Prepared in cooperation with the
FORT PECK TRIBES

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

By

R.J. Omang

INTRODUCTION

Knowledge of the extent of the flood plain along Porcupine Creek (fig. 1) that would be inundated by a peak discharge having a recurrence interval of 100 years (the 100-year flood) is needed by the Fort Peck Tribes to control flood damage in the Fort Peck Indian Reservation. One approach for decreasing flood damage is 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 Porcupine Creek to identify areas along the creek subject to flooding. A 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.

The magnitude of the 100-year flood was determined using techniques described in a report by Omang (1992), using data from an existing U.S. Geological Survey streamflow-gaging station (station 06175000 located at Nashua) on Porcupine Creek, and using procedures recommended by the Interagency Advisory Committee on Water Data (1982). Fifty-seven channel and flood-plain cross sections were surveyed and 20 cross sections were synthesized along a 29-mi reach. Physical dimensions of hydraulic structures were measured. Manning's roughness coefficients were determined at each cross section. Field survey data and a hydraulic model were used to calculate water-surface elevations for the 100-year flood at each cross section. These elevations were used to determine the inundated area for the 100-year flood.

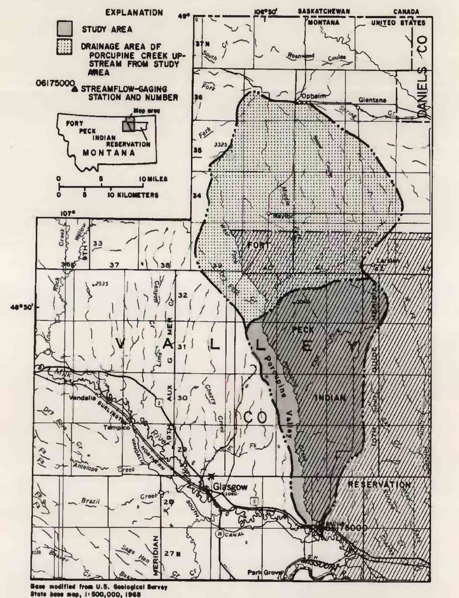


Figure 1.--Location of study area.

General Description of the Area

From its origin near the town of Opheim, Porcupine Creek flows southerly about 50 mi through northeastern Montana and joins the Milk River near the town of Nashua. The study area includes the drainage of Porcupine Creek from a point 1.9 mi downstream from the joining of the Middle and West Forks downstream to the mouth. The Porcupine Creek basin is sparsely populated and consists of gently rolling hills and broad, flat valleys. Areas of the valley adjacent to the stream are densely vegetated with bushes and trees. The land surface has little relief, with elevations ranging from 2,050 to 2,600 ft. The West Fork and mainstem of Porcupine Creek form the west boundary of the reservation.

The climate is typical of the northern plains, with hot, moderately dry summers and cold, dry winters. Mean daily temperatures at Glasgow range from 86 °F in July to -2 °F in January. Average annual precipitation is about 12 in.; more than 8 in. of the total is received from May through September. June is the wettest month, with an average of about 3 in. of precipitation, and December is the driest, with an average of 0.3 in. (U.S. Environmental Data Service, 1971, p. 10).

Streamflow Conditions and Flooding

Porcupine Creek has perennial flow and all tributaries that enter the river are intermittent or ephemeral. Most runoff results from snowmelt in the spring and rainfall from thunderstorms during the summer. Occasionally, late snowmelt and rain combine to cause runoff.

Porcupine Creek is commonly affected by ice during spring breakup. The elevation of maximum observed ice-affected stage at the gaging station for the period of record (intermittently 1908-92) was 2,053.4 ft in 1986. For comparison, the 100-year flood elevation at the gage was determined to be about 2,055.3 ft.

Prior to 1939, flow was partly regulated by a dam on the Middle Fork Porcupine Creek, 23 mi south of Opheim. Remnants of this structure, which was washed out in 1939, have no appreciable effect on the 100-year flood in either the upstream or the downstream reaches.

The largest known peak discharge on Porcupine Creek recorded at the gaging station was 3,600 ft^3/s on April 13, 1982. Floodwaters reached an elevation of 2,053.9 ft. A peak discharge of 35,000 ft^3/s on March 24, 1939, was caused by the failure of the dam on the Middle Fork. That discharge was determined by the U.S. Indian Service (now the U.S. Bureau of Indian Affairs).

METHODS OF ANALYSIS

Standard hydrologic and hydraulic methods were used to analyze the flood hazard for Porcupine 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. This 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. The analyses reported herein reflect flooding potentials based on conditions existing in the basin in 1991.

Hydrologic Analysis

Flood-discharge values for Porcupine Creek are based on a statistical analysis of discharge records at the gaging station at Nashua, techniques developed for predicting flood-frequency information, and procedures recommended by the Interagency Advisory Committee on Water Data (1982). Twenty-three years of peak-discharge records are available at this station: 1909, 1912-21, 1923-24, 1939, 1982-90. The peak discharges were analyzed by the standard log-Pearson type III method as described by the Interagency Advisory Committee on Water Data (1982). The peak discharge for 1939 (35,000 ft^3/s) was not used in the analysis because it occurred as the result of dam failure. Using this method, the 100-year flood discharge determined for the drainage area at the gaging station was 6,900 ft^3/s. The drainage area at the gaging station is the sum of drainage areas for both the main channel and the overflow channel, which is near the downstream end of the study area. Thus, part of the 6,900 ft^3/s discharge will be contained in the overflow channel.

Because the record of floods at the gaging station was short and large floods probably occurred in years when the gage was not operated, such as 1952, the 100-year flood discharge also was determined using techniques developed by Omang (1992). This discharge was computed to be 12,500 ft^3/s. The two 100-year flood discharges were weighted using methods described by the Interagency Advisory Committee on Water Data (1982, p. 8-1), and the resultant 100-year flood was computed to be 8,750 ft^3/s.

The flood discharge at the gaging station was transferred from the station to the upstream part of the study area using the following transfer equation developed by Omang (1992, p. 12).

$$Q_{tu} = \left(\frac{Au}{Ag}\right)^{0.49} \cdot Q_{tg}$$

where

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

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

Ag = drainage area at gaged site, in square miles;

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

The transfer method gives reasonably accurate results when the ungaged drainage area does not differ from the gaged drainage area by more than about 50 percent. In the reach analyzed, the drainage area at the upstream part of the study area (510 mi^2) differs from the drainage area at the gaging station (733 mi^2) by about 30 percent. The flood-discharge value computed by the transfer method (7,330 ft^3/s) was used from the northern boundary of the study area downstream to cross section 43, then was increased at cross section 42 to the discharge computed at the gaging station for the rest of the study reach. The change was made at cross section 42 because of significant tributary inflow from the East Fork just upstream from that location. The results of the analysis are given in table 1.

Table 1.--*Summary of 100-year discharges*

Flooding source	Drainage area (square miles)	100-year flood discharge (cubic feet per second)
Porcupine Creek basin upstream from cross section 43	510	7,330
Porcupine Creek basin upstream from gaging station at Nashua (station 06175000)	733	8,750

Hydraulic Analysis

The hydraulic characteristics of the channel cross sections along Porcupine Creek were analyzed to determine the elevations of the 100-year flood. The method used to define hydraulic characteristics requires cross-section geometry data and roughness-coefficient estimates.

Cross-section data were obtained from field surveys conducted during the summer of 1991. Fifty-seven cross sections were surveyed and 20 were synthesized. The synthesized cross sections (sections 5, 9, 15, 17, 19, 21, 23, 24, 45, 48, 51, 53, 56, 58, 61, 66, 68, 70, 72, and 75 on the principal map) were estimated from adjacent surveyed sections and topographic maps. Structural geometry and elevations were also obtained for four bridges. Cross sections were located upstream and downstream from the bridges to permit computation of the backwater effects of these structures. Cross sections typical of channel and flood-plain conditions in the upstream and downstream reaches 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 roughness coefficients 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 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 values along Porcupine Creek range from 0.030 to 0.085 for the main channel and from 0.035 to 0.100 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, 1990).

WSPRO is a computer program that is used to analyze one-dimensional, gradually varied, steady flow in open channels. Cross-section geometry and location, roughness coefficients, and starting water-surface elevation data are needed to compute water-surface profiles using step-backwater techniques. The surveyed and synthesized cross sections then were used to define the physical characteristics of the channel. In this computer program, the surveyed and synthesized cross sections were used to define the hydraulic characteristics of the channel. The location of each cross section at Porcupine Creek was selected to represent the hydraulic characteristics of a reach, and each section was surveyed to define its shape.

For the WSPRO assumption of gradually varied, steady-state flow to be valid within a stream reach, the distance between cross sections needs to be short. However, for the great distance of Porcupine Creek involved in this study, the cost to survey sufficient cross sections would have been prohibitive. Therefore, the number of cross sections surveyed for this report was limited to 57. Twenty additional cross sections were synthesized and added to the WSPRO program to decrease possible step-backwater computation errors. If additional surveyed cross sections are added to the WSPRO input data set for Porcupine Creek in the future, computed water-surface elevations associated with the estimated peak discharge from a 100-year flood could be subject to change. For the downstream end of the study area from cross section 7 to cross section 1, flood flows were divided into a main channel and an overflow channel. Each channel in this area was considered as a separate reach. The portion of the 100-year flood discharge (8,750 ft^3/s) that will flow in each channel was determined by methods described by Davidian (1984, p. 30). The main-channel flood discharge was determined to be 5,100 ft^3/s, and the overflow-channel discharge was determined to be 3,650 ft^3/s. The starting water-surface elevation used to compute the flow in each channel for Porcupine Creek at the downstream end of the study area was determined by using a slope-conveyance computation to estimate normal depth. The computed elevation (2,056.3 ft) for the portion of 100-year flood discharge at cross section 6 where the gaging station is located was converted to the datum used at the station (0.0 ft gage datum = 2,038.0 sea-level datum) and plotted on the gage height-discharge curve (fig. 5). The gage height-discharge relation matches the computed, theoretical water-surface elevation to within 0.2 ft. The close agreement helps to substantiate the hydraulic model used.

WATER-SURFACE PROFILE

The water-surface profile for the 100-year flood (fig. 6) was drawn for the entire reach within the study area. The reach at the downstream end (cross sections 1-7) was drawn showing a profile for the main channel and a profile for the overflow channel upstream to near cross section 8, where the two channels converge. 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 analyses were based on unobstructed flow. The flood elevations shown on the profile thus are considered to be valid only if hydraulic structures remain unobstructed and do not fail.

All field surveys and elevations are referenced to sea level. The data were tied to a network of control points, and elevation reference marks were established during the field surveys. Reference-mark locations are shown on the principal map and reference-mark descriptions are given in table 2.

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 flood elevations determined 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 flood 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 analyze flood-hazard data for Porcupine 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 Porcupine Creek extending from a point 1.9 mi downstream from the joining of the Middle and West Forks downstream to about 1 mi upstream from the mouth near Nashua. The flood-discharge was determined to range from 7,330 to 8,750 ft^3/s, depending on location.

Data used for 57 channel and flood-plain cross sections were obtained from field surveys of a 29-mi reach of the river. Twenty additional cross sections were synthesized from adjacent surveyed sections and topographic maps. These data were used to compute water-surface elevations for the 100-year flood at each cross section, using WSPRO, a step-backwater computer program.

The water-surface profile was drawn showing computed water-surface elevations of a 100-year flood. The flood profile was drawn for the main channel and the overflow channel from the downstream end of the study area upstream to near cross section 8, where the channels converge, and then from cross section 8 upstream for the entire reach. The flood profile also shows the streambed elevations and location of bridges and cross sections used in the hydraulic analysis. Flood boundaries were delineated using the flood elevations determined at each cross section and contour lines on topographic maps.

REFERENCES CITED

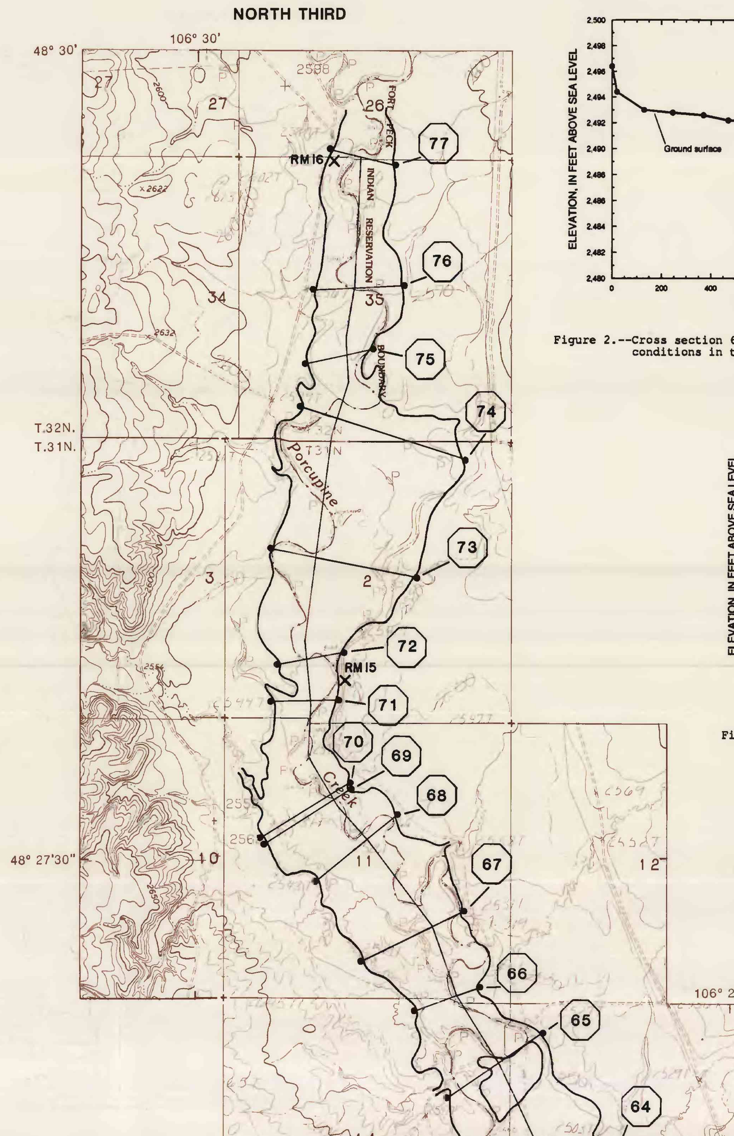
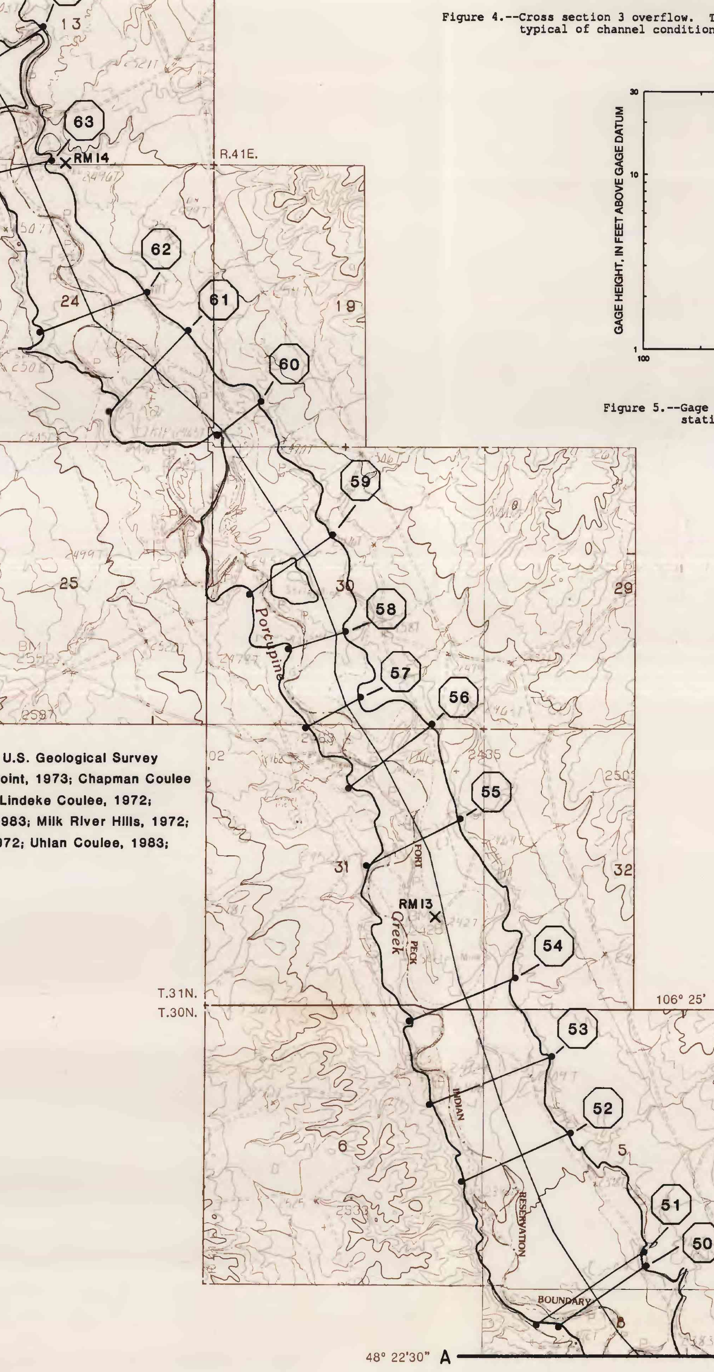
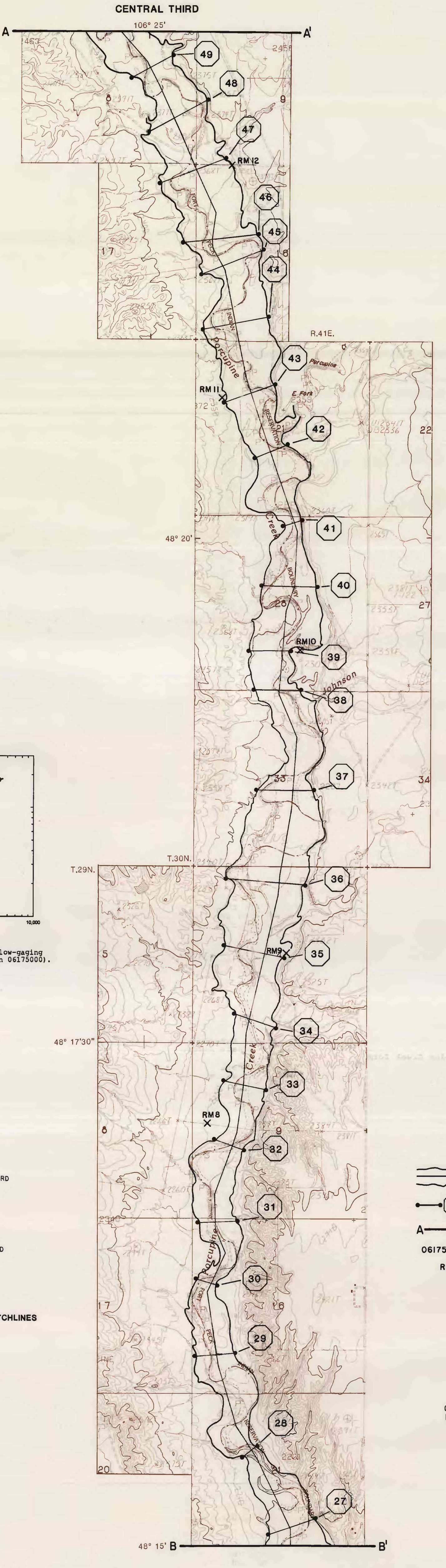
Davidian, Jacob, 1984, Computation of water-surface profiles in open channels: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chap. A15, 48 p.

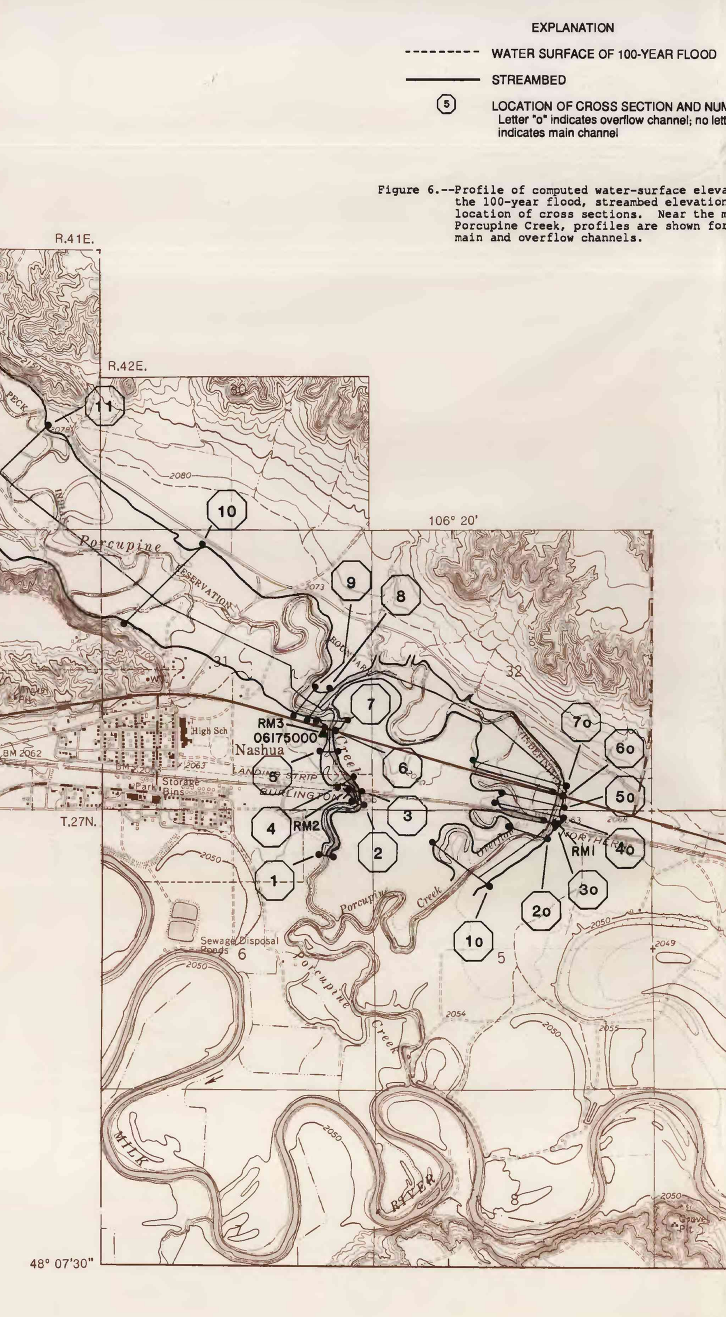
Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency--Bulletin 17B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination, 183 p.

Omang, R.J., 1992, Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4048, 70 p.

Shearman, J.O., 1990, User's manual for WSPRO--A computer model for water surface profile computations: U.S. Department of Transportation, 177 p. [Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as Report FHWA-IP-89-027].

U.S. Environmental Data Service, 1971, Climate of Montana: Department of Commerce, National Oceanic and Atmospheric Administration, Climatography of the United States No. 60-24, 21 p.



Base from U.S. Geological Survey Cameron Point, 1973; Chapman Coulee NE, 1968; Lindeke Coulee, 1972; Lookout, 1983; Milk River Hills, 1972; Nashua, 1972; Uhlan Coulee, 1983; 1:24,000

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

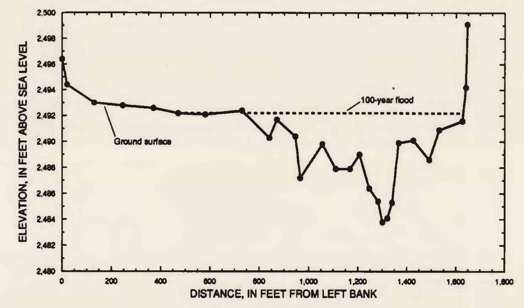


Figure 2.--Cross section 43, which is typical of channel and flood-plain conditions in the upstream reaches of the study area.

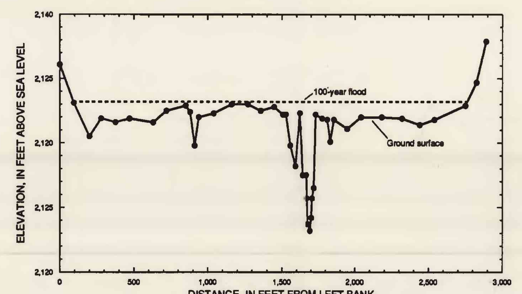


Figure 3.--Cross section 18, which is typical of channel and flood-plain conditions in the downstream reaches of the study area.

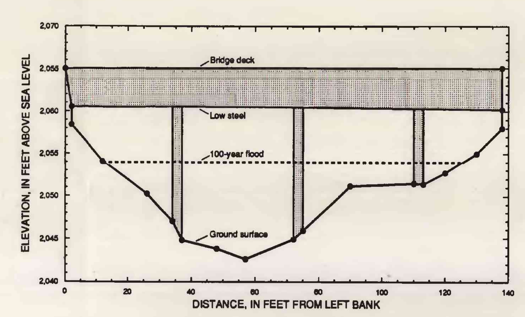


Figure 4.--Cross section 3 overflow. This section is typical of channel conditions at bridges.

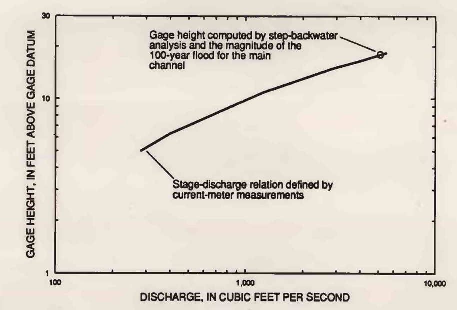
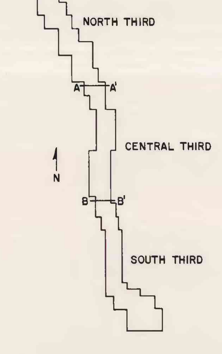


Figure 5.--Gage height-discharge relation at streamflow-gaging station Porcupine Creek at Nashua (station 06175000).



INDEX MAP SHOWING MATCHLINES

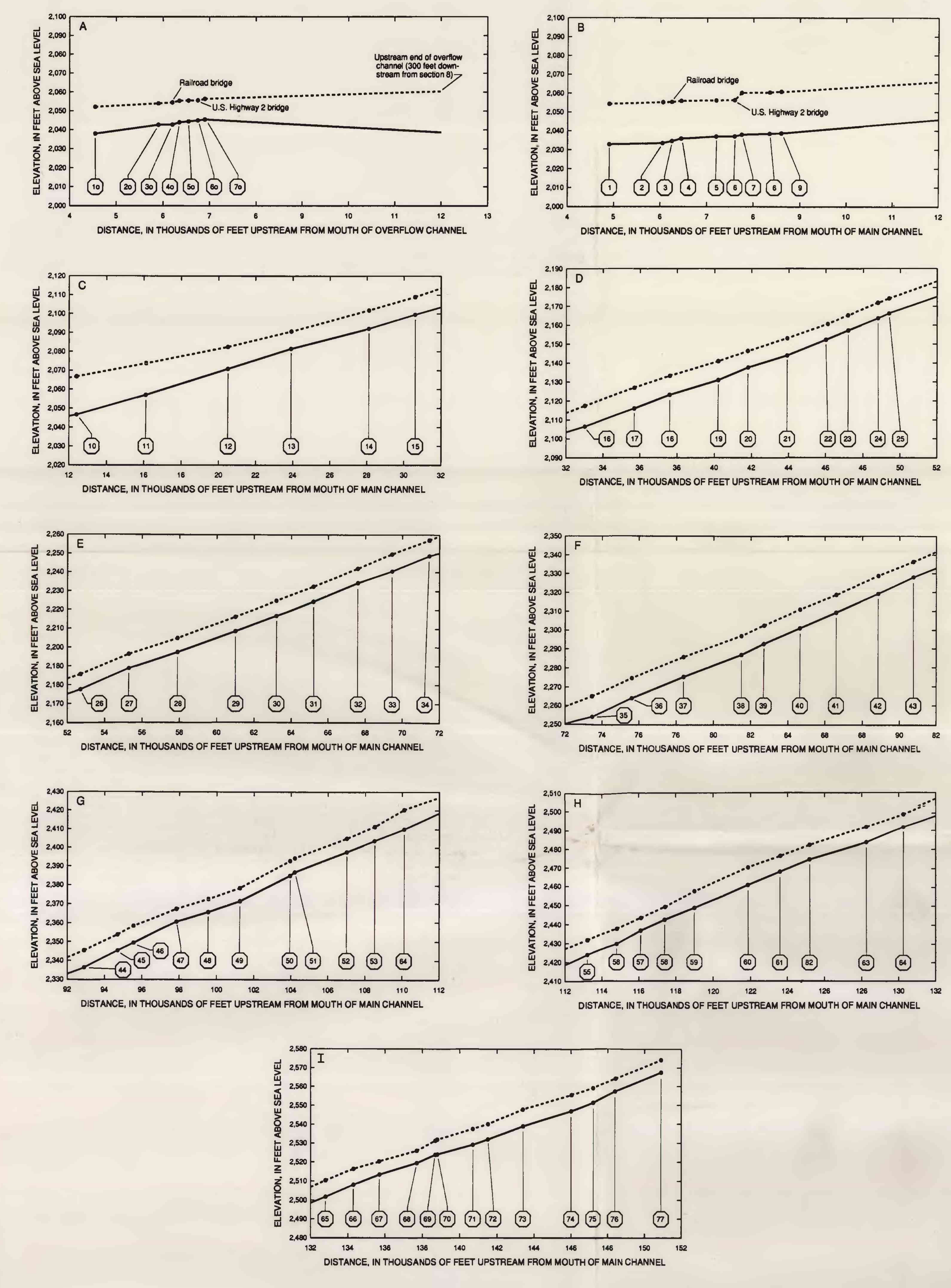


Figure 6.--Profile of computed water-surface elevations for the 100-year flood, streambed elevations, and location of cross sections. Near the mouth of Porcupine Creek, profiles are shown for both the main and overflow channels.

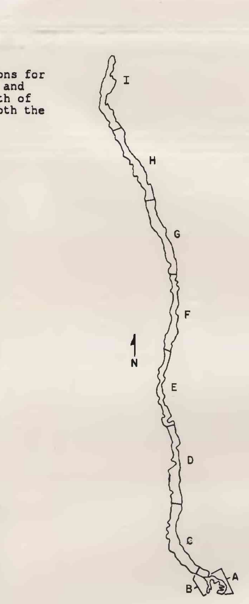


DIAGRAM SHOWING RELATIVE POSITION OF SEGMENTS OF THE PROFILE ALONG PORCUPINE CREEK

Table 2.--*Elevation reference marks*

Reference mark	Elevation (feet above sea level)	Description of location
RM1	2,063.37	A standard U.S. Coast and Geodetic Survey benchmark disk, stamped "V 356 1948" and set in the east end of Burlington Northern Railroad bridge crossing Porcupine Creek overflow channel, is located 1.5 mi east from the railroad station at Nashua, in the top of the north end of the east concrete abutment, 6.4 ft north of the north rail of the track, and 1.6 ft lower than the rail.
RM2	2,066.18	A standard U.S. Coast and Geodetic Survey benchmark disk, stamped "W 356 1948" and set in the west end of Burlington Northern Railroad bridge crossing Porcupine Creek, is located 0.8 mi east from the railroad station at Nashua, in the top of the south end of the west concrete abutment, 5.5 ft south of the south rail of the track, and 1.0 ft lower than the rail.
RM3	2,064.10	Top of steel bolt, painted red and located in the west end of U.S. Highway No. 2 bridge crossing Porcupine Creek, is located 0.5 mi east of Nashua, in the top of the south side of the bridge abutment.
RM4	2,081.25	Top of steel fence post, projecting 2.5 ft above ground, is located 1.8 mi northwest of Nashua, along Porcupine Creek, on north-south property-line fence of Bernice Stohl Ranch, on right bank, near right edge of cross section 12.
RM5	2,092.45	Top of upstream end of concrete headgate is located 2.5 mi northwest of Nashua, along Porcupine Creek, at Bernice Stohl Ranch, on right bank, 300 ft west of house.
RM6	2,133.09	Top of steel crank support for corral chute post is located 5.1 mi northwest of Nashua, along Porcupine Creek, on right bank, 40 ft south of county road crossing Porcupine Creek.
RM7	2,188.11	Top of rock, with painted "X," is located 7.2 mi northwest of Nashua, along Porcupine Creek, on right bank, 240 ft west of trail, on knoll surrounded by rock teepee ring.
RM8	2,250.06	Top of steel fence post, painted orange, is located 10.8 mi northwest of Nashua, along Porcupine Creek, on right bank, 1,400 ft west of stream, along east-west fenceline.
RM9	2,267.26	Top of spike, 1.7 ft above ground in north side of gate post, is located 11.8 mi northwest of Nashua, along Porcupine Creek, in center of sec. 4, on left bank, 1,300 ft east of stream.
RM10	2,307.76	Top of bottom gate pin on green gate is located 13.5 mi northwest of Nashua, along Porcupine Creek, on left bank, on gate at Doug Tihista's house.
RM11	2,343.27	Top of spike, 3 ft above ground in 20-ft tall cottonwood tree, is located 15.1 mi northwest of Nashua, along Porcupine Creek, on right bank, 900 ft west of stream.
RM12	2,370.50	Top of green steel fence post is located 16.4 mi northwest of Nashua, along Porcupine Creek, on section line between secs. 9 and 16, on left bank, 1,300 ft east of stream.
RM13	2,427.53	A standard U.S. Geological Survey aluminum disk, stamped "13 JRJ 1977" and set in concrete post projecting 0.5 ft above ground, is located 19.1 mi northwest of Nashua, along Porcupine Creek, on left bank, 25 ft south of trail, and 1.0 ft north of witness post.
RM14	2,494.02	Top of cap, on 1.5-in. diameter test well projecting 2.0 ft above ground, is located 22.1 mi northwest of Nashua, along Porcupine Creek, on left bank, next to 4.0-in.-diameter casing pipe stamped "C4," on left bank, 1,000 ft east of stream.
RM15	2,572.41	Top of rock, with painted "X," is located 24.5 mi northwest of Nashua, along Porcupine Creek, on left bank, 100 ft east of stream.
RM16	2,573.90	Top of spike, 3 ft above ground in 3-ft-diameter cottonwood tree, is located 26.4 mi northwest of Nashua, along Porcupine Creek, on right bank, 400 ft west of stream.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	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--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 1929.

For additional information write to:

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