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# Flood-Inundation Maps for the Iowa River at the Meskwaki Settlement in Iowa, 2019


Scientific Investigations Report 2019–5050

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

**Front and back cover.** Photograph looks north at the floodwaters flowing over and damaging Battleground Road, Iowa, March 18, 2019. Photograph taken by Roxane Warnell, Meskwaki Natural Resources.

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DAVID BERNHARDT, Secretary

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

U.S. Geological Survey, Reston, Virginia: 2019



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## Figures



## Tables

# Conversion Factors

U.S. customary units to International System of Units

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | Flow rate | |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |

# Datum

Vertical coordinate information is referenced to (1) stage, the height above an arbitrary datum established at a streamgage, and (2) elevation, the height above the North American Vertical Datum of 1988 (NAVD 88).

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

# Flood-Inundation Maps for the Iowa River at the Meskwaki Settlement in Iowa, 2019

By Charles V. Cigrand


## Abstract

Digital flood-inundation maps for a 9.3-mile reach of the Iowa River along the Meskwaki Settlement, Iowa, were created by the U.S. Geological Survey (USGS) in cooperation with the Sac and Fox Tribe of the Mississippi in Iowa. The flood-inundation maps, which can be accessed through the USGS Flood Inundation Mapping Science website at https://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgage 05451770 on the Iowa River at County Highway E49 near Tama, Iowa. Near-real-time stages at this streamgage may be obtained on the internet from the USGS National Water Information System at https://waterdata.usgs.gov/or the National Weather Service (NWS) Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/, which also forecasts flood hydrographs at this site.

Flood profiles were computed for the stream reach by means of a calibrated one-dimensional and two-dimensional step-backwater hydraulic model. The model was calibrated by using the current stage-discharge relation at the USGS streamgage 05451770 on the Iowa River at County Highway E49 near Tama, Iowa, and stage and discharge data from historic flooding events that were recorded at the streamgage.

The hydraulic model was then used to compute eight water-surface profiles for flood stages at 1-foot intervals referenced to the streamgage datum and ranging from the NWS "action stage" of 11 feet (ft) to 18 ft, the stage exceeding the estimated 0.2-percent annual exceedance probability (500-year recurrence interval) flood, as determined at the USGS streamgage 05451770. The simulated water-surface profiles were then combined with a geographic information system digital elevation model to delineate the area flooded at each flood stage (water level).

In addition, potential modifications to hydraulic structures within the flood plain were modeled so any effects from the potential modifications could be evaluated. Four comparison points, which were along the flood plain, showed little to no change (less than 0.1 ft) in flood elevation from the existing conditions within the flood plain for the 11- to 16-ft stages as referenced to the USGS streamgage 05451770. There were greater changes (more than 0.1 ft) in flood elevation for the 2 comparison points that were closest to the modified hydraulic structure for the 2 highest modeled stages of 17 and 18 ft.

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


## Introduction

The Meskwaki Settlement are tribal lands belonging to the Sac and Fox Tribe of the Mississippi in Iowa (Meskwaki Nation). The core of the settlement is nearly 7,400 acres in Tama County of central Iowa and an additional 700 acres in northwest Iowa (not shown) (fig. 1). In 1856, the State of Iowa passed a law allowing the Tribe to purchase 80 acres of land in 1857, in Tama County, Iowa. This purchase of land kept the Meskwaki Nation from relocating to federally operated Indian reservations in Kansas (Sac and Fox Tribe of the Mississippi in Iowa, 2017).

The Sac and Fox Tribe of the Mississippi in Iowa is the only federally recognized Indian tribe in the state. The Meskwaki Nation has nearly 1,400 enrolled tribal members and is considered the largest employer in Tama County, employing more than 1,200 people. The Tribe also has its own constitution, codified laws, full-time police force, and a fully functional court system. Tribal members are committed to protecting their inherent sovereignty, preserving and promoting their culture, and improving the quality of life for future generations (Sac and Fox Tribe of the Mississippi in Iowa, 2017).

Areas of the Meskwaki Settlement lie within the Iowa River flood plain and are prone to flooding events from the Iowa River. Prior to this study, emergency responders in the Meskwaki Settlement relied on several information sources to make decisions on how to best alert the public and mitigate flood damages. One source is the Federal Emergency Management Agency (FEMA) flood insurance study (FIS) for Tama County (FEMA, 2009). A second source of information is the U.S. Geological Survey (USGS) streamgage 05451770, Iowa River at County Highway E49 near Tama, Iowa, from which current (2018) and historical (since 2011) water levels and discharges, including annual peak flows, can be obtained (https://waterdata.usgs.gov/ia/nwis/uv/?site_no=05451770&PARA meter_cd=00065,00060) (U.S. Geological Survey, 2018c). A third source of flood-related information is the National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS), which displays the USGS stage data from the USGS streamgage 05451770 on the Iowa River at County Highway E49 near Tama, Iowa, and issues river forecasts of stage for this location as needed during times of high-stage flows (https://water.weather.gov/ahps2/hydrograph.php?wfo=dmx&gage=tmai4)(National Weather Service, 2018a).

Although the current stage at a USGS streamgage is particularly useful for residents in the immediate vicinity of 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 danger 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 may have disregarded. During 2017–18, the USGS, in cooperation with the Meskwaki Nation, conducted a project to produce a library of flood-inundation maps for the Iowa River at the Meskwaki Settlement.

## Purpose and Scope

This report describes the development of a series of estimated flood-inundation maps for a 9.3-mile (mi) reach of the Iowa River from upstream near E Avenue to downstream near the intersection of County Highway E49 and H Avenue (fig. 1) and identifies where on the internet the maps can be found and ancillary data (geographic information system flood polygons and depth grids) can be downloaded. The maps were produced for flood levels referenced to the stage recorded at the USGS streamgage 05451770 on the Iowa River at County Highway E49 near Tama, Iowa (fig. 1 and table 1). The gage is approximately 3.1 mi upstream from the downstream reach limit.

The maps cover a range in stage from 11 to 18 feet (ft), referenced to the streamgage datum. The 11ft stage is defined by the NWS 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 significant hydrologic activity (NWS, 2018b). The 18ft stage exceeds the stage that corresponds to the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval flood) and also exceeds the “major flood stage” of 14 ft as defined by the NWS. The geospatial datasets used in this study are available through a companion data release at https://doi.org/10.5066/P912FO3L (Cigrand, 2019). In addition, potential modifications to hydraulic structures within the flood plain were modeled. The results will help the Meskwaki Nation assess any effects from these modifications on tribal land in the flood plain.

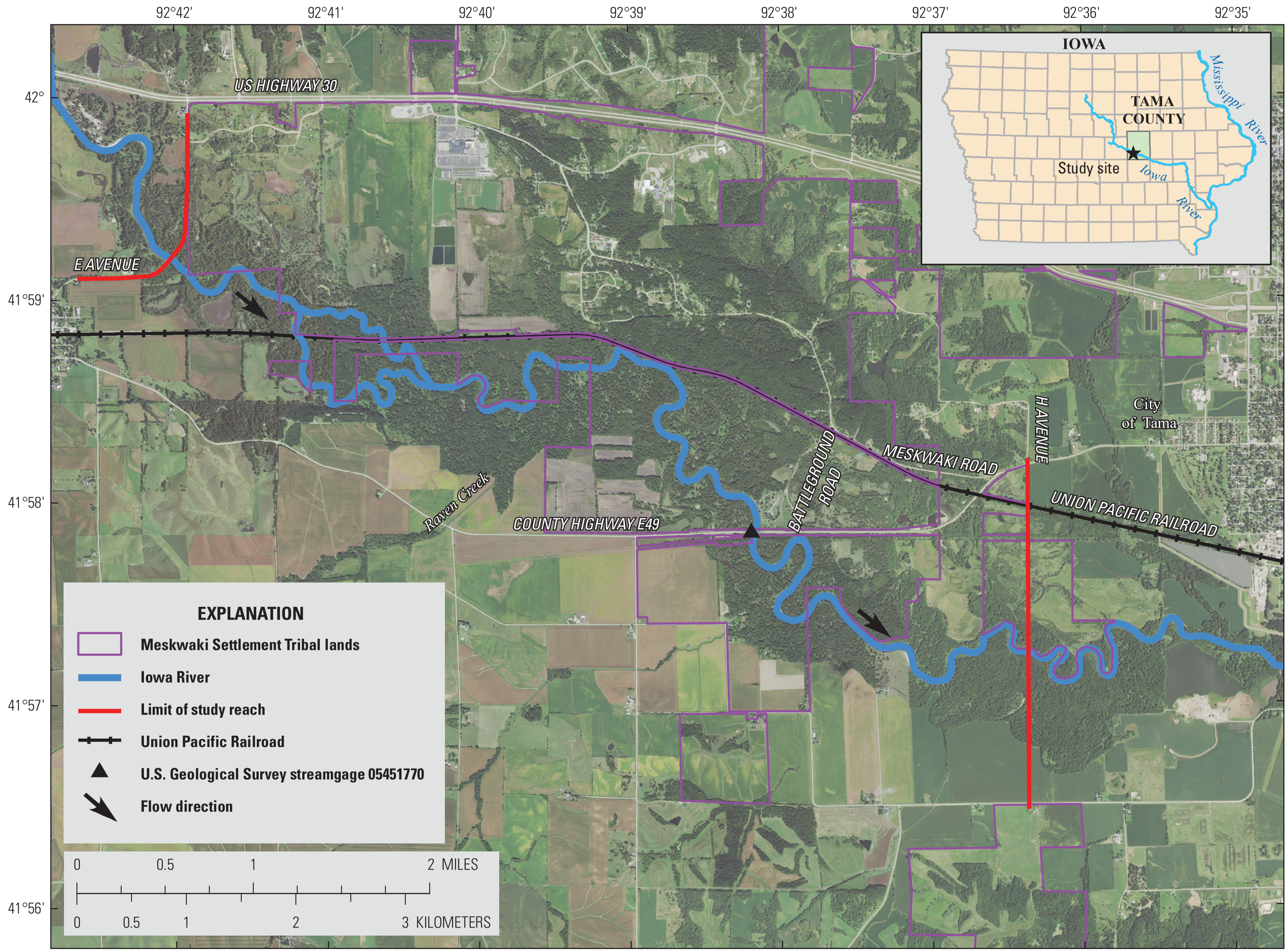
## Study Area Description

The Iowa River originates in far north-central Iowa and flows for about 323 mi in a generally south to southeast direction until its confluence with the Mississippi River in southeast Iowa. Within the study reach, the Iowa River is highly sinuous and meanders through a broad flood plain with numerous oxbow lakes and meander scars. These features help create an environment abundant in wetlands, marshes, and woody vegetation. The flood plain is bordered by loess mantled bluffs, hills, and ridges of the Southern Iowa Drift Plain landform region where much of the land is used for agriculture production, with some woodlands and developed areas. This landform is also defined by a well-integrated drainage network of rills and streams (Prior, 1991). Although there are no major tributaries within the study reach, several small streams enter the Iowa River within the study reach; the largest is Raven Creek, which has a drainage area of about 26 square miles ($mi^2$) (USGS, 2018a).

The drainage area of the Iowa River at the upstream end of the modeled reach is about 1,840 $mi^2$; at USGS streamgage 05451770, 1,882 $mi^2$; and at the downstream extent of the study reach, 1,890 $mi^2$ (USGS, 2018a). The study reach is about 9.3 mi in length and has an average top-of-bank channel width of 220 ft and an average channel slope of 1.45 feet per mile. Within this study reach, the river and its flood plain are dissected by three roads and a railroad; a total of 14 bridges for the study reach include 4 main channel bridges for the roads and railroad and 10 overflow bridges throughout the flood plain.

## Previous Studies

The current FIS for Tama County, Iowa, and incorporated areas (FEMA, 2009) is a compilation of earlier community FISs and was last revised by Black and Veatch to include the tribal areas of the Meskwaki Settlement. This revised version maps an area which corresponds to the 1-percent annual exceedance probability (AEP) within the flood plain for the Iowa River. This study does not provide a detailed hydraulic analysis, so no base flood elevations or flood depths are provided for this area.




Universal Transverse Mercator projection Zone 15
Horizontal coordinate information is referenced to the
North American Datum of 1983 (NAD 83)

Orthophotograph modified from Farm Services Administration,
National Agriculture Imagery Program, 2013

**Figure 1.** Location of study reach of the Iowa River at the Meskwaki Settlement, Iowa, and location of U.S. Geological Survey streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa.

**Table 1.** Information on U.S. Geological Survey streamgage 05451170, Iowa River at County Highway E49 near Tama, Iowa.

[Station location is shown on figure 1. mi², square mile; ft, foot; NAVD 88, North American Vertical Datum of 1988; ft³/s, cubic foot per second; °, degrees; ', minutes; ", seconds]

| Station name | Station number | Drainage area (mi²) | Latitude | Longitude | Period of record | Maximum recorded stage (ft), water-surface elevation (ft, NAVD 88), and date | Maximum streamflow (ft³/s) and date |
|---|---|---|---|---|---|---|---|
| Iowa River near Tama, Iowa | 05451770 | 1,882 | 41°57'51" | 92°38'11" | 2011–present | 15.20<br>825.67<br>May 28, 2013 | 26,700<br>May 28, 2013 |

# Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (USGS, 2018b) 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 maps for the Iowa River at the Meskwaki Settlement, Iowa, were (1) collection of topographic and bathymetric data for selected cross sections and geometric data for structures and bridges along the study reach, (2) estimation of energy-loss factors (roughness coefficients) in the stream channel and flood plain and determination of unsteady-flow data, (3) computation of water-surface profiles using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Centers River Analysis System (HEC–RAS; USACE, 2016), (4) production of estimated flood-inundation maps at various stream stages using the USACE HEC–RAS program and a geographic information system (GIS), and (5) preparation of the maps, both as shapefile polygons that depict the areal extent of flood inundation and as depth grids that provide the depth of floodwaters for display on a USGS flood-inundation mapping application.

## Computation of Water-Surface Profiles

The water-surface profiles used to produce the eight flood-inundation maps in this study were computed by using HEC–RAS, version 5.0.5 (USACE, 2016). HEC–RAS is a one or two-dimensional, step-backwater model for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options.

### Hydrologic Data

The study reach includes one USGS streamgage (05451770; figure 1; table 1) that has been in operation since June 2011. Stage is measured every 15 minutes, transmitted hourly by a satellite radio in the streamgage, and made available on the internet through the USGS National Water Information System (NWIS; USGS, 2018c). Stage data from this streamgage are referenced to a local datum but can be converted to water-surface elevations referenced to the North American Vertical Datum of 1988 (NAVD 88) by adding 810.47 ft. Continuous records of discharge are computed from a stage-discharge relation (Turnipseed and Sauer, 2010), which has been developed for the streamgage, and are available through the USGS NWIS website.

The estimated discharges used in the model simulations (table 2) were taken from the current stage-discharge relation also known as a rating curve (number 2.0, effective March 10, 2013; fig. 2) and corresponded with the target stages. The rating curve was extended from 15.5 ft to 18 ft by a straight-line extension of the log-log plot (fig. 2). The extension was needed so that it included the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval flood). No major tributaries join the Iowa River within the 9.3-mi study reach; therefore, the streamgage-derived discharges 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. Elevation data for cross-sections and the two-dimensional mesh were obtained from a digital elevation model (DEM) that was derived from light detection and ranging (lidar) data that were collected during 2007–10 by the Sanborn Map Company, Inc., as part of the statewide Iowa lidar project (State of Iowa, 2018). The original lidar data have horizontal resolution of 3.28 ft (1.0 meter) and vertical accuracy of 0.59 ft (18 centimeters) at a 95-percent confidence level for the “open terrain” land-cover category (root mean squared error of 0.61 ft [18.5 centimeters]). By these criteria, the lidar data support production of 2-ft contours (Dewberry, 2012). By using HEC–GeoRAS, a set of procedures, tools, and utilities for processing geospatial data in ArcGIS, elevation data were extracted from the DEM for 69 cross sections and subsequently input to the HEC–RAS model (USACE, 2009). Because lidar data cannot provide ground elevations below a stream’s water surface, channel cross sections were surveyed by USGS field crews during March 2017. The DEM-generated

**Table 2.** Estimated discharges for corresponding stages and water-surface elevations at U.S. Geological Survey streamgage 05451170 Iowa River at County Highway E49 near Tama, Iowa, used in the hydraulic model of the Iowa River near Tama, Iowa

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

| Stage (ft)[1] | Water-surface elevation (ft, NAVD 88) | Estimated discharge of study reach (ft³/s) |
|---|---|---|
| 11 | 821.47 | 7,248 |
| 12 | 822.47 | 9,593 |
| 13 | 823.47 | 13,330 |
| 14 | 824.47 | 18,520 |
| 15 | 825.47 | 25,150 |
| 16 | 826.47 | 33,490 |
| 17 | 827.47 | 43,820 |
| 18 | 828.47 | 56,470 |

[1]Stages of water surface at gage are 1-foot increments of stage, referenced to the gage datum of the U.S. Geological Survey streamgage, Iowa River near Tama, Iowa (05451770).

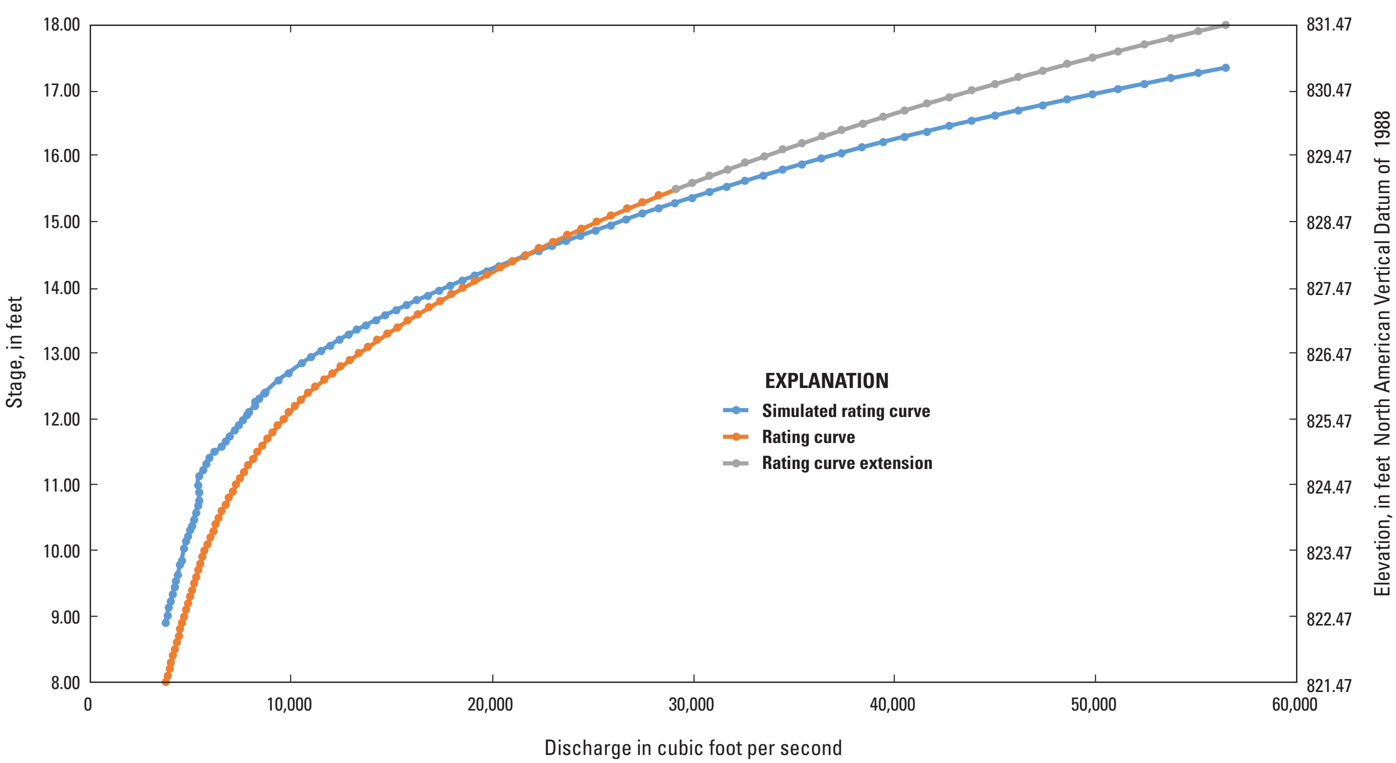



**Figure 2.** Current and simulated rating curve with extension derived from HEC-RAS simulation for U.S. Geological Survey streamgage 05451170 Iowa River at County Highway E49 near Tama, Iowa. (NAVD 88, North American Vertical Datum of 1988)

cross sections were made to coincide with the locations of the within-channel field-surveyed cross sections, and the within-channel data were directly merged with the DEM data.

A differential global positioning system with real-time kinematic technology was used to derive horizontal locations and the elevation of the water surface at each surveyed cross section. Elevations determined by a real-time kinematic differential global positioning system at benchmark locations were within 0.07–0.14 ft of the known elevations, an error range that falls within the accuracy of the lidar data (Rydlund and Densmore, 2012). Cross-sectional elevations within the channel were measured by wading in water depths less than 1 ft and by using hydroacoustic instrumentation in water depths greater than 1 ft.

## Hydraulic Structures

The study reach encompasses three roadways (Highway E49, E Avenue, and Battleground Road) and one railroad (Union Pacific Railroad) that transverse the Iowa River within the study reach and have the potential to affect water-surface elevations during floods. The roads and railroad crossing consist of 4 main channel bridges (1 at Highway E49, 1 at E Avenue, 2 at Union Pacific Railroad, fig. 1) and 10 overflow and drainage bridges throughout the flood plain that were included in the HEC–RAS model (not shown on fig. 1). Bridge-geometry data were obtained from field surveys conducted by personnel from the USGS Central Midwest Water Science Center for bridges on the roads. Bridge-geometry data also were obtained from the Union Pacific Railroad for bridges on the railroad (Adam D. Studts, Union Pacific Railroad, written commun., 2018).

## 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) (Arcement and Schneider, 1989). Initial (precalibration) n-values were selected on the basis of field observations and high-resolution aerial photographs (FSA, NAIP, 2013). The main channel of the Iowa River within the study reach consists of a sandy to muddy bed bottom with log jams found throughout the reach. An initial n-value of 0.030 was selected for the main channel. The flood plain n-values were assigned, by landcover, to include 0.030 for water, 0.100 for forests, 0.035 for grasslands, 0.040 for cultivated fields, 0.200 for buildings and other built structures, and 0.020 for impervious areas such as roads.

The initial n-values were adjusted as part of the calibration process, which involved minimizing the differences between simulated and observed water-surface elevations at the streamgage. Calibrated n-values were 0.035 for the main channel, 0.035 for water, 0.135 for forested areas, 0.045 for grasslands, 0.055 for cultivated fields, 0.200 for buildings and other built structures, and 0.020 for impervious surfaces such as roads.

## Hydraulic Model

The HEC–RAS analysis for this study was done by using the two-dimensional unsteady-state flow computation option. Unsteady-state flow data consisted of flow regime, boundary conditions, and streamflow hydrographs. Subcritical (tranquil) flow regime was assumed for the simulations owing to the low gradient of the river. Normal depth, based on an estimated average water-surface slope of 0.0004 from a field survey conducted by the USGS, was used as the downstream model boundary condition. Streamflow hydrographs from the USGS streamgage 05451770 and an artificial rising limb hydrograph were used as the upstream model boundary condition. The hydrographs that were used in the model are discussed in the section "Hydrologic Data."

Stage and streamflow hydrographs, and the current rating curve, from the USGS streamgage 05451770 on the Iowa River were used to calibrate the HEC–RAS model. Model calibration was accomplished by adjusting Manning's n values until the results of the hydraulic computations closely agreed with the observed water-surface elevations for given flows. Figure 2 shows the current rating curve for the USGS streamgage 05451770 and the simulated rating curve from the HEC–RAS model. Figure 3 shows hydrographs from the HEC–RAS model and the USGS streamgage 05451770 during a June–July 2014 flood event. During this flood, the HEC–RAS model had a peak stage of 14.86 ft, whereas the observed peak stage was 15.07 ft. Differences between observed and simulated water-surface elevations for the eight simulated flows at the USGS streamgage were equal to or less than 0.90 ft (table 3). The results demonstrate that the model is capable of simulating accurate water levels over a wide range of flows in the study area.

## Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for a total of eight stages at 1-ft intervals from 11 ft to 18 ft as referenced to the local datum of the USGS streamgage 05451770 on the Iowa River. These stages correspond to elevations of 821.47 ft and 828.47 ft, NAVD 88, respectively. Streamflows corresponding to the various stages were obtained from the current rating curve for the USGS streamgage 05451770 on the Iowa River.

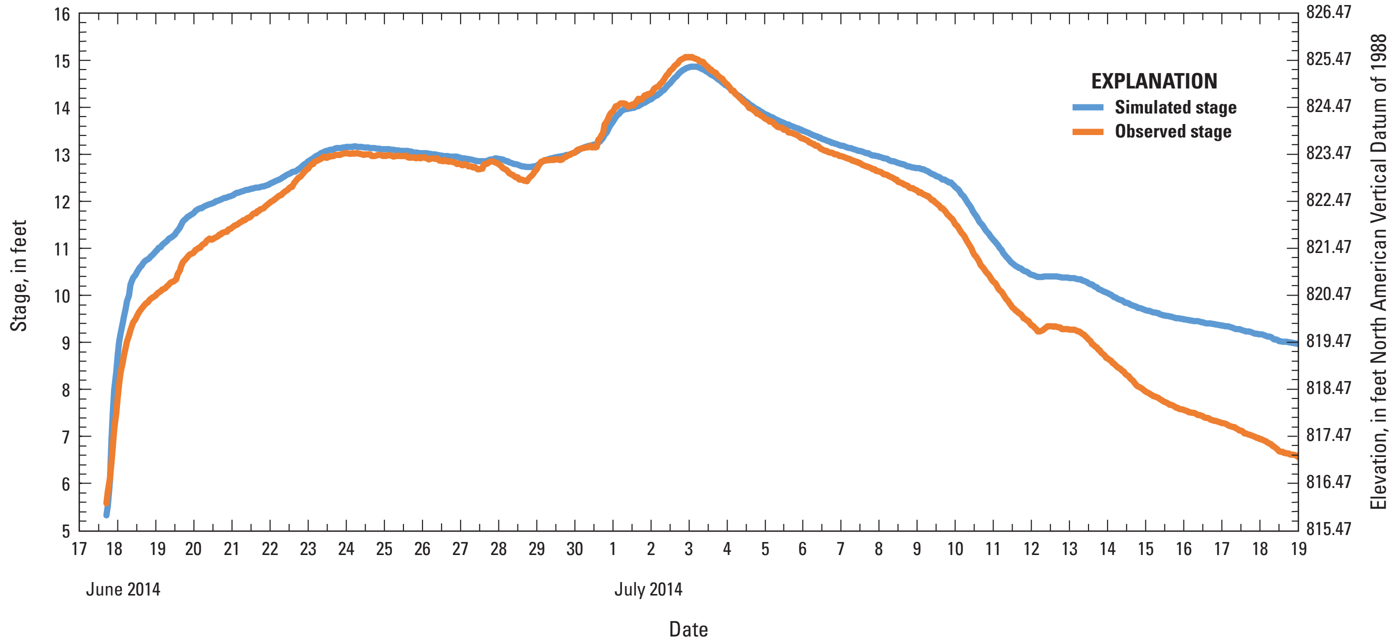



**Figure 3.** HEC–RAS model-simulated stage and observed stage at streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa, during the June–July 2014 flood event. (NAVD 88, North American Vertical Datum of 1988)

**Table 3.** Calibration of simulated to target water-surface elevations at U.S. Geological Survey streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; difference in elevation equals simulated water-surface elevation minus target water-surface elevation]

| Stage (ft)[1] | Simulated water-surface elevation (ft, NAVD 88) | Target water-surface elevation (ft, NAVD 88) | Difference in elevation (ft) |
|---|---|---|---|
| 11 | 822.37 | 821.47 | 0.90 |
| 12 | 822.87 | 822.47 | 0.40 |
| 13 | 823.83 | 823.47 | 0.36 |
| 14 | 824.57 | 824.47 | 0.10 |
| 15 | 825.34 | 825.47 | -0.13 |
| 16 | 826.18 | 826.47 | -0.29 |
| 17 | 827.01 | 827.47 | -0.46 |
| 18 | 827.82 | 828.47 | -0.65 |

[1]Stages of water surface at gage are 1-foot increments of stage, referenced to the gage datum of the U.S. Geological Survey streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa.

## Development of Flood-Inundation Maps

Flood-inundation maps were created in a GIS for the eight water-surface profiles by combining the profiles and DEM data. The DEM data were derived from the same lidar data described previously in the section "Topographic and Bathymetric Data" and have an estimated vertical accuracy of 1.18 ft (plus or minus 0.59 ft). Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (USACE, 2009), which allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (USACE, 2016). Shapefile polygons and depth grids of the inundated areas for each profile were modified, as required, in the ArcMap application of ArcGIS (Esri, 2018) 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. 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 flood map corresponding to the highest simulated water-surface profile, a stage of 18 ft, is presented in figure 4.

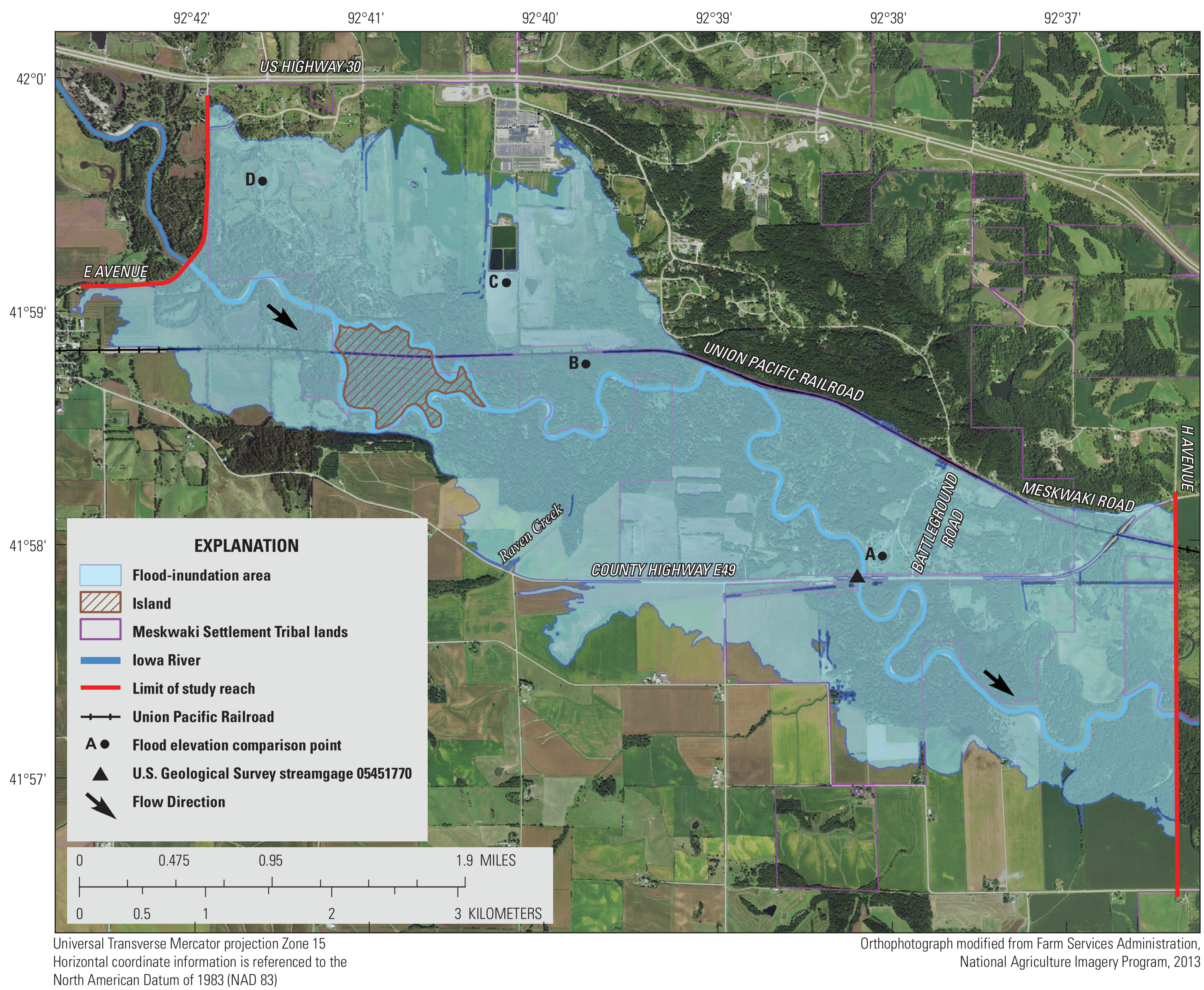



**Figure 4.** Flood-inundation map for the Iowa River near Tama, Iowa, corresponding to a stage of 18.00 feet at the U.S. Geological Survey streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa, and flood elevation comparison points.

## Flood-Inundation Map Delivery

The current study documentation is available online at the USGS Publications Warehouse (https://doi.org/10.3133/sir20195050). Also, a Flood Inundation Mapping Science website (USGS, 2018c) has been established to make USGS flood-inundation study information available to the public. That site links to a mapping application that presents map libraries and provides detailed information on flood extents and depths for modeled sites. The mapping application enables the production of customized flood-inundation maps from the map library for the Iowa River near Tama, Iowa. A link on this website connects to the USGS NWIS (USGS, 2018c), which presents the current stage and discharge at the USGS streamgage 05451770 to which the inundation maps are referenced. A second link connects to the NWS AHPS site (NWS, 2018a) so that the user can obtain applicable information on forecasted peak stage. The estimated flood-inundation maps are displayed in sufficient detail so that preparations for flooding and decisions for emergency response can be 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. Bridge surfaces are shown as not inundated 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, that bare earth surfaces in the vicinity of 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 discharges at selected USGS streamgages. Water-surface elevations along the stream reach were estimated by unsteady-state hydraulic modeling, assuming unobstructed flow, and used discharges and hydrologic conditions anticipated at the USGS streamgage. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of October 2018. Unique meteorological factors (timing and distribution of precipitation) may cause actual discharges 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 digital elevation model used to simulate the land surface.

If this series of flood-inundation maps will be used in conjunction with NWS river forecasts, the user should be aware of additional uncertainties that may be inherent or factored into NWS forecast procedures. The NWS uses forecast models to estimate the quantity and timing of water flowing through selected stream reaches in the United States. These forecast models (1) estimate the amount of runoff generated by precipitation and snowmelt, (2) simulate the movement of floodwater as it proceeds downstream, and (3) predict the flow and stage (and water-surface elevation) for the stream at a given location (AHPS forecast point) throughout the forecast period (every 6 hours and 3 to 5 days out in many locations). For more information on AHPS forecasts, please see http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

# Potential Modifications Within the Flood Plain

The Meskwaki Nation is interested in modeling potential modifications to hydraulic structures within this reach of the Iowa River flood plain in order to evaluate any potential effects. These modifications include raising the elevation for the portion of a railroad bed that spans the Iowa River flood plain, along with the addition of two overflow bridges on the portion of railroad located on the island labeled in figure 4. The potential modifications were included in the model as “proposed conditions” so that modeling results could be compared with the existing conditions within the Iowa River flood plain. The Meskwaki Nation chose four locations within the Iowa River flood plain to be used as comparison points (A, B, C, and D; fig 4).

The same model boundaries and energy-loss factors were used in the proposed and existing conditions. Flood elevations were then determined from model outputs for the four comparison points. The flood elevations were extracted from the model for each of the 1-foot stages that were used for the flood inundation modeling (table 4). Flood elevations at the comparison points showed little to no change (less than 0.1 ft) between the proposed and existing conditions for the 11- to 16-ft stages as referenced to the USGS streamgage 05451770. A greater change was seen for the 17- and 18-ft stages but only at comparison points B and C, which are closer to the railroad

**Table 4.** Flood elevations at comparison points for existing and proposed conditions on the Iowa River near Tama, Iowa.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; difference in flood elevations equals simulated flood elevation for proposed conditions minus simulated flood elevation for existing conditions]

| Stage (ft)[1] | Flood elevations for existing conditions (ft, NAVD 88) | Flood elevations for proposed conditions (ft, NAVD 88) | Difference in flood elevations (ft) |
|---|---|---|---|
| | Comparison point A | | |
| 11 | 822.36 | 822.37 | 0.01 |
| 12 | 822.82 | 822.82 | 0.00 |
| 13 | 823.88 | 823.88 | 0.00 |
| 14 | 824.68 | 824.68 | 0.00 |
| 15 | 825.51 | 825.51 | 0.00 |
| 16 | 826.37 | 826.37 | 0.00 |
| 17 | 827.14 | 827.14 | 0.00 |
| 18 | 827.85 | 827.85 | 0.00 |
| | Comparison point B | | |
| 11 | 826.51 | 826.53 | 0.02 |
| 12 | 827.49 | 827.49 | 0.00 |
| 13 | 828.91 | 828.90 | -0.01 |
| 14 | 829.86 | 829.85 | -0.01 |
| 15 | 830.72 | 830.72 | 0.00 |
| 16 | 831.57 | 831.57 | 0.00 |
| 17 | 832.51 | 832.44 | -0.07 |
| 18 | 833.63 | 833.34 | -0.29 |
| | Comparison point C | | |
| 11 | 829.16 | 829.16 | 0.00 |
| 12 | 829.16 | 829.16 | 0.00 |
| 13 | 830.02 | 830.04 | 0.02 |
| 14 | 830.64 | 830.64 | 0.00 |
| 15 | 831.42 | 831.42 | 0.00 |
| 16 | 832.58 | 832.57 | -0.01 |
| 17 | 833.83 | 834.01 | 0.18 |
| 18 | 834.78 | 835.58 | 0.80 |
| | Comparison point D | | |
| 11 | 832.50 | 832.47 | -0.03 |
| 12 | 832.70 | 832.70 | 0.00 |
| 13 | 833.57 | 833.54 | -0.03 |
| 14 | 834.86 | 834.82 | -0.04 |
| 15 | 835.95 | 835.91 | -0.04 |
| 16 | 837.08 | 837.04 | -0.04 |
| 17 | 838.13 | 838.15 | 0.02 |
| 18 | 839.10 | 839.19 | 0.09 |

[1]Stages of water surface at gage are 1-foot increments of stage, referenced to the gage datum of the U.S. Geological Survey streamgage 05451770 Iowa River at County Highway E49 near Tama, Iowa.

than the other points. The section of railroad near comparison points B and C was overtopped by floodwater for existing conditions with the 17- and 18-ft stages. This section of railroad was not overtopped by floodwater with the raised railroad elevations of the proposed conditions, which correlated with the flood elevations of comparison points B and C. Comparison point B is on the downstream side of the railroad and has lower flood elevations of -0.07 and -0.29 ft for the proposed conditions with the 17- and 18-ft stages, respectively. Because comparison point B was no longer receiving flows overtopping the railroad, it has lower flood elevations. Comparison point C is on the upstream side of the railroad and has higher flood elevations of 0.18 and 0.80 ft for the proposed conditions with the 17- and 18-ft stages, respectively. Comparison point C has higher flood elevations because floodwaters were no longer overtopping the railroad downgradient from its location, so a greater backwater effect was seen. These increases were seen even with the addition of two overflow bridges on the railroad. One of these overflow bridges could be moved to the left bank side of the river near comparison points B and C (fig. 4). Left and right bank are based on the perspective of looking downstream. Additional floodwater conveyance through this section of railroad could help alleviate any additional backwater effect from the raised railroad elevations of the proposed conditions.

## Summary

A series of eight digital flood-inundation maps were developed in cooperation with the Sac and Fox Tribe of the Mississippi in Iowa for the Iowa River near Tama, Iowa. The maps cover a reach about 9.3 miles long from upstream near E Avenue to downstream near the intersection of County Highway E49 and H Avenue. The maps were developed by using the U.S. Army Corps of Engineers' HEC–RAS and 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 current stage-discharge relation at the Iowa River streamgage and to hydrographs from selected flooding events from the Iowa River streamgage. The model was used to compute eight water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the streamgage datum and ranging from 11 ft, or "action stage," as defined by the National Weather Service, to 18 ft, which exceeds the stage that corresponds to the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval flood).

The simulated water-surface profiles were then combined with a geographic information system digital elevation model derived from light detection and ranging data to delineate estimated flood-inundation areas as shapefile polygons and depth grids for each profile. These flood-inundation polygons were overlaid on high-resolution, georeferenced aerial photographs of the study area. The flood maps are available through a mapping application that can be accessed on the USGS Flood Inundation Mapping Science website (https://water.usgs.gov/osw/flood_inundation/).

Interactive use of the maps on this mapping application can give users a general indication of depth of water at any point by using the mouse cursor to click within the shaded areas. These maps, in conjunction with the real-time stage data from the U.S. Geological Survey streamgage 05451770 on the Iowa River at County Highway E49 near Tama, Iowa, and forecasted flood stage data from the National Weather Service Advanced Hydrologic Prediction Service will help guide the general public in taking individual safety precautions and will provide emergency management personnel with a tool to efficiently manage emergency flood operations and postflood recovery efforts.

In addition, potential modifications to hydraulic structures within the flood plain were modeled so any effects from the potential modifications could be evaluated. The four comparison points, which are located along the flood plain, show little to no change (less than 0.1 ft) in flood elevation from the existing conditions within the floodplain for the 11- to 16-ft stages as referenced to the USGS streamgage 05451770. There are greater changes (more than 0.1 ft) in flood elevation for the two comparison points that are closest to the modified hydraulic structure for the two highest modeled stages of 17 and 18 ft.

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