WATER-SURFACE PROFILE AND FLOOD BOUNDARIES FOR THE COMPUTED 100-YEAR FLOOD, TONGUE RIVER, NORTHERN CHEYENNE INDIAN RESERVATION AND ADJACENT AREA, MONTANA

By R.J. Omang and Charles Parrett

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 Northern Cheyenne Indian Reservation are of interest to the Northern Cheyenne Tribe 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 Northern Cheyenne Reservation. An area of concern is the flood plain of the Tongue River (fig.1).

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 Northern Cheyenne Tribe, conducted a hydrologic and hydraulic analysis of the Tongue River to identify areas along the river within the reservation that are 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 1994.

The magnitude of the 100-year flood was determined using a Big Horn County Flood Insurance Study (Federal Emergency Management Agency (1981) and a report by Omang (1992). Channel and flood-plain elevations were surveyed at 59 cross sections along a 34-mile reach of the Tongue River. An additional four cross sections along the same reach were synthesized. Physical dimensions of hydraulic structures were measured. Manning's roughness coefficients were determined at each cross section. Field survey data and a computer program were used to calculate water-surface elevations for the 100-year flood at each section. These elevations were used to determine the inundated area for the 100-year flood.

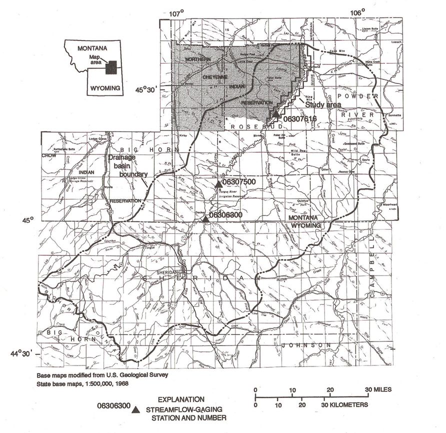

Figure 1. Location of upper Tongue River drainage basin and study area, northern Wyoming and southeastern Montana.

General Description of the Area

The Tongue River originates in Wyoming and flows northeasterly through southeastern Montana toward the mouth. The study area lies within the drainage basin of the upper Tongue River from the southern boundary of the Northern Cheyenne Indian Reservation downstream to the northern boundary near Ashland. The headwaters of the Tongue River drain the eastern slopes of the Bighorn Mountains, which generally are steep and tree covered. The basin consists of gently rolling hills and broad valleys. Areas of the valley adjacent to the stream are densely vegetated with bushes and trees. The elevations of the land surface range from 2,840 to 4,410 feet in the upper Tongue River basin.

The climate is semiarid with cold winters and warm summers. Based on data from 1961-90, mean monthly temperatures at Busby range from 70 °F in July to 18 °F in January. Average annual precipitation at Busby is about 15 in. with about 43 percent occurring from April through June. June is the wettest month, with an average of about 2.7 in. of precipitation; February is the driest month, with an average of 0.6 in. (National Oceanic and Atmospheric Administration, 1992).

Streamflow Conditions and Flooding

The Tongue River and its major tributaries, Hanging Woman Creek and Otter Creek, are perennial streams. All other tributaries are intermittent or ephemeral. Most runoff results from snowmelt in the spring and from rainfall from thunderstorms in the summer. Occasionally, snowmelt and rain combine to produce runoff.

The U.S. Geological Survey operates streamflow-gaging stations on the Tongue River in the upper basin at locations 1.0 mile north of the Wyoming-Montana State line (station 06306300), downstream from Tongue River Dam (station 06307500), and 6.5 miles northeast of Birney (station 06307616). The largest recorded flows for station 06306300 (17,500 cubic feet per second) and for station 06307500 (10,800 cubic feet per second) were during the flood of May 1978. Station 06307616 was not in operation during the May 1978 flood.

METHODS OF ANALYSIS

Standard hydrologic and hydraulic methods were used to analyze the flood hazard for the Tongue River. 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 Northern Cheyenne Tribe 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, such floods could occur rarely at shorter intervals or even within the same year. The analyses reported herein reflect flooding potentials based on conditions in the basin in 1994.

Hydrologic Analysis

Flood-discharge values for the Tongue River are based on a Flood Insurance Study (Federal Emergency Management Agency, 1981), and techniques described by Omang (1992). Based on the Flood Insurance Study, the 100-year flood discharge at the southern boundary of Rosebud County was determined to be 11,100 cubic feet per second. This 100-year flood discharge figure was adjusted to two stream reaches in the study area using the transfer equation developed by Omang (1992, p.12). The changes in discharge were made because of significant tributary inflow between the county line and the southern boundary of the study area, and because of tributary inflow from Otter Creek. The results determined for each stream reach are shown in table 1.

Table 1. Summary of computed 100-year flood discharges

Flooding source	Drainage area (square miles)	100-year flood discharge (cubic feet per second)
Tongue River downstream from southern reservation boundary to cross section 13	2,621	13,500
Tongue River from cross section 13 to northern reservation boundary (cross section 1)	3,595	15,800

Hydraulic Analysis

The hydraulic characteristics of the cross sections along the Tongue River 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 at 59 cross sections along a 34-mile reach of the Tongue River from field surveys conducted during summer 1993 and 1994. An additional four cross sections along the same reach were synthesized. The synthesized cross sections (sections 6, 11, 18, 27 on the northern half of the principal map) were estimated from adjacent surveyed sections and topographic maps. Structural geometry data also were obtained for three bridges from field surveys. Cross sections were located upstream and downstream from the bridges to permit computation of the backwater effects of these structures. Cross sections that are examples 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 showing channel conditions at a bridge 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 used in the hydraulic computations were based on engineering judgment of onsite observations (Barnes, 1967). Roughness values used along the Tongue River range from 0.030 to 0.045 for the main channel and from 0.035 to 0.110 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 to define average channel shape throughout the reach. 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 sections. The starting water-surface elevation used to compute the 100-year flood profile for the Tongue River at cross section 1 was determined by using a slope-conveyance computation to estimate normal depth (Shearman, 1990). Water-surface elevations for the 100-year flood discharge 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 (cross-section subreach) 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.

Based on initial computations using WSPRO, four additional cross sections 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 the Tongue River. 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 river 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 because of 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 the Tongue River. 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 the Tongue River extending from the southern boundary of the Northern Cheyenne Reservation downstream to the northern boundary near Ashland. The 100-year flood discharge was determined to range from 13,500 cubic feet per second to 15,800 cubic feet per second, depending on location.

Data used for 59 channel and flood-plain cross sections were obtained from field surveys of a 34-mile reach of the river. Four additional cross sections were synthesized from adjacent surveyed sections and topographic maps. These data were used to compute the water-surface elevation 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 the 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 the 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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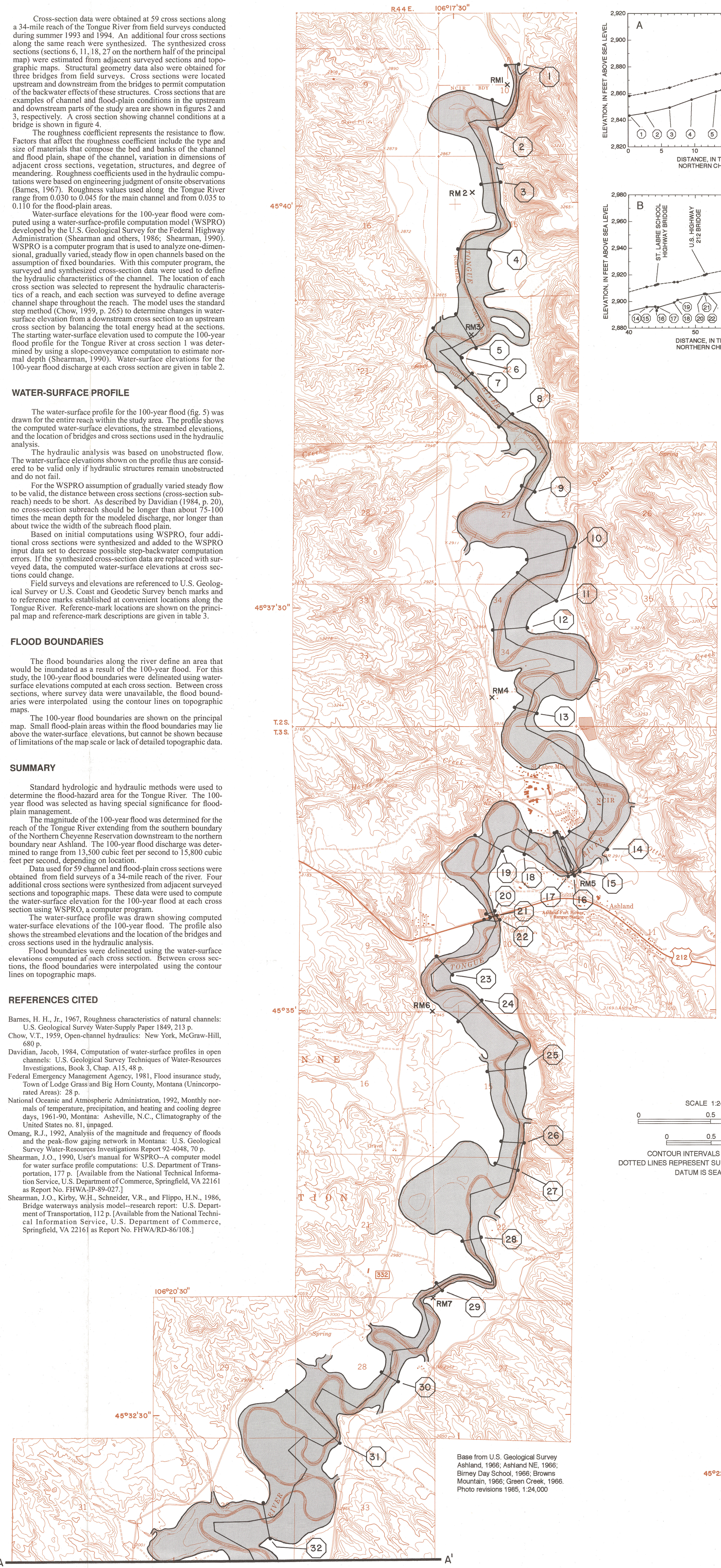
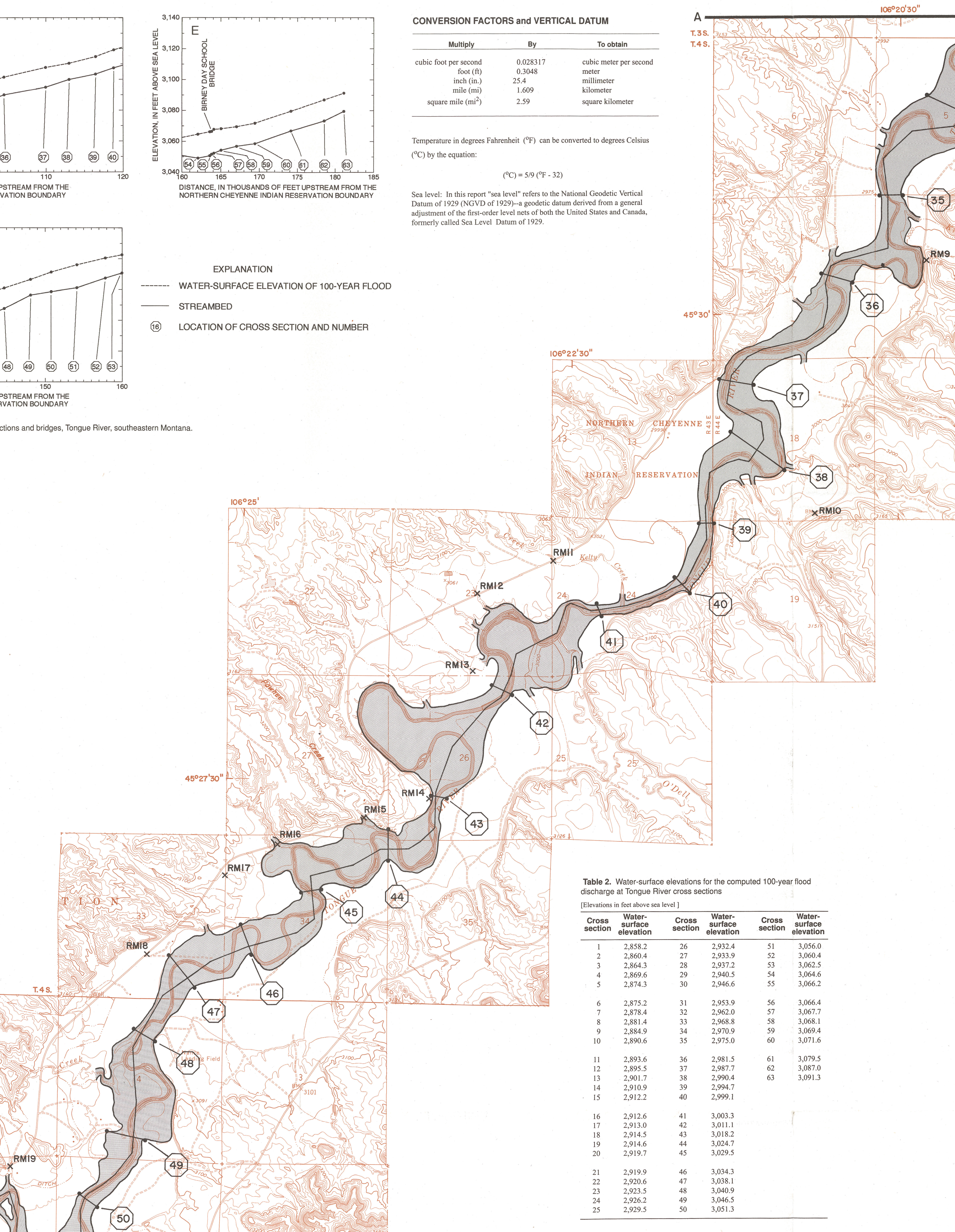
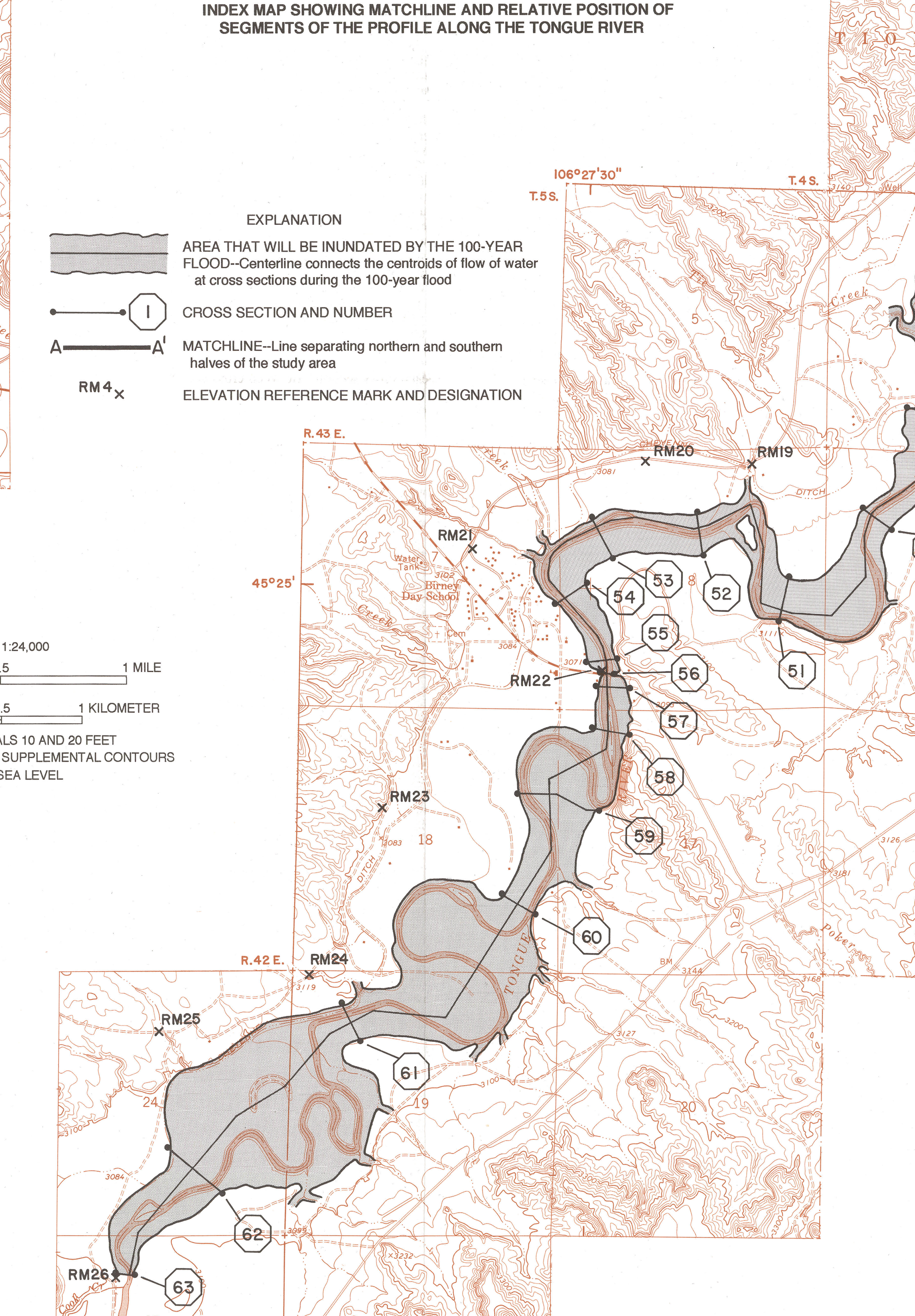
Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model--research report: U.S. Department of Transportation, 112 p. [Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as Report No. FHWA/RD-86/108.]



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 and southern halves of the study area

RM4 × ELEVATION REFERENCE MARK AND DESIGNATION

SCALE 1:24,000

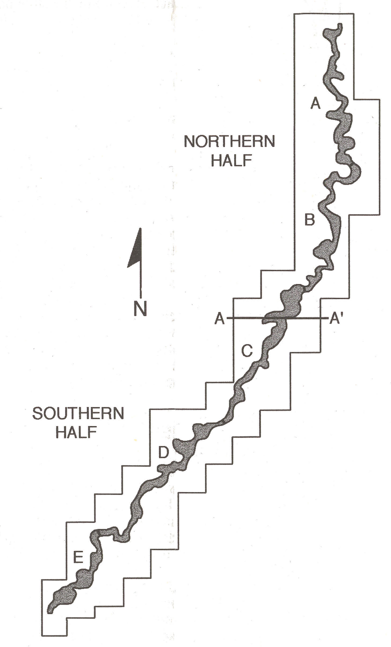
0 0.5 1 MILE

0 0.5 1 KILOMETER

CONTOUR INTERVALS 10 AND 20 FEET
DOTTED LINES REPRESENT SUPPLEMENTAL CONTOURS
DATUM IS SEA LEVEL

Base from U.S. Geological Survey
Ashland, 1966; Ashland NE, 1966;
Birney Day School, 1966; Browns
Mountain, 1966; Green Creek, 1966.
Photo revisions 1965, 1:24,000

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



INDEX MAP SHOWING MATCHLINE AND RELATIVE POSITION OF SEGMENTS OF THE PROFILE ALONG THE TONGUE RIVER

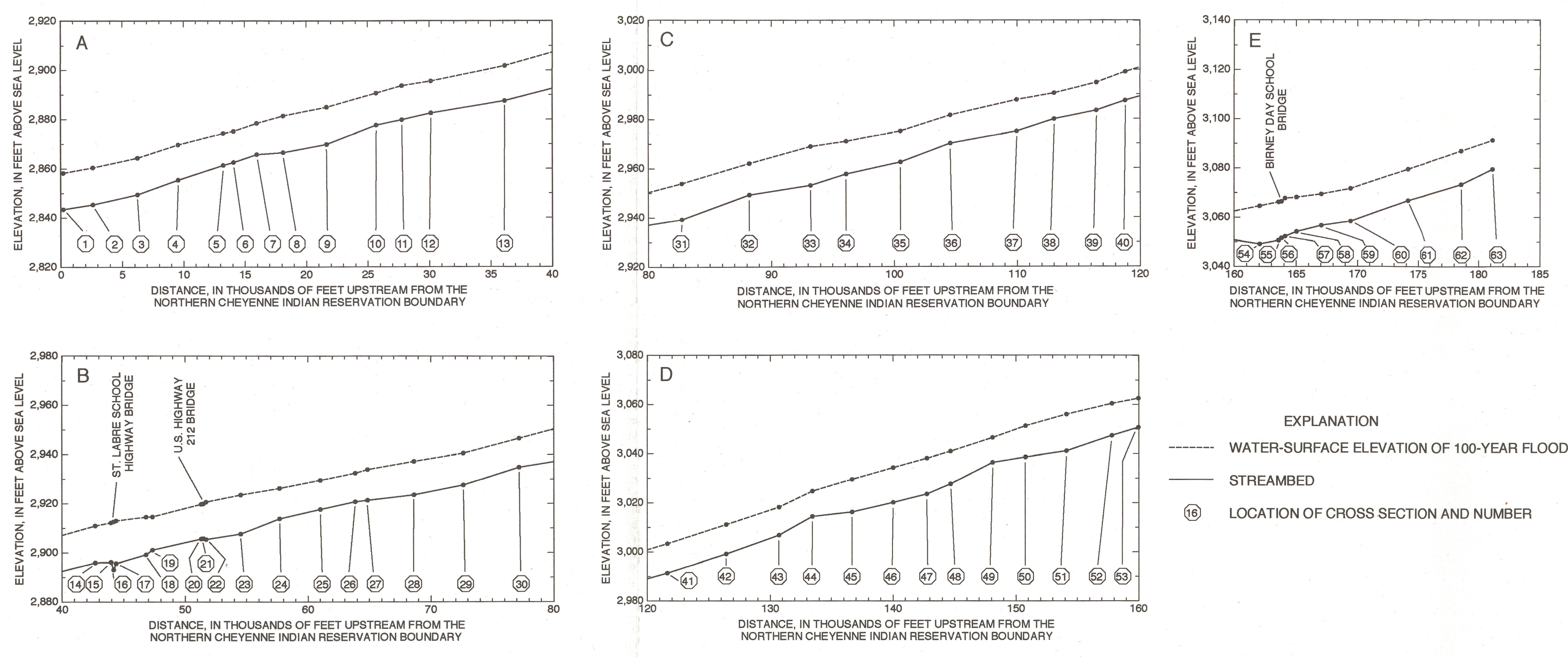


Figure 5. Profile of computed water-surface elevations for the 100-year flood, streambed elevations, and location of cross sections and bridges, Tongue River, southeastern Montana.

EXPLANATION

WATER-SURFACE ELEVATION OF 100-YEAR FLOOD

STREAMBED

LOCATION OF CROSS SECTION AND NUMBER

CONVERSION FACTORS and VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second	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:

$$(^{\circ}C) = 5/9\,(^{\circ}F - 32)$$

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.

Table 2. Water-surface elevations for the computed 100-year flood discharge at Tongue River cross sections

[Elevations in feet above sea level]

Cross section	Water-surface elevation	Cross section	Water-surface elevation	Cross section	Water-surface elevation
1	2,858.2	26	2,932.4	51	3,056.0
2	2,860.4	27	2,933.9	52	3,060.4
3	2,864.3	28	2,937.2	53	3,062.5
4	2,869.6	29	2,940.5	54	3,064.6
5	2,874.3	30	2,946.6	55	3,066.2
6	2,875.2	31	2,953.9	56	3,066.4
7	2,878.4	32	2,962.0	57	3,067.7
8	2,881.4	33	2,968.8	58	3,068.1
9	2,884.9	34	2,970.9	59	3,069.4
10	2,890.6	35	2,975.0	60	3,071.6
11	2,893.6	36	2,981.5	61	3,079.5
12	2,895.5	37	2,987.7	62	3,087.0
13	2,901.7	38	2,990.4	63	3,091.3
14	2,910.9	39	2,994.7		
15	2,912.2	40	2,999.1		
16	2,912.6	41	3,003.3		
17	2,913.0	42	3,011.1		
18	2,914.5	43	3,018.2		
19	2,914.6	44	3,024.7		
20	2,919.7	45	3,029.5		
21	2,919.9	46	3,034.3		
22	2,920.6	47	3,038.1		
23	2,923.5	48	3,040.9		
24	2,926.2	49	3,046.5		
25	2,929.5	50	3,051.3		

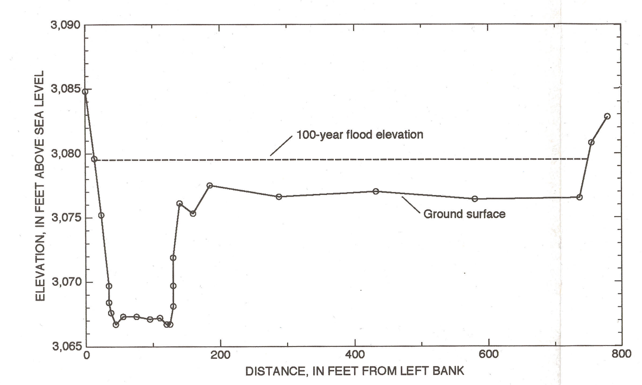


Figure 2. Cross section 61, which is typical of channel and flood-plain conditions in the upstream part of the study area.

VIEW IS LOOKING DOWNSTREAM (figs. 2, 3, and 4)

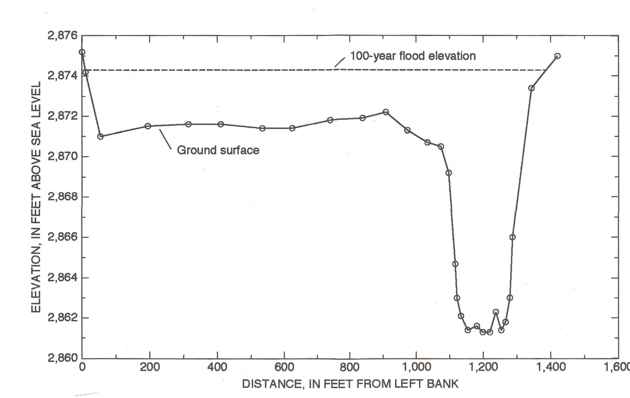


Figure 3. Cross section 5, which is typical of channel and flood-plain conditions in the downstream part of the study area.

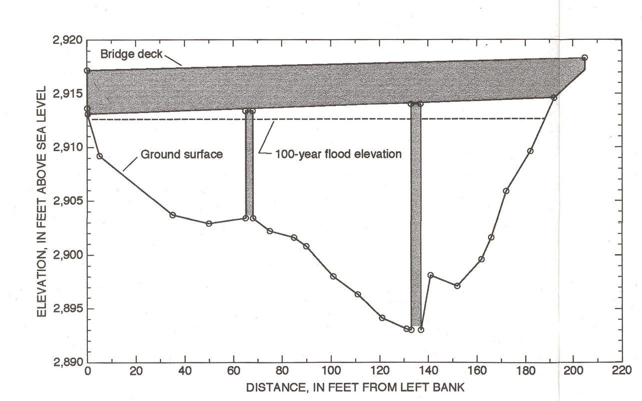


Figure 4. Part of cross section 16, which is typical of channel conditions at bridges in the study area.

Table 3. Elevation reference marks along the Tongue River
[Abbreviations: BIA, Bureau of Indian Affairs; ft, foot; in., inch; mi, mile; sec., section]

Reference mark	Elevation (feet above sea level)	Description of location
RM1	2,857.86	Top of brass cap, stamped "C 1/4 S10" and set in top of iron section post projecting 0.4 ft above ground, is located along the Tongue River, at center of section 10, on left bank, 0.15 mi upstream from reservation boundary.
RM2	2,866.23	Top of brass cap, stamped "NW 1/16 S15" and set in top of iron section post projecting 1.1 ft above ground, is located along the Tongue River, on left bank, 0.9 mi upstream from reservation boundary.
RM3	2,873.84	Top of steel casing on well, 0.5 ft in diameter, 1.9 ft above the ground, 40 ft east of BIA gage house, is located along the Tongue River, on left bank, 1.9 mi upstream from reservation boundary.
RM4	2,911.60	Top of steel auto gate, painted red, at local access driveway along county road 332, is located along the Tongue River, on left bank, 4.5 mi upstream from reservation boundary.
RM5	2,921.04	Top of concrete handrail on right end of upstream side of bridge, 2.5 ft above highway, on bridge crossing the Tongue River, is located on road to St. Labre Mission, at Ashland, Mont.
RM6	2,945.00	Top of brass cap, stamped "S9 S10 S16 S15, T3S R44E, 1917" and set in top of iron section post projecting 0.5 ft above ground, is located along the Tongue River, at corner of secs. 9, 10, 15, and 16, on left bank, 0.12 mi east of county road 332, 0.55 mi from U.S. Highway 212.
RM7	2,941.08	Top of brass cap, stamped "T3S R44E, S21 S22, 1987-BLM" and set in top of iron section post projecting 0.4 ft above ground, is located along the Tongue River, at corner of secs. 21, 22, 27, and 28, on right bank, 2.55 mi upstream from U.S. Highway 212.
RM8	2,998.85	A standard U.S. Coast and Geodetic Survey bench mark disk, stamped "B 223 1934" and set in top of concrete post projecting 0.4 ft above ground, is located along the Tongue River, along county road leading to Birney, 0.2 mi southeast of a ranch house, on a hill, 40 ft northeast of the centerline of the road, 2 ft southwest of a fence, and about level with the road, 5.8 mi from the post office at Ashland.
RM9	3,018.37	A standard U.S. Coast and Geodetic Survey bench mark disk, stamped "A 223 1934" and set in top of concrete post projecting 0.5 ft above ground, is located along the Tongue River, along county road leading to Birney, 113 ft northeast of the right bank of Tongue River, 65 ft northeast of the centerline of the road, on a large sandstone outcrop, 7.7 mi from the post office at Ashland.
RM10	3,062.34	A standard U.S. Coast and Geodetic Survey bench mark disk, stamped "Z 222 1934" and set in top of concrete post projecting 0.4 ft above ground, is located along the Tongue River, along county road leading to Birney, 0.9 mi southeast of Tongue River, 0.2 mi east of a ranch house, 50 ft southeast of the centerline of the road, 3.5 ft higher than the road, 9.6 mi from the post office at Ashland.
RM11	3,042.58	Downstream crown of 6-ft corrugated metal culvert, is located at crossing along Kelty Creek, at culvert on county road 332, 0.45 mi north of main channel of Tongue River, 8.5 mi upstream from U.S. Highway 212.
RM12	3,037.97	Downstream crown of 4.5-ft corrugated metal culvert, is located at crossing along unnamed creek, at culvert on county road 332, on left bank of Tongue River, near center sec. 23, 9.0 mi upstream from U.S. Highway 212.
RM13	3,014.81	Top of brass cap, stamped "C_L S23 S26" and set in top of iron section post projecting 0.7 ft above ground, is located along the Tongue River, on left bank, on centerline of sec. 23, 9.4 mi upstream from U.S. Highway 212.
RM14	3,044.86	Top of brass cap, stamped "SW1/16 S26, 1928" and set in top of iron section post projecting 0.6 ft above ground, is located along the Tongue River, on left bank, 10.5 mi upstream from U.S. Highway 212.
RM15	3,048.43	Downstream crown of 9-ft corrugated metal culvert, is located at crossing along Pawnee Creek, at culvert on county road 332, on left bank of Tongue River, 11.0 mi upstream from U.S. Highway 212.
RM16	3,036.59	Downstream crown of 6-ft corrugated metal culvert, is located at crossing along unnamed creek, 0.5 mi southwest of Pawnee Creek, at culvert on county road 332, on left bank of Tongue River, 11.5 mi upstream from U.S. Highway 212.
RM17	3,079.35	Top of brass cap, stamped "S33 S34" and set in top of iron section post projecting 0.5 ft above ground, is located along the Tongue River, on left bank at 1/16 corner between sec. 33 and 34, 11.8 mi upstream from U.S. Highway 212.
RM18	3,041.61	Top of nail in corner post of farmer's gate at local access driveway, is located on south side of gate, at driveway on county road 332, on left bank of Tongue River, 12.5 mi upstream from U.S. Highway 212.
RM19	3,063.93	Top of nail in middle post of a set of three posts at local driveway, is located at driveway on county road 332, on left bank of Tongue River, 14.2 mi upstream from U.S. Highway 212.
RM20	3,068.86	Top of nail, 0.5 ft above the ground, in corner fence post, is located at mile marker 1 along county road 332, on left bank of Tongue River, 14.6 mi upstream from U.S. Highway 212.
RM21	3,101.19	Top of nail in 55 MPH road sign, is located in sign along county road 332, on left bank of Tongue River, 0.10 mi north of Birney Day School, 15.4 mi upstream from U.S. Highway 212.
RM22	3,070.52	Top of nut, painted red, and located in the west end of bridge crossing the Tongue River, on the upstream side of bridge rail on county road 332 bridge, southeast of Birney Day School, 16.2 mi upstream from U.S. Highway 212.
RM23	3,097.62	Top of sandstone rock ledge, painted red, and located along trail south of Birney Day School, 50 ft west of centerline of trail, 400 ft southwest of blue house, 12 ft higher than trail, on left bank of Tongue River, 0.9 mi south of Birney Day School.
RM24	3,112.05	Top of nail, 1.0 ft above ground in power pole by Northern Cheyenne Indian Ceremonial Ground, by left edge of cross section 61, is located along the Tongue River, on trail 1.6 mi south of Birney Day School.
RM25	3,131.54	Top of brass cap, stamped "C N1/16, S24, 1928" and set in top of iron section post projecting 0.6 ft above ground, is located along the Tongue River, on left bank on trail 2.3 mi south of Birney Day School.
RM26	3,093.28	Top of concrete headwall, on irrigation ditch on north side of Cook Creek, is located on the downstream side of headwall, on left bank of Tongue River, near the southern boundary of the Northern Cheyenne Indian Reservation.

For additional information write to:

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