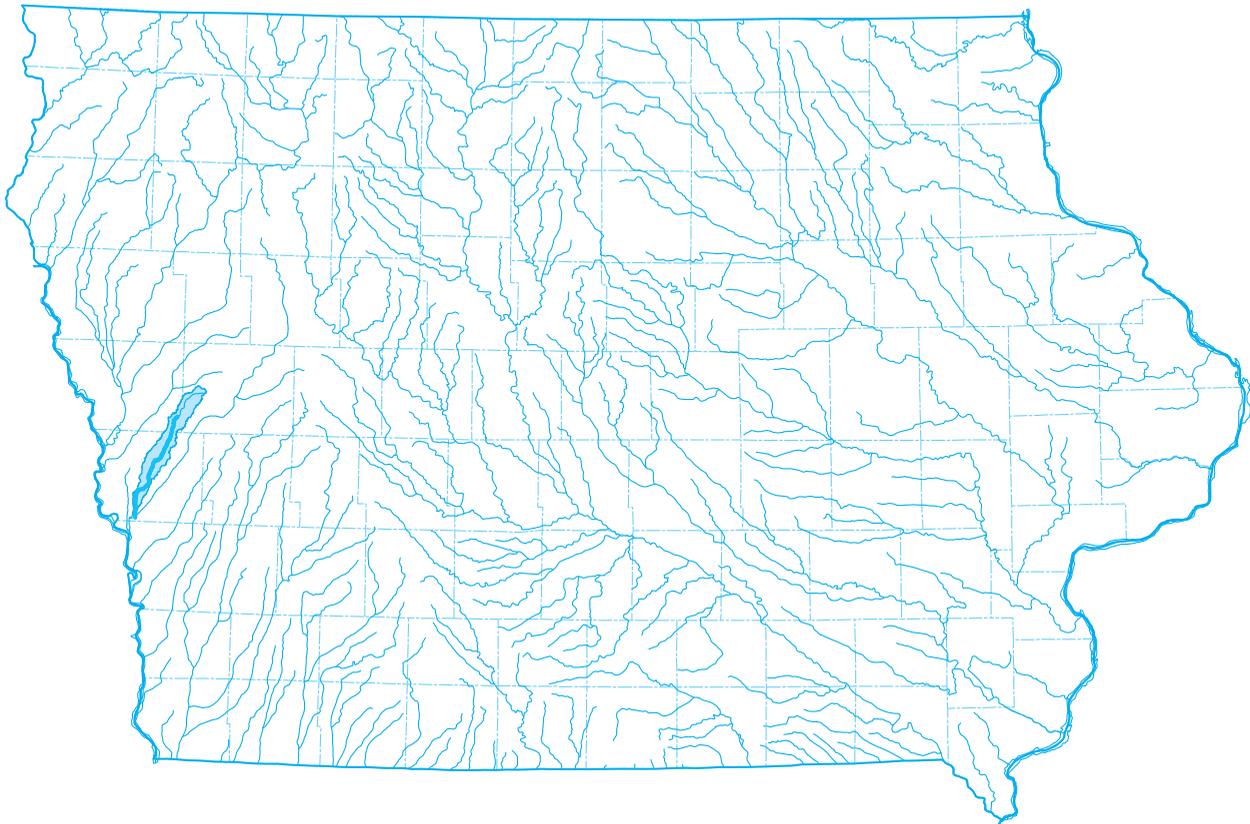


Prepared in cooperation with the Iowa Department of Transportation and Iowa Highway Research Board (Project HR-140)

Flood of May 6, 2007, Willow Creek, West-Central Iowa



Open-File Report 2008–1229

Front cover: Map of Iowa showing location of Willow Creek drainage basin and river reach profiled in the report.

Flood of May 6, 2007, Willow Creek, West-Central Iowa

By Edward E. Fischer and David A. Eash

Prepared in cooperation with the Iowa Department of Transportation and Iowa
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Open-File Report 2008–1229

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

U.S. Department of the Interior
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Conversion Factors and Datums

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
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)

Elevation or vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929).

Elevation refers to distance above or below NGVD 1929. NGVD 1929 can be converted to the North American Vertical Datum of 1988 by using the National Geodetic Survey conversion utility available at <http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html>.

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

Water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which the water year ends and that includes 9 of the 12 months. Thus, the water year ending September 30, 2007, is called the "2007 water year."

Flood of May 6, 2007, Willow Creek, West-Central Iowa

By Edward E. Fischer and David A. Eash

Abstract

Major flooding occurred May 6, 2007, in the Willow Creek drainage basin in Harrison County following severe thunderstorm activity over west-central Iowa. More than 7 inches of rain were recorded for the 72-hour period ending 7 a.m., May 6, at the Logan, Iowa weather station. The peak discharge in Willow Creek at Medford Avenue near Missouri Valley, Iowa, was 17,000 cubic feet per second. The recurrence interval of the flood is 160 years, which was estimated using regional regression equations. Information about the basin, the storms, the flooding, and a profile of high-water marks measured at 10 locations along Willow Creek between the mouth at the Boyer River and State Highway 37 in Monona County, a distance of almost 33 river miles, are presented in this report.

Introduction

Severe thunderstorms May 5–6, 2007, caused flooding in the Willow Creek and adjacent drainage basins in west-central Iowa. Fields were inundated and highways were closed. Interstate Highway 29 (I-29) west of the Willow Creek drainage basin also was closed. The levee on both sides of Willow Creek failed upstream of the city of Missouri Valley and flooded parts of the city. Water from the levee break may have contributed to the flooding of I-29 as the water spread over the flood plain. A flood of similar magnitude occurred on Willow Creek 50 years earlier on June 16, 1957.

This report provides information about the May 2007 thunderstorms and ensuing flooding in the Willow Creek drainage basin. High-water marks at selected sites along Willow Creek are presented in a flood profile from the mouth of Willow Creek at the Boyer River to State Highway 37 in Monona County, a distance of slightly less than 33 river miles. The report also provides information about the flooding and closure of I-29 west of the Willow Creek drainage basin.

This report was prepared in cooperation with the Iowa Department of Transportation (Iowa DOT) and the Iowa Highway Research Board. A list of other Iowa flood reports can be obtained by contacting the U.S. Geological Survey (USGS), Iowa Water Science Center, at <http://ia.water.usgs.gov/projects/profiles/>.

River Basin

Willow Creek is a tributary of the Boyer River (fig. 1), which is a tributary of the Missouri River (not shown on figure 1). The stream originates in Crawford County, flows southwesterly through the southeast corner of Monona County into Harrison County, and empties into the Boyer River in southern Harrison County. The drainage area at the mouth is 146 square miles (Larimer, 1957). The drainage basin lies in three of Iowa's landform regions (not shown on figure 1): the approximate upstream half of the basin is in the Southern Iowa Drift Plain, most of the downstream half is in the Loess Hills, and the downstream-most part is in the Missouri Alluvial Plain (Alluvial Plain) (Prior, 1991). County Road L20 (Loess Hills Trail) traces the geographic boundary between the Loess Hills and the Alluvial Plain landform regions (fig. 1). The topography of the Southern Iowa Drift Plain is rolling hills and valleys; whereas, the topography of the Loess Hills is wide valleys bordered by steeply-sloped ridges. Loess soil is highly erodible and is very unstable when exposed surfaces become saturated with water. The topography of the Alluvial Plain is flat; most of the surface drainage is by dug channels and ditches. See *Landforms of Iowa* (Prior, 1991) for more-extensive descriptions of the landform regions.

Long stretches of Willow Creek have been straightened throughout the basin (fig. 1). Channel-straightening work began in the late 1800's and early 1900's; the Willow Creek Drainage District was formed in 1905 (Liz Lenz, Harrison County Drainage Clerk, oral commun., November 14, 2007). Levees line the channel along the entire length in the Alluvial Plain and for a short distance into the Loess Hills. Land use in the basin is predominantly agricultural. There are no reservoirs or other structures in the drainage basin that substantially affect streamflows.

Storm and Flood of May 6, 2007, Description

Heavy rains were reported in west-central and southwest Iowa for the period May 4–7 (Hillaker, 2007). At the Logan, Iowa, weather station, 7.61 inches were recorded by 7 a.m., May 6, for the preceding 72 hours; of that total, 5.57 inches

2 Flood of May 6, 2007, Willow Creek, West-Central Iowa

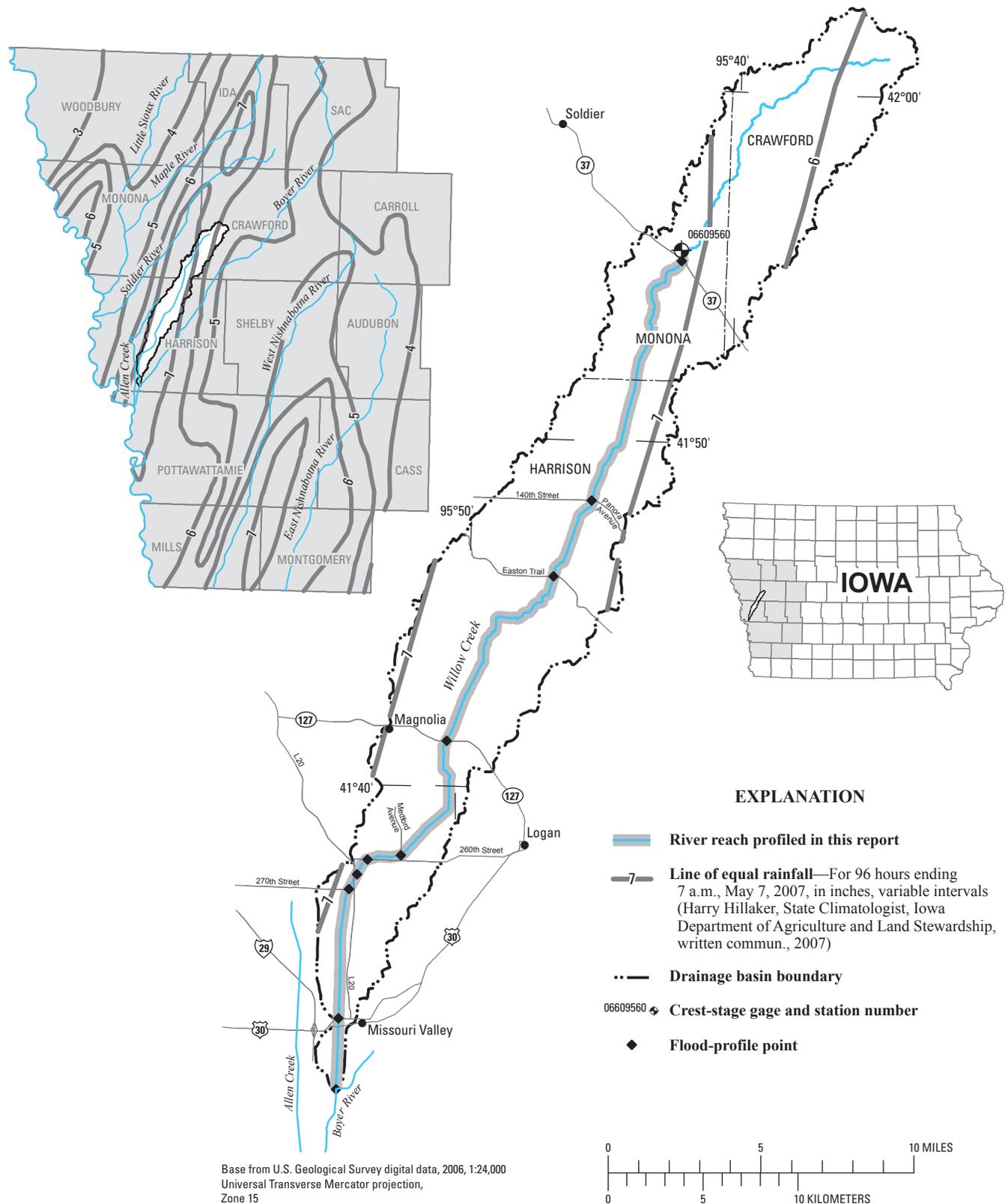


Figure 1. Willow Creek drainage basin and lines of equal rainfall for 96 hours ending 7 a.m., May 7, 2007.

were recorded during the final 24 hours. A 96-hour isohyetal map for the period ending 7 a.m., May 7, is shown in figure 1. The rain saturated the soil and caused mudslides that closed County Road L20 (Loess Hills Trail) north of Missouri Valley (Swenson, 2007).

The heavy rains caused Willow Creek to flood fields and roads throughout the basin. In one instance, a land owner said that water overflowed Medford Avenue from “after midnight until about 2:30 the following afternoon” (Chase Olsen, May 30, 2007, oral commun.; Mr. Olsen spoke with USGS personnel when the Medford Avenue site was surveyed for an indirect discharge measurement). According to the County Engineer, the Harrison County roads infrastructure sustained an estimated \$3 million damage (Tom Stoner, Harrison County Engineer, oral commun., November 14, 2007). High water caused the levee along Willow Creek to fail upstream of the city of Missouri Valley. The levee failures occurred on both banks near 270th Street. Homes and businesses in Missouri Valley were flooded as the water spread downstream (Swenson, 2007).

Water from the levee break may have contributed to the flooding and closure of I-29 in the adjacent drainage basin because of the flat topography of the Alluvial Plain. Flood waters crossed I-29 near Allen Creek north of the U.S. Highway 30 interchange at Missouri Valley. As described by Iowa DOT personnel, during the evening of May 6 the water had risen onto the shoulder of north-bound I-29, then the driving lane, and began to cross the north bound lanes in a thin sheet about 7 p.m. The water spilled into the median, filling the median for about an hour before flowing over the south bound lanes. By 10 p.m. the flow over the highway “was more than just sheet flow” as stated by DOT personnel. During peak flooding, water spread between mile markers 76.5 and 77.35 (James Bane, Iowa Department of Transportation, written commun., October 2007). Because of the complex interaction of floodwaters from Allen and Willow Creeks, a precise

determination of the source and spreading of floodwater in the Alluvial Plain was beyond the scope of this study.

An indirect measurement of the flood peak discharge in Willow Creek was made at the Medford Avenue bridge on May 30, 2007 (fig. 1). The estimated peak discharge was 17,000 cubic feet per second (ft³/s), which includes road overflow on the right flood plain. An indirect peak discharge measurement had been made by the USGS at the same location 50 years earlier for a flood that occurred June 16, 1957. The estimated peak discharge in 1957 was 20,000 ft³/s, which also included road overflow. Upstream at crest-stage gage 06609560 Willow Creek near Soldier, Iowa, the peak discharge on May 6, 2007, was 6,110 ft³/s (U.S. Geological Survey, 2008). The gage is located on an old abutment of the State Highway 37 bridge, about 300 feet (ft) downstream of the current bridge.

The recurrence interval of the peak discharge at the Medford Avenue bridge was estimated to be 160 years. Recurrence interval is a statistical measure of the likelihood, or probability, a particular flood discharge will be equaled or exceeded once during the stated interval. A flood discharge that is expected to be exceeded on average once during any 100-year period has a 1-percent chance of being exceeded during any particular year. The recurrence interval of the peak discharge in 1957 was estimated to be 380 years. Both recurrence intervals were estimated using regional regression equations (Eash, 2001). The recurrence interval of the 2007 peak discharge at crest-stage gage 06609560 Willow Creek near Soldier, Iowa, was estimated to be 30 years, which was interpolated using Bulletin 17B flood-frequency analyses (Interagency Advisory Committee on Water Data, 1982). The discharges and respective recurrence intervals at both sites are listed in table 1. Two additional crest-stage gage peak discharges and recurrence intervals that were measured in prior years are listed in the table for comparison purposes.

Table 1. Maximum discharges and corresponding recurrence intervals for selected peak flows in the Willow Creek drainage basin, west-central Iowa.

[mi², square miles; ft³/s, cubic feet per second; --, not applicable]

Site	Period of peak-flow record (water years)	Drainage area (mi ²)	Date	Peak stage ¹ (feet)	Peak discharge (ft ³ /s)	Recurrence interval (years)
Crest-stage gaging station, 06609560 Willow Creek near Soldier, Iowa	1966–2007	29.1	07/09/1993	84.66	6,840	² 40
			07/17/1996	83.02	5,660	² 25
			05/06/2007	83.67	6,110	² 30
Miscellaneous discharge measurements, Willow Creek at Medford Avenue near Missouri Valley, Iowa	--	126	06/16/1957	--	20,000	³ 380
			05/06/2007	--	17,000	³ 160

¹ Current gage datum.

² Interpolated using Bulletin 17B flood-frequency analyses (Interagency Advisory Committee on Water Data, 1982), rounded to nearest 5 years.

³ Computed using regional regression equations (Eash, 2001), rounded to nearest 20 years.

Flood Profile

The USGS measured the elevation of high-water marks (HWMs) at 10 locations between the mouth of Willow Creek in Harrison County and State Highway 37 in Monona County to develop a flood profile (fig. 1). The locations include all Federal, State, and County numbered highway bridges, and several local highway bridges. The length of the profile is almost 33 river miles.

HWMs at each location except Medford Avenue were surveyed to bench marks within 6 days of the flood peak. The HWMs at Medford Avenue were flagged within 6 days and surveyed to a bench mark at the time of the indirect discharge measurement. HWMs at the bridges were flagged on both the upstream and downstream sides. The upstream marks were located about one bridge length from the bridge and the downstream marks were located immediately downstream of the bridge. The downstream HWMs at County Road L16 (Panora Avenue) were measured downstream of the flume (described later). Bridge deck, bridge low-chord, and low-flow reference-point elevations also were measured with respect to the bench marks. The reference points were established so that low-flow water-surface elevations could be measured by using a weight suspended on a measuring tape. All elevations were subsequently referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929) by running level lines to the bench marks from other established bench marks or by using global positioning system (GPS) technology. The bench marks and reference points used in this study and a brief discussion regarding the elevation measurement methods are presented in an appendix to this report.

Distances to the HWM locations were measured in river miles from the mouth of Willow Creek at the Boyer River. The distances to half of the locations were determined in a previous study (Eash, 2003). The remaining distances were measured from the existing data by using a geographic information system. The river miles were obtained from USGS 1:24,000-scale topographic-maps (Eash, 2003). The HWM locations and elevations used in the flood profile are listed in table 2.

The HWMs are plotted and referenced to the distance upstream of the mouth of Willow Creek in figure 2. The profile in figure 2 is expanded in figures 3 and 4. The line connecting the marks approximates the high-water surface between the marks. This line does not account for any features between the HWM locations that may have locally affected high-water levels during the flood, such as bridges where HWMs were not measured. The lower line connects the low-flow water-surface elevations that were measured August 22, 2007. The lower line also is an approximation of the water surface between measurement locations. The large step in the profile near river mile 24 (fig. 4) is at the concrete flume at County Road L16 (Panora Avenue). The flume is a stream stabilization structure that lowers the stream bed 24 feet (Golden Hills Resource Conservation and Development, 1994, sec. 3, p. 47).

Only bridges where HWMs were measured are shown in the figures. These bridges are symbolized by an I-beam cross section where the bottom flange represents the lowest elevation of the low chord and the top flange represents the elevation of the bridge deck above the same point.

Table 2. Locations and elevations of high-water marks used in the Willow Creek flood profile, flood of May 6, 2007.

[HWM, high-water mark; NGVD 1929, National Geodetic Vertical Datum of 1929; --, not applicable]

Distance from mouth (river miles)	Site location	Downstream HWM (feet NGVD 1929)	Upstream HWM (feet NGVD 1929)
0.15	Corrugated metal pipe field drain outlet	1,004.84	--
2.35	U.S. Highway 30 (West Erie St.) in Missouri Valley	1,010.85	1,011.03
6.58	County Road F50 (270th St.)	1,026.06	1,026.36
7.11	County Road L20 (Loess Hills Trail)	1,028.05	1,028.63
7.70	County Road F50 (260th St.)	1,030.79	1,033.25
9.03	Medford Avenue; indirect discharge measurement site	1,038.48	1,038.49
13.42	State Highway 127	1,065.71	1,066.10
20.71	County Road F20L (Easton Trail)	1,121.52	1,121.52
23.68	County Road L16 (Panora Ave.) (downstream HWM is downstream of flume)	1,136.57	1,156.43
32.89	Crest-stage gage 06609560 Willow Creek near Soldier, Iowa	1,231.44	--
32.94	State Highway 37	1,233.05	1,235.21

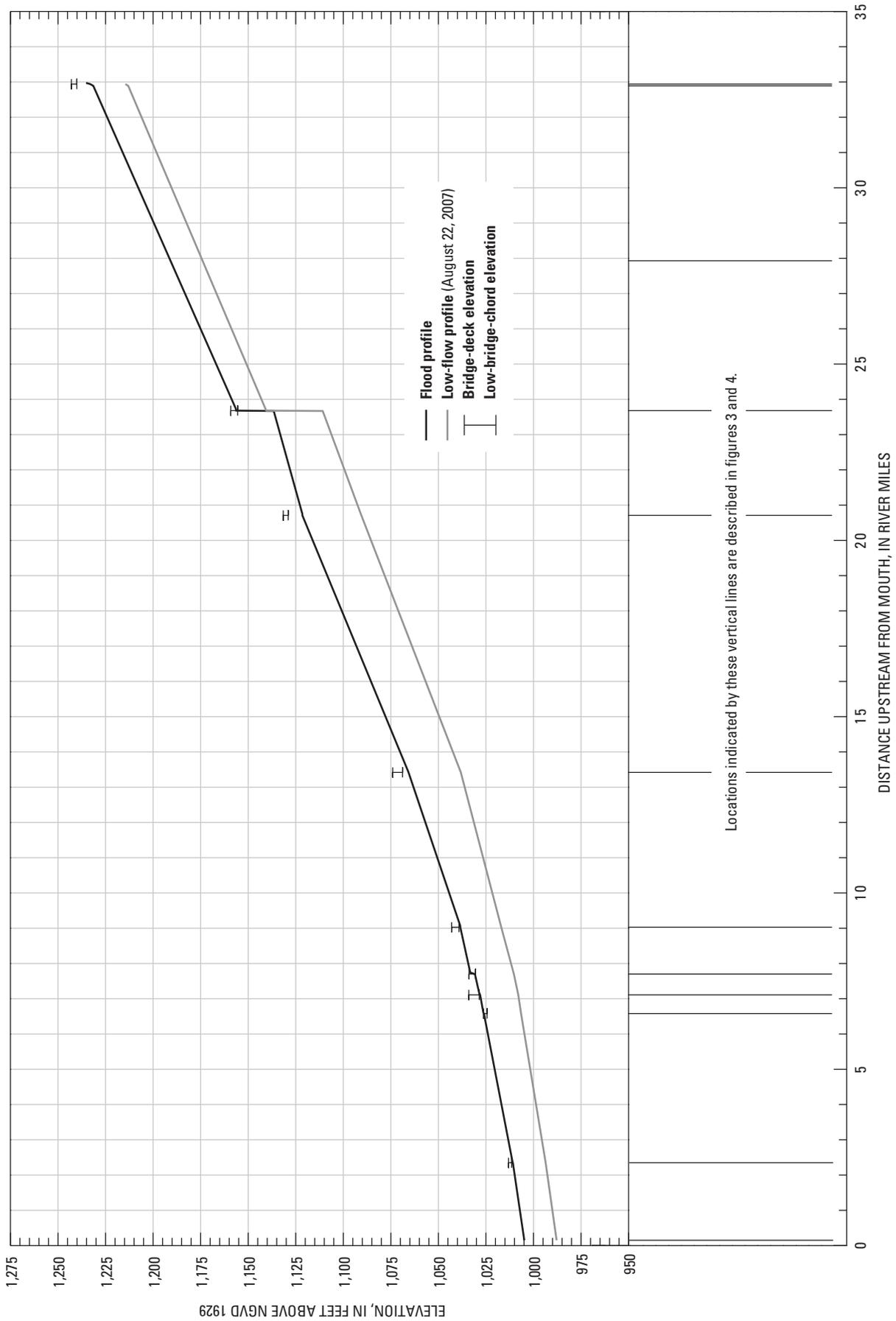


Figure 2. Profile of the May 6, 2007, flood in Willow Creek, river miles 0 to 33.

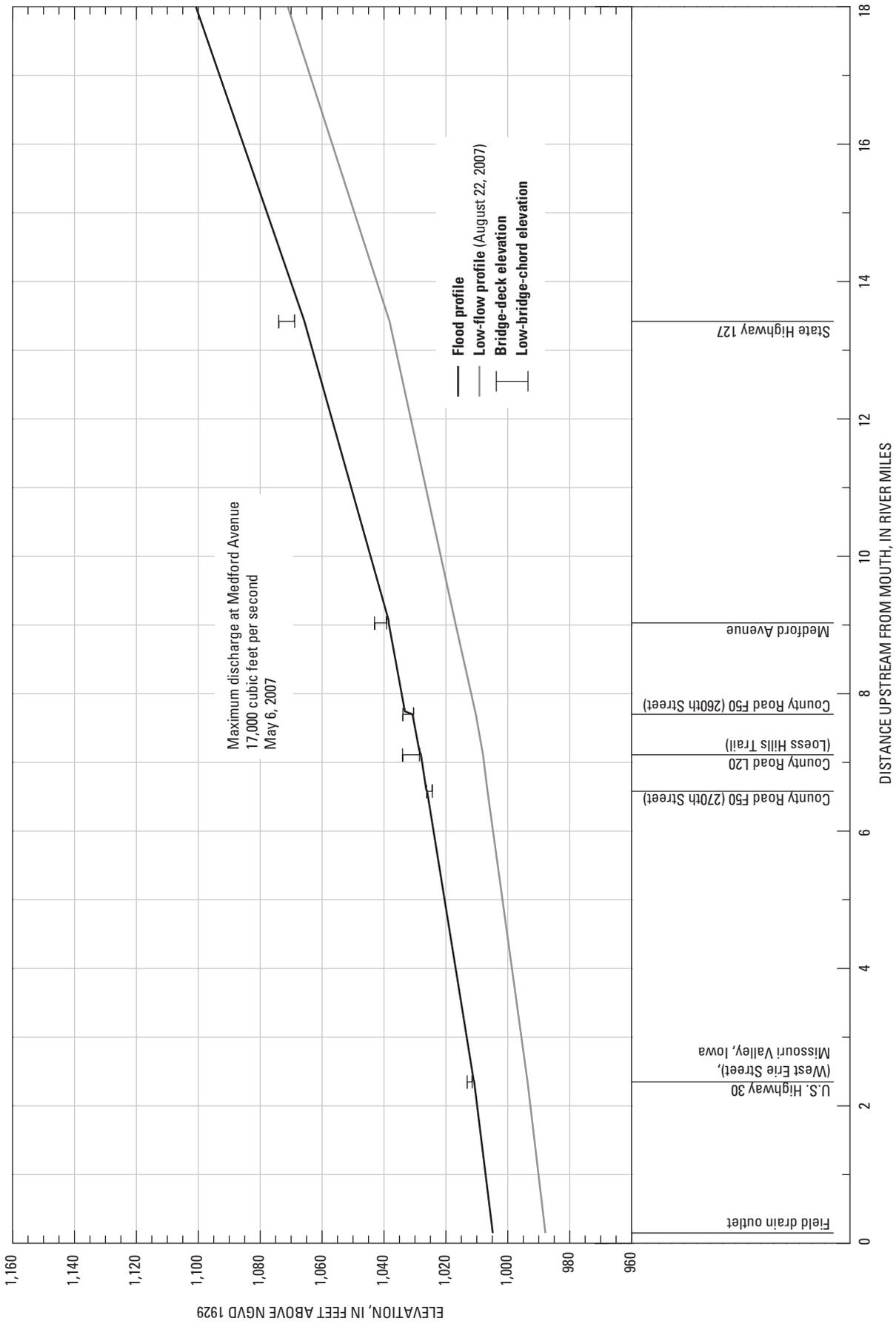


Figure 3. Profile of the May 6, 2007, flood in Willow Creek, river miles 0 to 18.

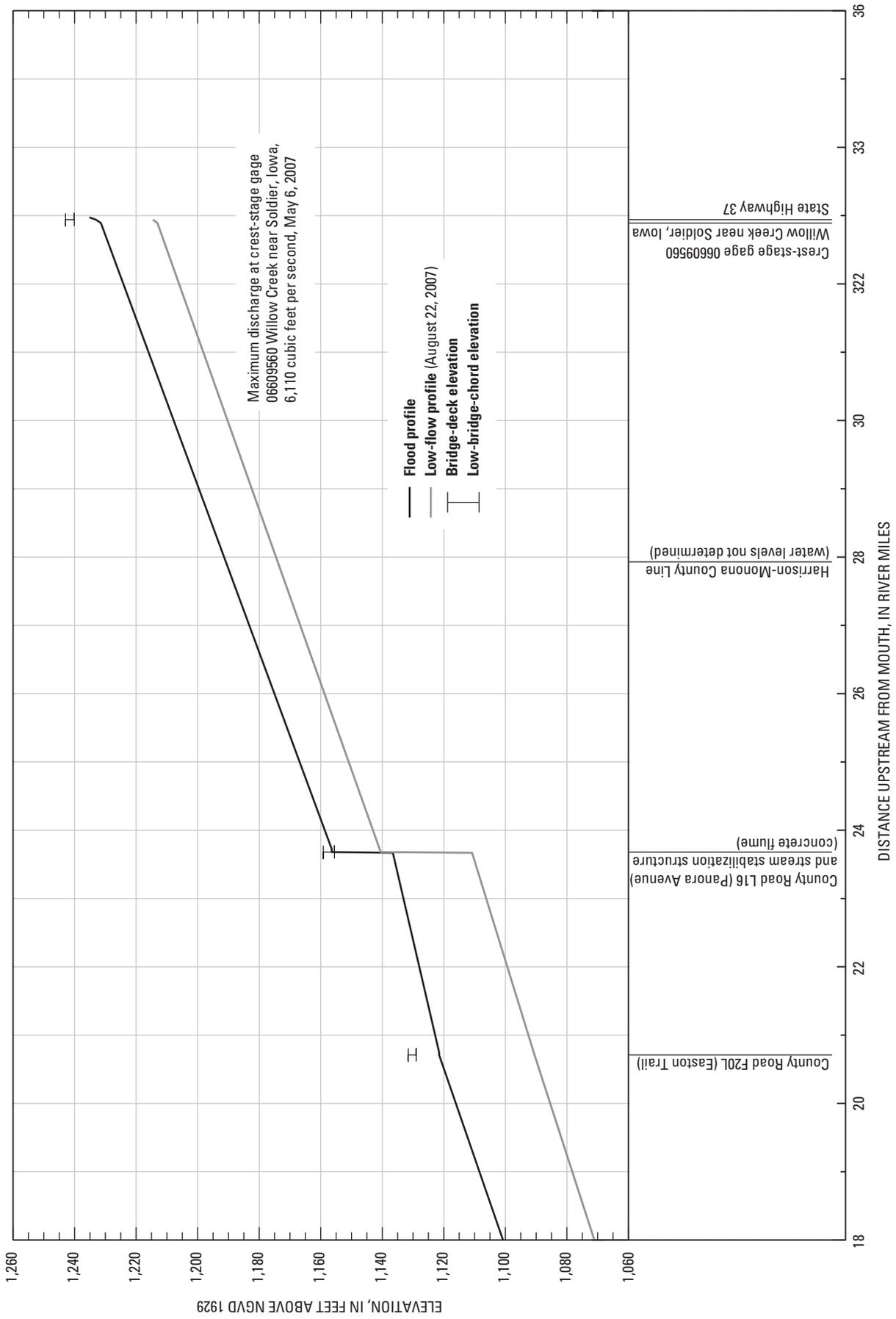


Figure 4. Profile of the May 6, 2007, flood in Willow Creek, river miles 18 to 33.

Summary

Major flooding occurred May 6, 2007, in the Willow Creek drainage basin in Harrison County following severe thunderstorm activity over west-central Iowa. More than 7 inches of rain were recorded by 7 a.m., May 6, for the preceding 72 hours at the Logan, Iowa, weather station. The peak discharge in Willow Creek at Medford Avenue near Missouri Valley, Iowa, was 17,000 ft³/s. The recurrence interval of the flood is 160 years, which was estimated using regional regression equations. The HWMs at 10 locations along Willow Creek were depicted in a flood profile from the mouth of Willow Creek at the Boyer River in Harrison County to State Highway 37 in Monona County. The length of the profile is almost 33 river miles.

U.S. Geological Survey, 2008, Water-resources data for the United States, Water Year 2007: U.S. Geological Survey Water-Data Report WDR-US-2007, site 06609560, accessed April 1, 2008, at <http://wdr.water.usgs.gov/>.

References Cited

- Eash, D.A., 2001, Techniques for estimating flood-frequency discharges for streams in Iowa: U.S. Geological Survey Water-Resources Investigations Report 00-4233, 88 p.
- Eash, D.A., 2003, Main-channel slopes of selected streams in Iowa for estimation of flood-frequency discharges: U.S. Geological Survey Water-Resources Investigations Report 03-4120, 215 p.
- Golden Hills Resource Conservation and Development, 1994, Stream stabilization in western Iowa, final report: Iowa Highway Research Board (Iowa DOT HR-352), 199 p. and appendices.
- Hillaker, H.J., 2007, Iowa climate review, May 2007: Iowa Department of Agriculture and Land Stewardship, Des Moines, Iowa, v. 21, no. 5, 21 p.
- Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: Hydrology Subcommittee Bulletin 17B, 28 p. and appendixes.
- Larimer, O.J., 1957, Drainage areas of Iowa streams: Iowa Highway Research Board Bulletin No. 7 (reprinted 1974), 439 p.
- Prior, J.C., 1991, Landforms of Iowa: Iowa City, Iowa, University of Iowa Press, 154 p.
- Swenson, B.C., 2007, Sunday morning flood-closed Loess Hills Trail becomes emergency route for flood-closed I-29 Sunday afternoon: Missouri Valley Times - News, May 10, 2007, accessed October 19, 2007, at http://www.zwire.com/site/index.cfm?newsid=18327096&BRD=326&PAG=461&dept_id=449012&rfti=8.

Appendix

Appendix. List of bench marks and reference points

The USGS used the bench marks and reference points listed here to facilitate measuring the elevations of HWMs, low-flow water surfaces, bridge decks, and bridge low-chords. Temporary bench marks were established at sites where an existing bench mark was not available. The reference points were established to facilitate measuring low-flow water-surface elevations. The reference points at the bridges shown in the profile were on the downstream side of each bridge above water.

The bench marks and measured HWMs are listed in upstream order. Each bench mark is identified by an index number composed of the Public Land Survey System township, range, section number, and quarter-section for each bench mark location. For example, 7844-28 SE means “township 78 north, range 44 west, section 28, southeast quarter-section.” Where two or more bench marks/reference points are in the same location, the bench marks/reference points are distinguished by a sequence number in parentheses. “Right” and “left” in the descriptions refer to the side of the river determined as an observer looks downstream. Users are cautioned that the bench marks and reference points used for this flood profile might be altered or destroyed since being used in 2007.

Level lines were run from first- or second-order bench marks established by the National Geodetic Survey or USGS to establish the third-order accuracy elevations of two of the bench marks. GPS technology was used to measure the elevations of the remaining bench marks. GPS data were collected by the USGS and submitted for processing to OPUS (Online Positioning User Service), an Internet service provided by the National Geodetic Survey (<http://www.ngs.noaa.gov/OPUS/>). The solution statistics of the GPS data were within the guidelines of “What to look for in a quality solution” (http://www.ngs.noaa.gov/OPUS/Using_OPUS.html, accessed April 15, 2008).

Elevations are referenced to NGVD 1929 (BM, bench mark; TBM, temporary bench mark; RP, reference point).

7844-28 SE — (TBM) About 2 miles south of U.S. Highway 30 bridge and about 0.15 miles upstream from the mouth of Willow Creek at the Boyer River, on the top of a corrugated metal pipe field-drain outlet on the right bank, on first corrugation nearest opening: 3 file marks. Elevation determined by using GPS.

Elevation 992.95 ft

7844-16 SE (1) — (BM) At Missouri Valley, on U.S. Highway 30 bridge, on right downstream wingwall: Iowa DOT bench mark. Elevation determined from National Geodetic Survey BM stamped “F136 1948.”

Elevation 1,016.50 ft

7844-16 SE (2) — (RP) At Missouri Valley, on U.S. Highway 30 bridge, on downstream side, on top of 8th metal guardrail post from left side of bridge: 3 file marks. Elevation determined from National Geodetic Survey BM stamped “F136 1948.”

Elevation 1,016.63 ft

7943-31 NW (1) — (TBM) About 4 miles north of Missouri Valley, on County Road F50 (270th St.) bridge, on left downstream concrete wingwall: head of lag bolt set in the concrete. Elevation determined by using GPS.

Elevation 1,028.90 ft

7943-31 NW (2) — (RP) About 4 miles north of Missouri Valley, on County Road F50 (270th St.) bridge, on downstream side of bridge, on top of 9th barrier-wall segment from right side of bridge: chiseled square. Elevation determined by using GPS.

Elevation 1,028.62 ft

7943-30 C (1) — (BM) About 4.5 miles north of Missouri Valley, on County Road L20 (Loess Hills Trail) bridge, on left upstream wingwall: Iowa DOT bench mark. Elevation determined by using GPS.

Elevation 1,036.88 ft

7943-30 C (2) — (RP) About 4.5 miles north of Missouri Valley, on County Road L20 (Loess Hills Trail) bridge, on downstream side, on top of concrete barrier wall at third drain hole from left end of bridge: chiseled square. Elevation determined by using GPS.

Elevation 1,037.81 ft

7943-30 NE (1) — (TBM) About 5 miles north of Missouri Valley, about 0.5 miles east of County Road L20, on County Road F50 (260th St.) bridge, on corner of right downstream wingwall: chiseled X. Elevation determined by using GPS.

Elevation 1,034.82 ft

7943-30 NE (2) — (RP) About 5 miles north of Missouri Valley, about 0.5 miles east of County Road L20, on County Road F50 (260th St.) bridge, on downstream side of bridge on metal guard rail to the right of 18th vertical guard rail support from right end of bridge: 3 file marks. Elevation determined by using GPS.

Elevation 1,036.58 ft

7943-20 SE (1) — (TBM) About 4 miles west of Logan, on the Medford Avenue truss bridge, on right upstream truss, top of bolt that is about 3 ft below the level of the bridge deck: filed X. Elevation determined by using GPS.

Elevation 1,041.63 ft

7943-20 SE (2) — (RP) About 4 miles west of Logan, on the Medford Avenue truss bridge, downstream side of bridge, first deck plank right of first vertical truss member from left end of bridge: top of plank (no mark). Elevation determined by using GPS.

Elevation 1,042.92 ft

7943-03 NW (1) — (BM) About 1.5 miles east of Magnolia, on State Highway 127 bridge, on left upstream wingwall: Iowa DOT bench mark. Elevation determined by using GPS.

Elevation 1,076.66 ft

7943-03 NW (2) — (RP) About 1.5 miles east of Magnolia, on State Highway 127 bridge, on downstream side of bridge on concrete barrier wall 8 ft right of second drain hole from right end of bridge: chiseled square. Elevation determined by using GPS.

Elevation 1,076.74 ft

8042-06 SE (1) — (BM) About 5 miles northwest of Woodbine, on County Road F20L (Easton Trail) bridge, on downstream side of bridge at center of bridge on concrete curb: standard USGS BM inscribed "7 RB 1971."

Elevation 1,132.47 ft

8042-06 SE (2) — (RP) About 5 miles northwest of Woodbine, on County Road F20L (Easton Trail) bridge, on downstream side of bridge on metal guard rail just left of 14th vertical guard rail support from right end of bridge: 3 file marks. Elevation determined from USGS BM inscribed "7 RB 1971."

Elevation 1,134.30 ft

8142-20 SE (1) — (TBM) About 7 miles northwest of Woodbine, site of concrete flume, on County Road L16 (Panora Avenue) bridge, on left upstream wingwall: chiseled square. Elevation determined by using GPS.

Elevation 1,159.83 ft

8142-20 SE (2) — (RP) About 7 miles northwest of Woodbine, site of concrete flume, on County Road L16 (Panora Avenue) bridge, on downstream side of bridge, 6th railing support from left end of bridge: filed arrow. Elevation determined by using GPS.

Elevation 1,161.50 ft

8142-20 SE (3) — (RP) About 7 miles northwest of Woodbine, on concrete flume at County Road L16 (Panora Avenue) bridge, on left side at bottom of flume, on horizontal metal railing 4 ft from joint with slope railing: 3 file marks. Elevation determined by using GPS.

Elevation 1,115.64 ft

8242-11 S (1) — (BM) About 6 miles southeast of Soldier, site of crest-stage gage 06609560 Willow Creek near Soldier, Iowa, on State Highway 37 bridge, on left upstream wingwall: Iowa DOT bench mark. Elevation determined by using GPS.

Elevation 1,244.22 ft

8242-11 S (2) — (RP) About 6 miles southeast of Soldier, site of crest-stage gage 06609560 Willow Creek near Soldier, Iowa, on State Highway 37 bridge, on downstream side of bridge, on curb 90 ft from left end of bridge: chiseled square. Elevation determined by using GPS.

Elevation 1,243.92 ft

8242-11 S (3) — (RP) About 6 miles southeast of Soldier, site of crest-stage gage 06609560 Willow Creek near Soldier, Iowa, about 300 ft south of State Highway 37 bridge, on right bank, on old concrete abutment: top of rebar. Elevation determined by using GPS.

Elevation 1,228.02 ft

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