U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with
THE CONFEDERATED SALISH AND KOOTENAI TRIBES
OF THE FLATHEAD NATION

SCIENTIFIC INVESTIGATIONS MAP 2912
(Sheet 3 of 3)
Chase and Parrett, 2006, Water-surface elevations and boundaries of the 100-year and 500-year floods and floodway for the Jocko River, western Montana

Flooding on the Jocko River, June 4, 2005. View is looking northwest (downstream) from near cross section 71 (sheet 2) about 3 miles upstream from Ravalli, Montana. Photograph by Les Evarts, the Confederated Salish and Kootenai Tribes of the Flathead Nation.

Water-Surface Elevation Data

Water-surface elevations were calculated for the 100- and 500-year flood discharges for all surveyed and several interpolated cross sections in the study area for both existing and hypothetical (no-levee) conditions (table 4). Also presented in table 4 are the minimum streambed elevations at the cross sections and the locations of bridges. Water-surface elevations were calculated for the 100-year flood discharge for both existing and hypothetical (no-levee) conditions for the main channel and left-flood plain for cross sections in the split-flow reaches (table 5). Also presented in table 5 are the minimum streambed elevations at the cross sections. For all cross sections shown in tables 4 and 5, cumulative distances upstream from cross section 1 (most downstream cross section) also are presented.

The water-surface elevation data in tables 4 and 5 can be used with the distance data to construct profiles of 100- and 500-year flood discharge throughout the study area. Flood profiles are useful for estimating water-surface elevations at selected locations between cross sections. Graphs showing flood profiles for the main channels of the Jocko River based on channel and flood-plain conditions at the time of the surveys (1999-2001) are included on sheet 2. The calculated water-surface elevations (tables 4 and 5) and flood-profile graphs are based on unobstructed flow and are valid only if hydraulic structures remain clear of debris and do not fail.

Boundaries of the 100- and 500-year Flood Discharges

The flood boundaries along the Jocko River define areas that would be inundated by the 100- and 500-year flood discharges (Map segments 1, 2, and 3). The flood boundaries were delineated using water-surface elevations calculated at each cross section. Between cross sections, the flood-profile graphs were used to determine water-surface elevations, which in turn were used to interpolate flood boundaries based on interpretation of aerial photography, limited onsite surveys, and onsite visual inspection.

Along the Jocko River, the ground surface of small areas within the flood boundaries for the 100-year flood discharge might be above the calculated water-surface elevation, but cannot be shown because of the limitations of the map scale or the lack of sufficiently detailed topographic data. Likewise, small areas within the flood boundaries for the 500-year flood discharge might be above the calculated water-surface elevation. Also, some locations in the study area might be subject to flooding from Valley Creek, Finley Creek, or other small tributaries to these streams or the Jocko River. In addition, other locations might also be subject to flooding from overflows from irrigation ditches. Flood boundaries for these streams and irrigation ditches are not shown.

A levee or bankline is shown on the left bank (south or western side of the Jocko River) in all split-flow reaches to indicate where the main channel and left-flood plain are delineated. Main channel areas on the right side of the bankline have calculated water-surface elevations for the 100- and 500-year flood discharges that are different from those in the left-flood plain. Although berms, levees, and banklines exist in numerous locations outside the split-flow reaches, they are not shown on Map segments 1, 2, or 3.

Boundaries of the Floodway

The area within the boundaries of the 100-year flood discharge is divided into two parts for flood-plain management purposes. The floodway, which is reserved for the passage of flood discharges, includes the channel and some adjoining flood plain. The flood fringe, which is allowed to be developed with structures elevated on suitable fill material, includes the outer parts of the area inundated by the 100-year flood discharge. The width of the floodway under Montana Administrative Rule 36.15.502 (1995) is determined by hydraulic calculation such that the water-surface elevation of the 100-year flood discharge is increased by no more than 0.5 ft by complete filling (encroachment) of the flood fringe. Montana Administrative Rule 36.15.502 (1995) further indicates that flood-plain areas where flow depths or velocities for the 100-year flood discharge exceed 3 ft or 3 ft/s, respectively, need to be included in the floodway. Figure 10 (sheet 3) shows a theoretical cross section with a floodway and water-surface elevations for the 100-year flood discharge with and without encroachment in the flood fringe.

The HEC-RAS hydraulic model was used to delineate floodway boundaries for existing conditions (1999-2001) by incrementally simulating encroachment on the 100-year flooded area from each side of each cross section and re-running the hydraulic model until calculated water-surface elevations for the 100-year flood discharge were increased by a maximum of 0.5 ft at all sections. Areas within the 100-year flood plain, where high depths (greater than 3 ft) and high velocities (greater than 3 ft/s) occurred, were included in the floodway even if the increase in the water-surface elevation was less than 0.5 ft. The floodway width was expanded to equal the flood-plain width at all cross sections in split-flow Reaches 2, 3, and 7. At a few cross sections, the calculated water-surface elevation for the 100-year flood discharge with a floodway was less than that without a floodway. The calculated lower water-surface elevation probably is the result of more efficient hydraulic transitions between adjacent cross sections with a delineated floodway than without. For those few sections with lower calculated water-surface elevations with a floodway, the lower elevations were raised to match those without a floodway.

Data for floodway widths and changes in water-surface elevations for the 100-year flood discharge as a result of floodway delineation are presented in table 6 (sheets 1, 2, and 3). Floodway boundaries are shown together with the 100- and 500-year flood boundaries (Map segments 1-3).

Summary

The Jocko River flows across the Flathead Indian Reservation in western Montana and provides irrigation water for several thousand acres of hay and grain that are produced throughout the Jocko River valley. Much of the agricultural land along the river is being considered for residential and commercial development. In addition, proposed levee modifications and stream-restoration work could further affect the Jocko River channel and its aquatic habitat. The potential for increased development highlighted the need for a better understanding of the boundaries of the 100- and 500-year floods.

The 100- and 500-year flood discharges for the Jocko River at Dixon were estimated by applying the log Pearson Type III probability distribution to the recorded and estimated annual-peak discharges for the period of record from 1907-1910, 1948, and 1986 to 2001. The large annual-peak discharges of 1908 (7,500 ft^3/s) and 1948 (3,700 ft^3/s) are considered to be the largest during the entire period from 1907 to 2001; thus, these values were treated as historic peak discharges (largest peak discharges in 94 years).

The 100- and 500-year flood discharges for the Jocko River near Arlee were estimated by applying the log Pearson Type III probability distribution to the recorded and estimated peak discharges at the USGS and CSKT gaging stations for the period of record from 1908, 1916, 1948, and 1990 to 2001. The peak discharges for 1908 (6,200 ft^3/s) and 1948 (2,660 ft^3/s) also were treated as historic peak discharges (largest peak discharges in 94 years).

HEC-RAS, version 3.1.1, a one-dimensional, hydraulic-flow model developed by the U.S. Army Corps of Engineers, was used to calculate water-surface elevations at cross sections for the 100-year and 500-year flood discharges and for the 1997 peak discharge. Channel and flood-plain geometry for 113 cross sections were surveyed between 1999 and 2001 for use in the model. Bridge geometries at 9 of the 113 sections located just downstream from bridge crossings also were surveyed. Surveyed cross section data downstream from the bridges were used to estimate channel and flood-plain geometry at the upstream and downstream edges of the bridges for use in the HEC-RAS model. For clarity, only the surveyed cross section immediately downstream from each bridge is shown on the map segments. Interpolated cross-section data were used at 15 more locations where the hydraulic-model results indicated that additional channel and flood-plain geometry were required. For clarity, only 5 of the 15 interpolated sections are shown on the map segments. Overall, a total of 146 cross sections (113 surveyed cross sections, 15 interpolated cross sections, and 18 cross sections at the upstream and downstream bridge edges) were used for hydraulic analyses. Data for the cross sections are available in files at the USGS Montana Water Science Center office in Helena, Mont.

Although berms and levees are present in all reaches of the Jocko River, only in Reaches 2, 3, and 5 are they long enough and high enough to create split-flow conditions. The berms and levees in Reaches 2, 3, and 5 tend to keep floodwater confined to the main channel, but overtopping floodwater from upstream is confined behind and along the left side of the berms and levees. In addition, the calculated water-surface elevations of the 100- and 500-year flood discharges are greater than the ground elevations along the top of the berms and levees in many locations in Reach 2. Thus, the amount of flood discharge on the left-flood plain continually increases in the downstream direction in Reach 2 as more floodwater from the channel spills over the top of the levees.

The flood boundaries along the Jocko River define areas that would be inundated by the 100- and 500-year flood discharges (Map segments 1, 2, and 3). The flood boundaries were delineated using water-surface elevations calculated at each cross section. Between cross sections, the flood-profile graphs were used to determine water-surface elevations, which in turn were used to interpolate flood boundaries based on interpretation of aerial photography, limited onsite surveys, and onsite visual inspection. The calculated water-surface elevations and flood-profile graphs are based on unobstructed flow and are valid only if structures remain clear of debris and do not fail. Some ground elevations within the flood boundaries might be higher than the calculated water-surface elevations. In these instances, the small areas of high-elevation ground generally cannot be shown due to lack of detailed topographic data and the map scale. Flood boundaries for tributary streams and irrigation ditches are not shown.

The boundaries of the floodway (for existing conditions) were calculated by incrementally simulating encroachment on the 100-year flooded area from each side of each cross section and re-running the hydraulic model until calculated water-surface elevations for the 100-year flood discharge increased by a maximum of 0.5 foot at all sections. Areas within the 100-year flood plain, where high depths (greater than 3 ft) and high velocities (greater than 3 ft/s) occurred, were included in the floodway even if the increase in the water-surface elevation was less than 0.5 ft. The floodway width was expanded to include the entire flood plain at all cross sections in split-flow Reaches 2, 3, and 7.

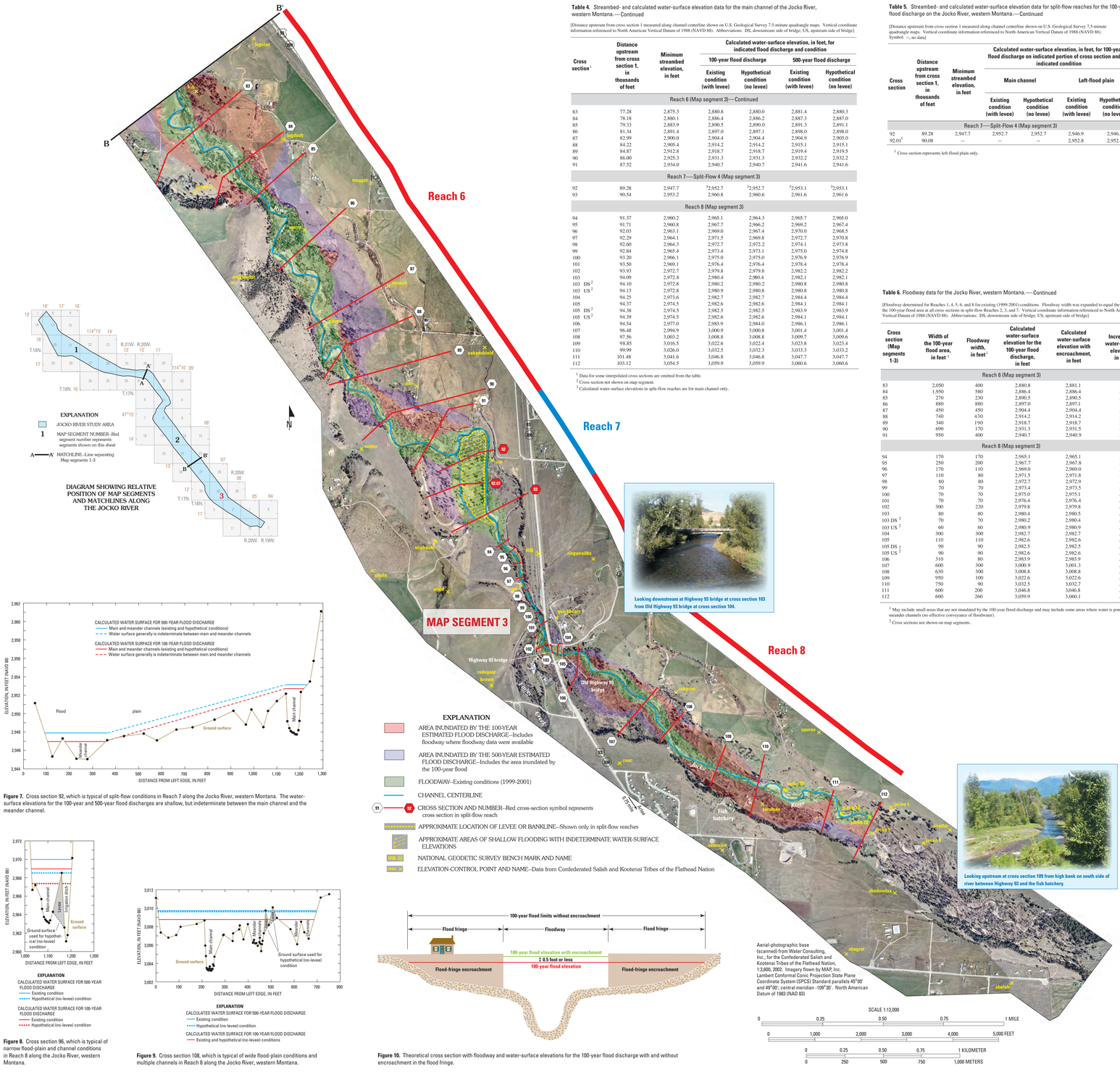

Figure 7. Cross section 92, which is typical of split-flow conditions in Reach 7 along the Jocko River, western Montana. The water-surface elevations for the 100-year and 500-year flood discharges are shallow, but indeterminate between the main channel and the meander channel.

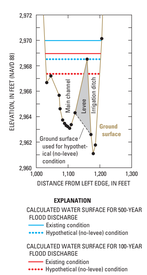

Figure 8. Cross section 96, which is typical of narrow flood-plain and channel conditions in Reach 8 along the Jocko River, western Montana.

Figure 9. Cross section 108, which is typical of wide flood-plain conditions and multiple channels in Reach 8 along the Jocko River, western Montana.

Figure 10. Theoretical cross section with floodway and water-surface elevations for the 100-year flood discharge with and without encroachment in the flood fringe.

Table 4. Streambed- and calculated water-surface elevation data for the main channel of the Jocko River, western Montana.—Continued

[Distance upstream from cross section 1 measured along channel centerline shown on U.S. Geological Survey 7.5-minute quadrangle maps. Vertical coordinate information referenced to North American Vertical Datum of 1988 (NAVD 88). Abbreviations: DS, downstream side of bridge; US, upstream side of bridge]

Cross section[1]	Distance upstream from cross section 1, in thousands of feet	Minimum streambed elevation, in feet	Calculated water-surface elevation, in feet, for indicated flood discharge and condition			
			100-year flood discharge		500-year flood discharge	
			Existing condition (with levee)	Hypothetical condition (no levee)	Existing condition (with levee)	Hypothetical condition (no levee)
Reach 6 (Map segment 3)—Continued						
83	77.28	2,875.3	2,880.8	2,880.0	2,881.4	2,880.3
84	78.18	2,880.1	2,886.4	2,886.2	2,887.3	2,887.0
85	79.33	2,883.9	2,890.5	2,890.0	2,891.3	2,891.1
86	81.34	2,891.4	2,897.0	2,897.1	2,898.0	2,898.0
87	82.99	2,900.0	2,904.4	2,904.4	2,904.9	2,905.0
88	84.22	2,905.4	2,914.2	2,914.2	2,915.1	2,915.1
89	84.87	2,912.8	2,918.7	2,918.7	2,919.4	2,919.5
90	86.00	2,925.3	2,931.3	2,931.3	2,932.2	2,932.2
91	87.52	2,934.0	2,940.7	2,940.7	2,941.6	2,941.6
Reach 7—Split-Flow 4 (Map segment 3)						
92	89.28	2,947.7	[3]2,952.7	[3]2,952.7	[2]2,953.1	[2]2,953.1
93	90.54	2,953.2	2,960.8	2,960.6	2,961.6	2,961.6
Reach 8 (Map segment 3)						
94	91.37	2,960.2	2,965.1	2,964.3	2,965.7	2,965.0
95	91.71	2,960.8	2,967.7	2,966.2	2,969.2	2,967.4
96	92.03	2,963.1	2,969.0	2,967.4	2,970.0	2,968.5
97	92.29	2,964.1	2,971.5	2,969.8	2,972.7	2,970.8
98	92.60	2,964.3	2,972.7	2,972.2	2,974.1	2,973.8
99	92.84	2,965.4	2,973.4	2,973.1	2,975.0	2,974.8
100	93.20	2,966.1	2,975.0	2,975.0	2,976.9	2,976.9
101	93.50	2,969.1	2,976.4	2,976.4	2,978.4	2,978.4
102	93.93	2,972.7	2,979.8	2,979.8	2,982.2	2,982.2
103	94.09	2,972.8	2,980.4	2,980.4	2,982.1	2,982.1
103 DS[2]	94.10	2,972.8	2,980.2	2,980.2	2,980.8	2,980.8
103 US[2]	94.13	2,972.8	2,980.9	2,980.8	2,980.8	2,980.8
104	94.25	2,973.6	2,982.7	2,982.7	2,984.4	2,984.4
105	94.37	2,974.5	2,982.6	2,982.6	2,984.1	2,984.1
105 DS[2]	94.38	2,974.5	2,982.5	2,982.5	2,983.9	2,983.9
105 US[2]	94.39	2,974.5	2,982.6	2,982.6	2,984.1	2,984.1
106	94.54	2,977.0	2,983.9	2,984.0	2,986.1	2,986.1
107	96.48	2,994.9	3,000.9	3,000.8	3,001.4	3,001.4
108	97.56	3,003.2	3,008.8	3,008.8	3,009.7	3,009.6
109	98.85	3,016.5	3,022.6	3,022.4	3,023.8	3,023.4
110	99.99	3,026.0	3,032.5	3,032.3	3,033.3	3,033.2
111	101.48	3,041.6	3,046.8	3,046.8	3,047.7	3,047.7
112	103.12	3,054.5	3,059.9	3,059.9	3,060.6	3,060.6

[1] Data for some interpolated cross sections are omitted from the table.
[2] Cross section not shown on map segment.
[3] Calculated water-surface elevations in split-flow reaches are for main channel only.

Table 5. Streambed- and calculated water-surface elevation data for split-flow reaches for the 100-year flood discharge on the Jocko River, western Montana.—Continued

[Distance upstream from cross section 1 measured along channel centerline shown on U.S. Geological Survey 7.5-minute quadrangle maps. Vertical coordinate information referenced to North American Vertical Datum of 1988 (NAVD 88). Symbol: --, no data]

Cross section	Distance upstream from cross section 1, in thousands of feet	Minimum streambed elevation, in feet	Calculated water-surface elevation, in feet, for 100-year flood discharge on indicated portion of cross section and for indicated condition			
			Main channel		Left-flood plain	
			Existing condition (with levee)	Hypothetical condition (no levee)	Existing condition (with levee)	Hypothetical condition (no levee)
Reach 7—Split-Flow 4 (Map segment 3)						
92	89.28	2,947.7	2,952.7	2,952.7	2,946.9	2,946.9
92.01[1]	90.08	--	--	--	2,952.8	2,952.8

[1] Cross section represents left-flood plain only.

Table 6. Floodway data for the Jocko River, western Montana.—Continued

[Floodway determined for Reaches 1, 4, 5, 6, and 8 for existing (1999-2001) conditions. Floodway width was expanded to equal the width of the 100-year flood area at all cross sections in split-flow Reaches 2, 3, and 7. Vertical coordinate information referenced to North American Vertical Datum of 1988 (NAVD 88). Abbreviations: DS, downstream side of bridge; US, upstream side of bridge]

Cross section (Map segments 1-3)	Width of the 100-year flood area, in feet[1]	Floodway width, in feet[1]	Calculated water-surface elevation for the 100-year flood discharge, in feet	Calculated water-surface elevation with encroachment, in feet	Increase in water-surface elevation, in feet
Reach 6 (Map segment 3)					
83	2,050	400	2,880.8	2,881.1	.3
84	1,950	580	2,886.4	2,886.4	.0
85	270	230	2,890.5	2,890.5	.0
86	880	880	2,897.0	2,897.1	.1
87	450	450	2,904.4	2,904.4	.0
88	740	430	2,914.2	2,914.2	.0
89	340	190	2,918.7	2,918.7	.0
90	690	170	2,931.3	2,931.5	.2
91	950	400	2,940.7	2,940.9	.2
Reach 8 (Map segment 3)					
94	170	170	2,965.1	2,965.1	.4
95	250	200	2,967.7	2,967.8	.1
96	170	110	2,969.0	2,969.0	.0
97	110	80	2,971.5	2,971.8	.3
98	80	80	2,972.7	2,972.9	.2
99	70	70	2,973.4	2,973.5	.1
100	70	70	2,975.0	2,975.1	.1
101	70	70	2,976.4	2,976.4	.0
102	300	220	2,979.8	2,979.8	.0
103	80	80	2,980.4	2,980.5	.1
103 DS[2]	70	70	2,980.2	2,980.4	.2
103 US[2]	60	60	2,980.9	2,980.9	.0
104	300	300	2,982.7	2,982.7	.0
105	110	110	2,982.6	2,982.6	.0
105 DS[2]	90	90	2,982.5	2,982.5	.0
105 US[2]	90	90	2,982.6	2,982.6	.0
106	310	80	2,983.9	2,983.9	.0
107	600	300	3,000.9	3,001.3	.4
108	630	300	3,008.8	3,008.8	.0
109	950	100	3,022.6	3,022.6	.0
110	750	90	3,032.5	3,032.7	.2
111	600	200	3,046.8	3,046.8	.0
112	600	260	3,059.9	3,060.1	.2

[1] May include small areas that are not inundated by the 100-year flood discharge and may include some areas where water is ponded in meander channels (no effective conveyance of floodwater).
[2] Cross sections not shown on map segments.

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Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
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)
Hydraulic gradient		
foot per foot (ft/ft)	1.0	meter per meter (m/m)
Velocity		
foot per second (ft/s)	0.3048	meter per second (m/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27) or to the North American Datum of 1983 (NAD 83) as noted. Surveyed vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), unless otherwise noted.

Water year definition:

Water year refers to the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends.

Acronyms used in this report:

CSKT	Confederated Salish and Kootenai Tribes of the Flathead Nation
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
USGS	U.S. Geological Survey

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WATER-SURFACE ELEVATIONS AND BOUNDARIES OF THE 100-YEAR AND 500-YEAR FLOODS AND FLOODWAY FOR THE JOCKO RIVER, WESTERN MONTANA

By
Katherine J. Chase and Charles Parrett

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