WATER-SURFACE PROFILE AND FLOOD BOUNDARIES FOR THE COMPUTED 100-YEAR FLOOD, BIG MUDDY CREEK, FORT PECK INDIAN RESERVATION AND ADJACENT AREA, MONTANA

By R.J. Omang

INTRODUCTION

Areas that would be inundated by a peak discharge having a recurrence interval of 100 years (the 100-year flood) along streams in the Fort Peck Indian Reservation are of interest to the Fort Peck Tribes because of the potential for development of the land. Knowledge of the extent of the flood plain also is needed to control flood damage in the Fort Peck Reservation. An area of concern is the flood plain of Big Muddy Creek (fig. 1).

Flood damage can be decreased by controlling land use adjacent to the stream by planned development and management of flood-hazard areas. Delineation of flood-hazard areas will allow selection of the type of desired development that is compatible with the flood risk.

The U.S. Geological Survey, in cooperation with the Fort Peck Tribes, conducted a hydrologic and hydraulic analysis of Big Muddy Creek to identify areas along the creek subject to flooding. The specific objective of the study was to determine the extent of flooding that would result from a 100-year flood. This report presents the results of the study based on conditions in the basin in 1993.

The magnitude of the 100-year flood was determined using techniques described in a report by Omang (1992), and data from a discontinued U.S. Geological Survey streamflow-gaging station (station 06183000, located at Plentywood) on Big Muddy Creek. Channel and flood-plain elevations were surveyed at 39 cross sections along a 41-mile reach of Big Muddy Creek. Two additional cross sections along the same reach were synthesized. Physical dimensions of hydraulic structures were measured. Manning's roughness coefficients were estimated at each cross section. Field survey data and a hydraulic computer model were used to calculate water-surface elevations for the 100-year flood at each section. These elevations were used to determine the inundated areas for the 100-year flood.

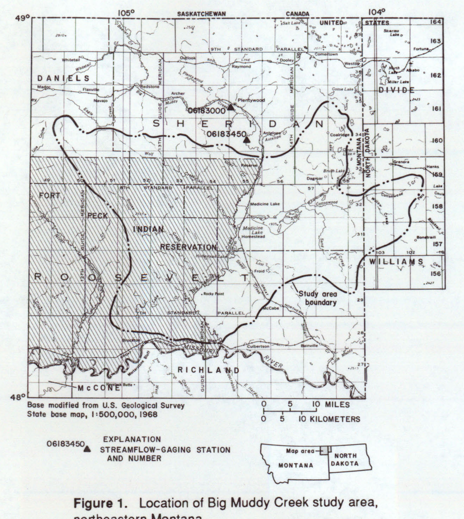

Figure 1. Location of Big Muddy Creek study area, northeastern Montana

General Description of the Area

Big Muddy Creek flows southwesterly from Saskatchewan, Canada, through part of northeastern Montana and joins the Missouri River about 65 miles south of the international boundary. The study area includes that part of the Big Muddy Creek drainage basin from the northern boundary of the Fort Peck Reservation downstream to near the southern boundary, near Culbertson. The Big Muddy Creek basin is sparsely populated and consists of gently rolling hills and broad, flat valleys. The land surface has little relief, with elevations ranging from 1,900 to 2,800 feet in the study area.

The climate is typical of the Northern Plains, with hot, moderately dry summers and cold winters. Mean daily temperatures at Culbertson range from 70 °F in July to 10 °F in January. Average annual precipitation is about 13 in.; more than 8 in. of the total is received from May through August. June is the wettest month, with an average of about 3.4 in. of precipitation; December, January, and February are the driest, with an average of 0.3 in. per month (U.S. Environmental Data Service, 1971, p. 10).

Streamflow Conditions and Flooding

Big Muddy Creek is considered to be a perennial stream and all tributaries that enter the creek are intermittent. Most runoff results from snowmelt in the spring and from rainfall from thunderstorms in the summer. Occasionally, snowmelt and rain combine to produce runoff. A streamflow-gaging station (station 06183450) having a short period of peak-flow record is located about 2 miles upstream from the study area. A streamflow-gaging station (station 06183000) having 19 years of peak-flow record is located about 8 miles upstream from the study area. The largest known peak flow at the station nearest the study area was 2,890 ft³/s on April 14, 1982. The largest known peak flow at the station farthest upstream from the study area was 8,000 ft³/s on June 30, 1953.

METHODS OF ANALYSIS

Standard hydrologic and hydraulic methods were used to analyze the flood hazard for Big Muddy Creek. The magnitude of a flood that is expected to be equaled or exceeded once on the average during any 100-year period (recurrence interval) was selected by the Fort Peck Tribes for analysis. The 100-year flood has a 1-percent chance of being equaled or exceeded in any given year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at shorter intervals or even within the same year.

Hydrologic Analysis

Flood-discharge values for Big Muddy Creek are based on a statistical analysis of discharge record for the streamflow-gaging station 06183000 located about 8 miles upstream from the study area and on techniques described in a report by Omang (1992). The streamflow-gaging station nearest the study area (06183450) was not used in the analysis because of its short record length. Nineteen years of peak-discharge record are available at station 06183000: 1948-53 and 1955-67. The peak discharges were analyzed by the standard log-Pearson type III method as described by the Interagency Advisory Committee on Water Data (1982). Using this method, the 100-year flood discharge determined for the streamflow-gaging station was 11,500 ft³/s. This flood discharge was transferred from the station to various stream reaches using the following transfer equation developed by Omang (1992, p. 12):

$$Q_{tu} = \left[\frac{Au}{Ag}\right]^{0.54} \cdot Q_{tg}$$

where

Q_{tu} = flood magnitude being estimated at the ungaged site, in cubic feet per second;

Au = drainage area at the ungaged site, in square miles;

Ag = drainage area at the gaged site, in square miles (850 square miles for station 06183000);

Q_{tg} = flood magnitude at the gaged site, in cubic feet per second.

The transfer equation was used to estimate 100-year flood discharge for four stream reaches along Big Muddy Creek: (1) from cross section 41 near the northern reservation boundary to cross section 24 at the Medicine Lake Diversion Ditch No. 1; (2) from cross section 22 just downstream from the mouths of Wolf Creek and Lake Creek to cross section 14 upstream from Smoke Creek; (3) from cross section 13 just downstream from the mouth of Smoke Creek to cross section 12 upstream from a second Lake Creek; and (4) from cross section 11 just downstream from the mouth of the second Lake Creek to cross section 1 near the southern reservation boundary. The estimated 100-year flood discharge for Big Muddy Creek increases in a downstream direction through the four reaches because of inflow from tributaries. In addition to the flow increases estimated by the transfer equation, a decrease in flow occurs just downstream from cross section 24 where flow is diverted from Big Muddy Creek into the Medicine Lake Diversion Ditch No. 1. The diverted flow during a 100-year flood was estimated to be 1,000 ft³/s, all of which would return to Big Muddy Creek upstream from cross section 22. The estimated flood discharge for Big Muddy Creek for the reach downstream from cross section 24 to cross section 23 thus is estimated to be 1,000 ft³/s less than that for the next upstream reach. The estimated 100-year flood discharge for each reach along Big Muddy Creek is shown in table 1.

Table 1. Summary of 100-year discharges
[--, not applicable]

Stream reach	Cross sections	Drainage area (square miles)	100-year flood discharge (cubic feet per second)
Big Muddy Creek downstream from northern reservation boundary to Medicine Lake Diversion Ditch No. 1	41-24	1,163	13,600
Big Muddy Creek downstream from Medicine Lake Diversion Ditch No. 1 to cross section 23	23	--	12,600
Big Muddy Creek downstream from mouths of Wolf Creek and Lake Creek to cross section 14	22-14	2,160	19,000
Big Muddy Creek downstream from mouth of Smoke Creek to cross section 12	13-12	2,447	20,400
Big Muddy Creek downstream from mouth of second Lake Creek to cross section 1	11-1	2,684	21,400

The 100-year flood discharge for the stream reach from cross section 1 to cross section 11 also was calculated using channel geometry equations described in a report by Parrett and others (1987). The 100-year discharge determined by this method (21,100 ft³/s) helped to validate the downstream 100-year flood discharge using the transfer method.

Hydraulic Analysis

The hydraulic characteristics of the cross sections along Big Muddy Creek were analyzed to determine the water-surface elevations of the 100-year flood. The method used to define hydraulic characteristics requires cross-section geometry data and estimates of the roughness coefficient (Manning's "n").

Cross-section data were obtained from field surveys conducted during the summer of 1993. Field surveys determined elevations for 39 cross sections along a 41-mile reach. Two additional cross sections along the same reach were synthesized. The synthesized cross sections (sections 29 and 36 on the principal map) were estimated from adjacent surveyed sections and topographic maps. Structural geometry data also were obtained for five bridges. Cross sections were located upstream and downstream from the bridges to permit computation of the backwater effects of these structures. Two bridges were located on road sections where numerous culverts also were located. Therefore, geometry data were obtained at 17 culverts located along cross section 16 and at 6 culverts located along cross section 20. The discharge through these culverts was determined using techniques developed by Bodhaine (1968). The discharge determined for the culverts at each cross section was then subtracted from the 100-year flood discharge at each section. The resultant discharge at each section was routed through the bridge and over the embankment. Cross sections typical of channel and flood-plain conditions in the upstream and downstream parts of the study area are shown in figures 2 and 3, respectively. A cross section typical of channel conditions at bridges is shown in figure 4.

The roughness coefficient represents the resistance to flow. Factors that affect the roughness coefficient include the type and size of materials that compose the bed and banks of the channel and flood plain, shape of the channel, variation in dimensions of adjacent cross sections, vegetation, structures, and degree of meandering. Roughness coefficients (Manning's "n") used in the hydraulic computations were based on engineering judgment of onsite observations. Roughness coefficients used along Big Muddy Creek range from 0.035 to 0.075 for the main channel and from 0.030 to 0.080 for the flood-plain areas.

Water-surface elevations for the 100-year flood were computed using a water-surface-profile computation model (WSPRO) developed by the U.S. Geological Survey for the Federal Highway Administration (Shearman and others, 1986; Shearman, 1990). WSPRO is a computer program that is used to analyze one-dimensional, gradually varied, steady flow in open channels based on the assumption of fixed boundaries. With this computer program, the surveyed and synthesized cross-section data were used to define the hydraulic characteristics of the channel. The location of each cross section was selected to represent the hydraulic characteristics of a reach, and each section was surveyed or synthesized to define its shape. The model uses the standard step method (Chow, 1959, p. 265) to determine changes in water-surface elevation from a downstream cross section to an upstream cross section by balancing the total-energy head at the section. The starting water-surface elevation used to compute the 100-year flood profile for Big Muddy Creek at cross section 1, which is 5,600 feet upstream from where Big Muddy Creek enters the Missouri River, was determined by using a slope-conveyance computation to estimate normal depth. Possible backwater effects of the Missouri River on flood elevations for Big Muddy Creek were considered to be insignificant because the Missouri River is highly regulated by upstream reservoirs. Water-surface elevations for the 100-year flood discharges at each cross section are given in table 2.

WATER-SURFACE PROFILE

The water-surface profile for the 100-year flood (fig. 5) was drawn for the entire reach within the study area. The profile shows the computed water-surface elevations, the streambed elevations, and the location of bridges and cross sections used in the hydraulic analysis.

The hydraulic analysis was based on unobstructed flow. The water-surface elevations shown on the profile thus are considered to be valid only if hydraulic structures remain unobstructed and do not fail.

For the WSPRO assumption of gradually varied, steady flow to be valid, the distance between cross sections needs to be short. As described by Davidian (1984, p. 20), no cross section subreach should be longer than about 75-100 times the mean depth for the modeled discharge, nor longer than about twice the width of the subreach flood plain. The cost to survey sufficient cross sections for this study limited the number of sections to 39. Therefore, two additional cross sections (29 and 36) were synthesized and added to the WSPRO input data set to decrease possible step-backwater computation errors. If the synthesized cross-section data are replaced with surveyed data, the computed water-surface elevations at cross sections could change.

Field surveys and elevations are referenced to U.S. Geological Survey or U.S. Coast and Geodetic Survey bench marks and to reference marks established at convenient locations along Big Muddy Creek. Reference-mark locations are shown on the principal map and reference-mark descriptions are given in table 3.

FLOOD BOUNDARIES

The flood boundaries along the stream define an area that would be inundated as a result of the 100-year flood. For this study, the 100-year flood boundaries were delineated using water-surface elevations computed at each cross section. Between cross sections, where survey data were unavailable, the flood boundaries were interpolated using the contour lines on topographic maps.

The 100-year flood boundaries are shown on the principal map. Small flood-plain areas within the flood boundaries may lie above the water-surface elevations, but cannot be shown owing to limitations of the map scale or lack of detailed topographic data.

SUMMARY

Standard hydrologic and hydraulic methods were used to determine the flood-hazard area for Big Muddy Creek. The 100-year flood was selected as having special significance for flood-plain management.

The magnitude of the 100-year flood was determined for the reach of Big Muddy Creek extending from the northern boundary of the Fort Peck Reservation downstream to the southern boundary near Culbertson. The flood discharge was determined to range from 12,600 ft³/s to 21,400 ft³/s depending on location.

Data used for 39 channel and flood-plain cross sections were obtained from field surveys of a 41-mi reach of the river. Two additional cross sections were synthesized from adjacent surveyed sections and topographic maps. These data were used to compute the water-surface elevations for the 100-year flood at each cross section, using WSPRO, a computer program.

The water-surface profile was drawn showing computed water-surface elevations of a 100-year flood. The profile also shows the streambed elevations and the location of the bridges and cross sections used in the hydraulic analysis. Flood boundaries were delineated using water-surface elevations computed at each cross section. Between cross sections, the flood boundaries were interpolated using the contour lines on topographic maps.

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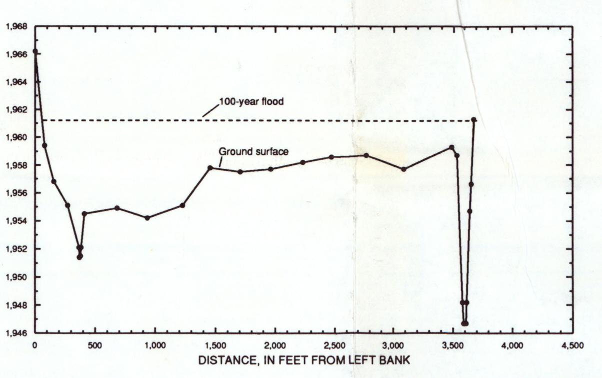


Figure 2. Cross section 39, which is typical of channel and flood-plain conditions in the upstream part of the study reach.

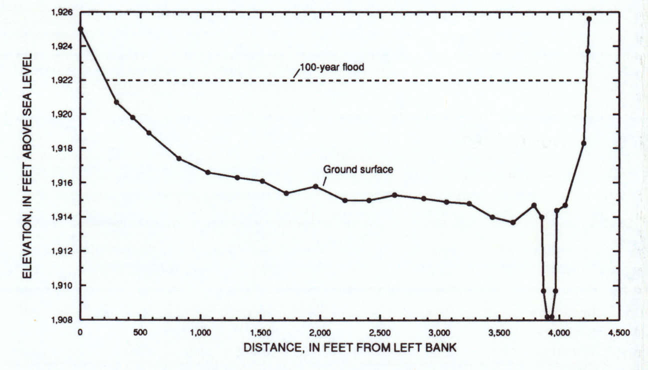


Figure 3. Cross section 9, which is typical of channel and flood-plain conditions in the downstream part of the study reach.

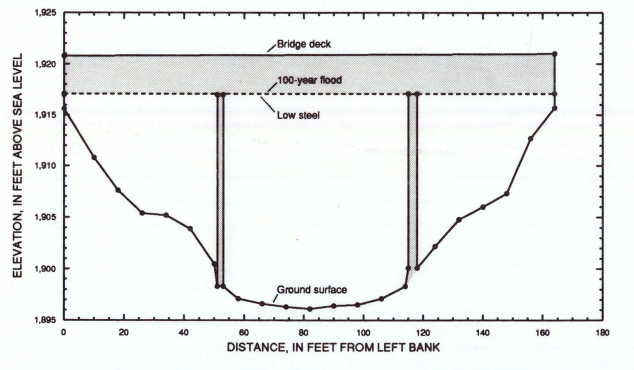
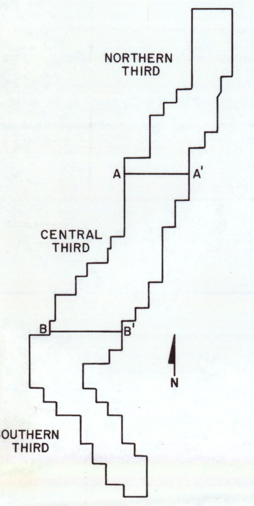
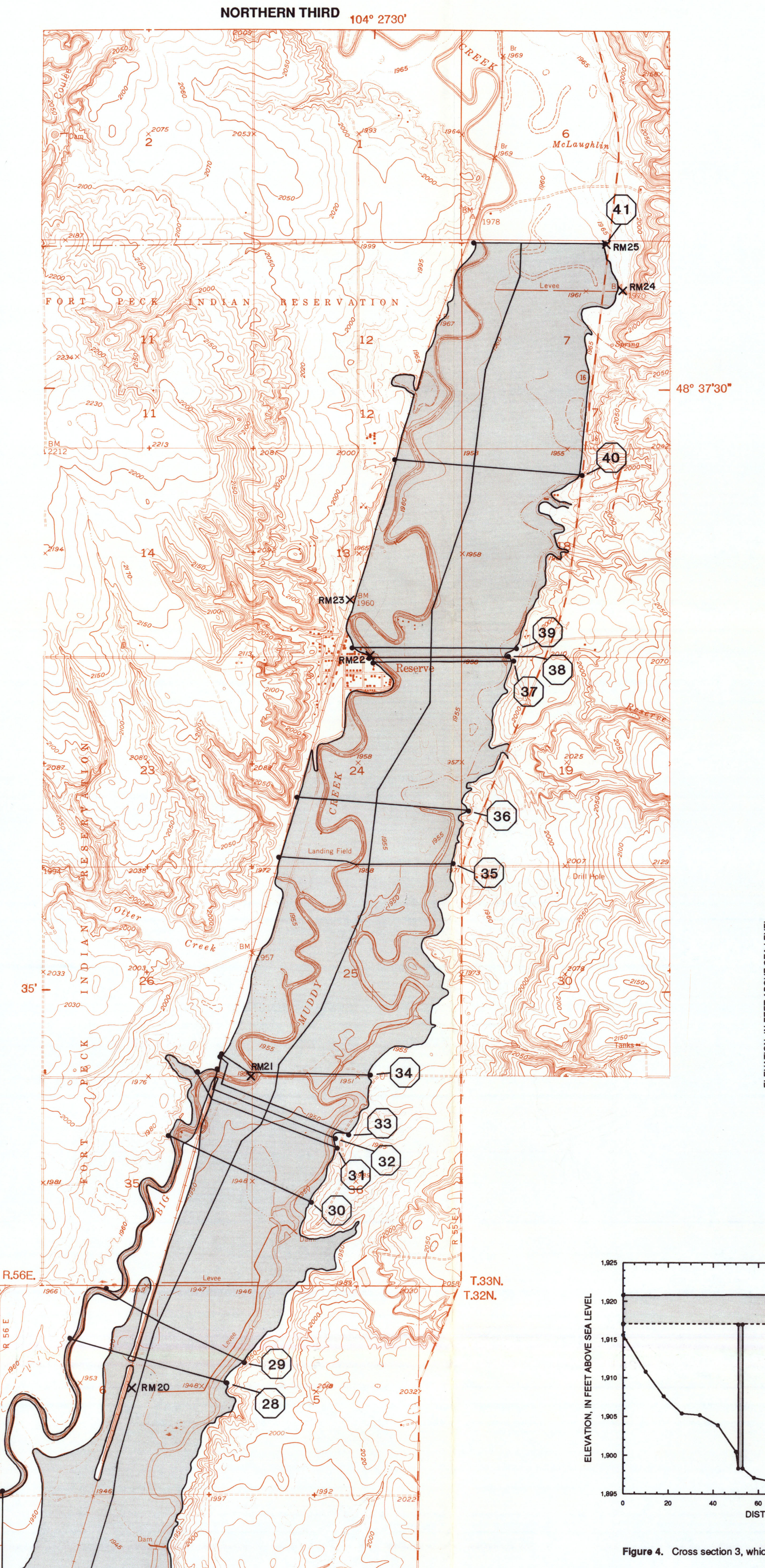
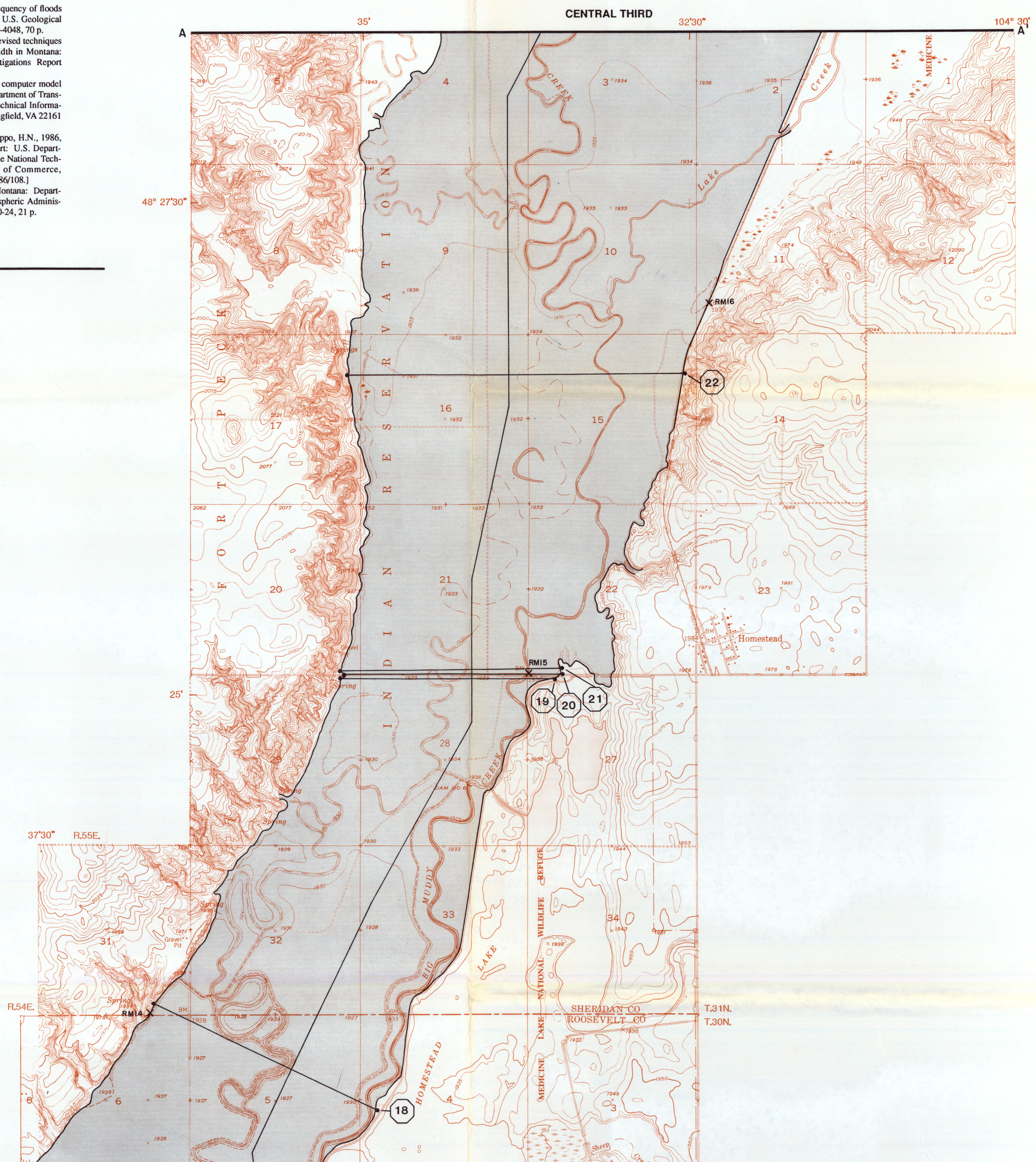


Figure 4. Cross section 3, which is typical of a bridge crossing in the study reach.



INDEX MAP SHOWING MATCHLINES





MAP SHOWING AREA INUNDATED BY THE 100-YEAR FLOOD, LOCATION OF CROSS SECTIONS, AND LOCATION OF ELEVATION REFERENCE MARKS

Base from U.S. Geological Survey Alkali Coulee, 1948; Antelope, 1948; Calais, 1950; Coyote Coulee, 1950; Culbertson, 1969; Fort Kipp, 1948; Homestead, 1947; Homestead NW, 1983; Johnson Lake, 1949; Reserve, 1948; Rocky Point, 1947. Provisional editions as of 1988 and 1989. 1:24,000

SCALE 1:24,000
CONTOUR INTERVAL 5 AND 10 FEET
DOTTED LINES REPRESENT SUPPLEMENTAL CONTOURS
DATUM IS SEA LEVEL

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second (ft³/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi²)	2.59	square kilometer

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the equation:

$$°C = 5/9 (°F - 32)$$

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

EXPLANATION

AREA THAT WILL BE INUNDATED BY THE 100-YEAR FLOOD--Centerline connects the centroids of flow of water at cross sections during the 100-year flood

CROSS SECTION AND NUMBER

MATCHLINE--Line separating northern, central, and southern thirds of the study area

ELEVATION REFERENCE MARK AND DESIGNATION

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