

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDRAULIC ANALYSIS, MAD
RIVER AT STATE HIGHWAY 41,
SPRINGFIELD, OHIO

OPEN-FILE REPORT 77-399

PREPARED IN COOPERATION WITH THE OHIO
DEPARTMENT OF TRANSPORTATION



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By Ronald I. Mayo

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
miles (mi)	1.609	kilometers (km)
square miles (mi ²)	2.590	square kilometers (km ²)
cubic feet per second (ft ³ /s)	.02832	cubic meters per second (m ³ /s)
foot (ft)	.3048	meter (m)

ERRATA SHEET

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change 0.4 foot to 0.2 foot

HYDRAULIC ANALYSIS OF MAD RIVER AT STATE HIGHWAY 41,
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by Ronald I. Mayo

ABSTRACT

A hydraulic analysis of the Mad River in a reach at Springfield, Ohio was made to determine the effects of relocating State Highway 41 in 1976. The main channel was cleaned by dredging in the vicinity of the new highway bridge and at the Detroit, Toledo and Ironton Railway bridge upstream. The new highway was placed on a high fill with relief structures for flood plain drainage consisting of a 12-foot corrugated metal pipe culvert and a bridge opening to accommodate the Detroit, Toledo and Ironton Railway and a property access road. The effect of the new highway embankment on drainage from the flood plain was requested. Also requested was the effect that might be expected on the elevation of flood waters above the new highway embankment if the access road through the new highway embankment were raised.

The study indicates that the improvement in the capacity of the main channel to carry water was such that, up to a discharge equivalent to a 25-year frequency flood, the water-surface elevation in the reach upstream from the Detroit, Toledo and Ironton Railway bridge would be about 0.6 foot lower than under conditions prior to the construction on State Highway 41. Diversion through the Mad River left bank levee break above the Detroit, Toledo and Ironton Railway bridge to the flood plain would be decreased about one-half in terms of rate of discharge in cubic feet per second. The maximum difference in elevation of the flood water between the upstream and downstream side of the new State Highway 41 embankment would be about 0.2 foot, with an additional 0.4 foot to be expected if the access road were raised 1.5 feet.

INTRODUCTION

A hydraulic study of a reach of the Mad River at a point where State Highway 41 was relocated in 1976, in the northwest part of Springfield, Ohio, was made in cooperation with the Ohio Department of Transportation (ODOT). The highway, relocated just upstream from its former site, consists of a high embankment, a bridge spanning the main channel of Mad River and two relief structures on the left bank. The channel was dredged in the vicinity of the new highway bridge and at the Detroit, Toledo and Ironton Railway bridge about 1400 feet upstream.

The purpose of this study is to analyze the effect of the new construction and channel cleaning on flood profiles along the main channel of the Mad River, and to determine whether or not the new State Highway 41 embankment across the left bank flood plain, east of the DT&I Railway would increase flood heights and delay drainage from that area compared to conditions that existed prior to construction of the new highway.

The flood plain upstream from State Highway 41 and east of the DT&I Railway may be flooded either through breaks in the levee upstream from the DT&I Railway bridge or from backwater in GOLF Course Ditch from the Mad River below State Highway 41. The effect on flood elevations upstream from the new highway embankment from raising the access road through the embankment by several feet was also analyzed in this study.

All elevations in this report are referenced to mean sea level, datum adjustment of 1929. This study is part of a continuing cooperative program between the Ohio Department of Transportation and the U. S. Geological Survey. A previous report on this project was presented to the ODOT in July 1970, during the design phase.

Available Data

The Ohio Department of Transportation provided the following data for use in this study:

- (1) Plans and profiles of relocated State Highway 41, bridges and relief structures.
- (2) Cross sections for the two reaches of dredged channel as surveyed before and following completion of the project.
- (3) Profiles of the access road to the upstream property north of the relocated State Highway 41, of relocated Gold Course Ditch downstream from the highway, and of the break in the levee upstream from the DT&I Railway bridge.
- (4) Aerial photos of the study area taken before and after relocation of State Highway 41.
- (5) Cross sections of Golf Course Ditch upstream from State Highway 41 prior to construction.
- (6) Cross sections and culvert data for the existing box culvert on Golf Course Ditch at old State Highway 41.

Also available were the following data:

- (1) Peak discharge data for the stream gaging stations on the Mad River near Urbana, at St. Paris Pike and at Springfield, and for Buck Creek at Springfield.
- (2) U.S. Geological Survey Hydrologic Atlas 43, titled "Floods at Springfield, Ohio in 1913 and 1959," showing highwater profile elevations and outlines of the flooded areas.

Description of the Study Area

The study area is a 2000-foot reach of Mad River at the crossing of State Highway 41 in the northwest part of Springfield, Ohio (fig. 1). This crossing is about 1.6 miles upstream from Buck Creek and 1.5 miles downstream from St. Paris Pike. The flood plain of Mad River is divided above State Highway 41 by the DT&I Railway which runs in a north-south direction. State Highway 41 runs east-west across the southerly part of the study area. The main channel of Mad River runs in a southwesterly direction from the upstream end of the study reach, passes under the DT&I Railway in a 300-foot long bridge and continues south about 1400 feet to the new bridge on State Highway 41. The main channel was improved during construction of this project by dredging at the railway bridge and at the new highway bridge. The old highway bridge was removed and the channelization continued to a point about 200 feet downstream. A reach about 800 feet long was left undisturbed midway between the new State Highway 41 and the DT&I Railway bridges.

The main channel of Mad River had been leveed in the early 1920's on both banks in the reach between the railway bridge and St. Paris Pike, and along the right bank downstream from old State Highway 41. The January 1959 flood breached the Mad River levee in several places upstream from the DT&I Railway bridge. These breaks were repaired by the Corps of Engineers, U.S. Army. Subsequent floods breached the Mad River left bank levee just upstream from the DT&I Railway bridge.

The left bank flood plain between St. Paris Pike and State Highway 41 is occupied by a small creek, Golf Course Ditch, which drains a small residential area in northwestern Springfield and serves as a drainage channel for a portion of the Mad River flood plain. This creek passes through the new State Highway 41 embankment in a 12-foot diameter corrugated metal pipe and continues through the old State Highway 41 embankment in a 24x10 foot concrete box culvert. Additional relief through the new State Highway 41 embankment is provided for flood waters at the bridge opening that spans the DT&I Railway and the access road.

Relocated State Highway 41 departs from the old highway about 700 feet east of Upper Valley Pike, crosses on a bridge over the main channel of Mad River about 100 feet upstream from the old highway, intersects U.S. Highway 68 about 400 feet north of the old highway, continues east across the valley and rejoins old State Highway 41 in Springfield.

About 1969, the right bank flood plain between the State Highway 41 and the DT&I Railway bridges was filled to within about 100 feet of the main channel for commercial development. The right bank downstream from State Highway 41 also has been filled in on the shoreside of the old levee to an elevation of about 907 feet. Golf Course Ditch, which formerly ended more or less in a swamp downstream from State Highway 41, was recently channalized from State Highway 41 to the mouth at Mad River by private developers.

MAGNITUDE AND FREQUENCY OF FLOODS

Records of flood stages and discharges are available for the Mad River at St. Paris Pike, drainage area 310 mi² (1966-75 water years); Mad River near Urbana, drainage area 162 mi² (1926-31, 1940-75); Buck Creek at Springfield, drainage area 139 mi² (1915-21, 1925-49, 1959-72); and Mad River near Springfield, drainage area 490 mi² (1915-75).

Flood Frequency

Statistical studies of the Mad River were made based on data at the gaging station at St. Paris Pike and regional analysis methods outlined by Webber and Bartlett (1976). Annual peaks for the Mad River at State Highway 41 at Springfield are listed in table 1, and shown graphically in figure 2. The flood-frequency curve resulting from this study is shown in figure 3.

As applied to floods, the frequency (or recurrence interval) is the average interval of time within which a flood of a given magnitude will be equalled or exceeded once.

Table 1.--Annual peaks, Mad River
at State Highway 41 at Springfield, Ohio

Water year	Month	Discharge (ft ³ /s)
1959	Jan	19,000
1960	Jan	2,300
1961	Apr	5,600
1962	Feb	6,300
1963	Mar	15,000
1964	Apr	7,900
1965	Apr	3,300
1966	Feb	3,100
1967	May	4,200
1968	May	5,100
1969	Aug	6,200
1970	Apr	6,800
1971	June	10,000
1972	May	5,000
1973	Nov	4,200
1974	Jan	4,400
1975	Feb	8,600

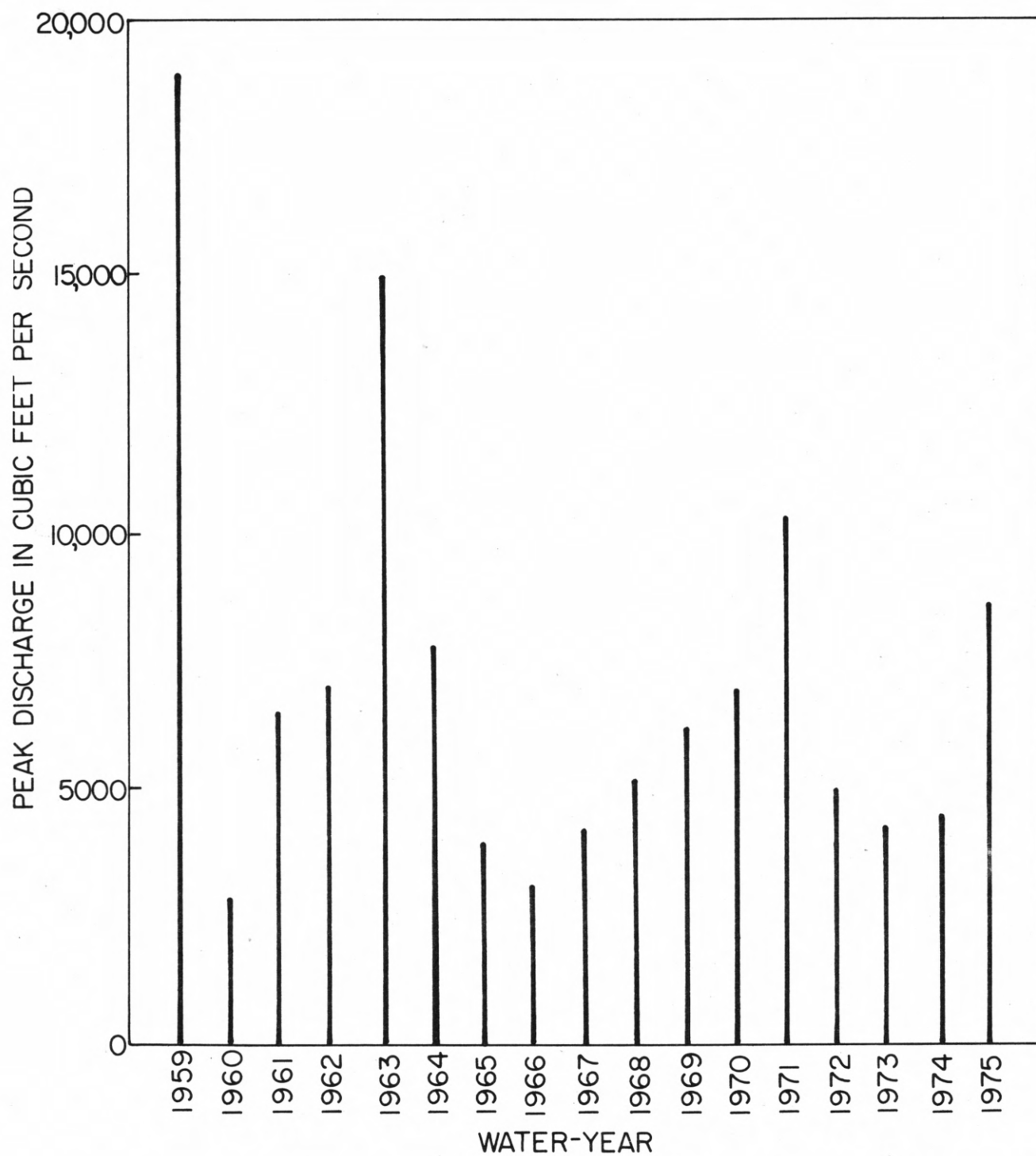


FIGURE 2.--ANNUAL PEAK DISCHARGES, MAD RIVER AT STATE HIGHWAY 41 AT SPRINGFIELD, OHIO.

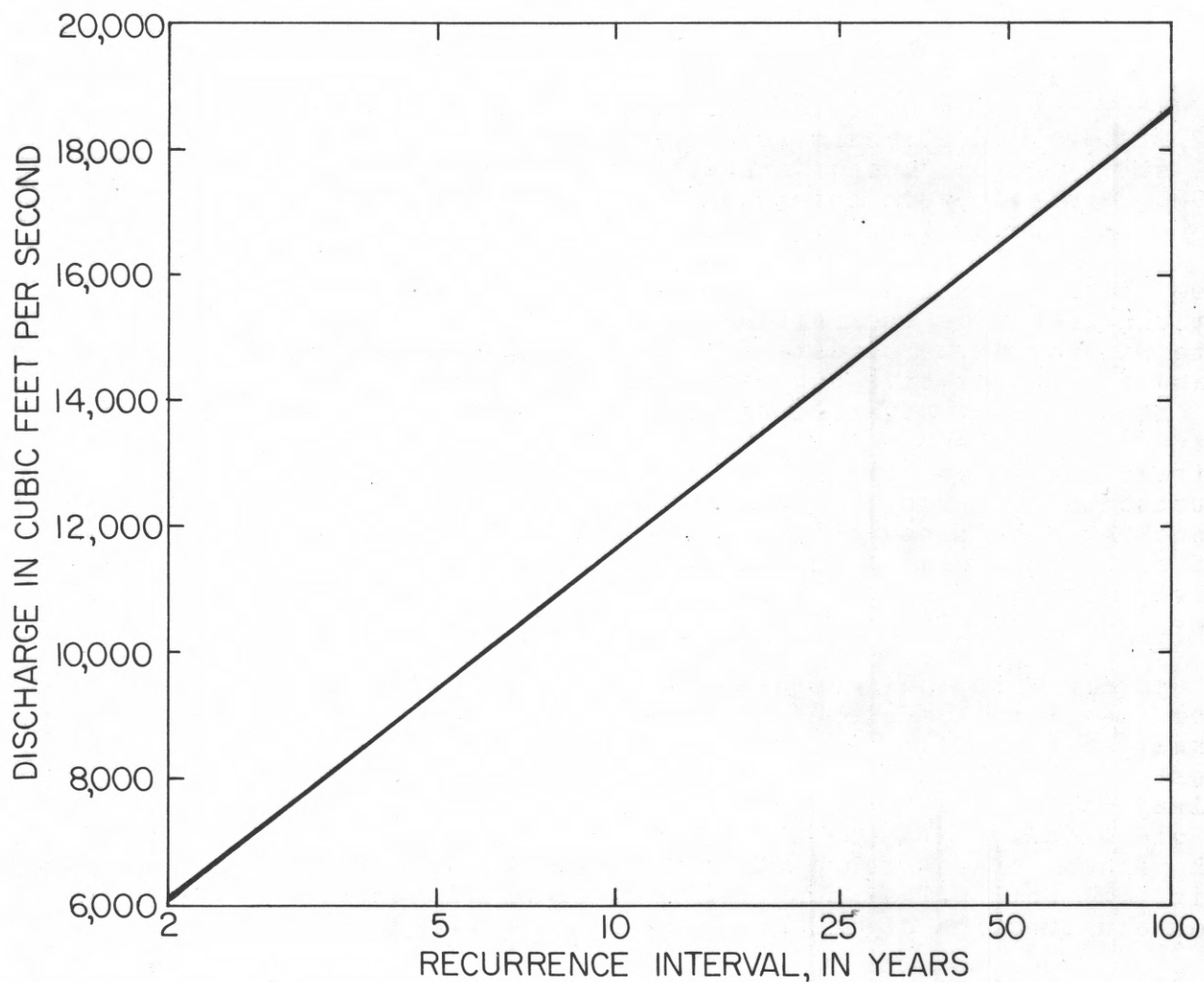


FIGURE 3.--DISCHARGE-FREQUENCY CURVE, MAD RIVER AT STATE HIGHWAY 41, SPRINGFIELD, OHIO.

ANALYSIS OF HYDRAULIC CONDITIONS

Water surface profiles for floods having recurrence intervals of 2, 5, 10, and 25 years were developed for the main channel in the study reach using standard step-backwater methods (Chow, 1959). Profiles were developed for conditions existing before and after the relocation of State Highway 41. The total flood discharge was divided into main channel and bypass flow at the levee break upstream from the DT&I Railway bridge and recombined just upstream from the initial rating section (figure 4) below State Highway 41. The data for these profiles are listed in table 2, and for comparative purposes the 2- and 25-year flood profiles for before and after construction of new State Highway 41, are plotted in figure 5. The elevation discharge relation at the upstream side of the DT&I Railway bridge shown on figure 6 illustrates the effect of the outflow from the Mad River main channel to the flood plain. The effect on the discharge onto the left bank flood plain through the levee break above the DT&I Railway bridge is shown in figure 7. A profile section of this levee break is shown in figure 8.

Profiles for discharges of various magnitudes from low to flood flow were developed for Golf Course Ditch using step-backwater methods. These profiles were developed from a section downstream from the old highway to the levee break above the DT&I Railway bridge. Ratings were computed for all openings in the new and old highway embankments. The time required to drain the left bank flood plain from a flood elevation of 913 feet, assuming no additional inflow, was computed for conditions existing before and after construction of the new highway, (figure 9).

A study was made to determine the effect on flood stages above the new State Highway 41 embankment from raising the elevation of the access road through the embankment. A discharge from the flood plain of $1200 \text{ ft}^3/\text{s}$ was used as a basis for this study. At this discharge there is about $300 \text{ ft}^3/\text{s}$ going over the old State Highway 41 embankment and the water surface upstream from the old embankment is at about 912 feet. A trial-and-error method was used to determine the elevation upstream from the new embankment for different elevations of the access road with a total discharge of $1200 \text{ ft}^3/\text{s}$ passing through the access road opening and the 12-foot corrugated metal pipe culvert under new State Highway 41. The elevation of the access road was raised in half-foot increments from the actual elevation of 907.5 feet to 909.0 feet.

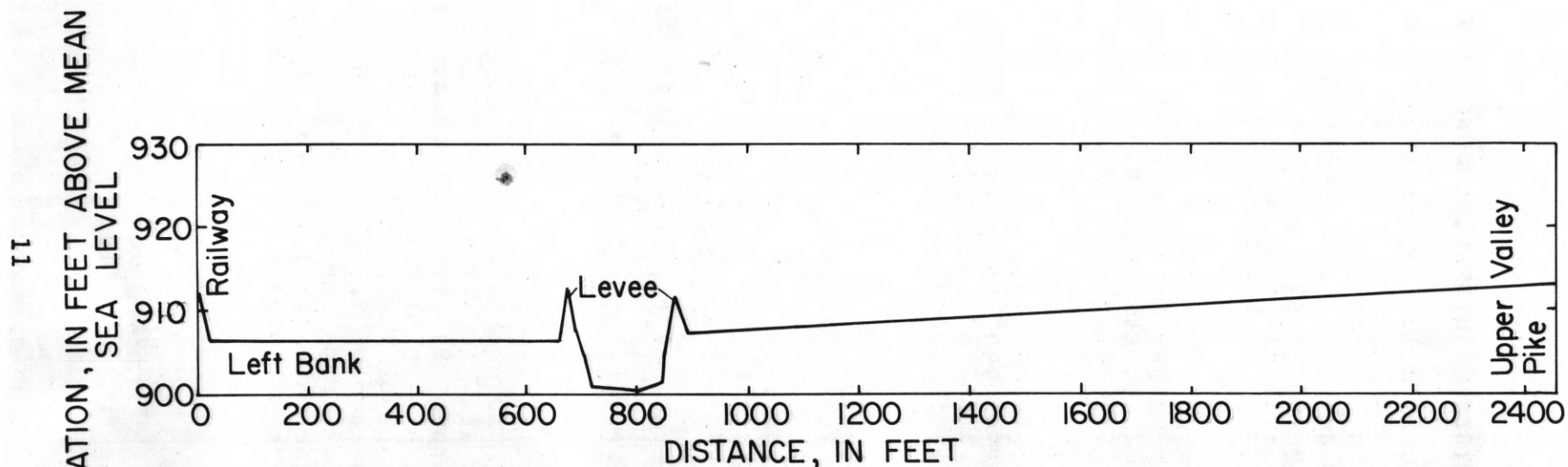


FIGURE 4.--MAD RIVER VALLEY CROSS SECTION AT SECTION I, 250 FEET DOWNSTREAM FROM OLD STATE HIGHWAY 41.

Table 2.--Water surface profile data, Mad River at State Highway 41, Springfield, Chic

Elevations in feet above mean sea level

Section	Location	Dis- tance ¹ (feet)	Recurrence interval of flood							
			2-year		5-year		10-year		25-year	
			Highway relocation		Highway relocation		Highway relocation		Highway relocation	
			Before	After	Before	After	Before	After	Before	After
1	Initial section ---	0	908.1	908.1	909.6	909.6	910.2	910.2	910.7	910.7
2	Old State Highway 41, downstream -	250	908.6	-----	910.1	-----	910.7	-----	911.2	-----
6	New State Highway 41, downstream -	360	-----	908.7	-----	910.2	-----	910.8	-----	911.2
7	Old State Highway 41, upstream ---	425	909.1	-----	910.8	-----	911.4	-----	912.0	-----
10	New State Highway 41, upstream ---	655	-----	909.0	-----	910.6	-----	911.2	-----	911.8
11	-----	1150	909.8	909.2	911.3	910.7	911.8	911.4	912.4	912.0
12	-----	1650	910.4	910.0	911.7	911.3	912.2	911.9	912.8	912.5
13	DT&I Railway bridge, downstream -----	1850	910.7	910.1	911.9	911.4	912.4	912.0	913.0	912.7
14	DT&I Railway bridge, upstream	2170	910.9	910.1	912.1	911.4	912.6	912.1	913.2	912.7

¹ Distance in feet upstream from initial section.

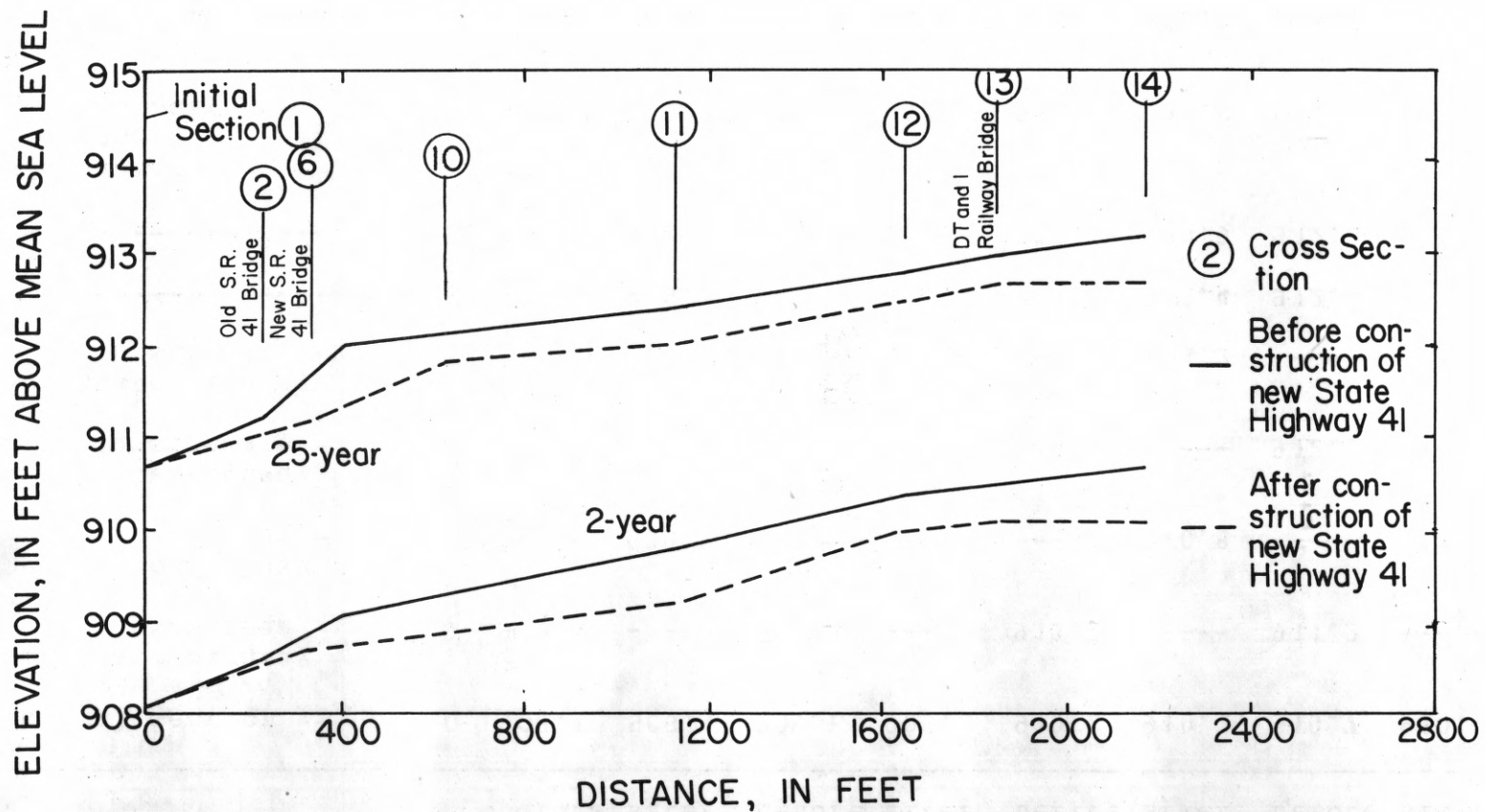


FIGURE 5.--WATER-SURFACE PROFILES OF 2- AND 25- YEAR FLOODS, MAD RIVER AT STATE HIGHWAY 41, SPRINGFIELD, OHIO.

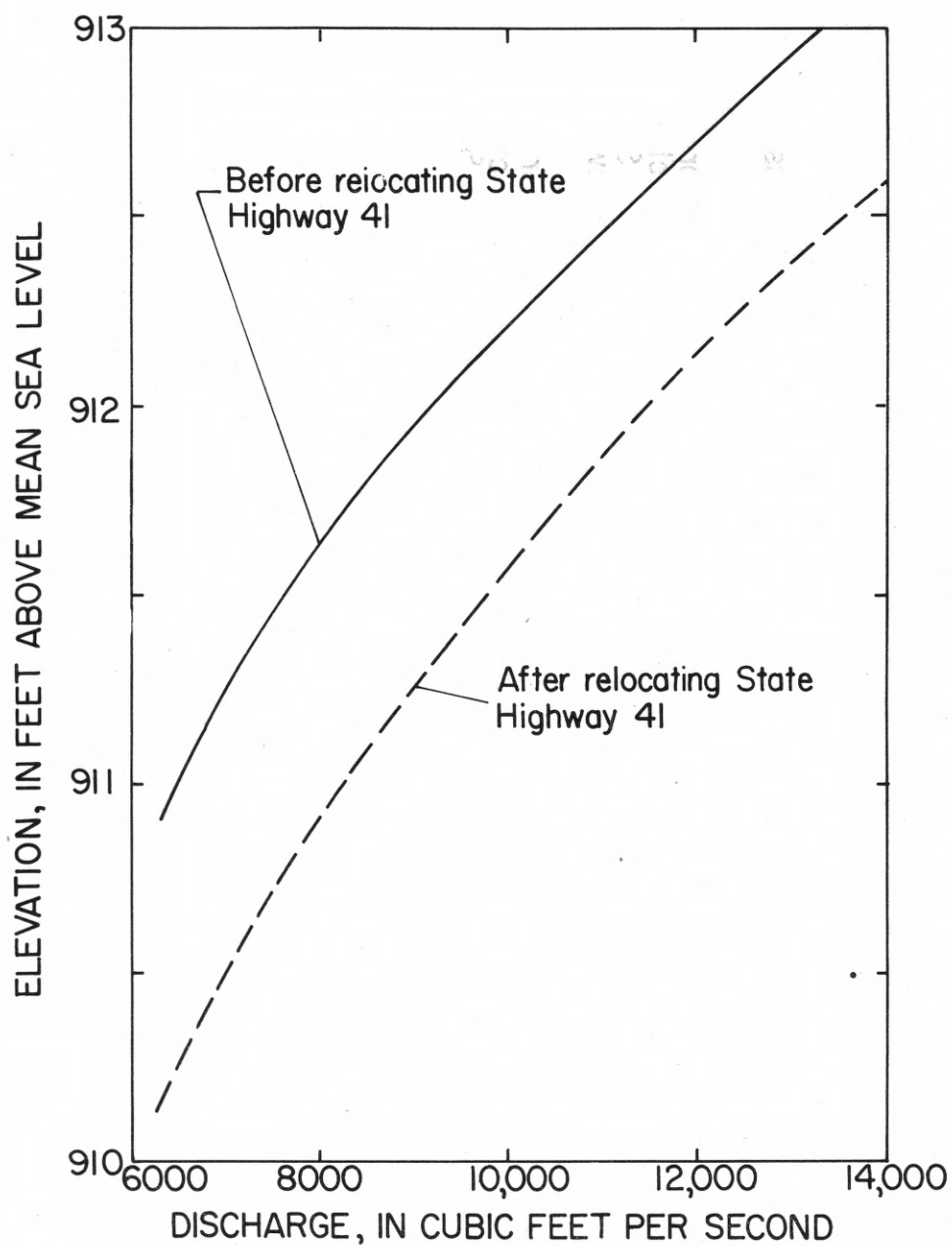


FIGURE 6.--ELEVATION-DISCHARGE RELATION
UPSTREAM FROM THE DT AND I RAILWAY
BRIDGE.

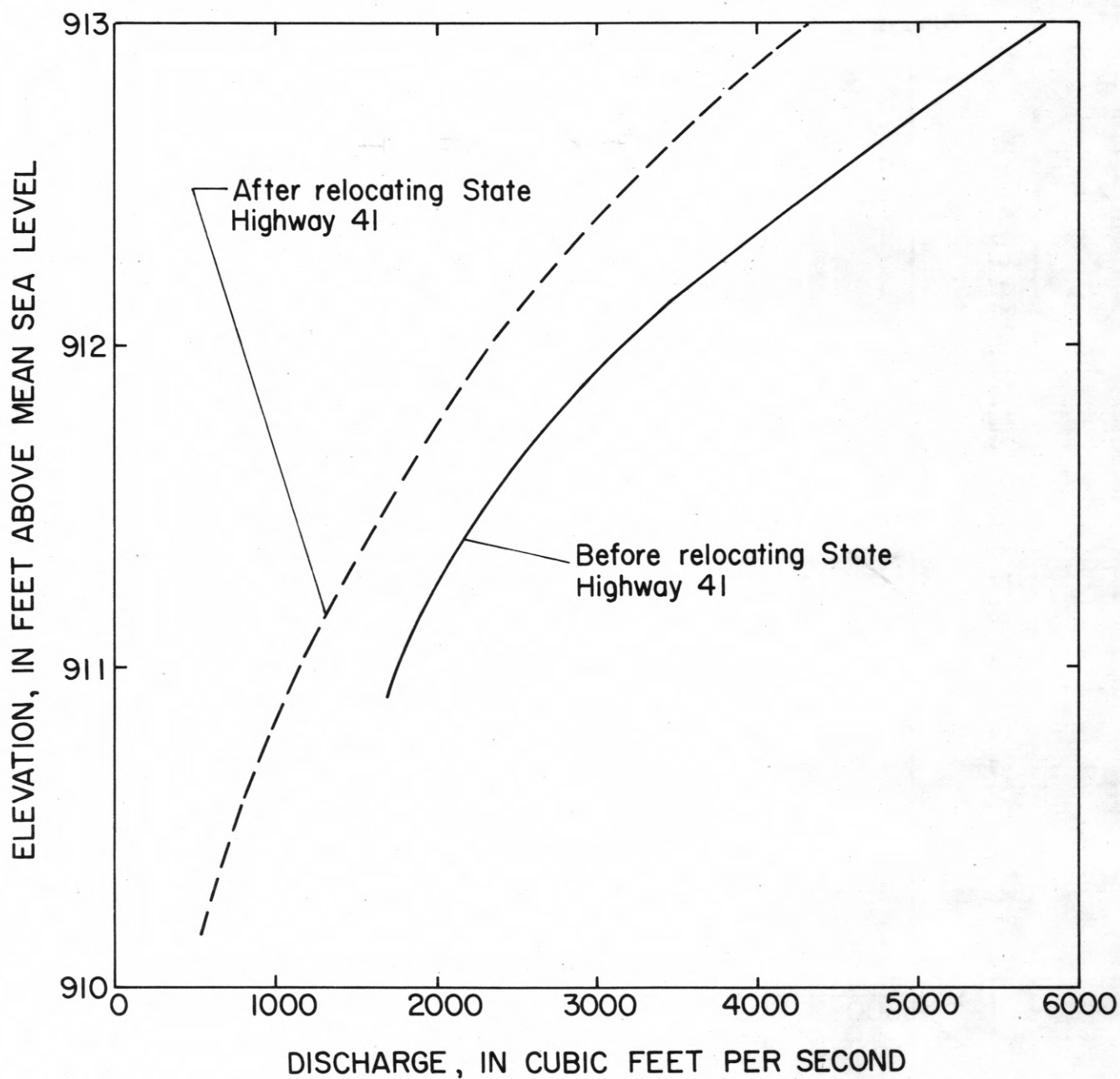


FIGURE 7.--DIVERSION THROUGH LEVEE BREAK ABOVE THE DT AND I RAILWAY BRIDGE.

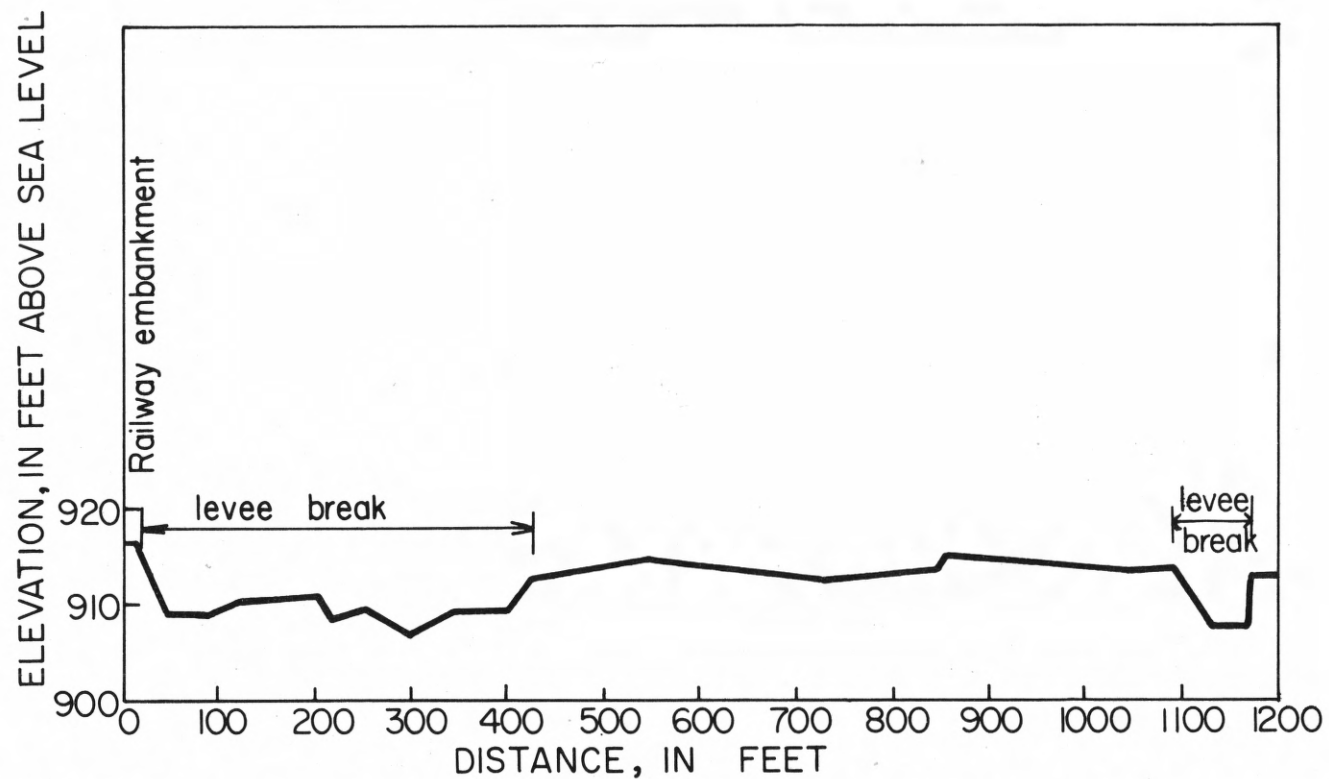


FIGURE 8.-- PROFILE OF MAD RIVER LEVEE ON LEFT BANK UPSTREAM FROM DT&I RAILWAY BRIDGE.

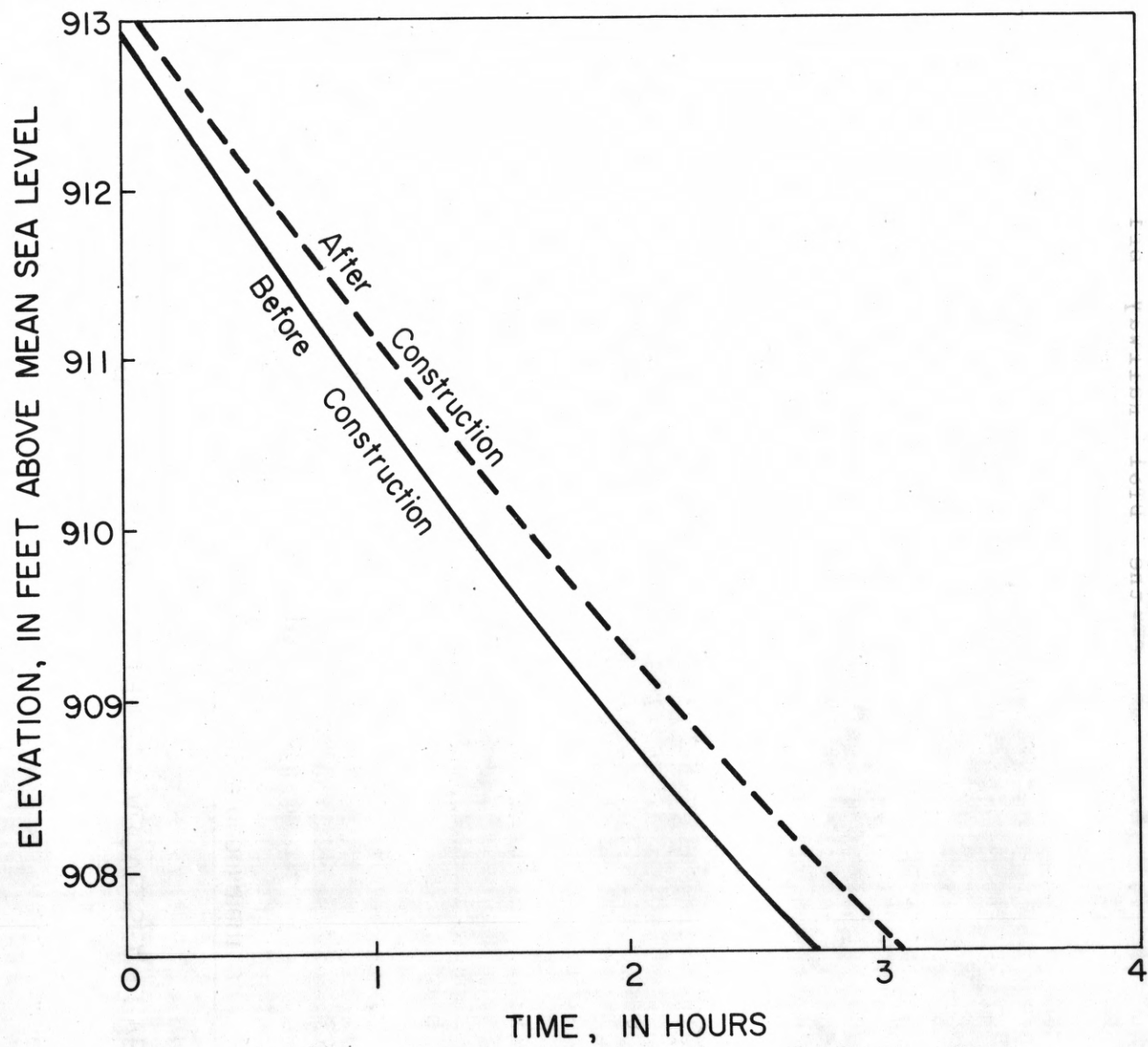


FIGURE 9.--TIME REQUIRED TO EMPTY FLOOD PLAIN UPSTREAM FROM STATE HIGHWAY 41.

SUMMARY

Mad River water surface profiles of floods having recurrence intervals of 2, 5, 10, and 25 years show about 0.6 foot lowering of the stream level above the DT&I Railway bridge due to improvement of the bridge section at new State Highway 41 and dredging at the State Highway 41 and DT&I Railway bridges. Elevation data for these flood frequencies are listed in table 2. The profiles for before and after conditions are shown for the 2- and 25-year floods in figure 5.

The gradient of the Mad River main channel and flood plain in the study area is relatively flat so that natural drainage of the flood plain following a flood is slow. Figure 10 showing the frequency of flood stages downstream from old State Highway 41 and figure 11 showing the low flow stream profile along Golf Course Ditch upstream from Mad River indicates that on an average of about once a year the flood plain in the vicinity of the new highway would be flooded by backwater from the Mad River to an elevation of 908 feet, even if there were no inflow to the floodplain from the Mad River main channel upstream from the DT&I Railway. Table 3, showing all Mad River floods above 5500 ft³/s since 1966, also indicates the relatively high flood risk on Golf Course Ditch from backwater of Mad River entering Golf Course Ditch at its mouth, downstream from State Highway 41.

Inflow to the left bank flood plain of the Mad River upstream from State Highway 41 is determined by the rate of rise in the main channel, the magnitude of the flood peak discharge and the effects of breaching in the levee system, and only slightly by the rate of outflow. For purposes of comparison of drainage from this flood plain before and after construction of the new highway embankment, it was assumed that there was no inflow and the computations were made at a starting elevation of 913 feet which is about as high as water in the flood plain will rise before overtopping the DT&I Railway tracks on the west side of flood plain, and reentering the main channel.

The relative length of time for the old State Highway 41 culvert and the new State Highway 41 culvert and access road opening to lower a flood in the left bank flood plain from an elevation of 913 feet to the elevation of the access road (907.5 ft) is shown in figure 9. The difference in time to drain this volume of overbank flood waters on Golf Course Ditch through the old or the new State Highway 41 culverts is less than one hour. This analysis included just the volume between old State Highway 41 and the DT&I Railway bridge and did not consider either the return flow to the main channel through the levee break, or drainage through the ground.

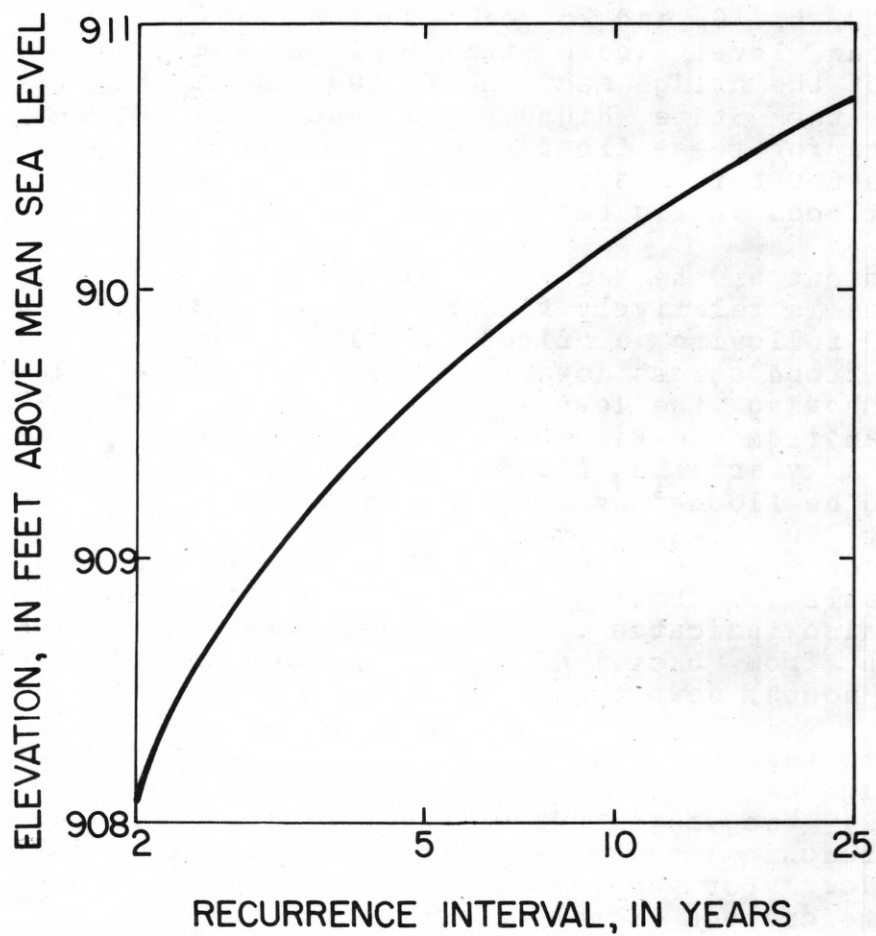


FIGURE 10.--ELEVATION-FREQUENCY CURVE,
MAD RIVER BELOW STATE HIGHWAY 41

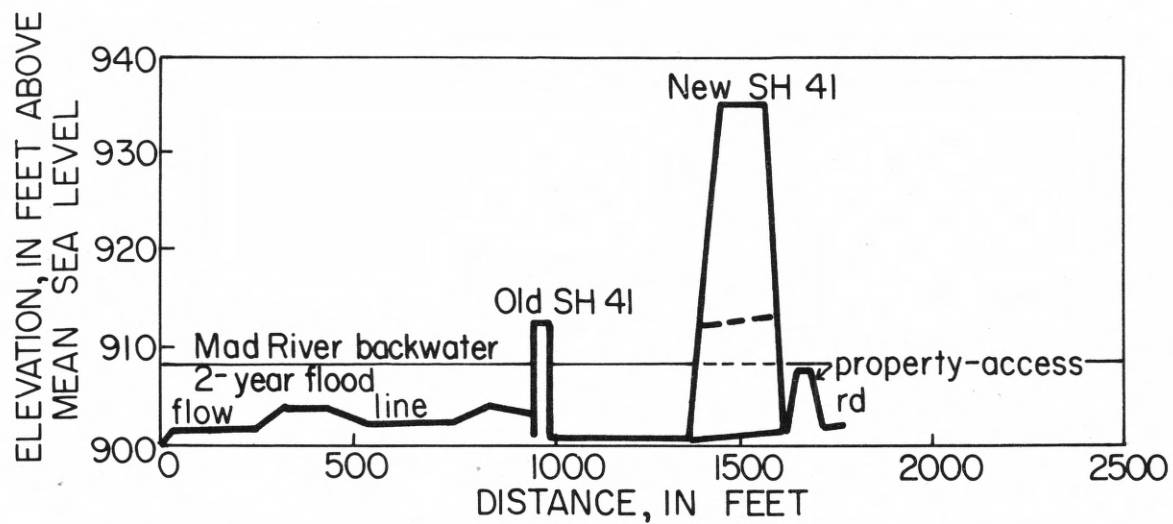


FIGURE 11.--PROFILES OF LOW-FLOW LINE AND BACK-WATER FROM 2-YEAR FLOOD FROM MAD RIVER ON GOLF COURSE DITCH.

Table 3.--Flood peaks¹ above 5,500 ft³/s, Mad River at State Highway 41, Springfield, Ohio

Water year	Month	Discharge (ft ³ /s)
1966	Feb	² 3,100
1967	May	² 4,200
1968	May	² 5,100
1969	Aug	6,200
1970	Apr	6,800
1971	June	10,000
1972	May	² 5,000
1973	Nov	² 4,200
1974	Jan	² 4,400
1975	Feb	8,600
1975	July	6,700

¹ All peaks during period of record which will cause backwater from the Mad River below State Highway 41 to overflow access road.

² Annual peaks in years when base (5,500 ft³/s) was not exceeded.

The effect of the new highway embankment on the elevation of water in the flood plain upstream is shown in table 4. Below an elevation of 905.6 feet the 12-foot pipe appears to act more efficiently than the original ditch as a carrier of water. Between this elevation and about 908 feet, where there is considerable flow through the access road opening, there is a slight backwater effect from the new fill. Above elevation 908.5 feet up to the point where water runs over the old highway embankment the openings in the new embankment carry more water than the old. At elevation 912, where old State Highway 41 overflows, there is only about 0.2 foot of increased backwater above the new fill. In summary, the effect of the new State Highway 41 embankment on flow out of the flood plain is practically insignificant.

A study of a proposal to raise the access road 1.5 feet through the new State Highway 41 embankment (fig. 12) shows that the water above the new embankment would be increased only a few tenths of a foot under high outflow conditions. Table 5 shows the increase of the upstream flood stages from raising the elevation of the access road.

SELECTED REFERENCES

- Chow, Ven Te, 1959, Open-channel hydraulics: New York McGraw-Hill Book Co., Inc., 680 p.
- Corps of Engineers, U.S. Army, 1974, Special flood hazard information report, Mad River, Springfield, Ohio.
- Webber, E. E., and Bartlett, W. P., Jr., 1976, Floods in Chic--magnitude and frequency: U.S. Geol. Survey open-file report 76-768.

Table 4.--Elevation for given discharge for
Golf Course Ditch before and after
construction of new State Highway 41
embankment

Discharge (ft ³ /s)	<u>Elevation (feet)</u> ¹	
	Before ²	After ²
30	905.2	904.1
50	905.4	904.6
70	905.6	905.1
100	905.7	905.6
500	908.5	908.5
800	910.4	³ 910.4
1000	911.3	³ 911.4
⁴ 1200	912.0	912.2

¹ Elevation at point upstream from the new highway embankment.

² Before and after construction of the new embankment.

³ Stage-discharge relation affected by the old highway culvert.

⁴ Flow over old highway embankment.

Table 5.--Effect of access road elevation on upstream
water surface elevation

Elevation of centerline of access road, in feet	Elevation of water surface ----- In feet -----		Difference in elevation (feet)
	Below new highway	Above new highway	
907.5	912.0	912.2	0.2
908.0	912.0	912.3	.3
908.5	912.0	912.3	.3
909.0	912.0	912.4	.4

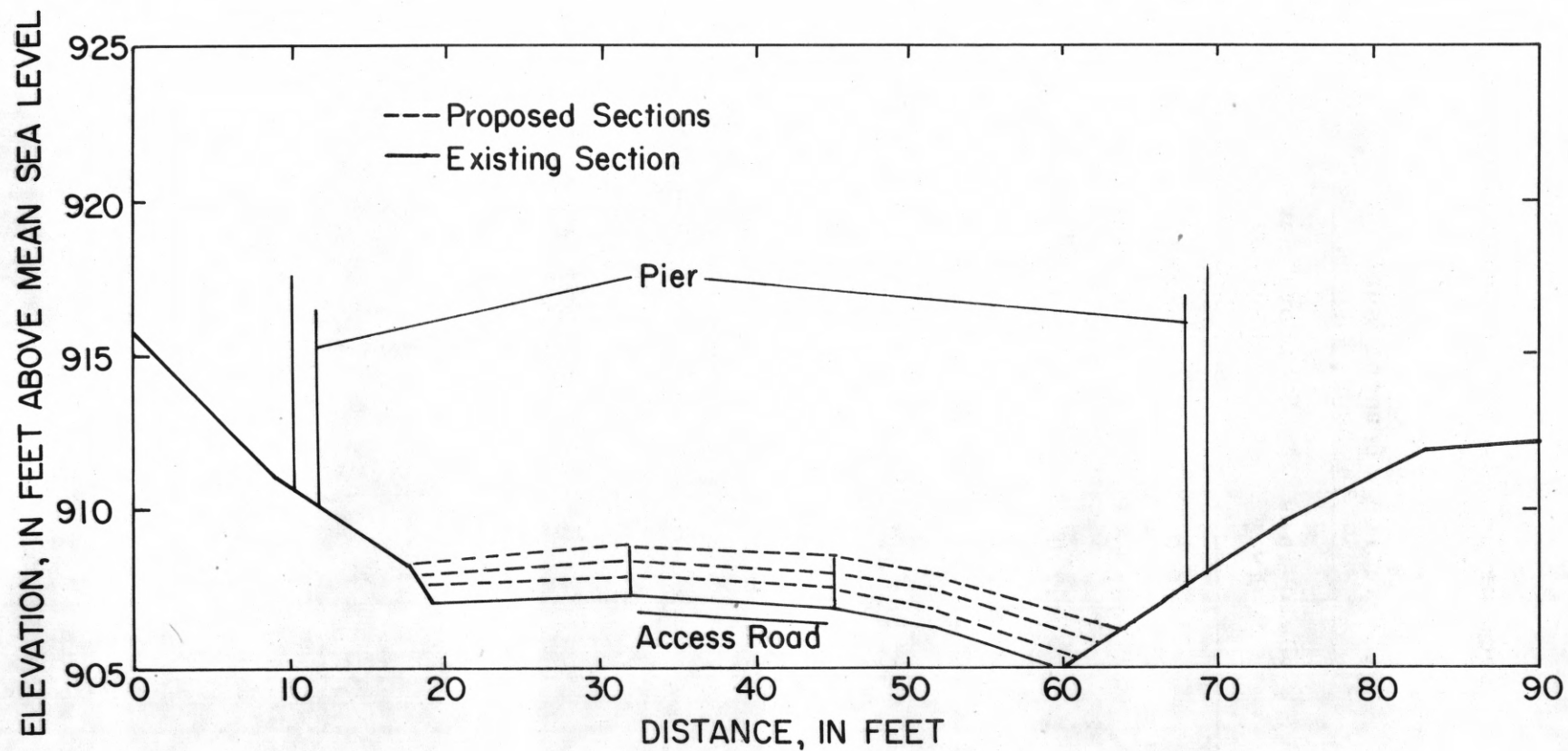


FIGURE 12.--ACCESS ROAD THROUGH NEW STATE HIGHWAY 41 EMBANKMENT.

