# FLOOD-PROFILE ANALYSIS, BIG DARBY CREEK AT STATE ROUTE 762, ORIENT, OHIO

By William P. Bartlett, Jr., and James M. Sherwood

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4276

Prepared in cooperation with the

OHIO DEPARTMENT OF TRANSPORTATION

Columbus, Ohio

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
975 West Third Avenue
Columbus, Ohio 43212

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## CONVERSION FACTORS

For readers who prefer to use the International System of units (SI), conversion factors for terms used in this report are listed below:

| Multiply inch-pound units | By | To obtain SI units |
|---|---|---|
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |

# FLOOD-PROFILE ANALYSIS, BIG DARBY CREEK AT STATE ROUTE 762, ORIENT, OHIO

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## ABSTRACT

The U.S. Geological Survey, in cooperation with the Ohio Department of Transportation, made a hydraulic analysis of the 25- and 100-year floods on Big Darby Creek where State Route 762 crosses the stream at Orient, Ohio. Two proposed bridge plans were analyzed to determine the effects on flood profiles subsequent to the placement of a 376-foot-long, four-span deck bridge across the stream 90 feet upstream of the existing State Route 762 bridge. In plan 1, the bridge is set at a 25-degree skew to the river and at sufficient elevation to pass the 100-year flood below it. In plan 2, the skew is 28 degrees and elevations are 3 feet lower than in plan 1, which would result in partial submergence of the bridge during the 100-year flood.

This analysis shows that the 25-year flood profiles upstream of the new bridge would increase by 0.4 foot if plan 1 is adopted and by 0.3 foot if plan 2 is adopted. Both profiles converge with the present-condition profiles 5,750 feet upstream. The profiles for the 100-year flood would increase by 0.6 foot for plan 1 and 1.1 feet for plan 2. This additional backwater affects profiles up to 5,750 feet upstream, where the plan 1 profile is 0.1 foot higher than for present conditions, and the plan 2 profile is 0.2 foot higher than profiles for present conditions.

## INTRODUCTION

The U.S. Geological Survey, in cooperation with the Ohio Department of Transportation, Division of Highways, made a hydraulic analysis of flood profiles for a reach of Big Darby Creek in the vicinity of State Route (SR) 762 near Orient, Ohio (fig. 1). The Division of Highways plans to construct a 376-foot-long, four-span deck bridge upstream of the existing 227-foot-long, single-span truss bridge, which will remain in place.

The proposed bridge is a deck-type structure having spill-through abutments and three sets of piers set parallel to the flow. Two proposed bridge plans were provided by the Division of Highways for hydraulic analysis. In plan 1 (fig. 2), the bridge has a skew of 25 degrees and has a low-chord elevation of 779.3 feet (NGVD of 1929). In plan 2 (fig. 3), the skew is 28 degrees and the bridge deck and road profiles are 3.0 feet lower than in plan 1. This study is part of a continuing cooperative program between the Ohio Department of Transportation, Division of Highways, and the U.S. Geological Survey, Water Resources Division.

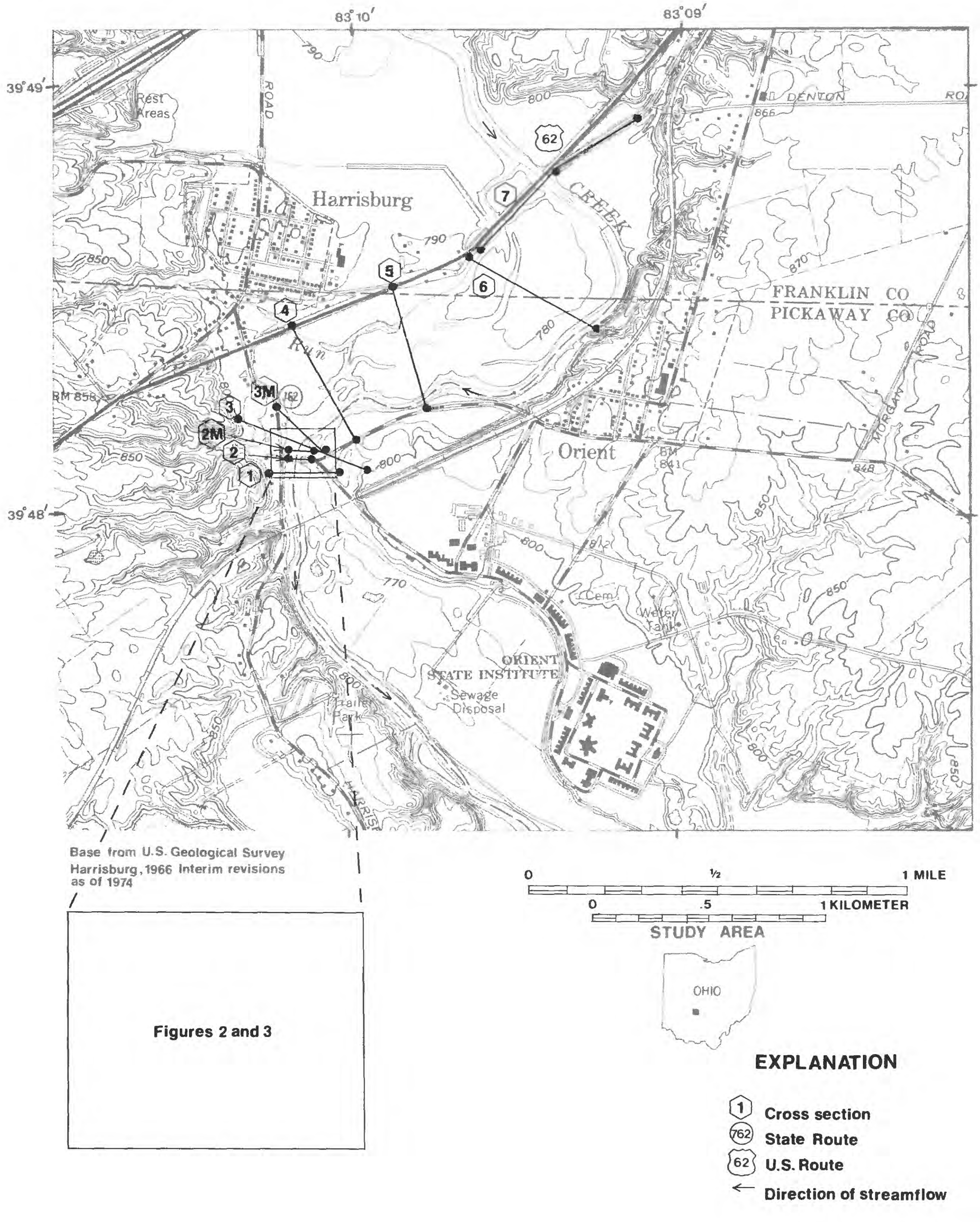


**Figure 1.--Study area, Big Darby Creek at Orient, Ohio.**

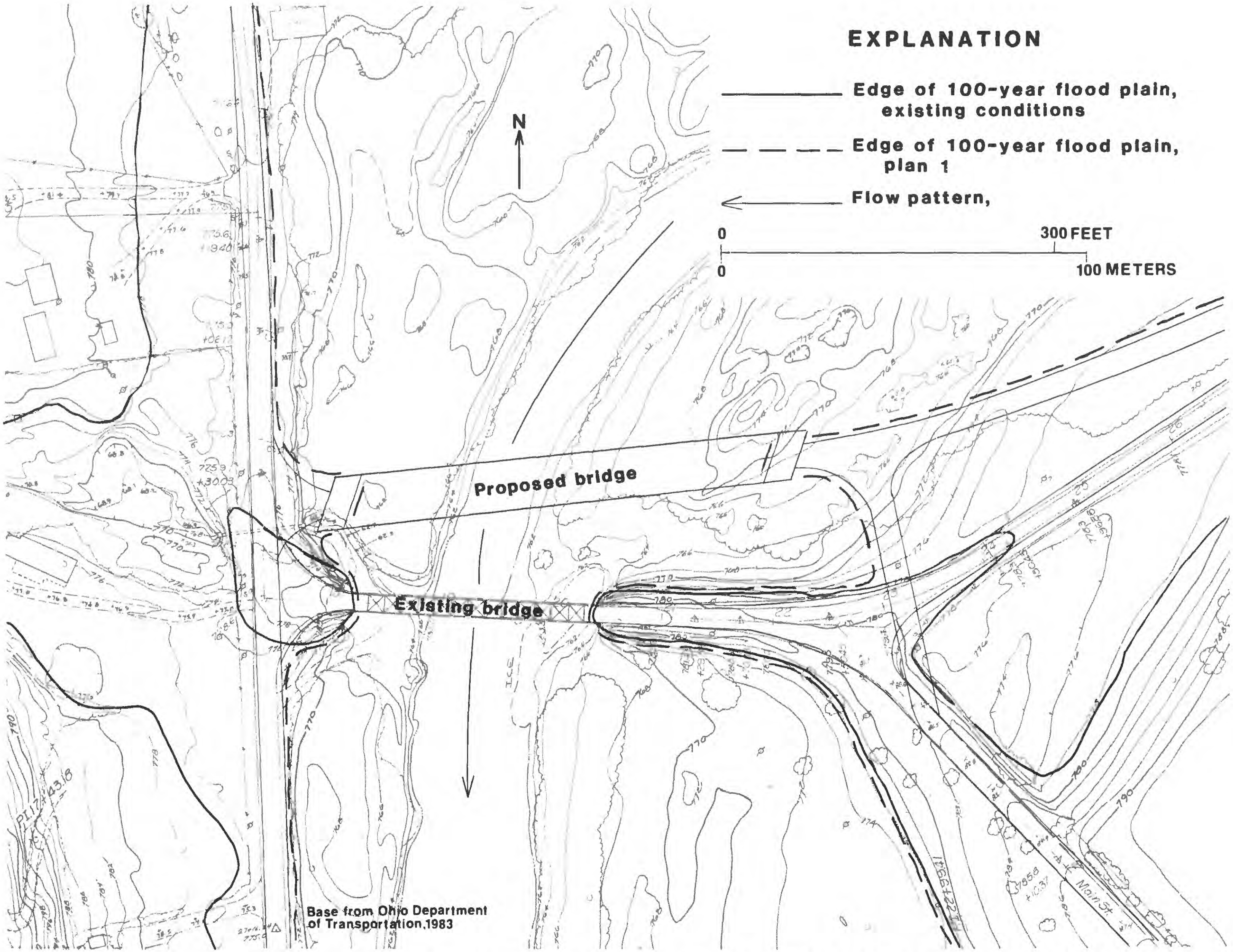


Figure 2.--Study area, Big Darby Creek at Orient, Ohio, plan 1 100-year flood plains and flow pattern.

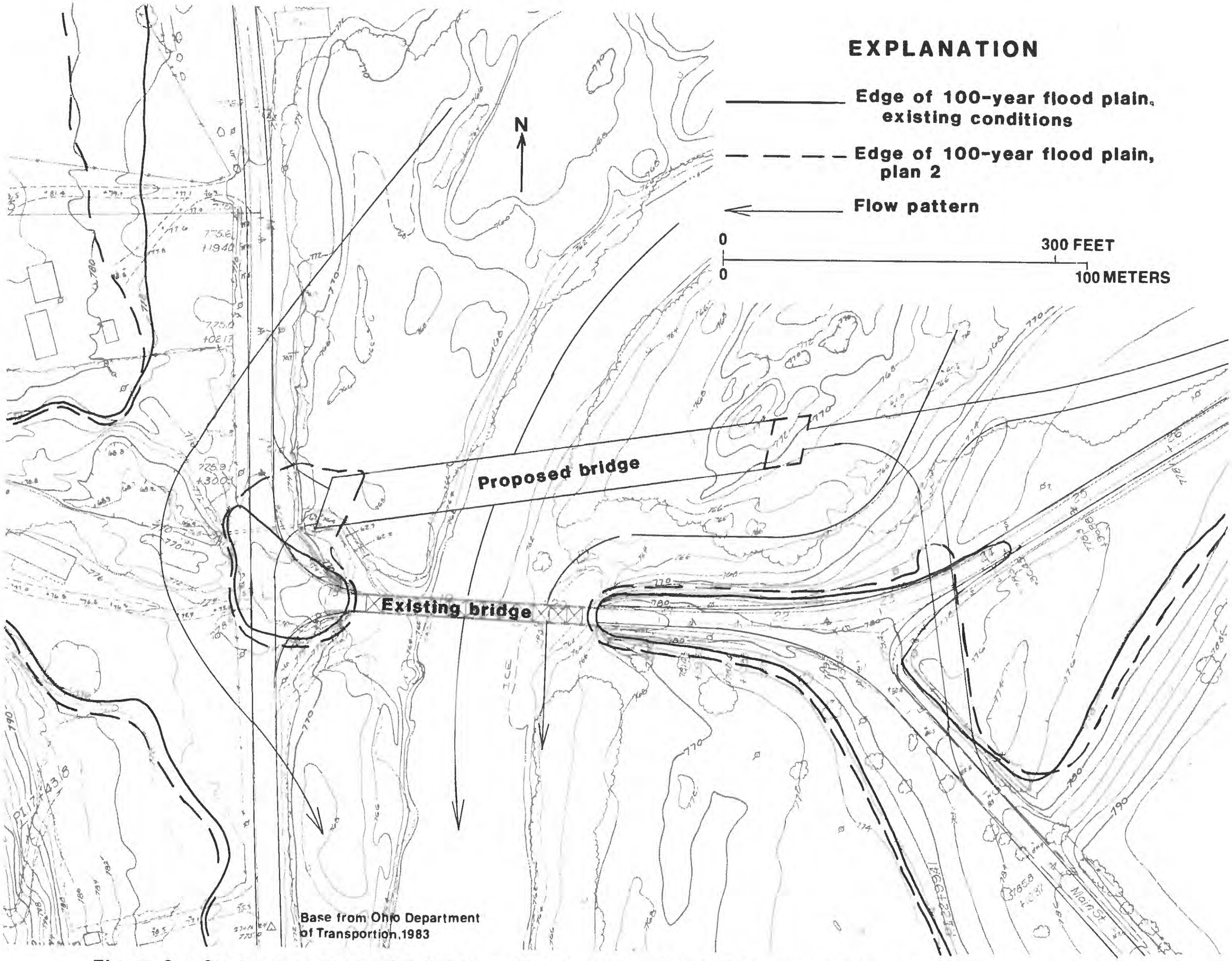


**Figure 3.--Study area, Big Darby Creek at Orient, Ohio, plan 2 100-year flood plains and flow pattern.**

## Purpose and Scope

The purpose of this report is to present water-surface profiles for the 25- and 100-year floods at Big Darby Creek at Orient, Ohio, under present conditions and two planned alternative conditions for the study reach. Corresponding velocities through the bridge sections also are presented.

## Description of the Study Reach

The investigation included a 7,100-foot reach of Big Darby Creek from section 1, located 250 feet downstream of the present SR 762 bridge, to section 7, located 6,850 feet upstream, near the US Route 62 bridge. Big Darby Creek flows southeast from US 62 for 2,000 feet, abruptly turns southwest and continues for about 2,000 feet, then flows generally west through a series of meanders for 3,000 feet, and turns south to flow through the present SR 762 bridge. The main channel is lined with a heavy brush and tree fringe that ranges from 50 to 200 feet in width on both banks. The flood plain is 2,000 feet wide from US 62 to a point 500 feet above SR 762, where it narrows to 500 feet.

# HYDRAULIC AND HYDROLOGIC DATA

Cross-section and flood data are required for the hydraulic analysis of flood profiles. A field investigation of the study reach was made by U.S. Geological Survey personnel to inspect the channel and flood plain, and to select cross-section locations and Manning roughness coefficients. Roughness coefficients ranged from 0.032 to 0.070 for the main channel and from 0.030 to 0.150 for the flood plains. Personnel of the Division of Highways surveyed the selected cross sections and provided drawings of plan and elevation views of the proposed bridges.

Flood data at the bridge site were derived from records of U.S. Geological Survey stream-gaging station 03230500, Big Darby Creek at Darbyville, which is located 11 miles downstream of the study reach. Fifty-three years of unregulated streamflow data were available for the periods 1922-36 and 1938-75. The annual peak discharges were analyzed by Webber and Bartlett (1977) using the Log-Pearson Type III frequency distribution (U.S. Water Resources Council, 1976) to derive the magnitude and frequency of floods at the gage. These flood-discharge values were transferred to the study-area reach of Big Darby Creek by a drainage-area factor, F:

$$F = (A_s / A_g)^{0.73}$$

where $A_s$ = 495 square miles = drainage area of the study site

and $A_g$ = 534 square miles = drainage area at gage;

thus, $F = (495/534)^{.73} = 0.95$.

The magnitudes of the requested 25- and 100-year floods are 22,500 cubic feet per second ($ft^3/s$) and 31,400 $ft^3/s$, respectively, in the reach studied.

## FLOOD-PROFILE ANALYSIS

The 25- and 100-year flood profiles were developed for the existing bridge and for both proposed plans for the new bridge. The starting elevations for all profiles were determined from a stage-discharge relationship at section 1. The analysis was done by means of the slope-conveyance method using the streambed slope and information from high-water profiles for a minor flood in February 1975 (16,500 $ft^3/sec$; recurrence interval approximately 8 years) and a major flood in January 1959 (46,600 $ft^3/sec$; recurrence interval greater than 100 years). The profiles for open-channel conditions downstream and upstream of the bridges were computed using the U.S. Geological step-backwater computer program E431 (Shearman, 1976). Profiles through the bridges were calculated using methods outlined by Cragwall (1958) and Matthai (1967), which determine changes in water-surface elevations caused by constrictions (bridges) in open channels.

In both proposed plans, the new bridge is about 90 feet upstream of the old bridge. In order to determine the normal water-surface elevation at cross section 3 (constricted section) of the new bridge, computations through the old bridge (Cragwall's methods) were made with the exit section of the new bridge as the approach section of the old bridge. The distance between the old bridge and the approach section to the old bridge was therefore set at 90 feet rather than the usual b-width distance of 225 feet. This resulted in a normal water-surface elevation at cross section 3 of the new bridge of 778.71 feet for the 100-year flood for plan 1.

As shown in figure 4, this elevation is 0.35 foot higher than the elevation determined by a linear interpolation between the water-surface elevation at the old bridge and the approach section to the old bridge at a point 90 feet upstream of the old bridge for present conditions during the 100-year flood. The normal water-surface elevation at cross section 3 for the new bridge determined by the first method (778.71 feet) was used because it represented a worst-case condition. The same procedure was used to determine the normal water-surface elevation at cross section 3 of the new bridge for the 25-year flood for plan 1, and for the 25- and 100-year floods for plan 2.

The 100-year flood profiles for present conditions are higher than the right road embankment, thus some of the flow bypasses the existing bridge. The road profile elevations for plan 1 are high enough to contain the 100-year flood (fig. 2). The 100-year flood profiles for plan 2 are higher than both confining road embankments, thus some of the flow bypasses the existing bridge and the new bridge (fig. 3). The right bypass misses both bridges, whereas the left bypass misses the new bridge, but rejoins the main-channel flow before passing through the old bridge. The total flow was divided at the downstream section into bypass and bridge components, and the elevations at the upstream section were calculated along the different flow paths. This process was repeated until the elevations for the separate waterways were within 0.02 foot of each other at the upstream section. The final divisions of the 100-year discharge for these bypass situations are shown in table 1.

Flood-profile elevations are presented in table 2 and shown in in figure 4. The average flow velocities through the bridge openings are presented in table 3. The 25-year profile at section 4 in plan 1 shows a maximum increase of 0.4 foot above the present-condition profile, whereas the profile for plan 2 shows an increase of 0.3 foot. The lower profile for plan 2 is a result of flatter abutment slopes, which increase the cross-sectional area of the bridge opening. Both modified-condition profiles converge with the present-condition profile 5,750 feet upstream, at section 7.

The profile for the 100-year flood at section 4 increases by 0.6 foot under plan 1 and 1.1 feet under plan 2. The higher profile for plan 2 is due to the 3-foot lower bridge deck, which results in partial submergence of the bridge. The additional wetted perimeter and the obstruction of flow by the bridge members cause a substantial decrease in conveyance. The effects of the additional backwater are diminished at section 7, where the profile for plan 1 is 0.1 foot higher than the present-condition profile, and the profile for plan 2 is 0.2 foot higher than the profile for present conditions.

## SUMMARY AND CONCLUSIONS

Water-surface profiles for the 25- and 100-year floods were determined for a reach of Big Darby Creek near Orient Ohio, under present conditions and two planned alternative conditions. Two proposed bridge plans were analyzed to determine the effects on flood profiles subsequent to the placement of a 376-foot-long, four-span deck bridge across the stream 90 feet upstream of the existing State Route 762 truss bridge.

The analysis shows that the 25-year flood (22,500 $ft^3$/sec) profiles immediately upstream of the new bridge would increase by 0.4 foot if plan 1 is adopted and by 0.3 foot if plan 2 is adopted. Both profiles converge with the present-condition profiles 5,750 feet upstream. The profile for the 100-year flood (31,400 $ft^3$/sec) would increase by 0.6 foot immediately upstream for plan 1 and by 1.1 feet for plan 2. This additional backwater affects profiles up to 5,750 feet upstream, where the plan 1 profile is 0.1 foot higher and the plan 2 profile is 0.2 foot higher than the profile for present conditions.

Table 1.--Distribution of flows through and around bridges for the 100-year flood, Big Darby Creek at Orient, Ohio

[100-year flood magnitude = 31,400 $ft^3/s$]

| Path of flow | Discharge ($ft^3/s$) |
|---|---|
| Present | |
| Existing bridge section | 30,480 |
| Right bypass | 920 |
| Left bypass | 0 |
| Plan 1 | |
| Proposed bridge section | 31,400 |
| Existing bridge section | 31,400 |
| Right bypass | 0 |
| Left bypass | 0 |
| Plan 2 | |
| Proposed bridge section | 30,080 |
| Existing bridge section | 30,960 |
| Right bypass | 440 |
| Left bypass[1] | 880 |

[1] Left bypass rejoins the main-channel flow before passing through old bridge.

Table 2.--Water-surface profile elevations, Big Darby Creek at Orient, Ohio

| Section ID | Distance (ft)[1] | Water-surface elevations (in feet, NGVD of 1929) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 25-year flood | | | 100-year flood | | |
| | | Present conditions | Plan 1 | Plan 2 | Present conditions | Plan 1 | Plan 2 |
| 1 | 3,750 | 775.6 | 775.6 | 775.6 | 777.6 | 777.6 | 777.6 |
| 2 | 4,000 | 775.8 | 775.8 | 775,8 | 777.9 | 777.9 | 777.9 |
| 2m | 4,090 | -- | 776.3 | 776.3 | -- | 778.7 | 778.7 |
| 3 | 4,250 | 776.7 | -- | -- | 779.1 | -- | -- |
| 3m | 4,480 | -- | 777.4 | 777.4 | -- | 780.0 | 780.7 |
| 4 | 5,100 | 777.8 | 778.2 | 778.1 | 780.1 | 780.7 | 781.2 |
| 5 | 6,350 | 778.9 | 779.1 | 779.1 | 780.9 | 781.3 | 781.8 |
| 6 | 8,300 | 780.6 | 780.7 | 780.7 | 782.2 | 782.5 | 782.8 |
| 7 | 10,850 | 783.3 | 783.3 | 783.3 | 784.6 | 784.7 | 784.8 |

1 Measured from Orient State Institute sewage treatment plant

Table 3.--Bridge-section velocities, Big Darby Creek at Orient, Ohio

| Simulated bridge-site conditions | Average bridge-section velocity (in feet per second) | | | | | |
|---|---|---|---|---|---|---|
| | 25-year flood | | | 100-year flood | | |
| | Existing bridge | New bridge (plan 1) | New bridge (plan 2) | Existing bridge | New bridge (plan 1) | New bridge (plan 2) |
| Present conditions ..... | 6.9 | -- | -- | 8.2 | -- | -- |
| Plan 1 conditions ....... | 6.9 | 6.5 | -- | 8.6 | 7.3 | -- |
| Plan 2 conditions ....... | 6.9 | -- | 6.4 | 8.4 | -- | 8.2 |

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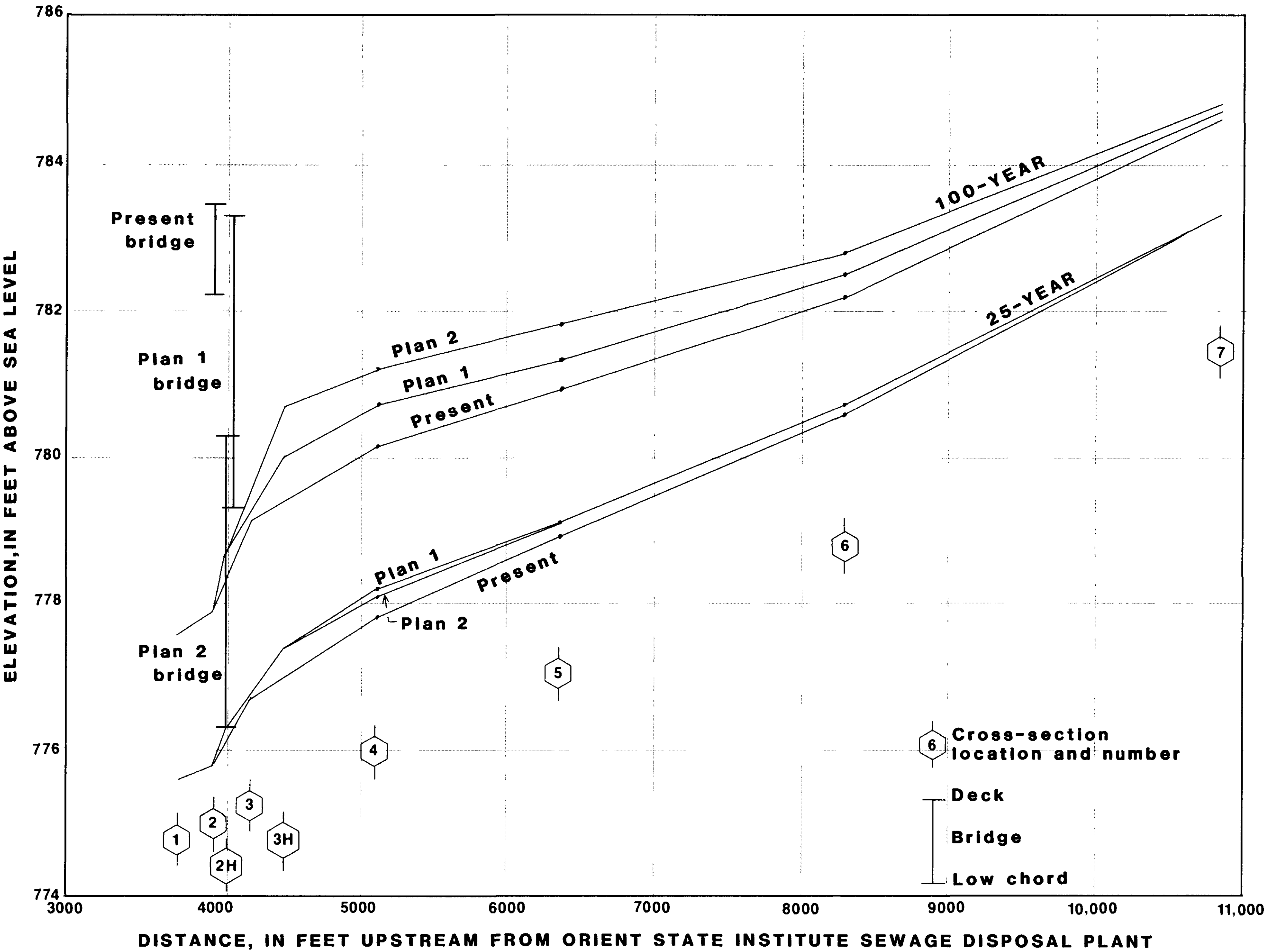


Figure 4.--Flood profiles for present and modified conditions, Big Darby Creek at Orient, Ohio.



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