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Development of a Flood-Warning Network and Flood-Inundation Mapping for the Blanchard River in Ottawa, Ohio

Scientific Investigations Report 2011–5189

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

Cover: Floodwaters from the Blanchard River at the Elm Street bridge over the Blanchard River in Ottawa, Ohio (looking north). (Photo taken February 2008 by Mary Terry. Courtesy of Findlay Engineer's Office, reproduced with permission.)

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

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Suggested citation:
Whitehead, M.T., 2011, Development of a flood-warning network and flood-inundation mapping for the Blanchard River in Ottawa, Ohio: U.S. Geological Survey Scientific Investigations Report 2011–1189, 8 p., 12 plates.

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Conversion Factors

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)
	Slope	
foot per mile (ft/mi)	0.1894	meter per Kilometer (m/km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Development of a Flood-Warning Network and Flood-Inundation Mapping for the Blanchard River in Ottawa, Ohio

By Matthew T. Whitehead

Abstract

Digital flood-inundation maps of the Blanchard River in Ottawa, Ohio, were created by the U.S. Geological Survey (USGS) in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service and the Village of Ottawa, Ohio. The maps, which correspond to water levels (stages) at the USGS streamgage at Ottawa (USGS streamgage site number 04189260), were provided to the National Weather Service (NWS) for incorporation into a Web-based flood-warning Network that can be used in conjunction with NWS flood-forecast data to show areas of predicted flood inundation associated with forecasted flood-peak stages.

Flood profiles were computed by means of a step-backwater model calibrated to recent field measurements of streamflow. The step-backwater model was then used to determine water-surface-elevation profiles for 12 flood stages with corresponding streamflows ranging from less than the 2-year and up to nearly the 500-year recurrence-interval flood. The computed flood profiles were used in combination with digital elevation data to delineate flood-inundation areas. Maps of the Village of Ottawa showing flood-inundation areas overlain on digital orthophotographs are presented for the selected floods.

As part of this flood-warning network, the USGS upgraded one streamgage and added two new streamgages, one on the Blanchard River and one on Riley Creek, which is tributary to the Blanchard River. The streamgage sites were equipped with both satellite and telephone telemetry. The telephone telemetry provides dual functionality, allowing village officials and the public to monitor current stage conditions and enabling the streamgage to call village officials with automated warnings regarding flood stage and/or predetermined rates of stage increase. Data from the streamgages serve as a flood warning that emergency management personnel can use in conjunction with the flood-inundation maps by to determine a course of action when flooding is imminent.

Introduction

The Village of Ottawa (hereafter referred to as Ottawa) is a small urban community with an estimated population of 4,400 (U.S. Bureau of Census, 2009), making it the largest municipality in Putnam County, Ohio. The Ohio Department of Natural Resources (ODNR) estimates that more than 330 flood-insurance policies are in effect in Ottawa, with approximately $25 million worth of property insured against flood damages (Steve Ferryman, ODNR, oral commun., 2008). Before August 2007, the insured losses paid for Ottawa totaled about $6.8 million (Steve Ferryman, ODNR, oral commun., 2008). Damage costs for the flood that occurred in August 2007 are reported to be $9.5 million (Denise Balbaugh, Village of Ottawa, 2009, written communication).

The unprecedented losses from the August 2007 flood prompted a study by the U.S. Geological Survey (USGS), in cooperation with Ottawa. Before this study, Ottawa officials relied on several information sources from which 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) (1986) for Ottawa. A second source of information is the USGS streamgage on the Blanchard River at Ottawa (04189260), from which water-level (stage) data can be accessed via telephone or the Web. The third source is the National Weather Service (NWS) forecasts of peak stage.

The NWS has statutory responsibility for hydrologic forecasts throughout the Nation. Peak-stage forecasts are based partly on data from precipitation gages and streamgages. In Ohio, the forecasts originate with the NWS River Forecast Center in Wilmington, Ohio, and warnings are issued to the public by regional NWS offices in Wilmington or Cleveland. Although stage information could be obtained from the USGS streamgage in Ottawa (04189260) before this study, upgrades and additions to the flood warning network were expected to enhance the flood-forecasting capabilities of the NWS for the Blanchard River in Ottawa (Brian Astifan, National Weather Service, oral communication, April 2007).

Description of the Study Area

Ottawa is in northwest Ohio, in east-central Putnam County (fig. 1). The headwaters of the Blanchard River originate in Hardin County, where the river flows generally north before turning west in central Hancock County. The Blanchard River flows through the middle of Ottawa before discharging to the Auglaize River, which eventually drains into Lake Erie. One major tributary to the Blanchard River near Ottawa is Riley Creek, which flows generally north and west into the Blanchard River just upstream from the Ottawa corporate limit. The basin terrain is relatively flat, and most of the basin is rural. The Blanchard River study reach has an average stream-channel slope of approximately 1.3 ft/mi and a total length of approximately 7.4 mi. The study reach extends from Township Road I–9 upstream to Road 8, which are the approximate corporate boundaries of Ottawa.

Purpose and Scope

The purpose of this report is to describe methods and results of hydrologic and hydraulic analyses of the Blanchard River within the corporate limits of Ottawa, Ohio. A series of flood-inundation maps was developed for selected stages of the Blanchard River at Ottawa streamgage (04189260).

Tasks specific to this study and discussed in this report were to (1) upgrade one existing streamgage and install two new streamgages, (2) install equipment enabling Ottawa officials to receive automated warnings about flood stage and/or predetermined rates of stage increase from the streamgages, and (3) estimate the areas of Ottawa that will be flooded at selected stages at the streamgage by developing flood-inundation maps.

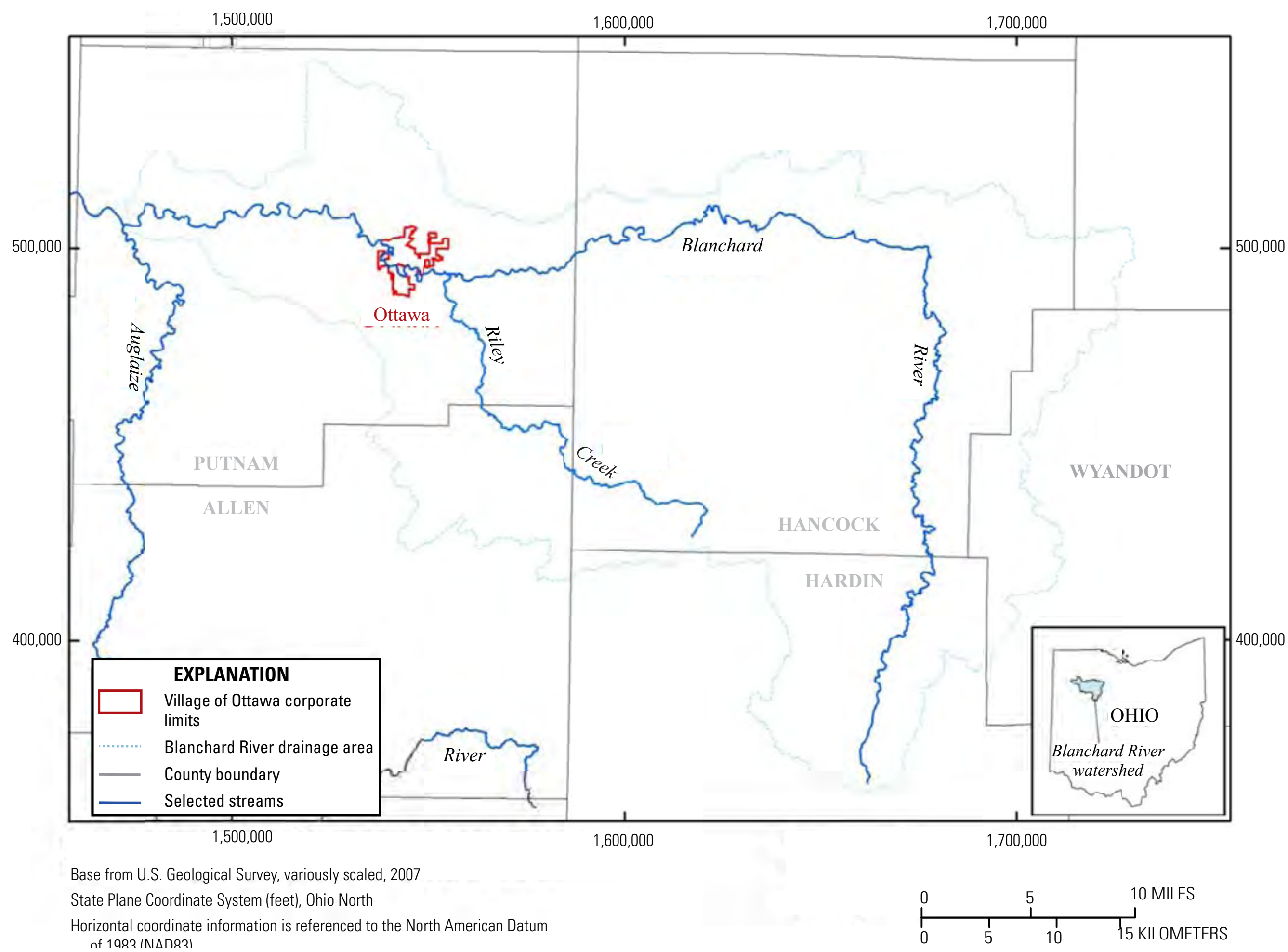

Figure 1. Blanchard River watershed and the corporate boundary for Ottawa, Ohio.

Installation and Upgrade of Streamgages

The USGS upgraded one streamgage and installed two new streamgages for this study (fig. 2). The existing USGS streamgage, Blanchard River at Ottawa (04189260), was put into operation in 1995. Prior to this study, only stage information was published for that gage. In 2009, USGS field crews began to make streamflow measurements at the Ottawa streamgage in an effort to establish a stage-discharge relation commonly referred to as a rating curve. From March 2009 to April 2011, 15 streamflow measurements were made at the Ottawa streamgage at stages ranging from 4.75 ft to 28.35 ft and were used to develop a stage-discharge relation at this location.

The USGS installed two new streamgages, Blanchard River at Gilboa (04189131) and Riley Creek below Pandora (04189174), in September 2009. Both streamgages are equipped with Geostationary Operational Environmental Satellite (GOES) transmitters and voice modems. Data are transmitted via GOES hourly to facilitate near-real-time monitoring of equipment performance and stage. The voice modem provides dual functionality, allowing village officials to call the gage to monitor current stage conditions and enabling the gage to call village officials with automated warnings regarding flood stage and/or predetermined rates of stage increase. Streamflow and stage data from these new streamgages, as well as other USGS streamgages in Ohio, can be found at *http://waterdata.usgs.gov/oh/nwis/current/?type=flow.*

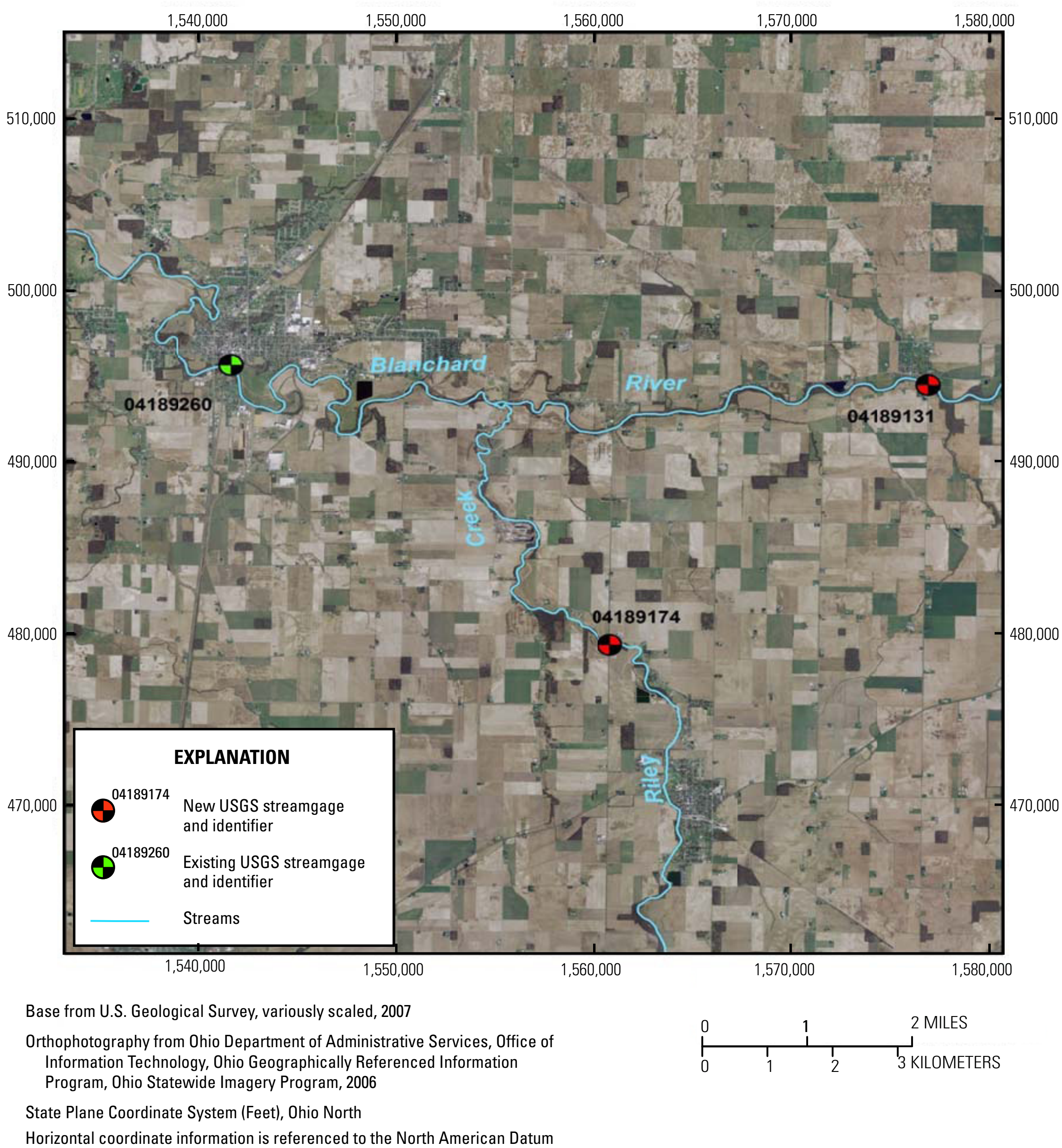

Figure 2. Locations of existing and new USGS streamgages (as of September 2009) in and near Ottawa, Ohio.

Locations of the newly installed streamgages were selected with input from officials at NWS and Ottawa with the goal of enhancing the ability of NWS to predict peak stage at the Blanchard River at Ottawa streamgage. Specifically, gage locations were selected to improve the coverage of streamflow data and provide information on changing upstream water-level conditions. The drainage areas for streamgages installed and upgraded for this study range from 70.3 to 628 mi^2 (table 1).

Table 1. Drainage areas of streamgages near Ottawa, Ohio.

[mi^2, square miles]

Streamgage name	USGS site number	Drainage area (mi^2)
Blanchard River at Ottawa	04189260	628
Blanchard River at Gilboa	04189131	503
Riley Creek below Pandora	04189174	70.3

Hydrology and Hydraulics

The hydraulic analyses were done with the U.S. Army Corps of Engineer's Hydrologic Engineering Center River Analysis System (HEC-RAS), version 4.0 (U.S. Army Corps of Engineers, 2008). HEC-RAS is a one-dimensional step-backwater model for computing water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. HEC-RAS is accepted by FEMA for use in the National Flood Insurance Program (NFIP). All hydraulic analyses for this report were done with the steady-state flow computation option.

Previous Study

Prior to this study, the Ottawa area had been a part of a larger modeling effort of the Blanchard River Basin extending from the mouth of the Blanchard River up to its headwaters (87 mi on Blanchard River), including some of its tributaries. The U.S. Army Corps of Engineers (USACE), Buffalo District, constructed that model to address flood-protection projects that are not relevant to this study. The USGS obtained the HEC-RAS model from USACE and modified the model for this study. Some modifications included (1) shortening the model to include only the area of interest in Ottawa, (2) adjusting selected cross-section overbank orientations, and (3) adding cross sections to shorten reach lengths between specific cross sections.

Model Calibration

On March 2, 2011, flooding at the Blanchard River at Ottawa attained a peak stage of 28.45 ft (726.88 ft NAVD). Between March 1 and 4, 2011, USGS field crews made four streamflow measurements at stages ranging from 21.90 to 28.35 ft and streamflows ranging from 4,070 to 13,600 ft^3/s, respectively (table 2). The two measurements of 13,200 and 13,600 ft^3/s have inversely proportionate stage values, but the measured streamflows are within 3 percent of each other. In an effort to be conservative, it was decided to calibrate the model to the streamflow measurement of 13,600 ft^3/s at a stage of 28.32 ft.

Table 2. Stage and streamflow values measured by USGS field crews in March 2011 on the Blanchard River at Ottawa, Ohio.

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

Date and time	Stage (ft)	Streamflow (ft^3/s)
2011–03–01 17:48	27.86	12,900
2011–03–02 12:20	28.35	13,200
2011–03–02 13:16	28.32	13,600
2011–03–04 11:15	21.90	4,070

To calibrate the model, Manning's roughness coefficients were uniformly raised from the original estimates in the HEC-RAS model provided by the USACE. Final Manning's roughness coefficients for the channel range from 0.053 to 0.055 and the overbanks from 0.050 to 0.236. These numbers may appear high at first glance, but the high degree of sinuosity of the stream and the vegetation on the banks warrant the high numbers. The final HEC-RAS model, with a streamflow of 13,600 ft^3/s, produced a stage of 28.29 ft, which is 0.03 ft different from the observed stage of the calibration target, 28.32 ft.

Model Validation

On August 23, 2007, a near-record peak stage of 31.40 ft (730.13 ft NAVD88) occurred at the Blanchard River at Ottawa streamgage. High-water marks were flagged and surveyed along the Blanchard River throughout the Ottawa area to help document the flooding (Straub and others, 2009). The 28 high-water marks surveyed showed fairly good local agreement, with the exception of 4 marks that appear to be outliers, as indicated by the trend suggested by the bulk of the other high-water marks (fig. 3).

The HEC-RAS model that was previously calibrated to the March 2, 2011 measurement was then used to estimate the streamflow associated with the August 23, 2007 stage of 31.40 ft (729.83 ft NAVD88). A profile using 20,600 ft^3/s produced a stage of 31.40 ft at the Ottawa streamgage. Figure 3 shows the modeled water-surface profile (using 20,600 ft^3/s) and the high-water marks surveyed from the 2007 flood in Ottawa.

A tabular comparison of water-surface elevations from the HEC-RAS model and elevations of high-water marks surveyed following the 2007 flood is given in table 3. Most of the high-water marks were not co-located with model cross sections. Therefore, to compare the modeled results to the high-water-mark profile, the water-surface elevations at the locations of the high-water marks were determined by linear interpolation from water-surface elevations at the nearest upstream and downstream cross sections defined in the HEC-RAS model.

The modeled and surveyed water-surface elevations are in close agreement with the exception of mark numbers 7, 9, 14 and 15 that are highlighted in table 3. As previously mentioned, these four high-water marks are outliers with respect to the other marks and are therefore suspect. Including all 28 high-water marks, the Root Mean Square (RMS) error of the differences in elevation is 0.72 ft. If the four suspect marks are removed from the RMS error calculation, the RMS error decreases to 0.24 ft.

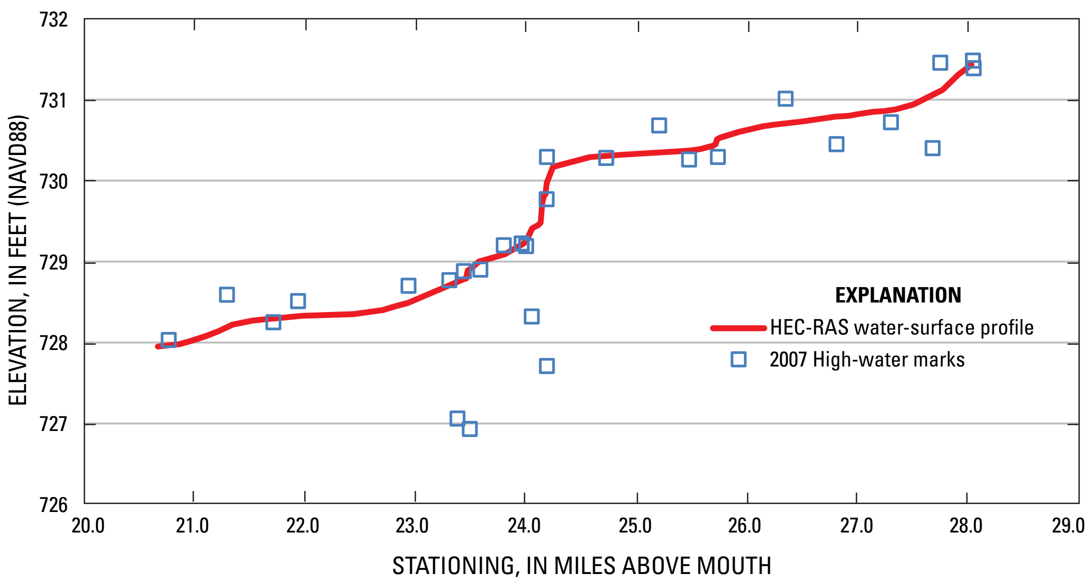

Figure 3. Profile plot of HEC-RAS modeled Blanchard River in Ottawa and surveyed high-water marks from August 2007.

Table 3. Comparison of hydraulic-model output and selected high-water-mark elevations from the August 23, 2007, flood on the Blanchard River.

High-water-mark number	River station (mi)	High-water-mark elevation (NAVD88, feet)	Model water-surface elevation (NAVD88, feet)	Elevation difference (feet)
1	20.77	728.03	727.94	0.09
2	21.30	728.59	728.15	0.44
3	21.72	728.25	728.30	−0.05
4	21.94	728.51	728.33	0.18
5	22.94	728.70	728.49	0.21
6	23.31	728.77	728.69	0.08
7	23.38	727.06	728.74	−1.68
8	23.44	728.88	728.78	0.10
9	23.49	726.93	728.91	−1.98
10	23.59	728.9	729.01	−0.11
11	23.80	729.2	729.09	0.11
12	23.96	729.21	729.21	0.00
13	24.00	729.19	729.26	-0.07
14	24.05	728.32	729.40	−1.08
15	24.19	727.71	729.99	−2.28
16	24.19	730.28	729.98	0.30
17	24.19	729.77	729.97	−0.20
18	24.73	730.28	730.31	−0.03
19	25.21	730.68	730.35	0.33
20	25.48	730.26	730.37	−0.11
21	25.74	730.29	730.52	−0.23
22	26.35	731.01	730.71	0.30
23	26.81	730.45	730.79	−0.34
24	27.30	730.72	730.87	−0.15
25	27.69	730.4	731.05	−0.65
26	27.75	731.45	731.10	0.35
27	28.04	731.47	731.43	0.04
28	28.05	731.36	731.43	−0.07

Determination of Water-Surface Profiles

Water-surface profiles were determined for a total of 12 stages (20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, and 31.4 ft) at the Blanchard River at Ottawa streamgage. After the HEC-RAS model was calibrated to the March 2011 measurements, streamflows corresponding to desired stage values were determined by means of an iterative process in which streamflows were changed until target stage values were obtained. A summary of resulting streamflows for the 12 modeled stages is given in table 4. The lowest stage of 20.0 is defined as the Action Stage by NWS, and the highest stage of 31.4 was the peak stage for the 2007 flood. The 12 estimates of peak discharge range from approximately below the 2-year to nearly the 500-year recurrence interval flood, which are shown in table 5.

Development of Flood-Inundation Maps

The USGS used topographic data developed in 2007 by means of LiDAR (Ohio Geographically Referenced Information Program, 2007) as the base mapping for the floodplain delineations. The digital 2-ft contours were generated by the USACE and used in the creation of the HEC-RAS model, as well as the modifications made to the model by the USGS.

Flood-inundation boundaries were initially determined with HEC-GeoRAS software (U.S. Army Corps of Engineers, 2002). HEC-GeoRAS is a software framework for processing geospatial data in ArcGIS using a graphical user interface. The interface facilitates extraction of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS (U.S. Army Corps of Engineers, 2002). USGS personnel modified the HEC-GeoRAS results to ensure a logical transition of the flood-inundation boundary between modeled cross sections relative to the contour data for the land surface. The flood-inundation boundaries were then overlain onto digital georeferenced aerial photography from the Ohio Statewide Imagery Program (Ohio Geographically Referenced Information Program, 2007) that was flown in 2007. The resulting estimated flood-inundation boundaries for the 12 stages can be found at the Web site *http://pubs.usgs.gov/sir/2011/5189/*.

Table 4. Stages and elevations (NAVD88), with corresponding streamflow estimates at the Blanchard River at Ottawa streamgage.

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

Stage (ft)	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.4
Elevation (ft, NAVD88)	718.4	719.4	720.4	721.4	722.4	723.4	724.4	725.4	726.4	727.4	728.4	729.8
Streamflow (ft^3/s)	3,310	4,070	5,040	6,130	7,350	8,620	9,950	11,400	13,000	15,200	17,300	20,600

Table 5. Streamflow estimates for selected recurrence intervals at the Blanchard River at Ottawa streamgage taken from the StreamStats Web site at *http://water.usgs.gov/osw/streamstats/ohio.html*.

Recurrence interval	2-year	10-year	50-year	100-year	500-year
Streamflow (ft^3/s)	7,510	12,400	16,200	17,800	21,100

Summary

A flood-warning network was developed for the Ottawa, Ohio, area by upgrading and adding streamgages to the existing network, installing equipment that enables emergency-response personnel and the public to quickly and easily access the predicted flood-inundation information, and delineating flood-inundation boundaries corresponding to selected flood stages.

The existing streamgage network was enhanced by beginning determination of streamflow at the Blanchard River at Ottawa streamgage and establishing two new streamgages upstream in the basin, one on the Blanchard River and one on Riley Creek. The streamflow and stage data from these streamgages will be used by the National Weather Service to improve the peak-stage predictions for the Blanchard River at Ottawa streamgage. In addition, Ottawa officials can now receive automated warnings about the current stage from the Blanchard River at Ottawa streamgage via a dedicated phone line with callout capabilities.

Water-surface profiles were determined by means of a step-backwater model, and corresponding flood-inundation boundaries were delineated within Ottawa for 12 stages at the Blanchard River at Ottawa, streamgage (04189260). The flood-inundation boundaries were overlain on digital georeferenced aerial photography. The stages for the 12 profiles correspond to streamflows with recurrence intervals ranging from approximately the 2-year flood to nearly the 500-year flood.

Near real-time streamgage information, flood-forecast predictions, and flood-inundation mapping corresponding to the flood forecasts can be accessed on various Web sites hosted by the USGS and the NWS. The increased availability of streamflow data, the enhanced flood-prediction capability, and public access to the data will improve the ability of officials in Ottawa to assess flood conditions, take appropriate steps to protect life and property, and reduce flood damages.

Acknowledgments

The author thanks the many local, state, and Federal agencies that support the operation and maintenance of the stream gages throughout the country. Individual thanks go to Jeffrey Loehrke, Community Development Director, Village of Ottawa, and Jason Phillips, Wastewater Director, Village of Ottawa, for their help with initial coordination of this study.

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Whitehead—**Development of a Flood-Warning Network and Flood-Inundation Mapping for the Blanchard River in Ottawa, Ohio**—Scientific Investigations Report 2011–5189