Floods of August 21–24, 2007, in Northwestern and North-Central Ohio

By David E. Straub, Andrew D. Ebner, and Brian M. Astifan

In cooperation with the Federal Emergency Management Agency

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Contents

Abstract 1
Introduction 1
Purpose and Scope 4
Meteorological Events Associated With the Flood 4
Antecedent Climatic Conditions 4
The Storm of August 19–22, 2007 4
General Description of the Floods 8
High-Water Marks 8
Flood Stages and Streamflows 10
Recurrence Intervals 12
Flood and Storm Damages Associated With FEMA–1720–DR 12
Summary 12
Acknowledgments 12
References Cited 12

Figures

1. Map showing location of nine communities within disaster area in northwestern and north-central Ohio in which the U.S. Geological Survey collected high-water-elevation data 2
2. Map showing Ohio counties declared as disaster areas under FEMA declaration 1720 3
3. Maps showing regionally averaged monthly total precipitation and percentage of normal precipitation for the 10 climatic regions and the monthly hyetograph of Ohio by National Weather Service for July and August 2007 5
4. Isohyetal map of 7-day rainfall totals for August 19–25, 2007, in northwest Ohio, from National Weather Service rain gages 7
5. Photographs showing examples of lines used as high-water marks at selected locations in the flooded area 9

6–14. Maps showing locations of high-water marks along studied streams—
6. Riley Creek in and near the village of Bluffton, Ohio 52
7. Sandusky River in and near the city of Bucyrus, Ohio 53
8. Spring Run in and near the village of Carey, Ohio 54
9. Plum Creek in and near the village of Columbus Grove, Ohio 55
10. East and west unnamed tributaries of Paramour Creek in and near the village of Crestline, Ohio 56
11. Blanchard River in and near the city of Findlay, Ohio 57
12. Rocky Fork Mohican River and Touby Run in and near the city of Mansfield, Ohio 58
13. Blanchard River in and near the city of Ottawa, Ohio 59
14. Black Fork Mohican River in and near the city of Shelby, Ohio 60

15–25. High-water mark profiles:
15. Riley Creek in and near the village of Bluffton, Ohio 61
16. Sandusky River in and near the city of Bucyrus, Ohio 61
17. Spring Run in and near the village of Carey, Ohio 62
18. Plum Creek in and near the village of Columbus Grove, Ohio 62
19. East unnamed tributary to Paramour Creek in and near the village of Crestline, Ohio 63
20. West unnamed tributary to Paramour Creek in and near the village of Crestline, Ohio 63
21. Blanchard River in and near the city of Findlay, Ohio 64
22. Rocky Fork Mohican River in and near the city of Mansfield, Ohio 64
23. Touby Run in and near the city of Mansfield, Ohio 65
24. Blanchard River in and near the city of Ottawa, Ohio 65
25. Black Fork Mohican River in and near the city of Shelby, Ohio 66
26–35. Maps showing estimated flood-inundation areas:
26. Riley Creek in and near the village of Bluffton, Ohio 67
27. Sandusky River in and near the city of Bucyrus, Ohio 68
28. Spring Run in and near the village of Carey, Ohio 69
29. Plum Creek in and near the village of Columbus Grove, Ohio 70
30. East and west unnamed tributaries of Paramour Creek in and near the village of Crestline, Ohio 71
31. Blanchard River in and near the city of Findlay, Ohio 72
32. Rocky Fork Mohican River and Touby Run in and near the city of Mansfield, Ohio 73
33. Blanchard River in and near the city of Ottawa, Ohio 74
34. Black Fork Mohican River in and near the city of Shelby, Ohio 75
35. Map showing location of selected USGS streamgages, with recurrence-interval ranges, in and around the designated disaster area for the flood of August 21–24, 2007 76

Tables

1. Precipitation totals and recurrence intervals for selected National Weather Service rain gages in Ohio, August 19–25, 2007 6
2. Extent of high-water-mark profiles within nine communities in affected disaster area FEMA–1720–DR 8
3. Elevation of high-water marks for selected locations in communities flooded on August 21–24, 2007 14
4. Peak stages, peak streamflows, and estimated recurrence-interval ranges at selected U.S. Geological Survey streamgage stations near communities in and around the affected flooded area in Ohio, August 21–24, 2007 50
5. Peak streamflows and estimated recurrence-interval ranges at selected communities in the flooded area in Ohio, August 21–24, 2007 11

Conversion Factors, Datums, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
kilometer (km)	0.621	mile (mi)
	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)
foot per second (ft/s)	0.3048	meter per second (m/s)
meter per second (m/s)	2.237	mile per hour (mi/h)
knot (kts)	1.15	mile per hour (mi/h)

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88), unless otherwise noted.

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

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

FEMA – Federal Emergency Management Agency

GIS – Geographical Information System

GPS – Global Positioning System

HEC-RAS – Hydrologic Engineering Center - River Analysis System

NOAA – National Oceanic and Atmospheric Administration

NWS – National Weather Service

Ohio EMA – Ohio Emergency Management Agency

ODNR – Ohio Department of Natural Resources

TIN – Triangulated Irregular Network

USACE – United States Army Corps of Engineers

USGS – U.S. Geological Survey

Floods of August 21–24, 2007, in Northwestern and North-Central Ohio

By D.E. Straub[1], A.D. Ebner[1], and B.M. Astifan[2]

Abstract

Heavy rains in northwestern and north-central Ohio on August 19–22, 2007, caused severe flooding and widespread damages to residential, public, and commercial structures in the communities of Bluffton, Bucyrus, Carey, Columbus Grove, Crestline, Findlay, Mansfield, Ottawa, and Shelby. On August 27, 2007, the Federal Emergency Management Agency (FEMA) issued a notice of a Presidential declaration of a major disaster affecting Allen, Crawford, Hancock, Hardin, Putnam, Richland, Seneca, and Wyandot Counties as a result of the severe flooding. Rainfall totals for most of the flooded area were 3 to 5 in., with some locations reporting as much as 8 to 10 in. Three National Weather Service (NWS) gages in the area indicated a rainfall recurrence interval of greater than 1,000 years, and two indicated a recurrence interval between 500 and 1,000 years. Total damages are estimated at approximately $290 million, with 8,205 residences registering for financial assistance.

The U.S. Geological Survey (USGS) computed flood recurrence intervals for peak streamflows at 22 streamgages and 8 ungaged sites in and around the area of major flooding. The peak streamflows at Sandusky River near Bucyrus streamgage and at seven of the eight ungaged sites had estimated recurrence intervals of greater than 500 years. The USGS located and surveyed 421 high-water marks and plotted high-water profiles for approximately 44.5 miles of streams throughout the nine communities.

Introduction

Heavy rains on August 19–22, 2007, caused severe flooding in northwestern and north-central Ohio. The flooding was the result of rain generated from the remnants of Tropical Storm Erin, combined with an east-west-oriented stationary front that stalled over northern Ohio. Waves of slow-moving thunderstorms continued across the area for 5 days, causing rivers to flood several communities in the area. The flooding was concentrated in the headwaters of three watersheds: the Maumee River, the Sandusky River, and the Muskingum River (fig. 1). Flood damages to residential, commercial, and public buildings were particularly severe in nine communities within these watershed areas. The cities of Findlay and Ottawa were severely damaged by floodwaters from the Blanchard River. The village of Bluffton was flooded by Riley Creek, a tributary to the Blanchard River. The village of Columbus Grove was flooded by Plum Creek, a small tributary to the Ottawa River. The Blanchard and Ottawa Rivers flow into the Auglaize River, a tributary to the Maumee River. The city of Bucyrus was flooded by the Sandusky River. The village of Carey was flooded by Spring Run, a tributary to Tymochtee Creek, which is a tributary to the Sandusky River. The city of Crestline was flooded by two tributaries to Paramour Creek, which is the head of the Sandusky River. The city of Mansfield was flooded by Touby Run, a tributary to Rocky Fork Mohican River, and by the Rocky Fork Mohican River. The city of Shelby was flooded by Black Fork Mohican River. The Rocky and Black Forks of the Mohican River are part of the Muskingum River watershed.

Because of the magnitude of and damages from this flood, a Presidential Disaster Declaration, FEMA–1720–DR (Federal Emergency Management Agency, 2007), was declared for eight counties (fig. 2) on August 27, 2007. Seven counties required both Individual[3] and Public[4] Assistance, and one required only Individual Assistance. A Presidential Disaster Declaration puts into motion long-term Federal recovery programs to assist individuals, businesses, and public entities.

The U.S. Geological Survey (USGS), in cooperation with the Federal Emergency Management Agency (FEMA), completed a study to document this historic flood by describing pertinent flood information including high-water marks, peak-streamflow and stage data, estimated recurrence intervals[5],

[1]U.S. Geological Survey, Columbus, Ohio.

[2]National Weather Service, Cleveland, Ohio.

[3] "Individual Assistance" is defined as assistance to individuals and households (Federal Emergency Management Agency, 2008a).

[4] "Public Assistance" is defined as assistance to state and local governments and certain private nonprofit organizations for emergency work and the repair or replacement of disaster-damaged facilities (Federal Emergency Management Agency, 2008b).

[5] Recurrence interval is the average length of time within which the magnitude of a given flood or rainfall event will be equaled or exceeded (Riggs, 1968). It is determined as the reciprocal of the probability that a given event will be equaled or exceeded in any given year. For example, the 100-year flood has a 0.01 (1 percent) probability of being equaled or exceeded in any given year. Rainfall recurrence intervals are reported as a function of both magnitude and storm duration, whereas flood recurrence intervals are reported only as a function of magnitude.

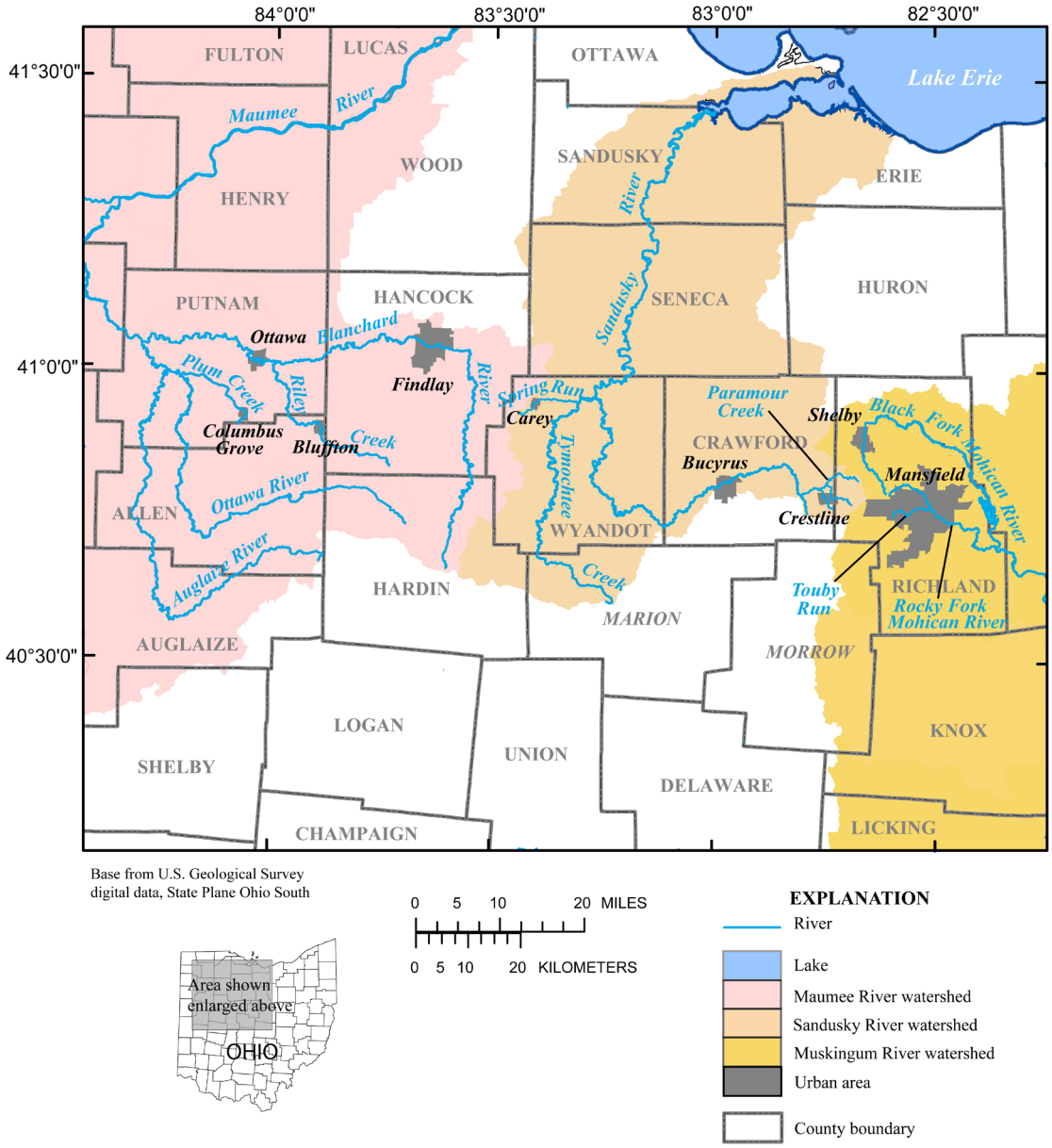

Figure 1. Location of nine communities within disaster area in northwestern and north-central Ohio in which the U.S. Geological Survey collected high-water-elevation data.

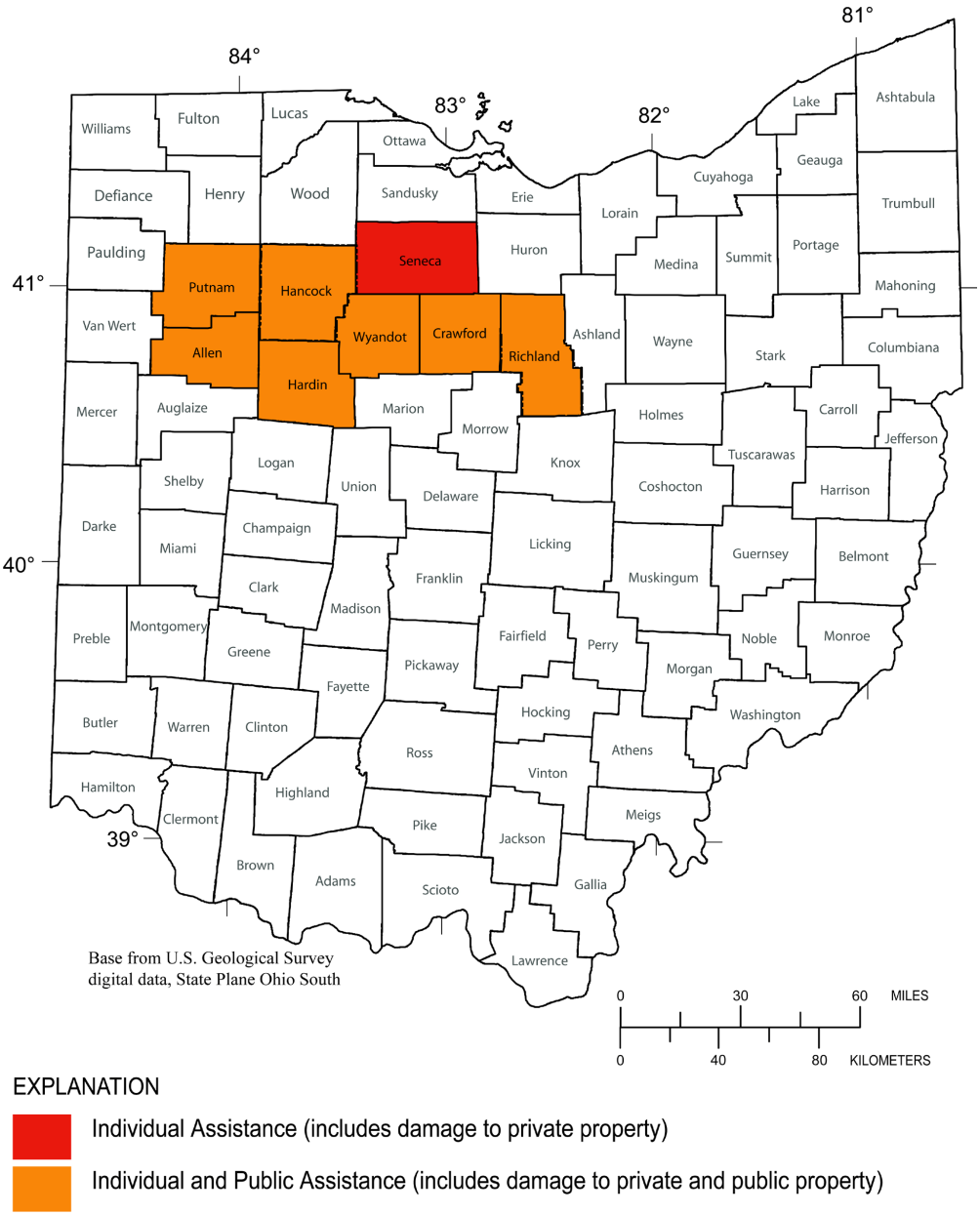

Figure 2. Ohio counties declared as disaster areas under FEMA declaration 1720 (modified from Federal Emergency Management Agency, 2008).

and maps of estimated flood inundation. Documentation of flood events can assist Federal, State, and local agencies in making informed decisions on flood-plain management and flood-emergency practices.

Purpose and Scope

This report describes the meteorological and hydrologic conditions leading to the floods, magnitude and frequency estimates for selected rainfall and stream sites, and damage estimates for the affected communities. The USGS located 421 high-water marks along approximately 44.5 mi of streams through the nine communities affected by the floods. The affected communities, main flooding source, extent of the high-water marks, and number of high-water marks within each community are described herein. Peak-streamflow and recurrence-interval estimates were determined for the main flooding source within each of the nine communites. Peak gage-height, streamflow, and recurrence-interval estimates were determined at 22 streamgages in and around the flooded area, 3 of which are located within the 9 communites.

Meteorological Events Associated With the Flood

The National Oceanic and Atmospheric Administration (NOAA) divides Ohio into 10 regions based on similar climatological characteristics. The storm of August 19–22, 2007, mainly affected parts of five regions in the northwest quarter of the State. The state and regional rainfall totals are summarized from the "Monthly Water Inventory Report for Ohio" from the Ohio Department of Natural Resources (ODNR). The conditions for the 3 months before the August 2007 storm are summarized in the May, June, and July 2007 reports (Kirk, 2007a, b, and c). The monthly report for August 2007 (Kirk, 2007d) includes the rainfall data from this storm and associated flood.

Antecedent Climatic Conditions

In general, the weather leading up to the storm was dry. Precipitation in the area was below normal[6] for May, June, and July. The State average precipitation amounts for these months in 2007 were 1.60, 2.92, 3.72 in., respectively. These State averages were 41, 76, and 91 percent of normal, respectively. May 2007 ranked as the third driest May over 125 years of record (Kirk, 2007a). June was also dry, with Putnam County receiving the least amount of precipitation in the State at 0.41 in. (Kirk, 2007b). In July, Ohio received some precipitation from scattered showers and thunderstorms. Much of Ohio received 0.25 to 0.50 in. of rain from July 4 through 6 and another 0.25 to 0.50 in. on July 10 and 11. Most of the State also received 1 to 3 in. between July 17 and July 28. During late July, the greatest amount of rain fell in an area from northwestern to east-central and southeastern Ohio (Kirk, 2007c). The 10 climatic regions of Ohio, the average precipitation and percent of normal of each region, and an isohyetal plot of the total precipitation for July are shown in figure 3A.

The "Monthly Water Inventory Report" for August (Kirk, 2007d) includes the rainfall during August 19–25 in the monthly totals. The precipitation for August was above normal for most of Ohio except the southern part of the State (fig. 3B). The statewide average was 5.75 in., 2.31 in. above normal. Precipitation was heaviest in the Northwest climatic region with a total of 10.10 in., which was 6.91 in. above normal. August 2007 was the seventh-wettest August during 125 years of record for the State as a whole. Regionally, this was the wettest August of record for the Northwest, North-Central, and Northeast climatic regions of Ohio. Upper Sandusky (Wyandot County) reported 13.77 in. and Pandora (Putnam County) reported 13.61 in. of precipitation in August. Radar estimates show that localized areas in Wyandot County probably received more than 15 in. of rain for the month, and unofficial reports indicated more than 17 in. (Kirk, 2007d).

The precipitation fell as showers and thunderstorms and varied greatly across the State. The first significant rain of the month occurred on August 5. Approximately 0.5–1.5 in. fell from northwestern to southeastern Ohio as showers and thunderstorms. During August 7–9, another storm generally dropped 1.5-3.0 in. of rain, with as much as 5.0 in. in some locations in northern Ohio. The most significant precipitation fell during August 19–22, with the northeastern two-thirds of Ohio receiving 1 to 3 in. of rain. A large area in northwestern and north-central Ohio received 3–5 in. of rain, with as much as 8–10 in. reported at some locations (Kirk, 2007d).

The Storm of August 19–22, 2007

The flooding that affected northwestern and north-central Ohio was caused primarily by the interaction between tropical moisture associated with the remnants of Tropical Storm Erin and an east-west-oriented stationary front that stalled over northern Ohio. Several waves of slow-moving thunderstorms moved across northwestern and north-central Ohio from the evening of Saturday, August 18, through the morning of Wednesday, August 22, producing widespread rainfall totals in excess of 4 in. across much of northwestern and north-central Ohio. The heaviest rainfall during the 5-day storm event fell from the evening of August 20 through the morning of August 21, with as much as 10 in. in 10 hours near the Upper Sandusky area (National Climatic Data Center, 2008). The 7-day precipitation totals for the area from August 19–25, 2007, based on data from 68 NWS rainfall stations (National Oceanic and Atmospheric Administration, 2007), are shown in figure 4. Rainfall intensities and recurrence intervals for selected National Weather Service (NWS) stations (National Weather Service, 2008) from the storms that affected Ohio from August

[6] "Normal" refers to the average value for the period 1951–2000 (Kirk, 2007 a, b, c, and d).

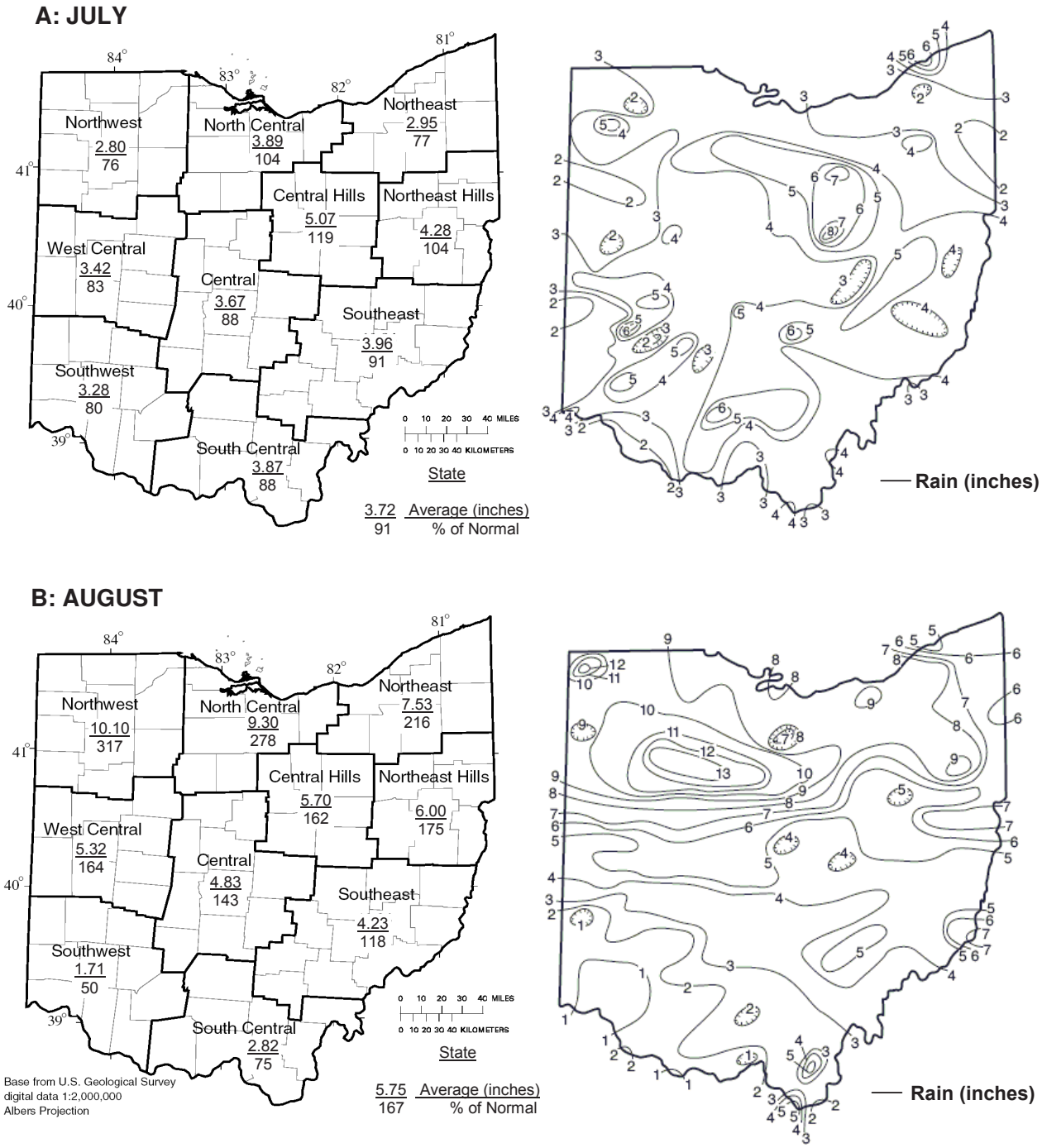

Figure 3. Regionally averaged monthly total precipitation and percentage of normal precipitation for the 10 climatic regions and the monthly hyetograph of Ohio by National Weather Service for July and August 2007 (from Kirk, 2007c, d).

19 to August 25 are listed in table 1. The time period used in table 1 is varied in order to show the most intense period of rainfall at each of the selected rain-gage sites. The 1-day precipitation totals at the Upper Sandusky, Bucyrus, and Ottawa rain gages correspond to a greater than 1,000-year recurrence interval.

The meteorological origins of the floods can be traced back to August 16, when Tropical Storm Erin made landfall along the Texas coastline while a cold front was moving southward through Ohio. This front eventually stalled on August 18 near the Tennessee River Valley before moving back north across Ohio on August 19 as a warm front and stalling once again just south of Lake Erie on August 20. As the front retreated, a subtropical high-pressure system strengthened over the southeastern United States. The clockwise circulation around this large high-pressure area brought the copious amounts of tropical moisture associated with the remnants of Tropical Storm Erin from Texas northward through the Mississippi River Valley then eastward across the Ohio River Valley.

Rainfall began across extreme northwestern Ohio on the evening of August 18 ahead of the warm front and slowly spread south and east through the rest of northern Ohio as the front stalled during the day on August 19. Following a lull during the evening of the 19th, thunderstorms redeveloped across northern Indiana in the early morning of August 20 and moved eastward across northern Ohio along the frontal boundary. These storms intensified during the late morning as they reached north-central Ohio, with as much as 4 in. of rain falling in less than an hour and a half from Medina County east to Mahoning County.

These storms dissipated along the eastern border of Ohio during the early afternoon as sunshine returned across Indiana and western Ohio, destabilizing the tropical airmass now in place and leading to yet another round of thunderstorms. These storms again tracked eastward along the frontal boundary, which had sagged slightly southward during the day and focused the heaviest rainfall along the U.S. 30 corridor through Ohio.

During the evening, a westerly nocturnal low-level jet[7] formed in the wake of the afternoon storms, once again triggering new thunderstorm development in western Indiana. This low-level jet intensified and pushed into northwest Ohio during the early morning, creating a moisture-rich breeding ground for continual thunderstorm development. Storms repeatedly moved over the same areas overnight, resulting in rainfall totals of 6 to 10 in. across a wide area stretching from northwest to north-central Ohio.

[7] A nocturnal low-level jet is defined as a jet stream (relatively strong winds concentrated within a narrow band in the atmosphere) that forms at night, typically near the Earth's surface below an altitude of about 2 km, and usually attains speeds of less than 60 knots (Ahrens, 2003).

Table 1. Precipitation totals and recurrence intervals for selected National Weather Service rain gages in Ohio, August 19–25, 2007.

[Data from National Oceanic and Atmospheric Administration, 2007; >, greater than]

Station Name	County	Dates (2007)	Period (days)	Precipitation (inches)	Recurrence interval[1] (years)
Upper Sandusky	Wyandot	August 21	1	9.35	> 1,000
Upper Sandusky	Wyandot	August 19–25	7	10.30	200–500
Pandora	Putnam	August 19–25	7	10.03	500–1,000
Bucyrus	Crawford	August 19–25	7	9.14	200–500
Bucyrus	Crawford	August 21	1	8.68	> 1,000
Ottawa	Putnam	August 19	1	8.14	> 1,000
Van Wert 1 S	Van Wert	August 19–25	7	9.98	500–1,000
Grover Hill	Paulding	August 21	1	6.76	200–500
Findlay WPCC	Hancock	August 19–25	7	7.61	100–200
Findlay FAA Airport	Hancock	August 19–25	7	6.42	25–50
Galion Water Works	Crawford	August 21	1	6.11	100–200
Lima WWTP	Allen	August 19–25	7	7.75	50–100
Mansfield WSO AP	Richland	August 19–25	7	6.78	25–50

[1]From National Weather Service (2008).

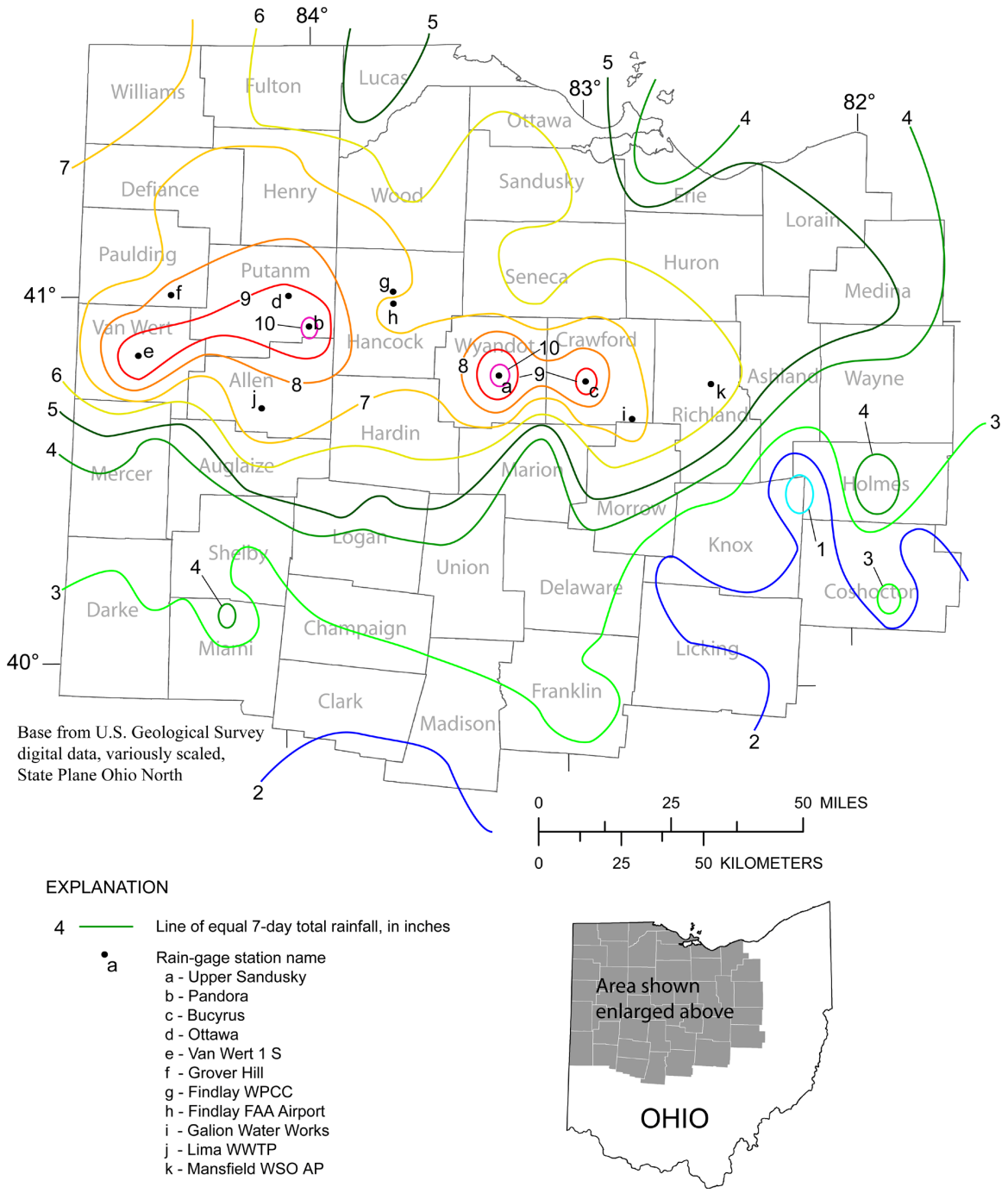

Figure 4. Isohyetal map of 7-day rainfall totals for August 19–25, 2007, in northwest Ohio, from National Weather Service rain gages.

General Description of the Floods

Water levels rose in many streams throughout the eight counties (fig. 2) as a result of the severe rain during August 19–24, 2007. Many homes, businesses, and structures were affected by floodwaters, particularly within nine communities of these counties (table 2). The USGS analyzed data from selected streamgages in and around the flooded counties to determine the extent of the flooding. Streamgage records and other streamflow-estimation techniques were used to determine the frequency and magnitude of this flood event within the disaster area. Data from streamgages in and around the disaster area are presented to show that the rivers outside and downstream from the flooded area were able to convey the water safely with minimal damages to residences and structures. The omission from this report of any rivers or communities that experienced flooding is not a reflection of the severity of the flooding or the impact on those communities but rather is due to the lack of available streamflow data and/or high-water-elevation data.

High-Water Marks

High-water marks are an indication of the water level at peak stage of a river during a flood event. They can be used to determine the peak streamflow or to calibrate peak-flow models used to determine flood-inundation areas. High-water marks are usually determined from mud, seed, or debris lines (or a combination thereof) left behind as the floodwaters receded. Examples of seed, mud, and or debris lines that indicated water elevations for this flood are shown in figure 5. Trees are generally a good place to find high-water marks because seeds and small debris get caught in the bark. Several distinct lines can be left after an event as floodwaters recede. For example, a flood with a secondary peak or an upstream bank failure can leave a distinct debris or mud line below the actual peak high-water mark (right picture figure 5B). The accuracy of the high-water marks is subjectively rated by the USGS personnel locating the mark, as outlined in Lumia and others (1986). High-water marks can be rated “excellent” (within 0.02 ft of the true high-water mark), “good” (within 0.05 ft), “fair” (within 0.10 ft), or “poor” (greater than 0.10 ft).

Table 2. Extent of high-water-mark profiles within nine communities in affected disaster area FEMA–1720–DR.

[Abbreviations: I, Interstate; SR, State Route; CR, County Road; TR, Township Road]

Community	County	Flooding source	Downstream limit	Upstream limit	Stream miles	Number of high-water marks
			Maumee River Watershed			
Bluffton	Allen	Riley Creek	Bentley Road	I–75	2.4	30
Columbus Grove	Putnam	Plum Creek	Road 11	TR 11R	2.9	27
Findlay	Hancock	Blanchard River	CR 140 (04189000)[1]	TR 241	7.6	87
Ottawa	Putnam	Blanchard River	Road I–9	CR 8	7.5	32
			Sandusky River Watershed			
Bucyrus	Crawford	Sandusky River	Kerstetter Road , CR 121 (04196000)[2]	SR 30	4.6	44
Carey	Wyandot	Spring Run	TR 100A	SR 15	2.9	30
Crestline	Crawford	West unnamed tributary to Paramour Creek	West Main Street, SR 30 N	West Bucyrus Street, CR 35	1.1	6
		East unnamed tributary to Paramour Creek	Oldfield Road, SR 61	Norfolk Southern Railroad	1.9	18
			Muskingum River Watershed			
Mansfield	Richland	Rocky Fork Mohican River	Lucas Road, SR39	Bowman Street	6.4	53
		Touby Run	Mouth	Home Road	4.3	51
Shelby	Richland	Black Fork Mohican River	London West Road/CR58	Mickey Road	2.9	43

[1] USGS streamgage Blanchard River near Findlay, Ohio.
[2] USGS streamgage Sandusky River near Bucyrus, Ohio.

A

B

C

Figure 5. Examples of lines used as high-water marks at selected locations in the flooded area. *A*, Seed line on buildings or trees. *B*, Mud lines on buildings. *C*, Debris lines on fence or ground.

The USGS located and surveyed 421 high-water marks along approximately 44.5 mi of streams within the 9 communities flooded in this event (figs. 6–14, at back of report). All high-water marks (table 3, at back of report) were surveyed and referenced to the North American Vertical Datum of 1988 (NAVD 88) and the North American Datum 1983 (NAD 83). The elevations of the high-water marks were determined by use of a Global Positioning System (GPS) and differential leveling. The initial horizontal position of each mark was determined by handheld GPS units and then repositioned directly on aerial photographs in a Geographical Information System (GIS).

To determine the high-water profile, a reference distance and elevation must be associated with each high-water mark. The reference distance is usually estimated by the distance along each stream's main channel from a selected location, usually the mouth or a bridge. Flood profiles were determined for each stream in the nine communities by this method (figs. 15–25, at back of report) except for the city of Ottawa. In and near Ottawa, the main channel of the Blanchard River has a high degree of meandering relative to the flood plain and, at several locations, the main-channel flow is against the general direction of the floodflow; therefore, the horizontal distance was estimated to align with the majority of the floodflow across the flood plain.

The USGS created maps of estimated flood inundation superimposed on aerial photographs for the nine communities (figs. 26–34, at back of report). The estimated flood-inundation areas were determined by the high-water-mark elevation data placed on a Triangulated Irregular Network (TIN) generated from LIDAR[8] data. The extent of this flood on the tributaries to the main flooding source may be greater than shown in the figures because high-water marks were not collected on the tributaries.

Flood Stages and Streamflows

The USGS examined the streamflow data from 22 streamgages (table 4 and fig. 35, at back of report) that were in and around the area affected by this storm. The USGS located and surveyed high-water marks around four streamgages in the flooded area: two active streamgages (Blanchard River near Findlay 04189000 and Sandusky River near Bucyrus 04196000); one discontinued (Touby Run at Mansfield 03130500); and one stage-only[9] (Blanchard River at Ottawa 04189260). Two more streamgages (Sandusky River near Upper Sandusky 04196500 and Tymochtee Creek at Crawford 04196800) are within the counties of the disaster declaration, but no high-water marks were collected. The remaining streamgages are listed to present the areal extent of the flooding.

Streamflow at a streamgage is generally determined by a rating curve, which is the relation between river stage, or gage height, and streamflow. Rating curves are usually developed by mathematically relating measured gage heights and corresponding measured streamflows —collectively termed "input points"—over a range of flows (Rantz and others, 1982). Streamflow between or beyond the input points is then determined by interpolation or extrapolation. Ideally, the measurements should span the entire probable range of flows at the gage, but high-flow data are sometimes difficult or unsafe to collect. Extrapolating the rating curve beyond the highest data point can lead to large errors in streamflow estimates (Rantz and others, 1982). Techniques to define high-streamflow data points on a rating curve are available by applying the energy and continuity equations at specific locations when direct measurements are not possible, practical, or safe. By indirectly determining the streamflow on the basis of high-water marks, the rating curve can be defined for extreme floodflows without physically measuring the flow during dangerous measurement conditions. Indirect methods also can be used to determine streamflow at ungaged locations where streamflow data are unavailable. Streamflows for the August 2007 Ohio event were determined by the rating-curve method at 20 of the 22 streamgages and are presented in table 4 (at back of report).

The USGS was able to directly measure the streamflow and gage height at several different water levels at both the Blanchard River near Findlay and Sandusky River near Bucyrus gages during the August 2007 flood. Direct measurements of stage and flow were made at the Blanchard River near Findlay streamgage at the peak gage height of 18.46 ft (772.22 ft, NAVD 88) and a streamflow of 14,500 ft^3/s at about 1:00 p.m. on August 22, 2007. Only once, during the 1913 flood, was there a higher estimated stage and streamflow (18.50 ft and 22,000 ft^3/s) in the 81 years of record[10]. Unfortunately, conditions at the Sandusky River near Bucyrus streamgage were considered unsafe when the streamgage and roadway were submerged by the flood; thus, field crews were unable to directly measure the peak streamflow. Measurements before and after the peak gage height, as well as high-water marks at the Bucyrus streamgage, helped to define the flood hydrograph for this event. As derived from surveyed high-water marks and indirect methods, the gage height and streamflow estimated for the Sandusky River near Bucyrus streamgaging station were 12.17 ft (967.21 ft, NGVD 29) and 15,800 ft^3/s. The peak streamflow was estimated to have occurred at about 10:00 p.m. on August 21, 2007; these were the highest recorded gage height and streamflow estimate at this site for the 55 years of record[11]. Because the Touby Run at Mansfield streamgage was not active and the Blanchard River at Ottawa streamgage was

[8] LIDAR (Light Detection and Ranging) is an optical remote-sensing technique used to determine ground elevations. The data were collected as part of the Ohio Geographically Referenced Information Program (OGRIP).

[9] A stage-only streamgage records the water level only; streamflow is not computed.

[10] The Blanchard River at Findlay streamgage was operated from October 1923 until present day. The 1913 flood information was determined by indirect methods for this gage site and was not part of the continuous systematic record.

[11] The Sandusky River near Bucyrus streamgage was operated from August 1925 to November 1935, July 1938 to December 1951, December 1963 to September 1981, and October 1995 to present day.

a stage-only gage, direct measurements were not done at these locations. Surveyed high-water marks on the upstream and downstream side of the concrete weir at the Touby Run at Mansfield streamgage site indicated a peak gage height of 5.29 ft. The streamflow was estimated to be 1,200 ft^3/s and was based on extrapolating the rating curve and an indirect method using a weir equation (Hulsing, 1967). The peak streamflow was estimated to have occured on August 21, 2007; the recorded gage height and the streamflow estimate at this site were the highest for the 33 years of record[12]. The Blanchard River at Ottawa streamgage recorded a gage height of 31.70 ft[13] on August 23, 2007. No streamflow information was available for the Blanchard River at Ottawa streamgage; however, by use of an indirect method, the streamflow was estimated to be between 25,600 and 49,400 ft^3/s.

An estimated streamflow was computed by an indirect method at seven of the nine communities, owing to the lack of streamflow data (table 5). Selection of the most appropriate indirect method was based on the quality of the high-water marks, required stream-geometry data, and channel characteristics associated with the particular indirect method. Four indirect methods were used to determine streamflow at the selected locations in the seven communities: (1) the slope-area method, which uses a uniform-flow equation based on channel geometry, water-surface profiles, and roughness coefficients (Dalrymple and Benson, 1968); (2) the contracted-opening method, which uses the energy equation to compute the drop in water surface at bridges or channel contractions (Matthai, 1967); (3) the Manning's equation method, which uses channel characteristics and roughness coefficients (Chow, 1959); and (4) the routing method using a Hydrologic Engineering Centers River Analysis System (HEC-RAS) model to match the water-surface profile based on high-water-mark elevations (U.S. Army Corps of Engineers, 2005).

[12] The Touby Run at Mansfield streamgage was operated from August 1946 to September 1978. A peak flow was also estimated for the July 2, 1987, event.

[13] The Blanchard River at Ottawa streamgage is a stage-only station operated from November 1995 to present. This station is a river forecast site for the National Weather Service. Historical stage data from before 1995 were obtained from the NWS Web page (National Weather Service, 2007).

Table 5. Peak streamflows and estimated recurrence-interval ranges at selected communities in the flooded area in Ohio, August 21–24, 2007.

[mi^2, square miles; ft, feet (above streamgage datum); ft^3/s, cubic feet per second; >, greater than; N/A, not available]

Streamflow determined at selected communities by indirect methods					
Community	**Stream**	**Drainage area (mi^2)**	**Method for determining streamflow**	**Streamflow (ft^3/s)**	**Estimated recurrence-interval range (years)[1]**
Bluffton	Riley Creek	35.8	Slope-area	10,300	> 500
Carey	Spring Run	3.51	Contracted-opening	597[2]	> 500
Columbus Grove	Plum Creek	17.1	Contracted-opening	1,780	100–500
Crestline	West Unnamed Tributary to Paramour Creek	5.29	Manning's Equation	3,000	> 500
Crestline	East Unnamed Tributary to Paramour Creek	1.76	Routing method (using HEC-RAS), Manning's Equation	698	> 500
Mansfield	Rocky Fork Mohican River	10.3	Contracted-opening	2,030	> 500
Ottawa	Blanchard River	625	Manning's Equation	25,600 to 49,400[3]	> 500
Shelby	Black Fork Mohican River	30.4	Contracted-opening	6,340	> 500

[1] Recurrence-interval estimated from StreamStats (Koltun and others, 2006).

[2] Spring Run overflowed its banks upstream from the contracted-opening site at the Toledo Street bridge. An undetermined quantity of that overflow may have escaped into the unnamed tributary to the north, thereby bypassing the contracted-opening site. Flow from the unnamed tributary enters Spring Run approximately 300 feet downstream from Toledo Street.

[3] Range based on Manning's equations at two different locations.

Recurrence Intervals

The recurrence intervals at each streamgage were estimated by comparing the peak streamflow of this event with the gage-weighted streamflow estimates as published in Koltun and others (2006). For streamgages where record was insufficient to compute a reliable recurrence-interval estimate and also for the ungaged sites, recurrence intervals were estimated by means of Ohio StreamStats (U.S. Geological Survey, 2008). Peak stage, peak streamflow, and recurrence-interval range for selected USGS streamgages for this flood event are listed in table 4 (at back of report). For stations on regulated streams, a recurrence interval is not given.

Record peak streamflow occurred on Touby Run at Mansfield (station 03130500), Sandusky River near Bucyrus (station 04196000), and Sandusky River near Upper Sandusky (station 04196500). The streamgage at Bucyrus indicated a greater than 500-year peak floodflow. At the Findlay streamgage, peak floodflow slightly exceeded the 100-year recurrence interval. Peak flows at the streamgages at Mansfield and Upper Sandusky were in the 50–100 year flood range. Recurrence intervals at the other streamgages were smaller.

The peak floodflows for the ungaged sites were compared to estimates from Ohio StreamStats to establish approximate recurrence intervals for this flood. At eight of the nine ungaged locations, the estimated recurrence interval was greater than 500 years. At the Plum Creek site in Columbus Grove, the estimated recurrence interval was between 100 and 500 years.

Flood and Storm Damages Associated With FEMA–1720–DR

Although it was not possible to determine an exact value of the damages caused by the flooding, Ohio Emergency Management Agency (Ohio EMA) was able to obtain some estimates of the extent of the damage. According to the Ohio EMA (Drew Whitehair, written commun., 2008), 8,205 households registered for assistance as a result of this flood. Damages to public property were estimated to be in excess of $290 million. FEMA approved nearly $124 million of assistance to aid in the repair of both public and private properties. The Small Business Administration approved an additional $114 million in loans to aid with repair of local businesses affected by the flooding.

Summary

A severe storm swept across northwestern and north-central Ohio during August 19–22, 2007, with as much as 10 in. of rain reported in some areas. Rainfall recorded at some National Weather Service sites exceeded a 1,000-year recurrence interval. Because of the intensity of the rainfall, several streams flooded homes and businesses in nine communities throughout the area. Eight counties were declared a Federal disaster area on August 27, 2007.

The USGS located 421 high-water marks and generated peak flood profiles on 11 streams throughout the nine communities. Peak streamflows, stages, and recurrence intervals were estimated by high-water marks and/or streamgage data at 30 locations in and around the flooded area.

The highest peak streamflow of record occurred at three streamgages: the Sandusky River near Bucyrus, the Sandusky River near Upper Sandusky, and Touby Run at Mansfield. The streamgage on the Blanchard River near Findlay recorded the second highest streamflow for the 81 years of record. Many of the streams in the selected communities of the flooded area had a peak-streamflow recurrence interval of greater than 500 years. Damage was estimated by the Ohio Emergency Management Agency at more than $290 million.

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Tables 3 and 4, High-Water-Mark Location Maps, Flood Profiles, and Inundation Maps

[In separate files]