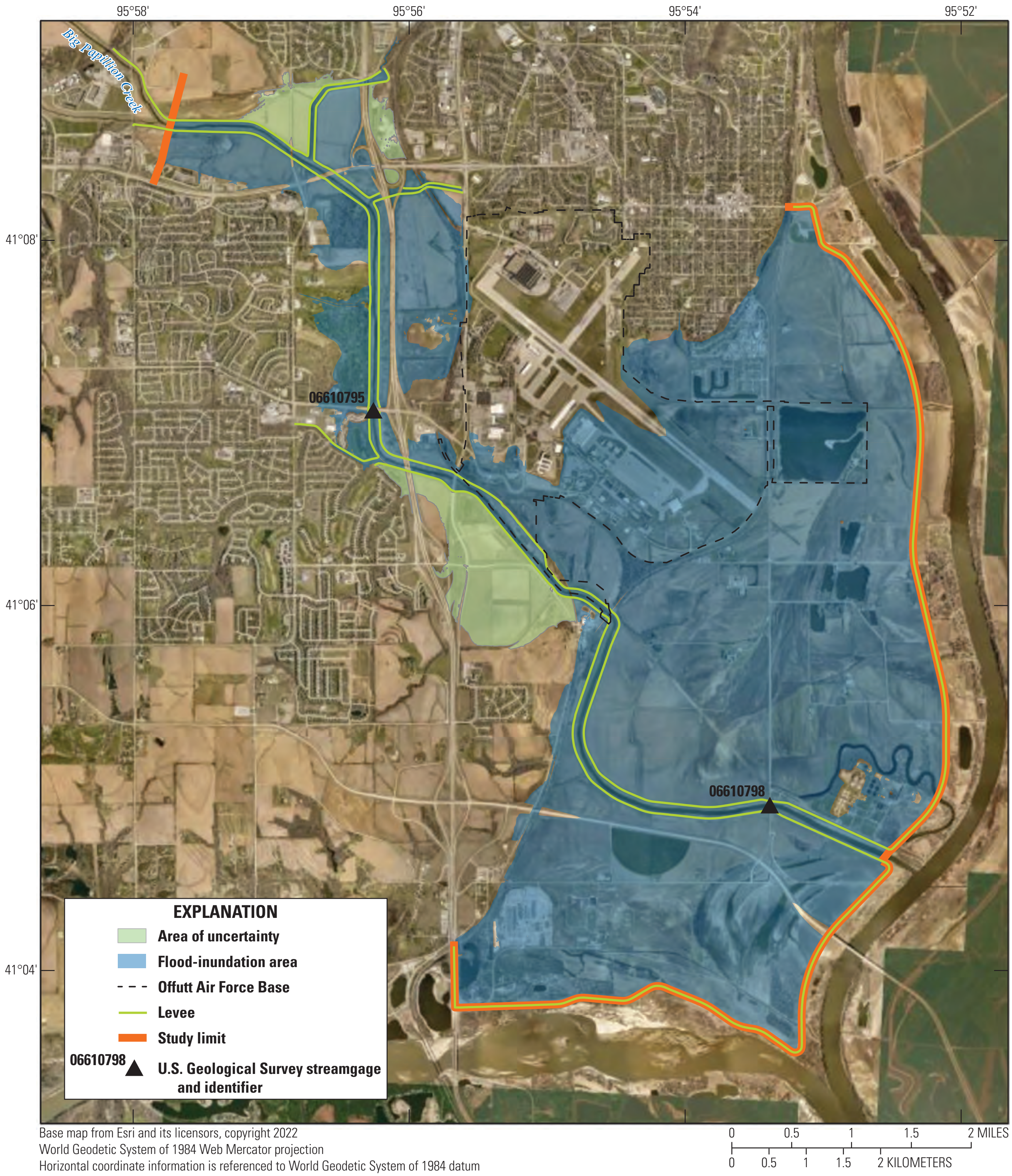

Figure 2. Flood-inundation map for Papillion Creek near Offutt Air Force Base, Nebraska, corresponding to a stage of 39 feet at the Papillion Creek at Fort Crook (U.S. Geological Survey station 06610795) streamgage and 30.9 feet at the Papillion Creek at Harlan Lewis Road (U.S. Geological Survey station 06610798) streamgage, Nebraska.

Summary

A series of 157 digital flood-inundation maps was developed by the U.S. Geological Survey (USGS) in cooperation with the U.S. Air Force, Offutt Air Force Base, for Papillion Creek near Offutt Air Force Base, Nebraska. 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 Papillion Creek at Fort Crook, Nebr. (station 06610795), and Papillion Creek at Harlan Lewis Road near La Platte, Nebr. (station 06610798). Near-real-time stages at these streamgages may be obtained from the USGS National Water Information System database at https://doi.org/10.5066/F7P55KJN or from the National Weather Service Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/.

The maps cover a reach about 8 miles long on Papillion Creek starting from 345 feet (ft) downstream from the confluence of Big Papillion Creek and continuing downstream to near the confluence of Papillion Creek and the Missouri River. The maps were developed using the U.S. Army Corps of Engineers Hydrologic Engineering Center-River Analysis System programs to compute water-surface profiles, delineate flood-inundation areas, and estimate depths of flooding for selected stream stages. The Hydrologic Engineering Center-River Analysis System hydraulic model was calibrated by adjusting roughness coefficients to best represent the current (2022) stage-streamflow relation at the USGS streamgage Papillion Creek at Fort Crook (station 06610795). The model was used to generate water-surface profiles for a total of 157 flood scenarios for Papillion Creek near Offutt Air Force Base. The flood scenarios corresponded to a range of Papillion Creek inflows combined with a range in backwater created by the confluence with the Missouri River. Papillion Creek inflows were represented by stage values in 1-ft stage intervals that ranged from 27 to 39 ft, as referenced to the local datum of the Papillion Creek at Fort Crook (station 06610795) streamgage. The range in the Missouri River backwater boundary condition was represented in 1-ft stage intervals from 13.9 to 30.9 ft, as referenced to the local datum of the Papillion Creek at Harlan Lewis Road near La Platte (station 06610798) streamgage. For some profiles, the minimum and maximum ranges vary because the combination of inflow value and the backwater condition created an invalid or impossible water-surface elevation. The simulated water-surface profiles then were combined with a geographic information system digital elevation model with a 3.281-ft grid derived from light detection and ranging data to delineate 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.

Interactive use of the maps on the USGS Flood Inundation 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 USGS streamgages, Papillion Creek at Fort Crook (station 06610795) and Papillion Creek at Harlan Lewis Road near La Platte (station 06610798), can help to guide users in taking individual safety precautions and can provide emergency management personnel with a tool to manage emergency flood operations and postflood recovery efforts efficiently.

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Publishing support provided by the
Rolla and Reston Publishing Service Centers

USGS

Strauch and Hobza—**Flood-Inundation Maps for an 8-Mile Reach of Papillion Creek near Offutt Air Force Base, Nebraska, 2022**—SIR 2023–5054

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20235054