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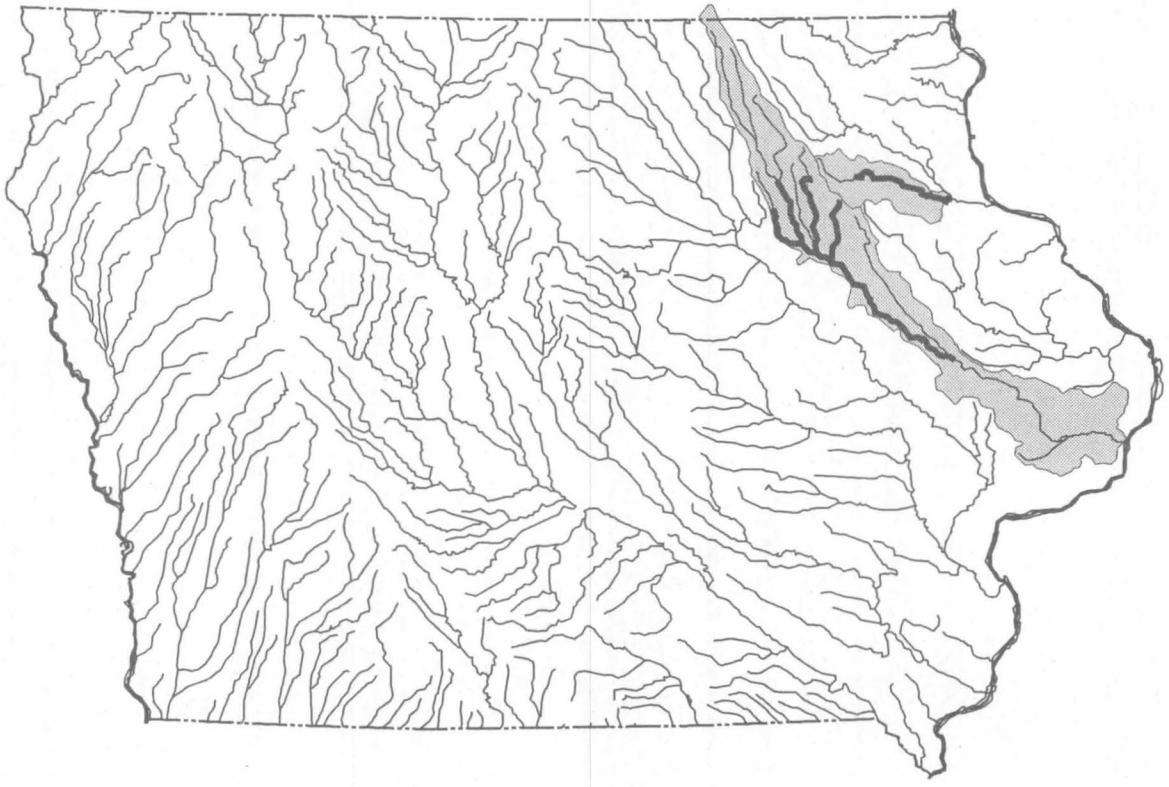
(Project HR-140)

Floods of May 17-20, 1999, in the Volga and Wapsipinicon River Basins, Northeast Iowa

Open-File Report 00-237



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FLOODS OF MAY 17-20, 1999, IN THE VOLGA AND WAPSIPINICON RIVER BASINS, NORTHEAST IOWA

by Jan L. Ballew and Edward E. Fischer

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1920.

Floods of May 17-20, 1999, in the Volga and Wapsipinicon River Basins, Northeast Iowa

by **Jan L. Ballew and Edward E. Fischer**

ABSTRACT

Record flooding occurred May 17-20, 1999, in the Volga and Wapsipinicon River Basins following thunderstorm activity over northeast Iowa. On Sunday, May 16, between 6 and 8 inches of rain fell during a 24-hour period over portions of Bremer, Butler, and Fayette Counties. Highest rainfall during this 24-hour period was 8.3 inches recorded north of Oelwein in southwest Fayette County. A peak discharge of 29,800 cubic feet per second in the Volga River at Mederville, 53,900 cubic feet per second in the Turkey River at Garber, and 31,100 cubic feet per second in the Wapsipinicon River at Independence set new peak discharge records. The peak discharge at Garber was greater than a theoretical 500-year flood, and the peak discharge at Independence was the equivalent of a 90-year flood. Information about the basins, rain storms, flooding, and a profile of high water marks are presented for selected intervals along the Volga River, Wapsipinicon River, Crane Creek, Little Wapsipinicon River, and Otter Creek.

INTRODUCTION

Thunderstorms caused major flooding on the Volga River, Wapsipinicon River, Crane Creek, Little Wapsipinicon River, and Otter Creek in northeast Iowa in May 1999. New maximum peak discharge records were set at streamflow-gaging stations in the Turkey and Wapsipinicon River Basins. Flooding occurred in several cities and left many homes and businesses damaged. Many highways were closed and numerous bridges were damaged or destroyed. The storms also caused flooding in other river basins in northeast Iowa.

The total economic damage in the Volga and Wapsipinicon River Basins due to flooding has not been completely evaluated. As of early March 2000, the Federal Emergency Management Agency approved more than $12 million of assistance to schools, businesses, and private non-profit businesses for road and bridge repair, demolition of homes or businesses declared hazardous, and essential utilities to recover from the damage. This amount does not include several uncompleted large projects that will be paid at cost, agricultural losses, losses sustained from loss of commerce, or unemployment (Jerry Ostendorf, Iowa Emergency Management Division, oral commun., March 2, 2000). The amount authorized for buyout assistance of 102 private homes in the Volga River Basin as of the middle of February 2000 is more than $4.5 million. The amount authorized for 111 homes in the Wapsipinicon River Basin is just over $6 million (Dennis Harper, Hazard Mitigation, Iowa Emergency Management Division, written commun., March 3, 2000). In the agricultural sector, many farmers were able to replant flooded areas because the flooding occurred early in the planting season. The greatest loss to agriculture was erosion of topsoil. The timing of the storm was such that there was no crop canopy to intercept the rainfall. Scour erosion, particularly in the Volga River flood plain, also was severe, leaving some scour holes 6 feet deep and 50 feet wide (Jerry Muff, District Conservationist, Natural Resources Conservation Service, oral commun., February 29, 1999).

This report provides information about the May 1999 rainstorm and ensuing floods in the Volga and Wapsipinicon River Basins. The report also provides information about the flooding in the Turkey River Basin near the mouth of the Volga River. High water marks at selected points along the Volga River, Wapsipinicon River, Crane Creek, Little Wapsipinicon River, and Otter Creek are presented in flood profiles. The Volga River is profiled from County Road X3C near Elkport to State Highway 93 at Fayette. The

Wapsipinicon River is profiled from U.S. Highway 151 near Anamosa to State Highway 93 near Tripoli. Crane Creek is profiled from State Highway 281 at Dunkerton to State Highway 3 near Readlyn. The Little Wapsipinicon River is profiled from Clayton Boulevard at Littleton to State Highway 93 near Sumner. Otter Creek is profiled from County Road D16 at Otterville to State Highway 3 near Oelwein. Flood profiles and low-flow profiles from previous years also are shown.

This report was prepared in cooperation with the Project Development Division of the Iowa Department of Transportation (Iowa DOT) and the Iowa Highway Research Board. Various Federal, State, and local agencies provide funding for the operation and maintenance of the streamflow-gaging stations in the Volga and Wapsipinicon River Basins. They are acknowledged in the annual water resources data reports of the U.S. Geological Survey (USGS) (Nalley and others, 2000). A list of other Iowa flood-profile reports published by the USGS can be obtained from the World Wide Web at URL (uniform resource locator) `http://ia.water.usgs.gov/projects/profiles/`.

Acknowledgments

The authors express their gratitude to Mike McClain, Jones County Engineer's Office; Bob Cummins, Linn County Engineer's Office; and Brian Keierleber, Buchanan County Engineer's Office for providing additional high water marks or information to establish sea level elevation for many of the bridges.

RIVER BASINS

The Volga River Basin, which is a subbasin of the Turkey River Basin, originates in northwest Fayette County and is oriented in a general northwest-southeast direction (fig. 1). The Volga River has a drainage area of about 403 square miles (Larimer, 1957, p. 101) and extends about 79 miles to the mouth. Land use in the basin is primarily agricultural with some timber operations. The topography of the Volga River Basin varies from east to west. The eastern part of the basin is similar to topography in extreme northeastern Iowa where bedrock is more important in determining surface features than in any other part of the State (Iowa Natural Resources Council, 1958, p. 8). The western part is characterized by a broad, flat to gently rolling till plain (U.S. Department of Agriculture, Soil Conservation Service, 1986, p. A1). Eastward, the valleys of the Volga River deepen and at the town of Mederville, the Volga River flows into a gorge 100 feet wide and more than 300 feet deep (Iowa Natural Resources Council, 1958, p. 8).

The Wapsipinicon River Basin is a long narrow basin oriented diagonally across the northeastern part of Iowa. The river originates in southeastern Minnesota and flows 225 miles to its mouth at the Mississippi River. The total drainage area is about 2,540 square miles, of which all but 10 square miles are in Iowa (Larimer, 1957, p. 106). Tributaries of the Wapsipinicon River profiled in this report include Crane Creek, Little Wapsipinicon River, and Otter Creek. Land use in the basin is primarily agricultural. The topography in the basin ranges from being relatively flat in the upper part of the basin, often characterized as a typical drift prairie stream, to gently rolling in the lower part. The lower part of the basin exhibits more relief but in only a few places does it have the rugged, high-relief form found in other streams in northeastern Iowa. At Troy Mills, the river follows a canyon 200-300 feet deep (Iowa Natural Resources Council, 1958, p. 8).

Streamflow in both the Volga and Wapsipinicon drainage basins ranges from well-defined and established streams with low gradients in the upper reaches to streams with higher gradients in the lower reaches. In the lower reaches, bedrock strongly controls the course of rivers and streams (Iowa Natural Resources Council, 1958, p. 8).

STORM DESCRIPTION

A large complex of thunderstorms moved over the northern half of Iowa May 16 and 17, 1999, and caused flooding in northeastern Iowa. One line of thunderstorms developed north to south across western Iowa and moved west. The second line developed east to west from Butler to Clayton Counties and moved east. Repeated development of thunderstorms in the second line resulted in extremely heavy rainfall across the Volga and Wapsipinicon River Basins. Twenty-four-hour rainfall amounts in excess of 4 inches were common over portions of Black Hawk, Bremer, Buchanan, Butler, Clayton, Delaware, Dubuque, and Fayette Counties (fig. 1). Rainfall in the Volga and Wapsipinicon Basins exceeding 6 inches for the 24-hour period was limited to southeast Bremer and

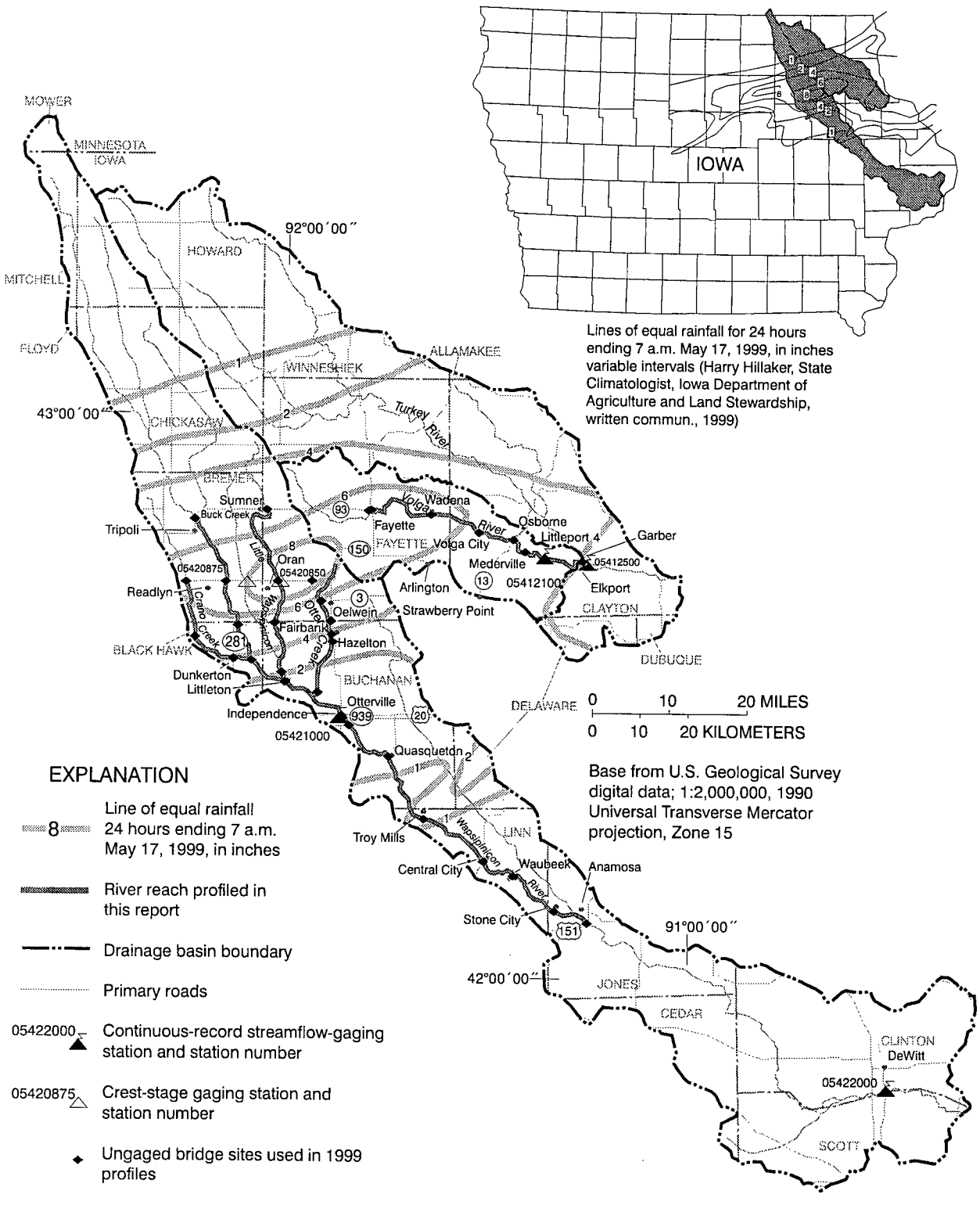

Figure 1.--Volga and Wapsipinicon River Basins and lines of equal rainfall for 24 hours ending at 7:00 a.m., May 17, 1999.

southwest Fayette Counties. The following storm summary is excerpted from the May 1999 Daily Storm Data and Unusual Weather Phenomena bulletins provided by National Weather Service meteorologists Jeff Zogg and Brad Small. The summaries will be published in *Storm Data* by the National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

(5-16-1999) A very active weather pattern was in place over the central U.S. A cold front had become stationary west of Iowa and had held there for two days prior. A strong upper level jet stream was in place with Iowa falling into the rear entrance region of the speed maximum. While the cold front was off to the west of Iowa, a warm front was located to the south of the state. This set the stage for an over running precipitation event. A low level jet stream developed during the early morning hours of the 16th with very moist air flowing over the top of the warm front to the south. Surface dew points south of the front were in the low to mid 70s. The air flowing over the front at the 850 mb level had dew point values around + 15 degrees C. During the predawn hours, a mesoscale convection system developed to the west of Iowa and moved east into the western part of the state. The system weakened after dumping hail over northwest Iowa, then began to intensify again during the later morning hours. Strong warm air advection continued throughout the day. This continued to feed the thunderstorms well into the afternoon. As the thunderstorms moved across the north half of Iowa, they dropped very heavy rainfall. Though the ground was able to absorb the rain initially, it did set the stage for flooding later in the day.

(5-17-1999) Heavy rainfall once again began falling over northeast Iowa during the morning hours. Rainfall occurred at the rate of an inch or more per hour. The soils over the area were already totally saturated by the heavy rainfall of the previous evening. As a result flash flooding took place easily. The additional damage was not major as the rain served only to exacerbate the flooding situation already taking place.

Rainfall amounts reported by the National Weather Service (Welvaert, March 2, 2000) and by Iowa Climatological Data (National Oceanic and Atmospheric Administration, v. 110, no. 5) at six locations are:

24-hour rainfall for May 16-17, 1999 (in inches)

Fayette	6.30	Tripoli	5.74
Strawberry Point	5.48	Oelwein	8.30
Garber	3.67	Independence	1.24

FLOOD DESCRIPTION

As a result of the intense storms, the Volga River was at or above flood stage from Fayette to the mouth near Garber. Two peaks were reported during the flood. A stage of 24.50 feet was reported at 6:00 a.m., May 17, at Volga City, and a second or "relative peak" was observed by two National Weather Service meteorologists and local residents at 2:00 p.m. The residents reported the second peak to be "at least 2 feet higher than the flood of 1947" and the meteorologists agreed that it appeared to be slightly higher than the first peak. Water-surface profiles are not available for the flood of June 1947; however, damage caused by the flood was extensive throughout the entire basin (Iowa Natural Resources Council, 1958, p. 72).

Two peak flood stages also were observed May 17th at the State Highway 13 Volga River bridge at Osborne. From high water marks, the stage of the first crest observed between 8:00 and 9:00 a.m. was estimated to be 23.77 feet. At 12:20 p.m., Iowa DOT workers used the wire-weight gage on the bridge to measure a stage of 21.77 feet. The second peak stage of about 24.20 feet occurred at 4:00 p.m. At 5:20 p.m., the workers reported a stage of 23.82 feet (Rod Swerman, National Weather Service, written commun., March 2000). Peak discharge of the Volga River at Mederville was determined to be 29,800 cubic feet per second and peak stage was 730.6 feet (table 1). The streamflow-gaging station at Littleport was not installed until September 1999; based on the discharge measurement at Mederville, however, the peak discharge at Littleport was estimated to be about 30,000 cubic feet per second on May 17 at a peak stage of 25.36 feet (table 1).

Table 1. *Maximum stages and discharges for 1999 and selected additional years, and the corresponding recurrence intervals at selected sites in the Volga, Turkey, and Wapsipinicon River Basins, Iowa*

[**boldfaced type**, flood profile included in this report. mi^2, square miles; ft^3/s, cubic feet per second; >, greater than; --, not determined]

Location (fig. 1)	Period of flood record (water years)	Drainage area (mi^2)	Date	Peak stage[1] (feet)	Peak discharge (ft^3/s)	Recurrence interval[2] (years)
			Volga River Basin			
Misc. measurement at ungaged bridge site Volga River at Mederville	**1999**	**339**	**5/17/1999**	**730.6[3]**	**29,800[4]**	**--**
Streamflow-gaging station 05412400 Volga River at Littleport	**1999**	**348**	**5/17/1999**	**25.36[5]**	**30,000[6]**	**--**
			Turkey River Basin			
Streamflow-gaging station 05412500 Turkey River at Garber	1902, 1914-16, 1919-27, 1929-30, 1933-99	1,545	2/23/1922	28.06[e,7]	32,300	30
			6/15/1991	30.10[e]	49,900[d]	375
			5/17/1999	30.91	53,900	>500
			Wapsipinicon River Basin			
Crest-stage gage 05420850 Little Wapsipinicon River near Oran	1966-99	94.1	8/30/1979	91.81	5,000	20
			8/25/1990	91.78	5,040	20
			5/17/1999	**94.15**	**12,800[d]**	**425**
Crest-stage gage 05420875 Buck Creek near Oran	1966-99	37.9	7/29/1979	90.06	1,500	--
			6/15/1991	90.18	1,720	--
			5/17/1999	91.02	--	--
Streamflow-gaging station 05421000 Wapsipinicon River at Independence	1934-99	1,048	**7/18/1968**	**21.11**	**26,800**	**50**
			8/26/1990	20.30	24,400	35
			5/18/1999	**22.35**	**31,100**	**90**
Streamflow-gaging station 05422000 Wapsipinicon River near De Witt	1935-99	2,330	5/17/1974	13.07	29,900	40
			6/17/1990	14.19	31,100	45
			5/24/1999	13.66	25,200	19

[1]All values at current datums except as noted.

[2]Interpolated from Bulletin 17B flood-frequency analysis (Interagency Advisory Committee on Water Data, 1982) and rounded to nearest 5 years for 20- to 50-year recurrence intervals, nearest 10 years for 50- to 100-year recurrence intervals, and to nearest 25 years for 200- to 500-year recurrence intervals.

[3]Elevation above sea level.

[4]Discharge computed from indirect measurement.

[5]Gage height determined by floodmark.

[6]Based on indirect measurement of discharge at Mederville.

[7]Maximum gage height known since 1890.

Approximately 1.2 miles downstream from the mouth of the Volga River, a record peak discharge of 53,900 cubic feet per second, stage 30.91 feet, was recorded for the Turkey River at Garber gage on May 17 at 11:00 a.m. The recurrence interval of this peak was greater than 500 years (table 1).

The Wapsipinicon River was at high flood stage from north of Tripoli to Anamosa with moderate flooding downstream from Anamosa to the mouth. Streamflow-gaging station 05421000 Wapsipinicon River at Independence was at or above flood stage from 10:00 a.m., May 17, to 4:00 p.m., May 20. A record peak discharge of 31,100 cubic feet per second, stage 22.35 feet, was recorded May 18 at 6:00 a.m. (table 1) (Jeff Zogg, National Weather Service, written commun., March 2000). At Anamosa, the Wapsipinicon River was at or above flood stage from May 19 at 12:00 a.m. to May 23 at 5:00 p.m., with a

record crest of 16.00 feet on May 20 at 4:00 p.m. (Jeff Zogg, written commun., March 2000). Streamflow-gaging station 05422000 Wapsipinicon River near De Witt was at or above flood stage from May 17 at 6:00 p.m. until June 2 at 10:00 a.m., with the second highest crest on record of 13.66 feet recorded at 1:00 a.m. on May 24 (table 1) (Jeff Zogg, written commun., March 2000). Additionally, two crest-stage gages upstream from Independence recorded measurements. Crest-stage gage 05420850 Little Wapsipinicon River near Oran recorded a peak stage of 94.15 feet (2.34 feet higher than the previous record stage), with a calculated peak discharge of 12,800 cubic feet per second and recurrence interval of 425 years (table 1). Crest-stage gage 05420875 Buck Creek near Oran recorded a new maximum stage of 91.02 feet; discharge was not determined (table 1).

PROFILES FOR THE FLOODS OF MAY 17-20, 1999, IN THE VOLGA AND WAPSIPINICON RIVER BASINS

To develop flood profiles, the USGS measured the elevations of high water marks (HWMs) at selected points along the Volga River, Wapsipinicon River, Crane Creek, Little Wapsipinicon River, and Otter Creek. Most of the marks were measured at Federal and State highway bridges and at USGS streamflow-gaging stations; HWMs at several county road bridges also were measured so marks would be no more than 10 miles apart. HWMs were measured at the upstream and downstream side of each bridge. The HWMs for the Volga and Wapsipinicon Basins are listed in tables 2-6 and are profiled and expanded in figures 2-20 (following references). The line connecting the marks is a linear interpolation and therefore only approximates the maximum flood stage between marks; it does not depict the effects on the profile caused by intermediate bridges or geomorphic (channel) features.

For comparison purposes, previously profiled floods are included with the May 1999 profiles where they are available. The Volga River profile includes profiles of floods from 1979 and 1991 (Eash and Koppensteiner, 1996). The Wapsipinicon River profile includes profiles from 1968 and 1969, the Crane Creek profile includes the profile from a 1968 flood (Schwob, 1971), and the Little Wapsipinicon River profile includes profiles of floods from 1966 and 1968. Otter Creek had not previously been profiled. Low-flow profiles also are shown for each river.

The HWMs included from previous floods are not always at the same locations used for the May 1999 profile. When a location has not been used in all years profiled, this is noted in the figure explanation describing the location of the corresponding HWM. Low-flow information collected from a location other than that used to collect HWMs in 1999 is noted in the figure explanation; however, low-flow elevations used in previous profiles collected at locations not used in 1999 are not noted but generally correspond to the location where the high water marks from previous floods were collected.

The Volga River profile shows that the May 1999 flood stages were greater throughout the entire reach than either the 1979 or 1991 flood stages (figs. 2-6). For example, the HWM elevation measured at the State Highway 13 bridge near Osborne following the 1991 flood was 747.22 feet (Eash and Koppensteiner, 1996), whereas the 1999 flood HWM elevation was 754.28 feet, just over 7 feet higher (table 2).

The Wapsipinicon River flood profile shows that flood stages from Anamosa to Stone City were greater in 1999 than in 1968 (fig. 8). For example, south of Anamosa at river mile 86.74 at Shaw Road bridge (320 feet downstream from the new bridge on U.S. Highway 151), the measured HWM elevation in 1968 was 777.90 feet (Schwob, 1971). At river mile 86.80 at the U.S. Highway 151 bridge, the HWM elevation in 1999 was 793.38 feet (table 3), a difference of more than 15 feet. From Stone City to Readlyn, however, flood stages in 1999 and 1968 are similar; 1999 HWM elevations are generally 1 to 1.5 feet higher than 1968 HWMs (figs. 8-12). At Independence, the USGS streamflow-gaging station recorded a peak discharge of 31,100 cubic feet per second or 4,300 cubic feet per second greater that the previous record of 26,800 feet per second set in 1968. The peak stage was recorded at 22.35 feet and was 1.24 feet higher than the previous record of 21.11 feet established in 1968 (table 1). The 1968 Wapsipinicon River profile was not extended upstream from Readlyn; however, a 1969 flood profiled from Fairbank to Tripoli is compared with the 1999 flood profile (figs. 12 and 13). The flood stages for the 1969 flood are greater than the flood of 1999. At State Highway 281 near Fairbank, the HWM elevation for the 1969 flood was 949.67 feet (Schwob, 1971) and the 1999 HWM elevation was 947.44 feet (table 3), a difference of 2.23 feet.

On Crane Creek, the profile shows that the 1968 and 1999 events resulted in similar flood stages as far north as Dunkerton. Northeast of Dunkerton and to the east of Readlyn the HWM elevations for May 1999 are generally 1 to 1.5 feet higher than the 1968 HWM elevations measured at the same locations (figs. 14-16; table 4).

The Little Wapsipinicon profile shows that the May 1999 flood stages were greater than either 1968 or 1966 flood stages (figs. 17-19). At State Highway 3 near Oran, the HWM elevation for 1999 was 997.30 feet (table 5) and the HWM elevation measured for 1968 was 993.10 feet (Schwob, 1971), a difference of more than 4 feet.

Otter Creek had not been profiled before the May 1999 event (fig. 20; table 6).

SUMMARY

Record flooding occurred May 17-20, 1999, in the Volga and Wapsipinicon River Basins following thunderstorm activity over northeast Iowa. On May 16-17, rainfall ranged from 6 to 8 inches over parts of Bremer and Fayette Counties. North of Oelwein, in southwest Fayette County, 8.3 inches of rain was recorded. Peak discharges recorded or calculated indirectly set new records. In the Volga River at the new gage at Littleport, peak discharge was estimated to be about 30,000 cubic feet per second and the peak stage was 25.36 feet. In the Wapsipinicon River at Independence, a new peak discharge of 31,100 cubic feet per second and a peak stage of 22.35 feet were recorded. The calculated recurrence interval is 90 years. The crest-stage gaging station on the Little Wapsipinicon River at Oran recorded a peak stage of 94.15 feet. The calculated peak discharge of 12,800 cubic feet per second has a theoretical recurrence interval of 425 years.

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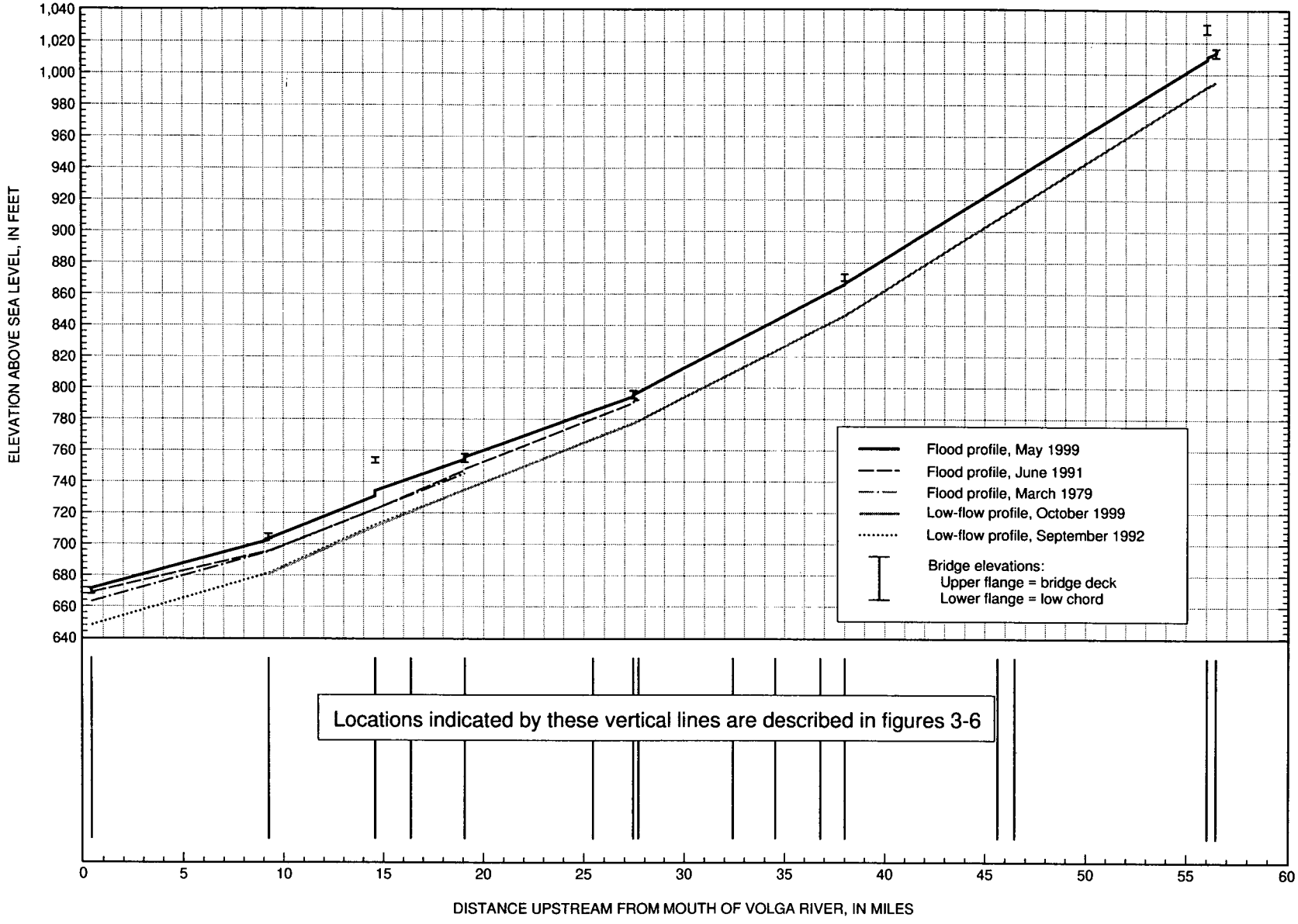

Figure 2.--Profile of the May 1999 flood in the Volga River, river miles 0 to 57.

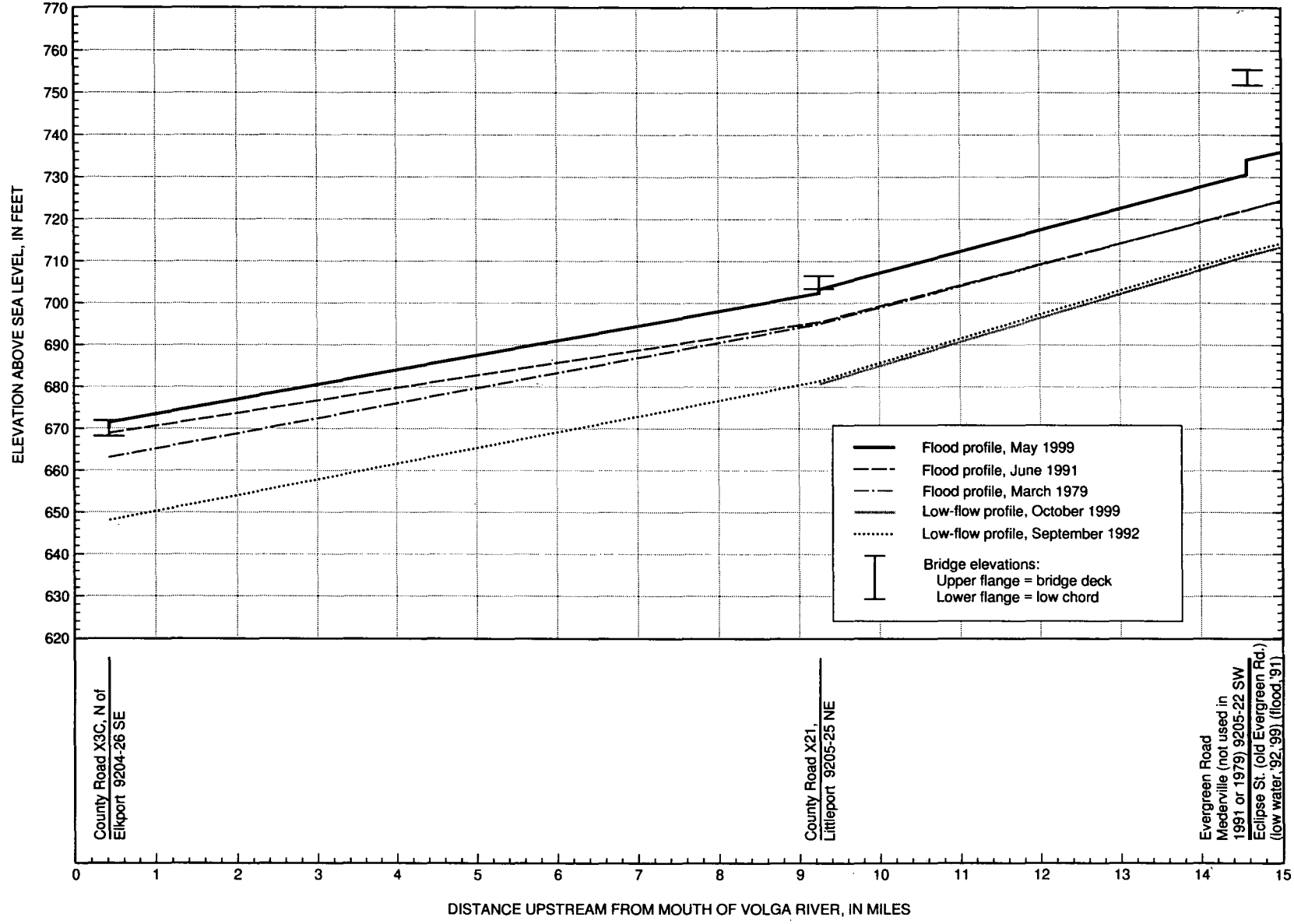

Figure 3.--Profile of the May 1999 flood in the Volga River, river miles 0 to 15.

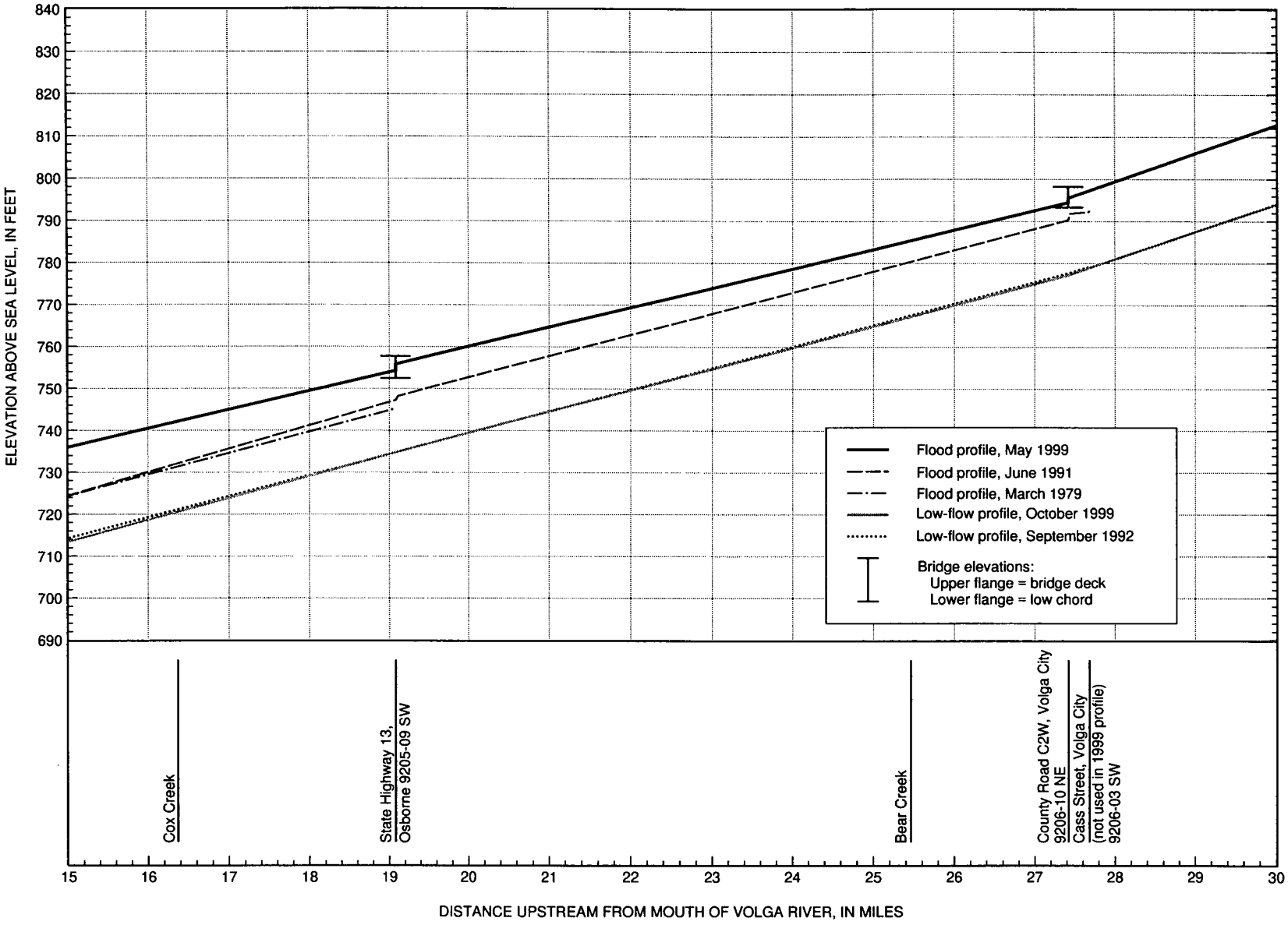

Figure 4.--Profile of the May 1999 flood in the Volga River, river miles 15 to 30.

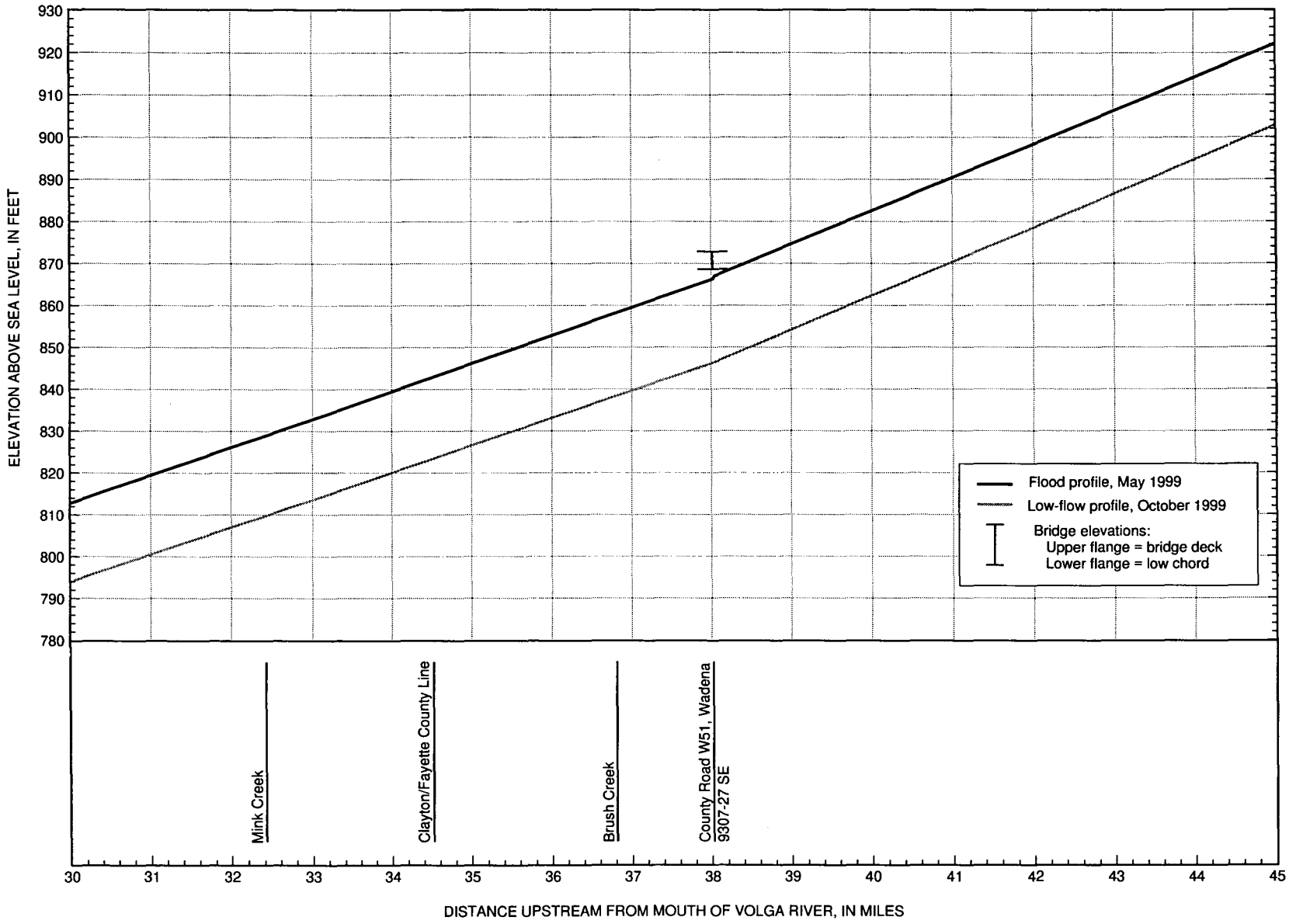

Figure 5.--Profile of the May 1999 flood in the Volga River, river miles 30 to 45.

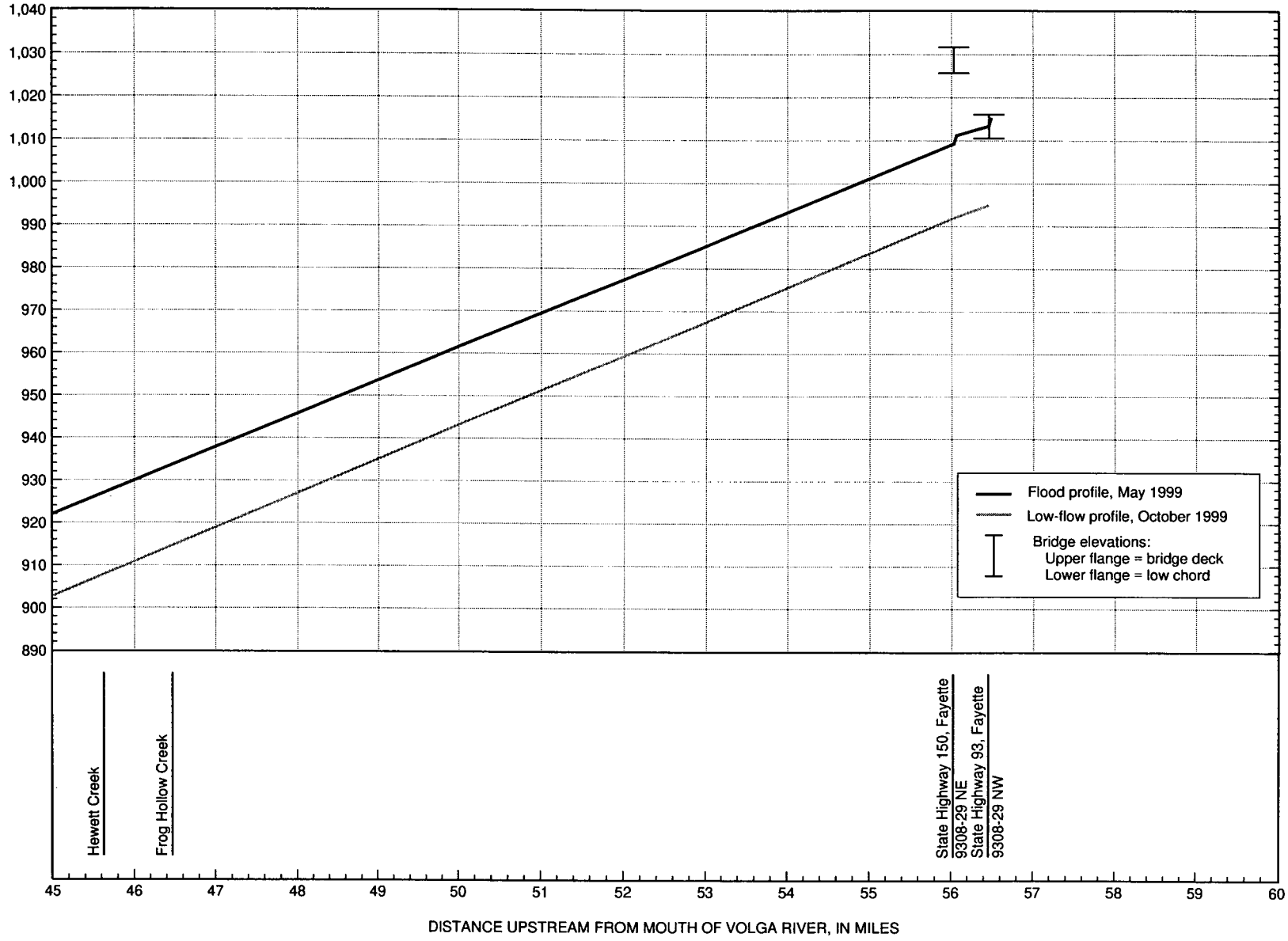

Figure 6.--Profile of the May 1999 flood in the Volga River, river miles 45 to 57.

Table 2. *Elevations of high water marks used in the Volga River flood profile, flood of May 17-20, 1999*
[HWM, high water mark; --, not measured]

Distance upstream from mouth of Volga River (river miles)	Description	Downstream HWM (feet above sea level)	Upstream HWM (feet above sea level)
0.42	County Road X3C, N of Elkport	670.02	671.42
9.25	County Road X21, Littleport	702.36	703.31
14.58	Evergreen Road, Mederville	730.60	734.10
14.60	Eclipse St. (old Evergreen Rd.), Mederville	--	--
19.08	State Highway 13, Osborne	754.28	755.79
27.42	County Road C2W, Volga City	794.47	795.54
38.02	County Road W51, Wadena	866.25	866.95
56.03	State Highway 150, Fayette	1,009.25	1,011.20
56.46	State Highway 93, Fayette	1,013.38	1,015.33

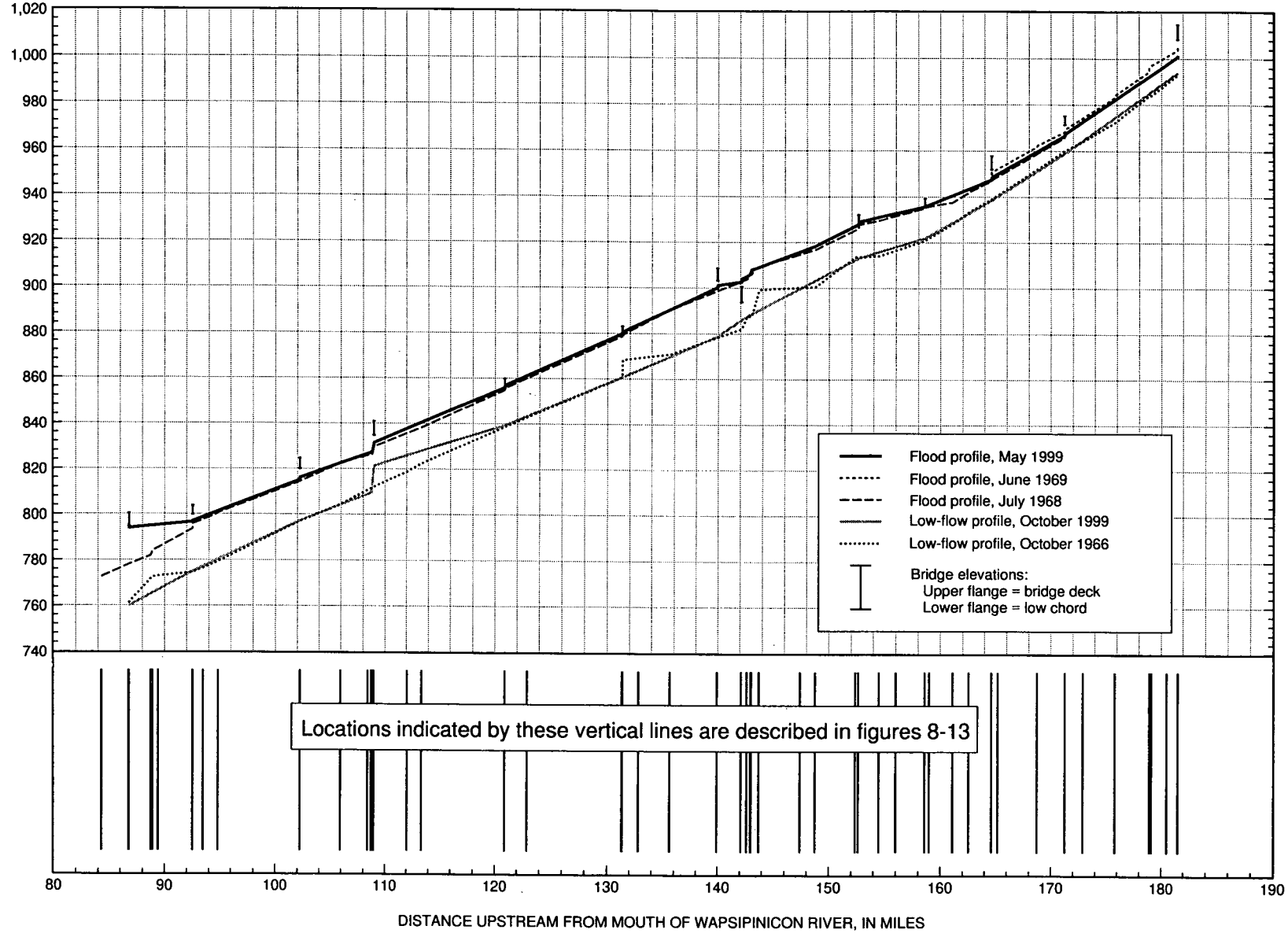

Figure 7.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 84 to 182.

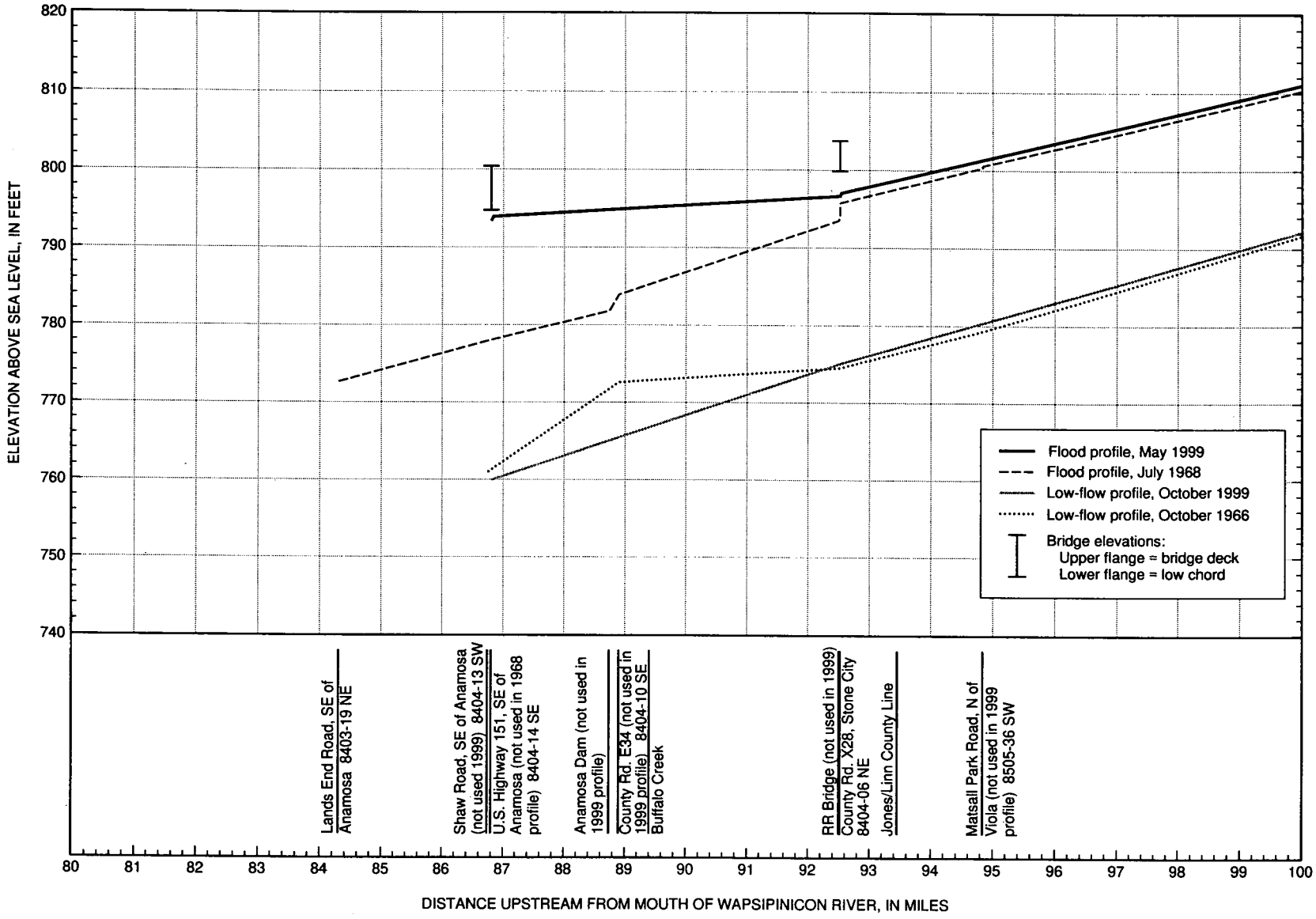

Figure 8.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 84 to 100.

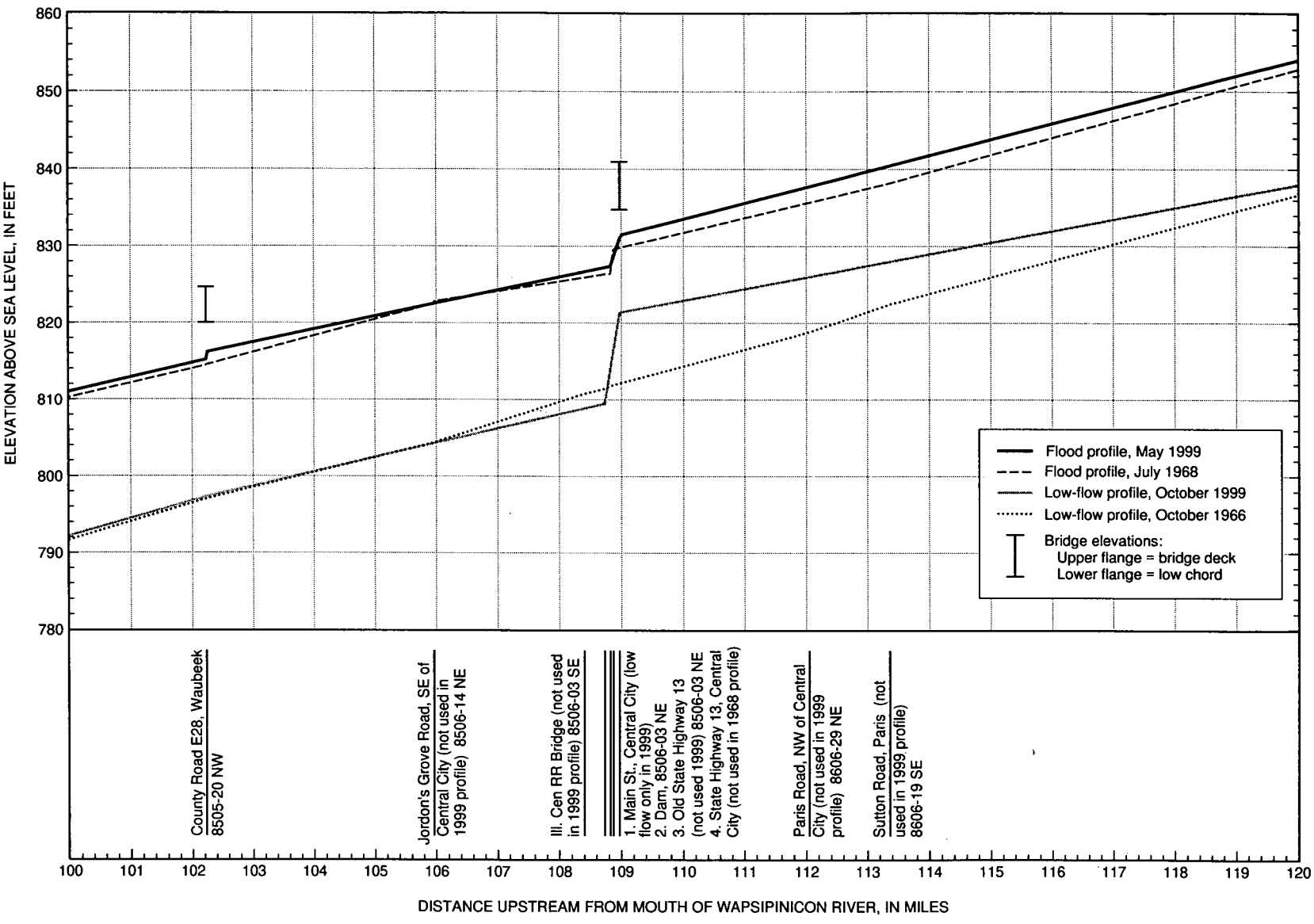

Figure 9.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 100 to 120.

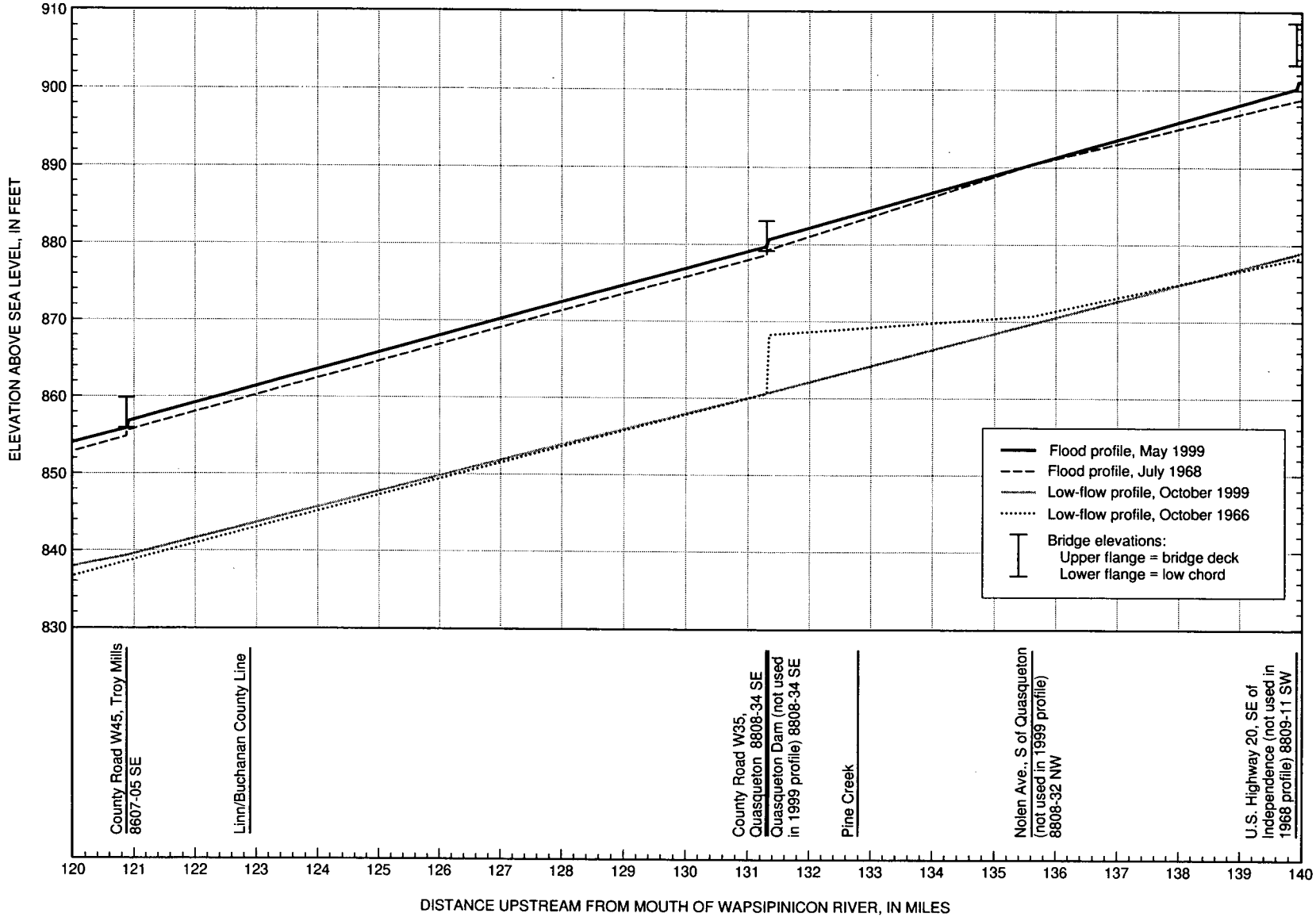

Figure 10.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 120 to 140.

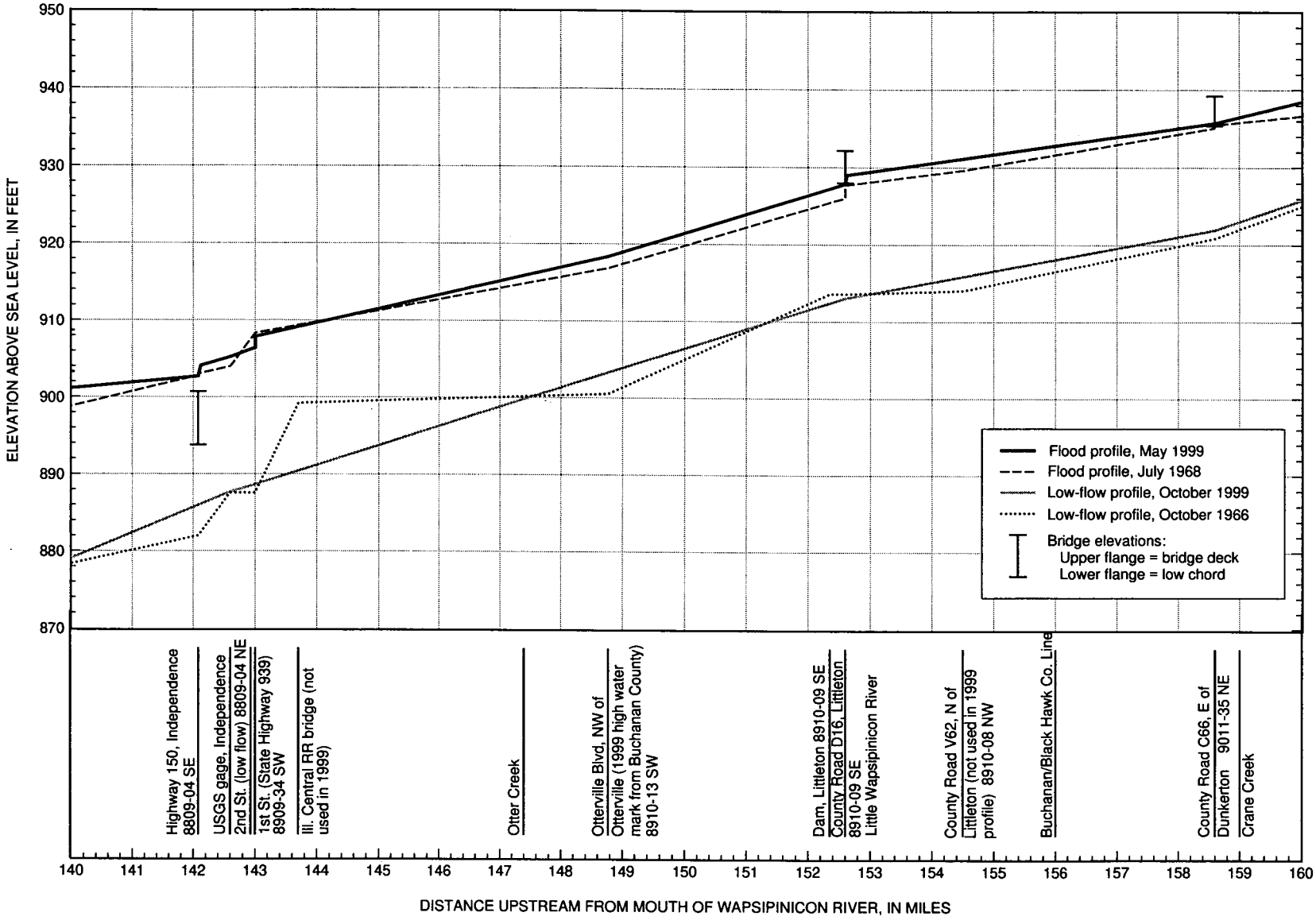

Figure 11.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 140 to 160.

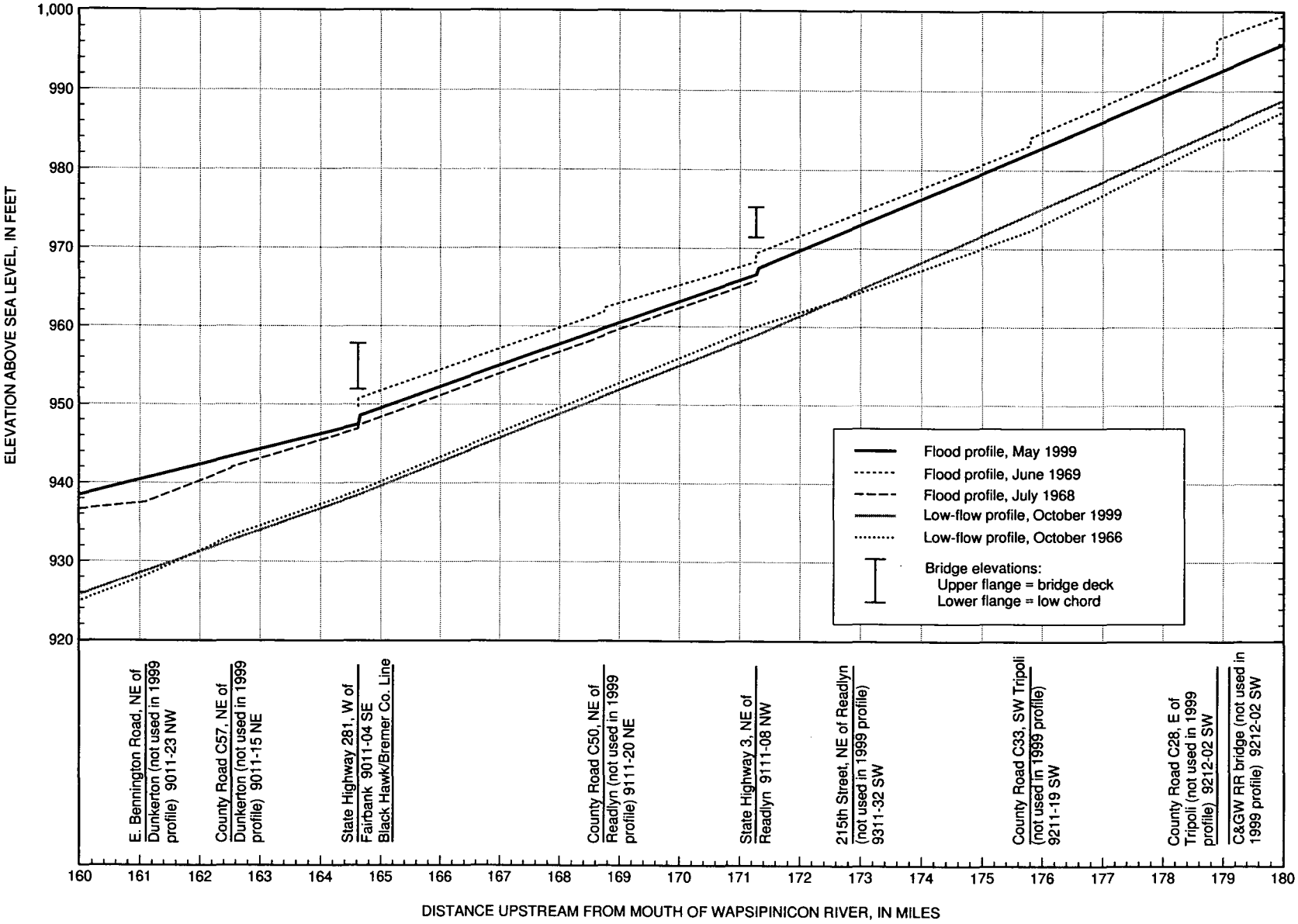

Figure 12.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 160 to 180.

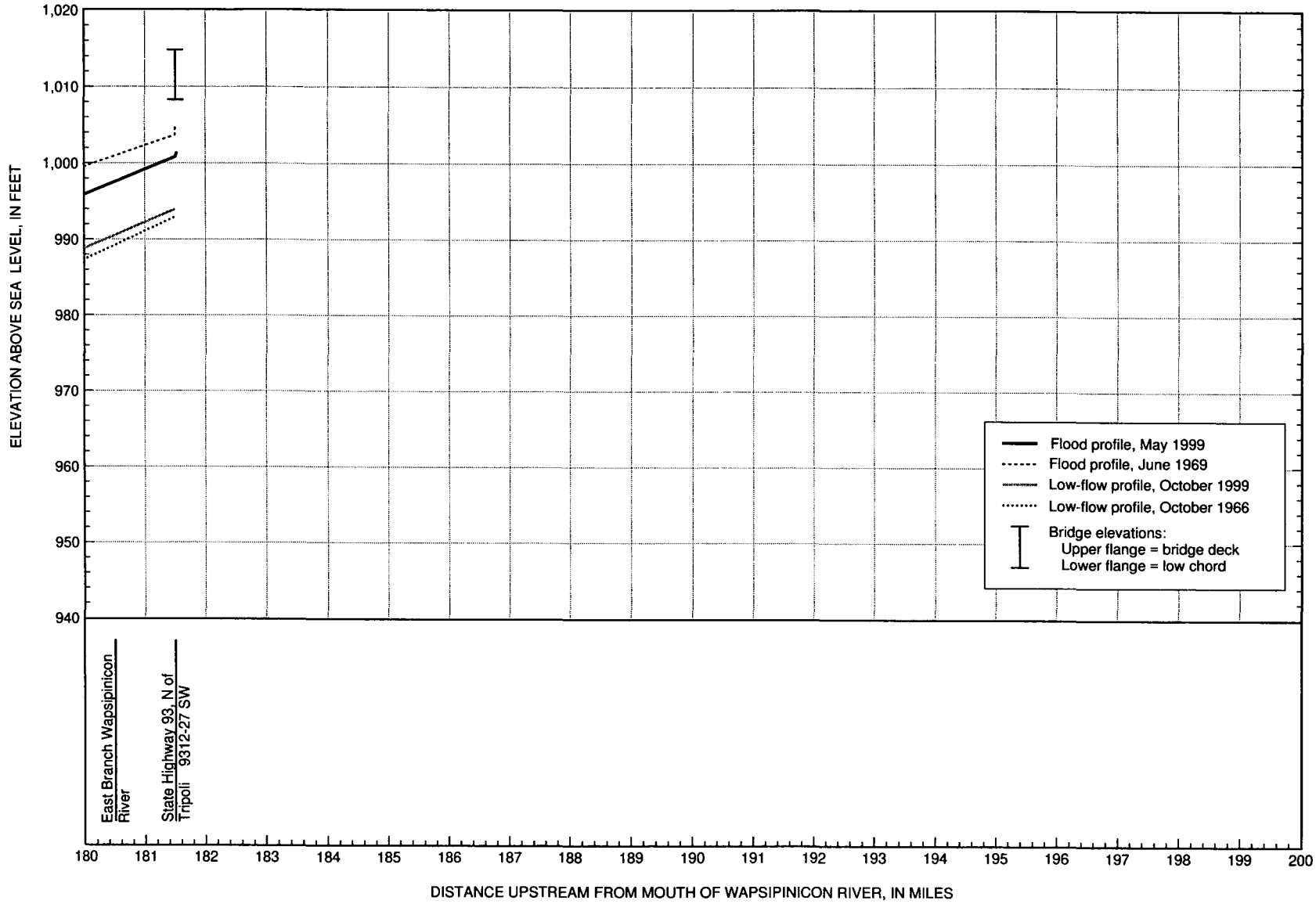

Figure 13.--Profile of the May 1999 flood in the Wapsipinicon River, river miles 180 to 182.

Table 3. *Elevations of high water marks used in the Wapsipinicon River flood profile, flood of May 17-20, 1999*
[HWM, high water mark; --, not measured]

Distance upstream from mouth of Wapsipinicon River (river miles)	Description	Downstream HWM (feet above sea level)	Upstream HWM (feet above sea level)
86.80	U.S. Highway 151, SE of Anamosa	793.38	793.92
92.52	County Road X28, Stone City	796.65	797.03
102.23	County Road E28, Waubeek	815.17	816.18
108.73	Main Street, Central City	--	--
108.82	Dam, Central City	827.38	--
108.97	State Highway 13, Central City	831.00	831.49
120.88	County Road W45, Troy Mills	855.85	856.80
131.30	County Road W35, Quasqueton	879.75	880.64
139.93	U.S. Highway 20, SE of Independence	900.20	901.10
142.08	State Highway 150, Independence	902.69	904.09
142.60	USGS gage (05421000) Independence	905.20	--
142.93	2nd Street, Independence	--	--
143.00	1st Street (State Highway 939), Independence	906.40	907.95
148.77	Otterville Blvd., NW of Otterville elevation provided by Buchanan Co. (written commun., March 2000)	--	918.35
152.60	County Road D16, Littleton	927.83	929.00
158.60	County Road C66, E of Dunkerton	935.71	--
164.62	State Highway 281, W of Fairbank	947.44	948.57
171.27	State Highway 3, NE of Readlyn	966.66	967.46
181.50	State Highway 93, N of Tripoli	1,000.81	1,001.44

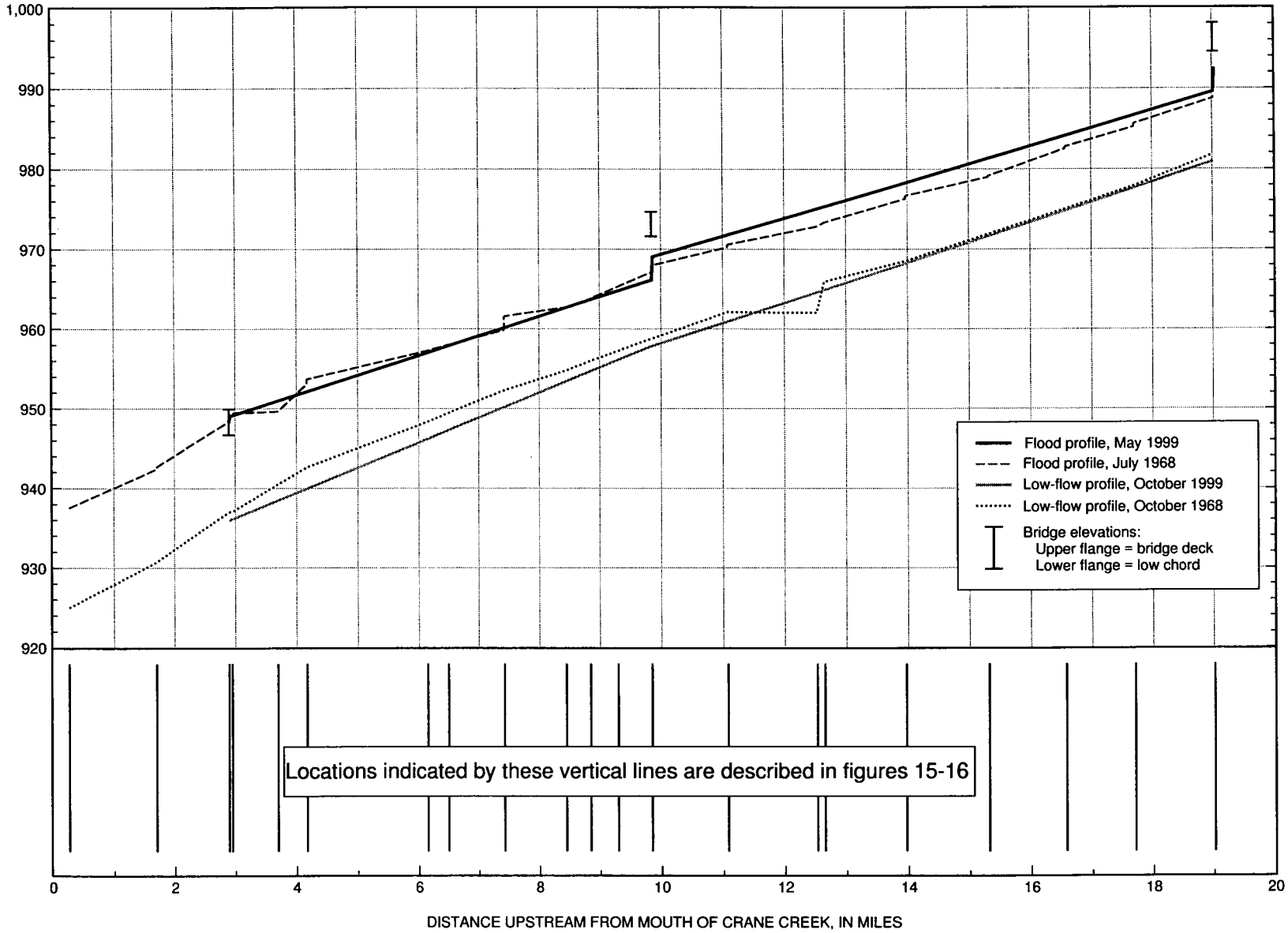

Figure 14.--Profile of the May 1999 flood in Crane Creek, river miles 2 to 20.

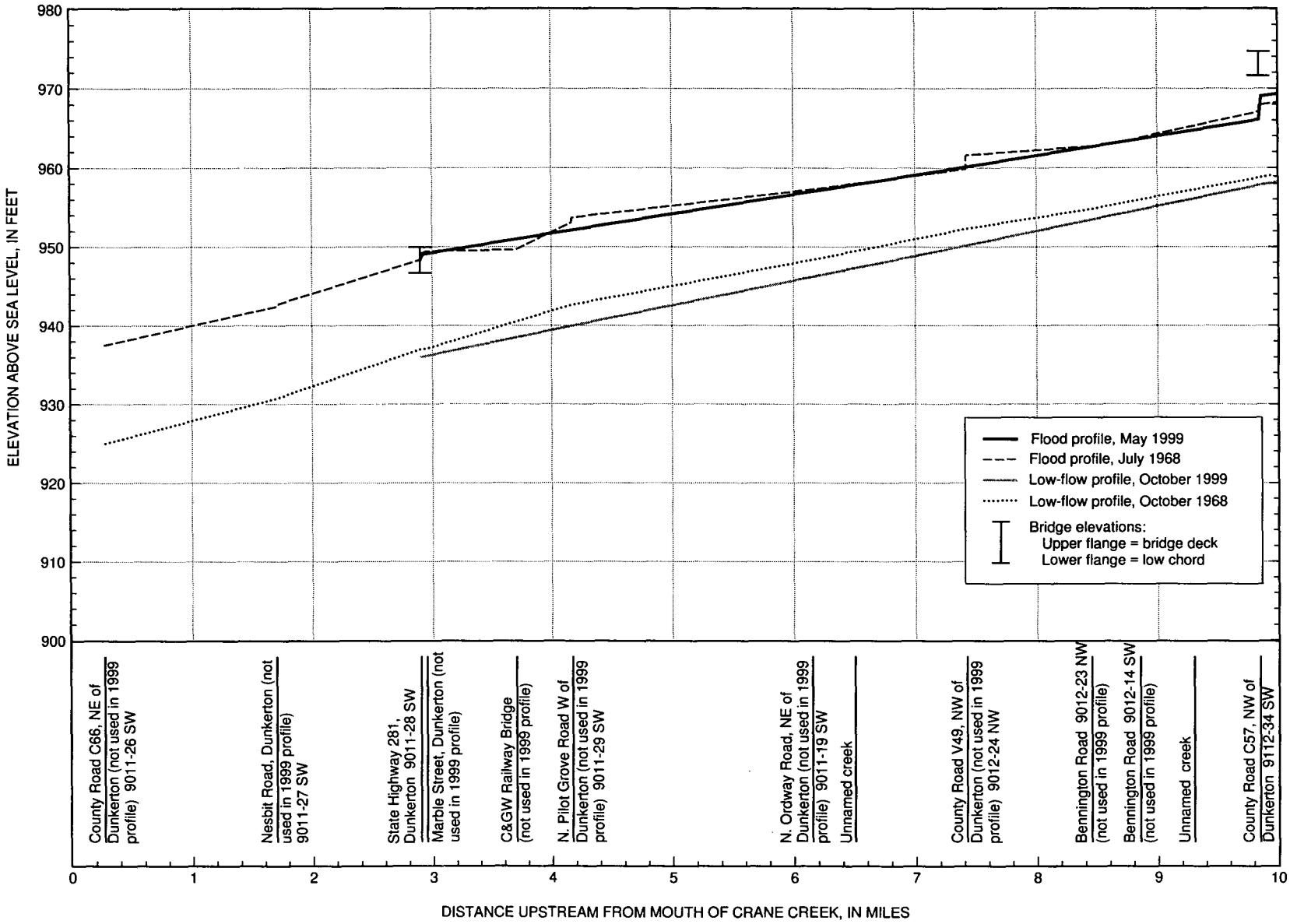

Figure 15.--Profile of the May 1999 flood in Crane Creek, river miles 2 to 10.

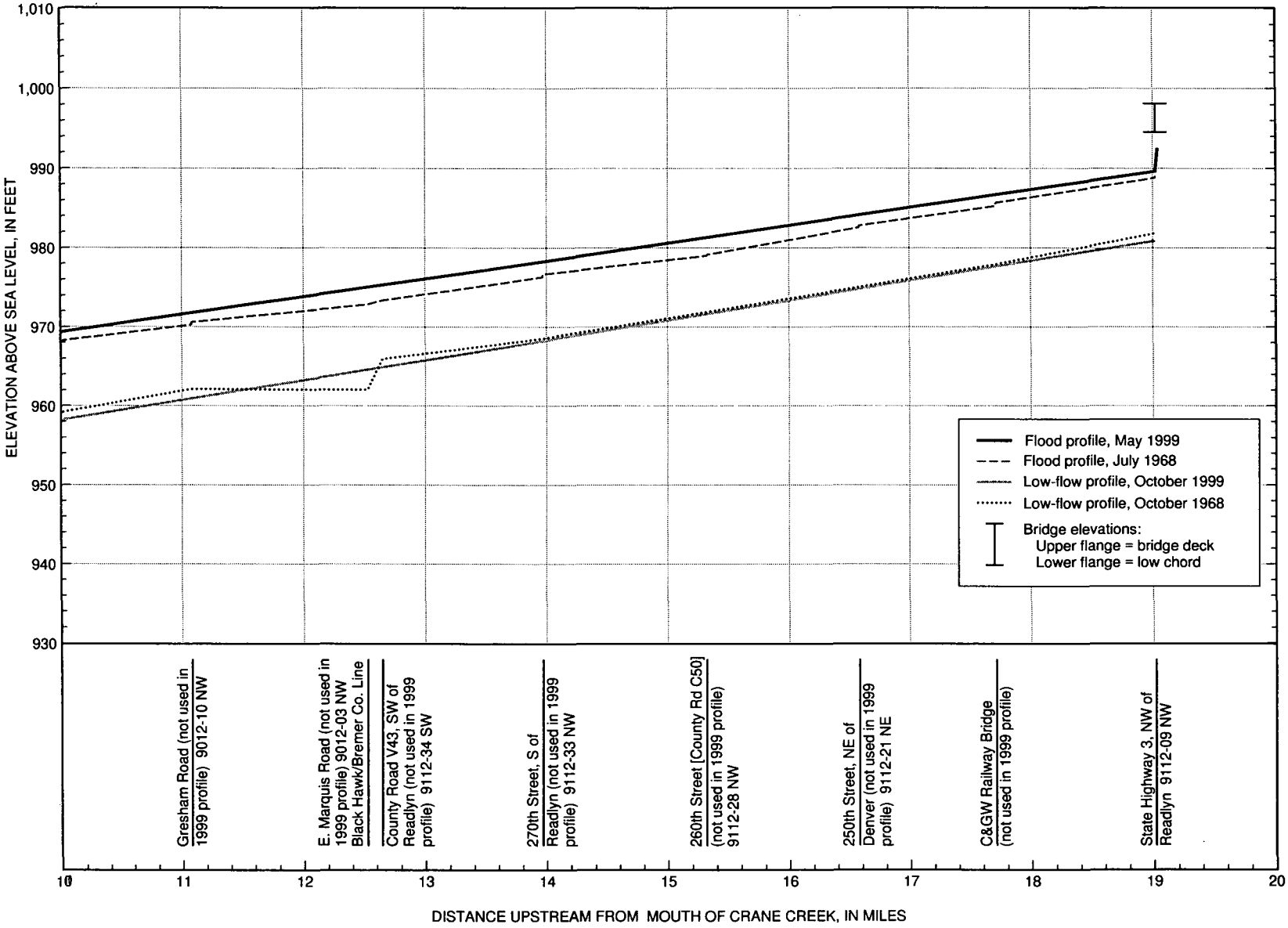

Figure 16.--Profile of the May 1999 flood in Crane Creek, river miles 10 to 20.

Table 4. *Elevations of high water marks used in the Crane Creek flood profile, flood of May 17-20, 1999*

[HWM, high water mark; --, not measured]

Distance upstream from mouth of Crane Creek (river miles)	Description	Downstream HWM (feet above sea level)	Upstream HWM (feet above sea level)
2.90	State Highway 281, Dunkerton	948.25	949.04
9.85	County Road C57, NW of Dunkerton	966.09	969.03
19.02	State Highway 3, NW of Readlyn	989.61	992.54

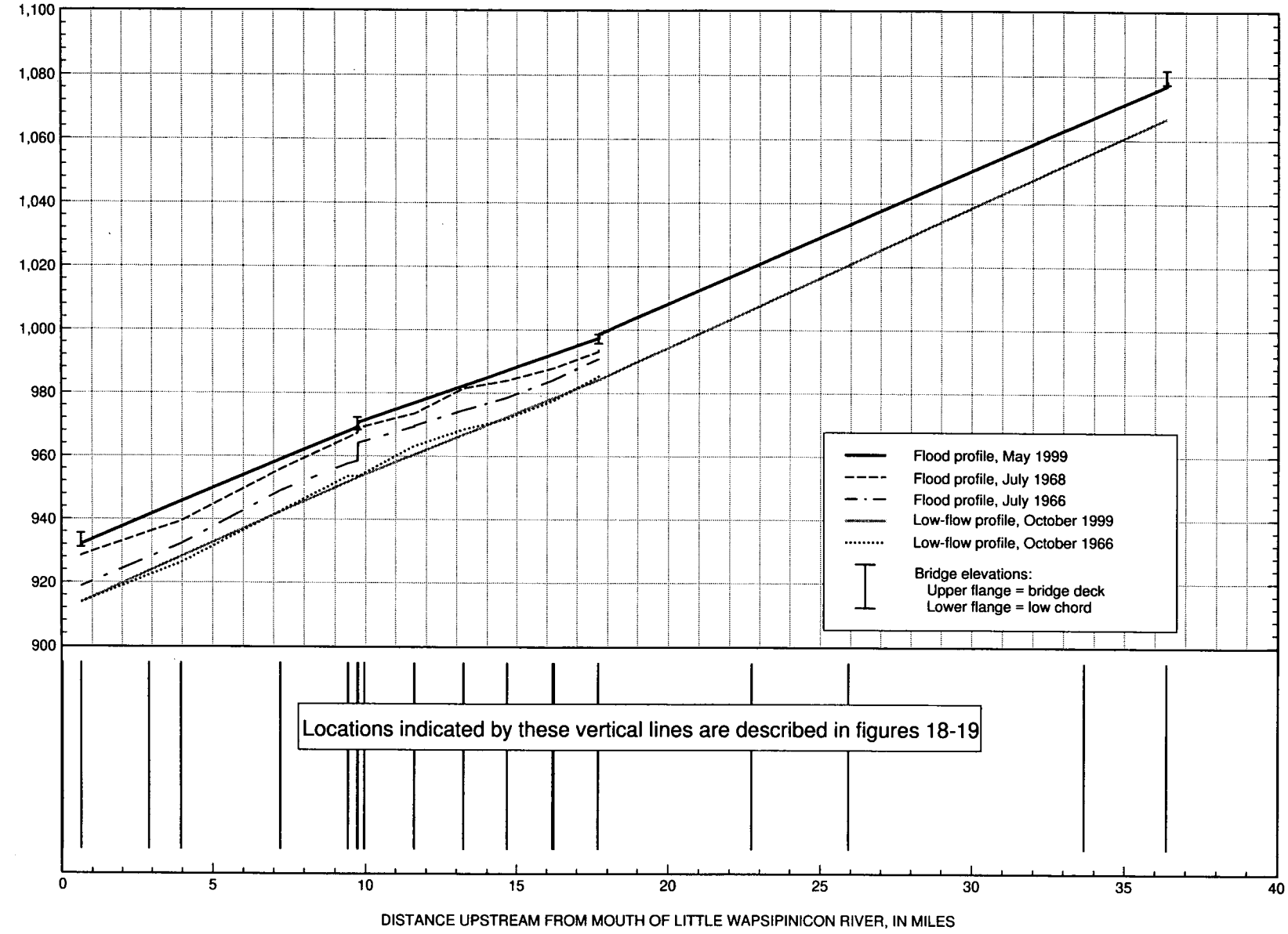

Figure 17.--Profile of the May 1999 flood in the Little Wapsipinicon River, river miles 0 to 37.

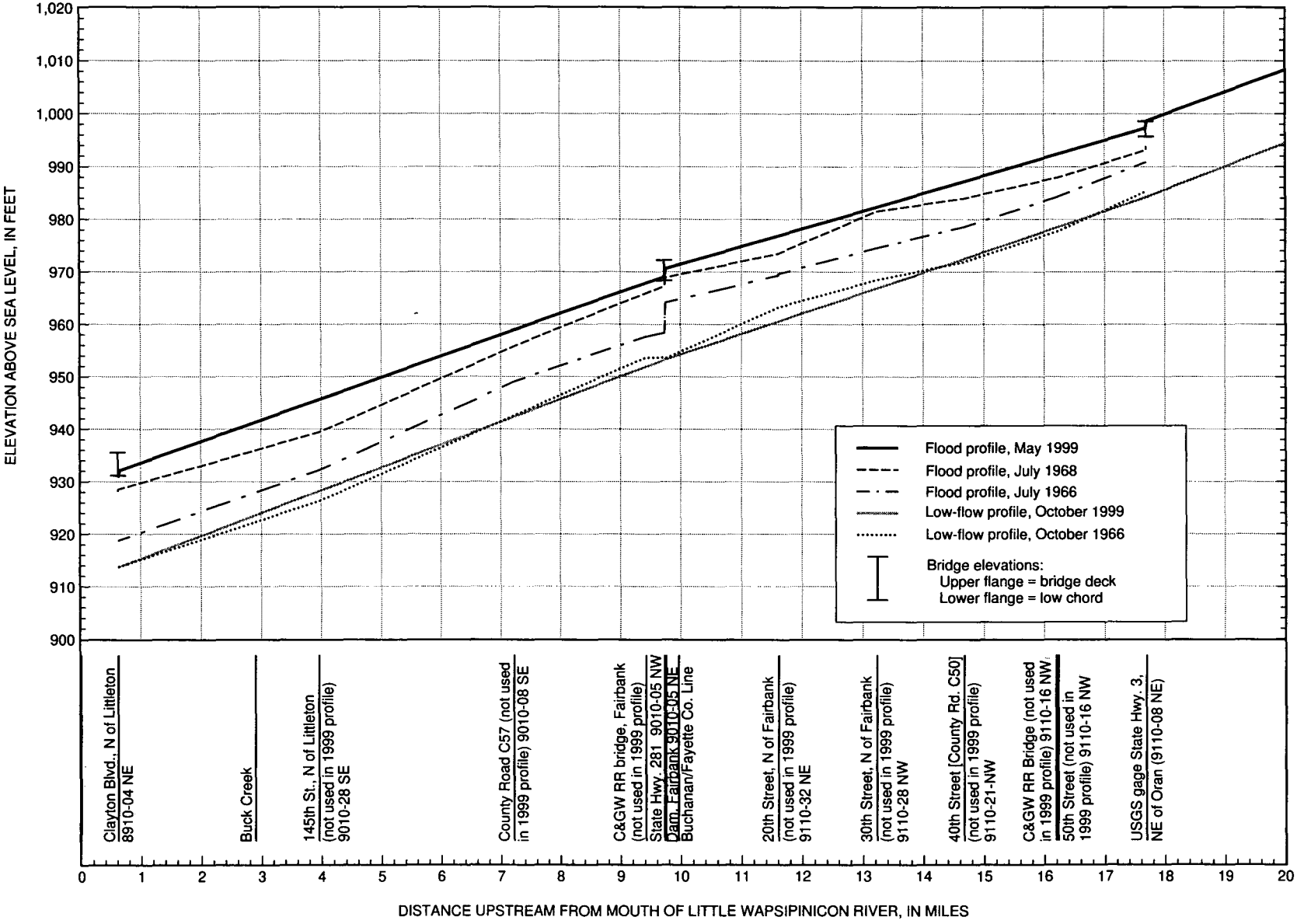

Figure 18.--Profile of the May 1999 flood in the Little Wapsipinicon River, river miles 0 to 20.

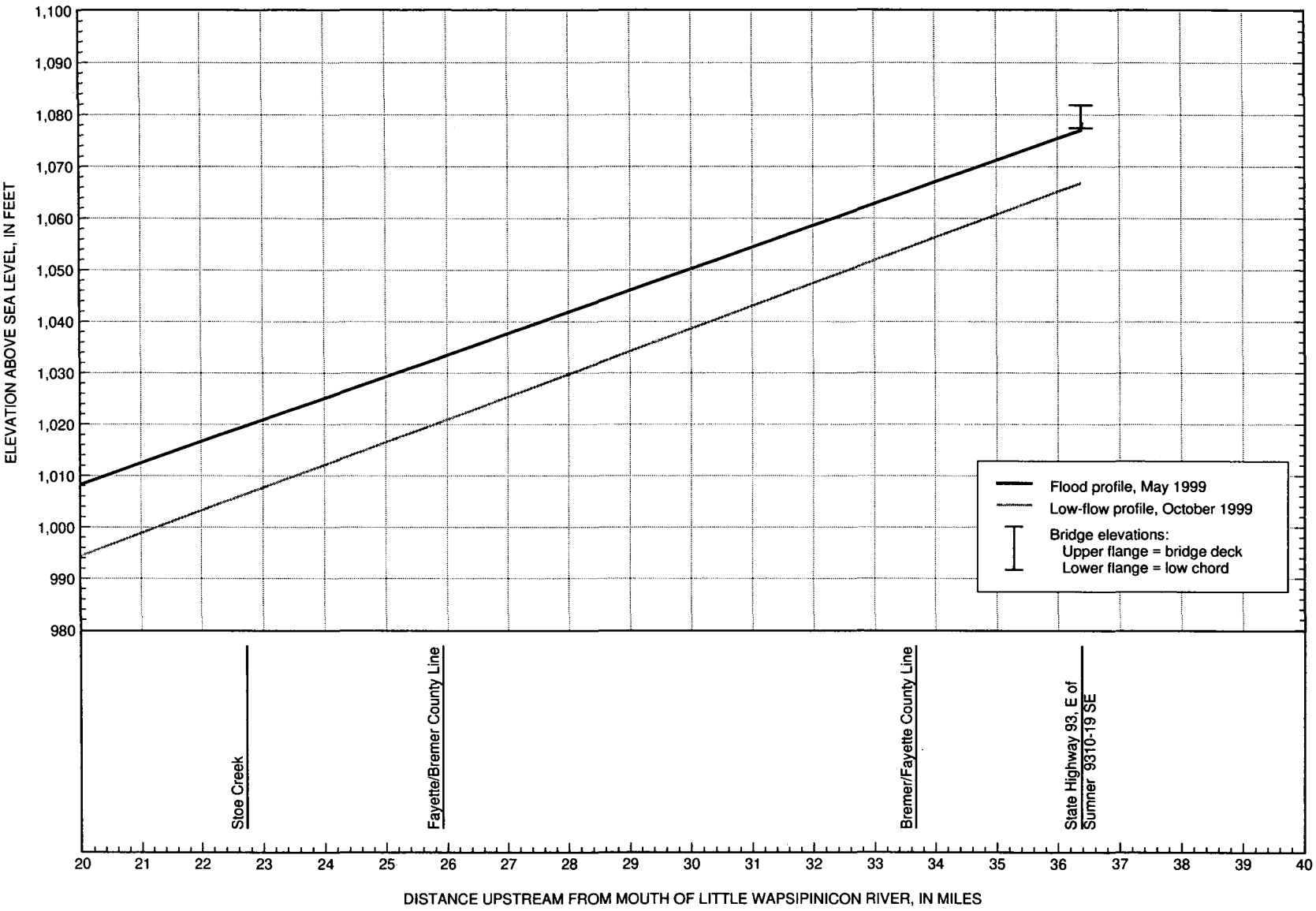

Figure 19.--Profile of the May 1999 flood in the Little Wapsipinicon River, river miles 20 to 37.

Table 5. *Elevations of high water marks used in the Little Wapsipinicon River flood profile, flood of May 17- 20, 1999*

[HWM, high water mark; --, not measured]

Distance upstream from mouth of Little Wapsipinicon River (river miles)	Description	Downstream HWM (feet above sea level)	Upstream HWM (feet above sea level)
0.62	Clayton Boulevard, N of Littleton	930.82	932.09
9.73	State Highway 281, Fairbank	969.08	--
9.75	Dam, Fairbank	--	970.60
17.69	State Highway 3, NE of Oran	997.30	998.65
36.38	State Highway 93, E of Sumner	1,077.03	1,078.55

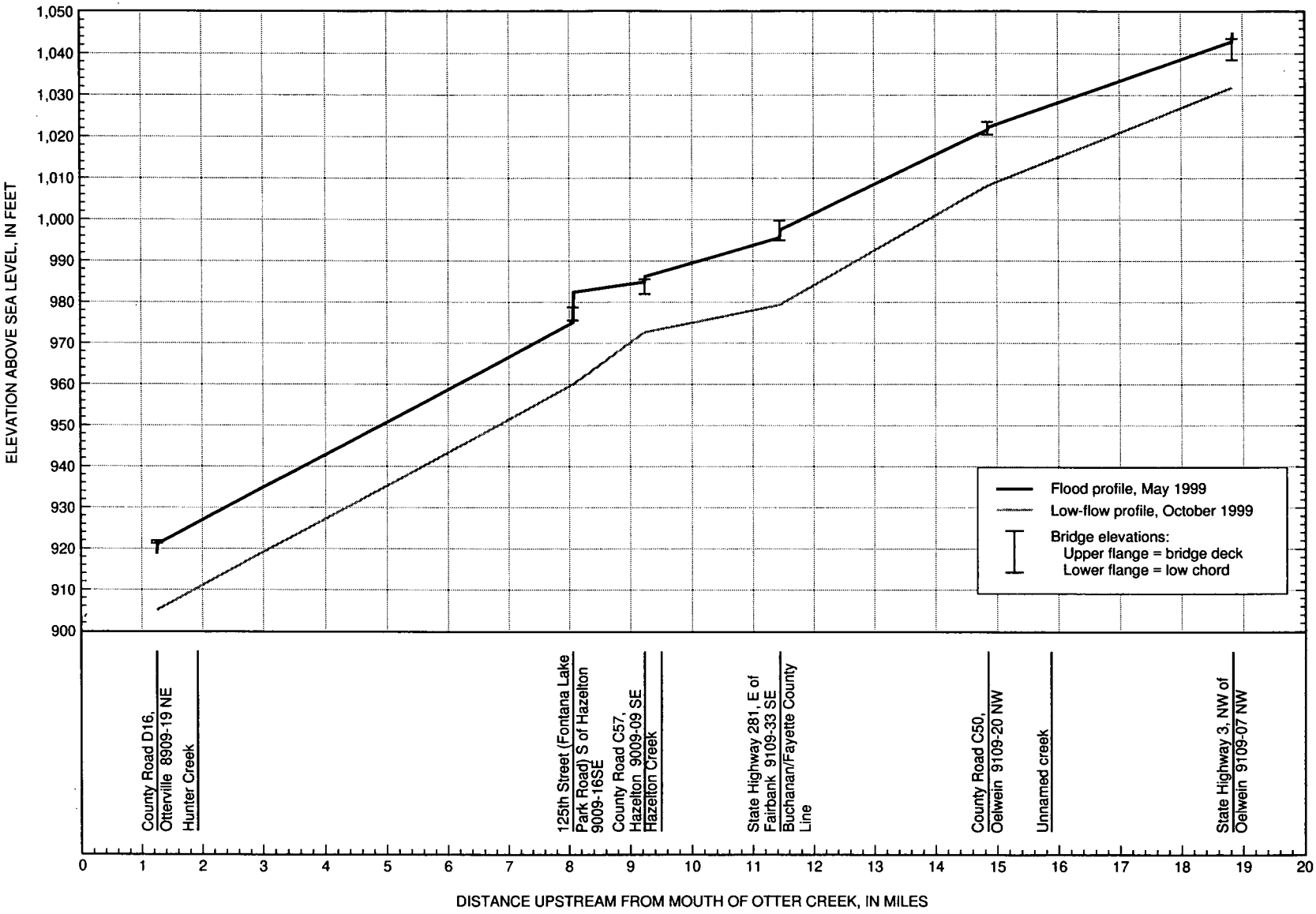

Figure 20.--Profile of the May 1999 flood in Otter Creek, river miles 1 to 19.

Table 6. *Elevations of high water marks used in the Otter Creek flood profile, flood of May 17-20, 1999*

[HWM, high water mark; --, not measured]

Distance upstream from mouth of Otter Creek (river miles)	Description	Downstream HWM (feet above sea level)	Upstream HWM (feet above sea level)
1.25	County Road D16, Otterville	918.65	921.10
8.06	125th Street, Fontana Lake Park Road, S of Hazelton	975.02	982.38
9.23	County Road C57, Hazelton	984.88	986.20
11.44	State Highway 281, E of Fairbank	995.66	997.50
14.85	County Road C50, Oelwein	1,021.69	1,022.24
18.83	State Highway 3, NW of Oelwein	1,042.85	1,045.07

APPENDIX: LIST OF BENCH MARKS

The USGS established the temporary bench marks (BMs) listed in this tabulation. The USGS also established the elevations for the BMs except those for which credit is given in the description of the BM. Existing marks were used wherever available, and the agency responsible for the mark, when known, is indicated in the description.

BMs and reference points were determined from differential leveling or from Global Positioning System (GPS) methods. Elevations determined using a GPS are noted next to the reference. BMs and reference points are listed for only those bridges used in the May 17-20, 1999, flood profiles. The BMs and reference points established for the earlier floods in the Volga Basin are referenced in "Floods of July 12, 1972, March 19, 1979, and June 15, 1991, in the Turkey River basin, northeast Iowa" (Eash and Koppensteiner, 1996).

The streams included in the level work were the Volga River, Wapsipinicon River, Crane Creek, Little Wapsipinicon River, and Otter Creek. BMs were set at all bridges.

Level lines to establish the third-order accuracy BMs shown herein were run from first- or second-order BMs established and adjusted by the National Geodetic Survey (NGS) or from third-order BMs established and adjusted by the National Mapping Division of the USGS. Errors of closure in the USGS level work were adjusted along the level line to the elevations published by the NGS and the National Mapping Division. These BMs are repeated in this listing. All elevations are referenced to sea level.

The BMs have been identified by an index number, which is composed of the township, range, and section number as mandated by Congress and the quarter section in which they are located. The township and range numbers have been combined into a four-digit number, such as 9205 for Township 92 North and Range 05 West. This four-digit number is followed by a dash and the section number in which the mark is located. Within the section, the quarter in which the mark is located is designated by NW, NE, SW, and SE. A number in parentheses following this letter designation indicates the number of the mark in that particular quarter section. The index number serves to describe the landline location of the mark without further reference in the body of the description. The physical location of the BM on a bridge dictates the appropriate legal description.

Standard marks, such as chiseled or filed squares, crosses, marks, or arrows, were used on concrete or steel. Marks indicated as (REFERENCE POINT) following the legal description were established to permit water-surface elevations to be determined by use of a tape and weight. Reference points are listed with the related benchmarks using the same legal description, though at times they are in a different section, range, or township as determined by upstream or downstream location. The terms "right"

and "left" in the descriptions are determined as viewed while facing in the direction of the flow of the stream. BMs and reference points are listed for each reach from the first downstream location to the last upstream location.

The user of this information is cautioned that BMs can be disturbed or destroyed, and they can move over time. Many of the marks that are listed herein are located on bridges that may have been repaired, replaced, or destroyed since the original level lines were run. Some of the marks may be disturbed or gone. It is the responsibility of the user to determine the condition and suitability of a BM.

Volga River

9205-25 NE (1) - At Littleport, on County Road X21 bridge over Volga River, on left upstream wingwall curb; USGS brass tablet stamped "15 JRE 1964 708."

Elevation 708.254 feet

9205-25 NE (2) - (REFERENCE POINT) At Littleport, on County Road X21 bridge over Volga River, on top of the upstream guardrail and left of 15th guardrail post from right end of bridge; filed three marks.

Elevation 709.64 feet

9205-22 SW (1) - At Mederville, on new Evergreen Road bridge over Volga River, on right downstream wingwall; Iowa DOT BM. Elevation determined using GPS.

Elevation 778.73 feet

9205-22 SW (1) - (REFERENCE POINT) At Mederville, on Eclipse Street (old Evergreen Road) bridge over Volga River, on third guardrail stone post from right downstream end of bridge, on streamward side of post; chiseled square.

Elevation 759.26 feet

9205-09 SW (1) - At Osborne, on State Highway 13 bridge over Volga River, on top of concrete guardrail at right downstream end of bridge; Iowa Highway Commission BM.

Elevation 758.80 feet

9206-03 SW (1) - At Volga City, on County Road C2W bridge over Volga River, on top of right upstream wingpost; chiseled square.

Elevation 800.52 feet

9206-03 SW (2) - (REFERENCE POINT) At Volga City, on County Road C2W bridge over Volga River, on top of upstream guardrail and right of 22d guardrail post from right end of bridge; filed two marks.

Elevation 800.59 feet

9307-27 SE (1) - At Wadena, on County Road W51 bridge over Volga River, on right downstream wingwall; chiseled square. Elevation determined using GPS.

Elevation 876.68 feet

9307-27 SE (2) - (REFERENCE POINT) At Wadena, on County Road W51 bridge over Volga River, on right downstream guardrail at 18th guardrail post; filed two marks. Elevation determined using GPS.

Elevation 876.44 feet

9308-29 NE (1) - At Fayette, on State Highway 150 bridge over Volga River, on left downstream concrete guardrail; Iowa DOT BM. Elevation determined using GPS.

Elevation 1,048.49 feet

9308-29 NE (2) - (REFERENCE POINT) At Fayette, on State Highway 150 bridge over Volga River, on left downstream concrete curb to right and below 15th guardrail post; chiseled arrow. Elevation determined using GPS.

Elevation 1,039.49 feet

9308-29 NW (1) - At Fayette, on State Highway 93 bridge over Volga River, on left upstream wingwall; Iowa DOT BM. Elevation determined using GPS.

Elevation 1,026.61 feet

9308-29 NW (2) - (REFERENCE POINT) At Fayette, on State Highway 93 bridge over Volga River, on left downstream concrete guardrail, approximately 100 feet to the right of the left wingwall; chiseled arrow. Elevation determined using GPS.

Elevation 1,023.45 feet

Wapsipinicon River

8404-14 SE (1) - 1.5 miles south of Anamosa, on U.S. Highway 151 bridge over Wapsipinicon River, on right downstream wingwall; USGS tablet stamped "15 ROD 1973."

Elevation 804.27 feet

8404-14 SE (2) - (REFERENCE POINT) 1.5 miles south of Anamosa, on U.S. Highway 151 bridge over Wapsipinicon River, on left downstream side of bridge above and 3 feet left of fifth drain; chiseled arrow.

Elevation 795.61 feet

8505-20 NW (1) - At Waubeek, on County Road E28 bridge over Wapsipinicon River, on right downstream wingwall curb; Linn County BM stamped "Linn Co. Eng." "408."

Elevation 825.52 feet

8505-20 NW (2) - (REFERENCE POINT) At Waubeek, on County Road E28 bridge over Wapsipinicon River, on right downstream guardrail on top of 24th guardrail post; filed arrow.

Elevation 827.53 feet

8506-03 NE (1) - At Central City, at bridge over Wapsipinicon River just east from intersection of West Main and River Sts. (Main Street Bridge), on top of right downstream guardrail post; Linn County Engineering Department disk 2450-1953.

Elevation 838.51 feet

8506-03 NW (1) - At Central City, on State Highway 13 bridge over Wapsipinicon River, on left upstream abutment; Iowa DOT BM. Elevation determined using GPS.

Elevation 843.33 feet

8506-03 NW (2) - (REFERENCE POINT) At Central City, on State Highway 13 bridge over Wapsipinicon River, on left downstream ledge above fifth drain; chiseled arrow. Elevation determined using GPS.

Elevation 844.26 feet

8607-05 SE (1) - At Troy Mills, on County Road W45 bridge over Wapsipinicon, on right upstream wingwall; brass disk stamped "Linn County Engineer's Department 952."

Elevation 860.37 feet

8607-05 SE (2) - (REFERENCE POINT) At Troy Mills, on County Road W45 bridge over Wapsipinicon River, on downstream guardrail at 20th post from left end of bridge; chiseled square.

Elevation 866.00 feet

8808-34 NE (1) - At Quasqueton, on County Road W35 bridge over Wapsipinicon River, on left downstream wingwall; chiseled square.

Elevation 883.44 feet

8808-34 SE (2) - At Quasqueton, on County Road W35 bridge over Wapsipinicon River, on right upstream wingwall curb; USGS tablet stamped "3 ROD 1973."

Elevation 893.640 feet

8808-34 NE (3) - (REFERENCE POINT) At Quasqueton, on County Road W35 bridge over Wapsipinicon River, on left downstream guardrail at 19th guardrail post; chiseled arrow.

Elevation 889.75 feet

8809-11 SW (1) - Approximately 1 mile southeast of Independence, on U.S. Highway 20 bridge (eastbound lane) over Wapsipinicon River, on right downstream wingwall; Iowa DOT BM. Elevation determined using GPS.

Elevation 911.07 feet

8809-11 SW (2) - (REFERENCE POINT) Approximately 1 mile southeast of Independence, on U.S. Highway 20 bridge (eastbound lane) over Wapsipinicon River, on right downstream concrete guardrail above fifth drain; chiseled two marks. Elevation determined using GPS.

Elevation 911.33 feet

8809-04 SE (1) - At Independence, USGS gaging station 0.33 mile downstream from Second Street bridge over Wapsipinicon River, on right bank at Sixth Street, set in concrete footing for stairway leading to gage shelter; standard USGS bronze tablet.

Elevation 898.19 feet

8809-04 NE (1) - At Independence, on Second Street bridge over Wapsipinicon River, on right upstream concrete abutment curb; NGS brass disk stamped "B75 Reset."

Elevation 908.72 feet

8809-04 NE (2) - (REFERENCE POINT) At Independence, on Second Street bridge over Wapsipinicon River, on right downstream concrete sidewalk ledge below 11th guardrail post; chiseled two marks.

Elevation 911.98 feet

8909-34 SW (1) - At Independence, State Highway 939 (First Street) bridge over Wapsipinicon River, on the right upstream side of bridge; Iowa DOT BM. Elevation determined using GPS.

Elevation 911.20 feet

8910-09 SE (1) - At west edge of Littleton, on County Road D16 bridge over Wapsipinicon River, on left downstream wingwall landward corner; chiseled square. Elevation determined using GPS.

Elevation 932.78 feet

8910-09 SE (2) - (REFERENCE POINT) At west edge of Littleton, on County Road D16 bridge over Wapsipinicon River, on left downstream guardrail at 11th guardrail post; filed three marks. Elevation determined using GPS.

Elevation 936.05 feet

9011-35 NE (1) - Approximately 2 2/3 mile east of Dunkerton on County Road C66 bridge over Wapsipinicon River, on left downstream corner; chiseled square.

Elevation 940.01 feet

9011-35 NE (2) - (REFERENCE POINT) Approximately 2 2/3 miles east of Dunkerton, on County Road C66 bridge over Wapsipinicon River, on left downstream concrete curb about 6 feet right of third drain and below 20th guardrail post; chiseled square.

Elevation 940.59 feet

9011-04 SE (1) - Approximately 5 miles west of Fairbank, on State Highway 281 bridge over Wapsipinicon River, on left downstream wingwall curb; chiseled square. Elevation determined using GPS.

Elevation 958.09 feet

9011-04 SE (2) - (REFERENCE POINT) Approximately 5 miles west of Fairbank, on State Highway 281 bridge over Wapsipinicon River, on top of left downstream concrete guardrail and 15 feet right of third drain; chiseled arrow. Elevation determined using GPS.

Elevation 961.28 feet

9111-08 NW (1) - Approximately 3 miles northeast of Readlyn, on State Highway 3 bridge over Wapsipinicon River, on left downstream wingwall; Iowa DOT BM. Elevation determined using GPS.

Elevation 978.22 feet

9111-08 NW (2) - (REFERENCE POINT) Approximately 3 miles northeast of Readlyn, on State Highway 3 bridge over Wapsipinicon River, on top of 30th guardrail post from left downstream end of bridge; filed three marks. Elevation determined using GPS.

Elevation 978.98 feet

9312-27 SW (1) - 2 miles north of Tripoli, on State Highway 93 bridge over Wapsipinicon River, on left downstream corner of abutment; Iowa DOT BM. Elevation determined using GPS.

Elevation 1,016.23 feet

9312-27 SW (2) - 2 miles north of Tripoli, on State Highway 93 bridge over Wapsipinicon River, on left upstream bridge abutment; chiseled square. Elevation determined using GPS.

Elevation 1,018.62 feet

Crane Creek

9011-28 SW (1) - At Dunkerton, on State Highway 281 concrete bridge over Crane Creek, at right end of downstream curb; head of bolt buried in curb.

Elevation 950.47 feet

9011-28 SW (2) - (REFERENCE POINT) At Dunkerton, on State Highway 281 concrete bridge over Crane Creek, right downstream at 10th guardrail post, on waterside edge of sidewalk; chiseled three marks.

Elevation 952.89 feet

9112-09 NW (1) - Approximately 2.6 miles northwest of Readlyn, on State Highway 3 bridge over Crane Creek, on left downstream wingwall (landward corner); chiseled square. Elevation determined using GPS.

Elevation 998.12 feet

9112-09 NW (2) - (REFERENCE POINT) Approximately 2.6 miles northwest of Readlyn, on State Highway 3 bridge over Crane Creek, on left downstream waterside curb above second drain; chiseled arrow. Elevation determined using GPS.

Elevation 998.67 feet

Little Wapsipinicon River

8910-04 SE (1) 1/2 mile north of Littleton on Clayton Boulevard bridge over Little Wapsipinicon River, on left downstream end of bridge curb; chiseled cross.

Elevation 936.34 feet

8910-04 SE (2) - (REFERENCE POINT) 1/2 mile north of Littleton on Clayton Boulevard bridge over Little Wapsipinicon River, on left downstream metal handrail at 18th handrail post; chiseled arrow.

Elevation 938.34 feet

9010-05 NW (1) - At Fairbank, on State Highway 281 bridge over Little Wapsipinicon River, on top downstream handrail, at fourth set of four rivets from right end of bridge; chiseled arrow.

Elevation 975.80 feet

9010-05-NW (2) - At Fairbank, on State Highway 281 bridge over Little Wapsipinicon, on right upstream bridge seat; Iowa DOT BM.

Elevation 972.84 feet

9010-05 NW (3) - (REFERENCE POINT) At Fairbank, on State Highway 281 bridge over Little Wapsipinicon River, on right downstream concrete sidewalk (waterside) below fifth set of four rivets; chiseled arrow.

Elevation 973.18 feet

9110-08 NE (1) - About 2 miles northeast of Oran, on State Highway 3 bridge over Little Wapsipinicon River, on right downstream corner of bridge curb; chiseled square.

Elevation 999.06 feet

9110-08 NE (2) - (REFERENCE POINT) About 2 miles northeast of Oran, on State Highway 3 bridge over Little Wapsipinicon River, on downstream handrail at seventh post from right end; chiseled arrow.

Elevation 1,001.30 feet

9310-19 SE (1) - Approximately 3/4 mile east of Sumner, on State Highway 93 bridge over Little Wapsipinicon River, on left upstream side; Iowa DOT BM. Elevation determined using GPS.

Elevation 1,084.13 feet

9310-19 SE (2) - (REFERENCE POINT) Approximately 3/4 mile east of Sumner on State Highway 93 bridge over Little Wapsipinicon River, on left downstream concrete guardrail above and 5 feet left of second drain; chiseled arrow. Elevation determined using GPS.

Elevation 1,084.44 feet

Otter Creek

8909-19 NE (1) - At Otterville, on County Road D16 bridge over Otter Creek, on left upstream wingwall; chiseled square. Elevation determined using GPS.

Elevation 922.30 feet

8909-19 NE (2) - (REFERENCE POINT) At Otterville, on County Road D16 bridge over Otter Creek, on left downstream handrail at 12th handrail post; filed arrow. Elevation determined using GPS.

Elevation 926.53 feet

9009-16 SE (1) - Approximately 1.5 miles south of Hazelton, on Fontana Lake Park Road bridge over Otter Creek, on left upstream guardrail at the first post; top bolt colored with red marker. Elevation determined using GPS.

Elevation 980.90 feet

9009-16 SE (2) - (REFERENCE POINT) Approximately 1.5 miles south of Hazelton, on Fontana Lake Park Road bridge over Otter Creek, on left downstream guardrail below 10th guardrail post on the metal sleeve holding post; filed two marks. Elevation determined using GPS.

Elevation 978.37 feet

9009-09 SE (1) - West edge of Hazelton, on Hayes Street bridge over Otter Creek, on left downstream guardrail on top of bolt; filed X and painted orange. Elevation determined using GPS.

Elevation 988.69 feet

9009-09 SE (1) - (REFERENCE POINT) West edge of Hazelton, on Hayes Street bridge over Otter Creek, on left downstream guardrail above second drain; filed arrow. Elevation determined using GPS.

Elevation 988.75 feet

9109-33 SE (1) - Approximately 2.5 miles northeast of Hazelton, on State Highway 281 bridge over Otter Creek, on left upstream wingwall; Iowa DOT BM. Elevation determined using GPS.

Elevation 1,002.25 feet

9109-33 SE (2) - (REFERENCE POINT) Approximately 2.5 miles northeast of Hazelton, on State Highway 281 bridge over Otter Creek, on left downstream concrete guardrail 5 feet west and above first drain; chiseled arrow. Elevation determined using GPS.

Elevation 1,002.06 feet

9109-20 NW (1) - At Oelwein, on County Road C50 bridge over Otter Creek, on right upstream wingwall: chiseled square. Elevation determined using GPS.

Elevation 1,026.46 feet

9109-20 NW (2) - (REFERENCE POINT) At Oelwein, on County Road C50 bridge over Otter Creek, on left downstream guardrail left of the 11th guardrail post and next to two bolts; filed arrow. Elevation determined using GPS.

Elevation 1,026.44 feet

9109-07 NW (1) - Approximately 5 miles northwest of Oelwein, on State Highway 3 bridge over Otter Creek, on right downstream top of streetward corner; chiseled square. Elevation determined using GPS. Elevation determined using GPS.

Elevation 1,046.54 feet

9109-07 NW (2) - Approximately 5 miles northwest of Oelwein, on State Highway 3 bridge over Otter Creek, on right downstream bridge curb under metal guardrail; Iowa DOT BM.

Elevation 1,044.21 feet

9109-07 NW (3) - (REFERENCE POINT) Approximately 5 miles northwest of Oelwein, on State Highway 3 bridge over Otter Creek, on right downstream guardrail on sixth guardrail post and in middle of four bolts; chiseled arrow. Elevation determined using GPS.

Elevation 1,046.40 feet

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