ATLAS HA-606

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION
AND THE LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS, TENMILE CREEK NEAR ELIZABETH, LOUISIANA

By George J. Arcement, B. E. Colson, and C. O. Ming

Prepared in cooperation with the
DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
and the
LOUISIANA DEPARTMENT OF
TRANSPORTATION AND DEVELOPMENT

HYDROLOGIC INVESTIGATIONS ATLAS
Published by the U.S. Geological Survey, 1979
W

ARCEMENT, COLSON, AND MING—BACKWATER, BRIDGES AND FLOOD PLAINS, ELIZABETH, LA. ATLAS HA-606

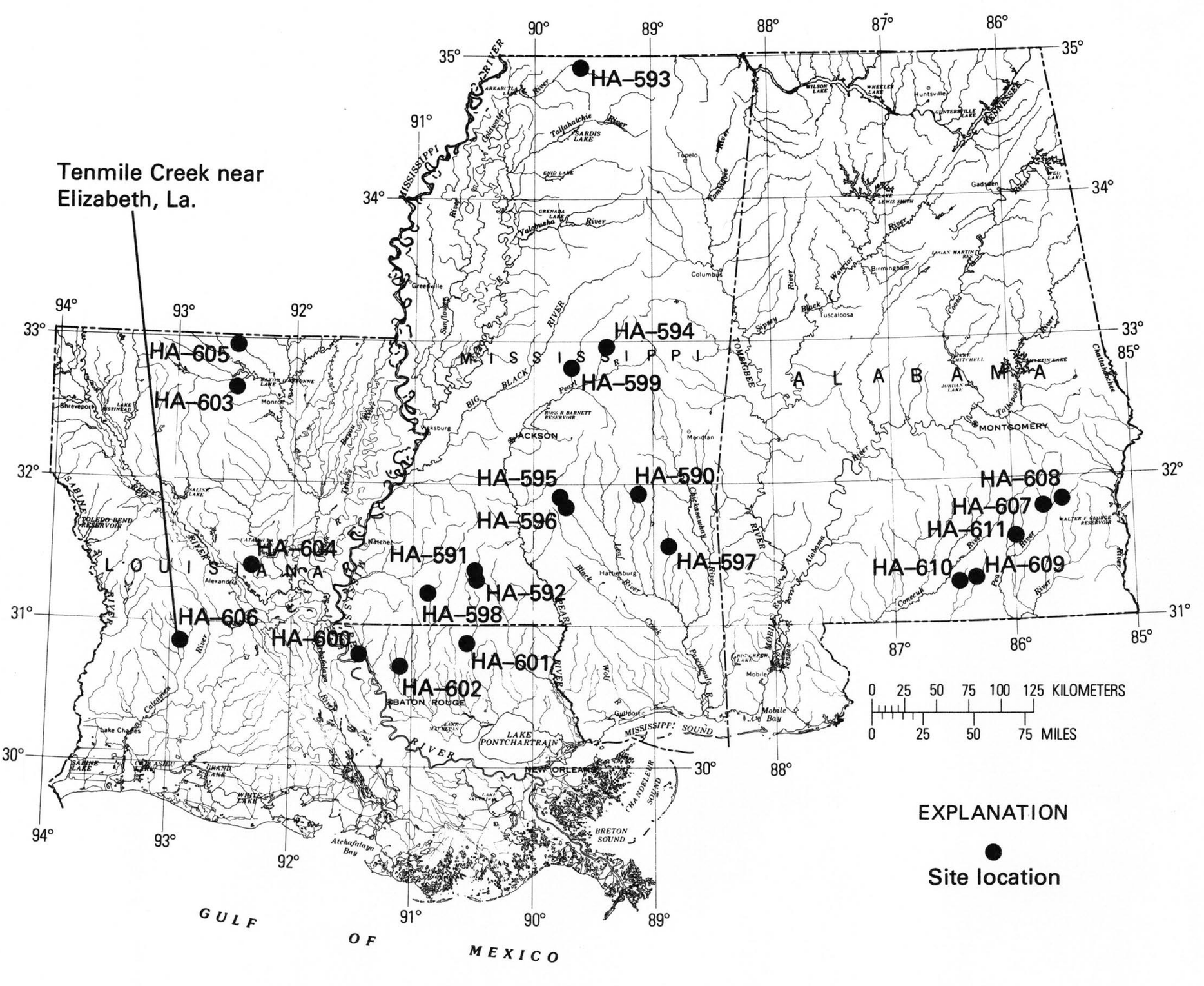

FIGURE 1.—INDEX MAP OF STUDY SITES IN THE BRIDGE BACKWATER INVESTIGATION PROJECT, ALABAMA, LOUISIANA, AND MISSISSIPPI.

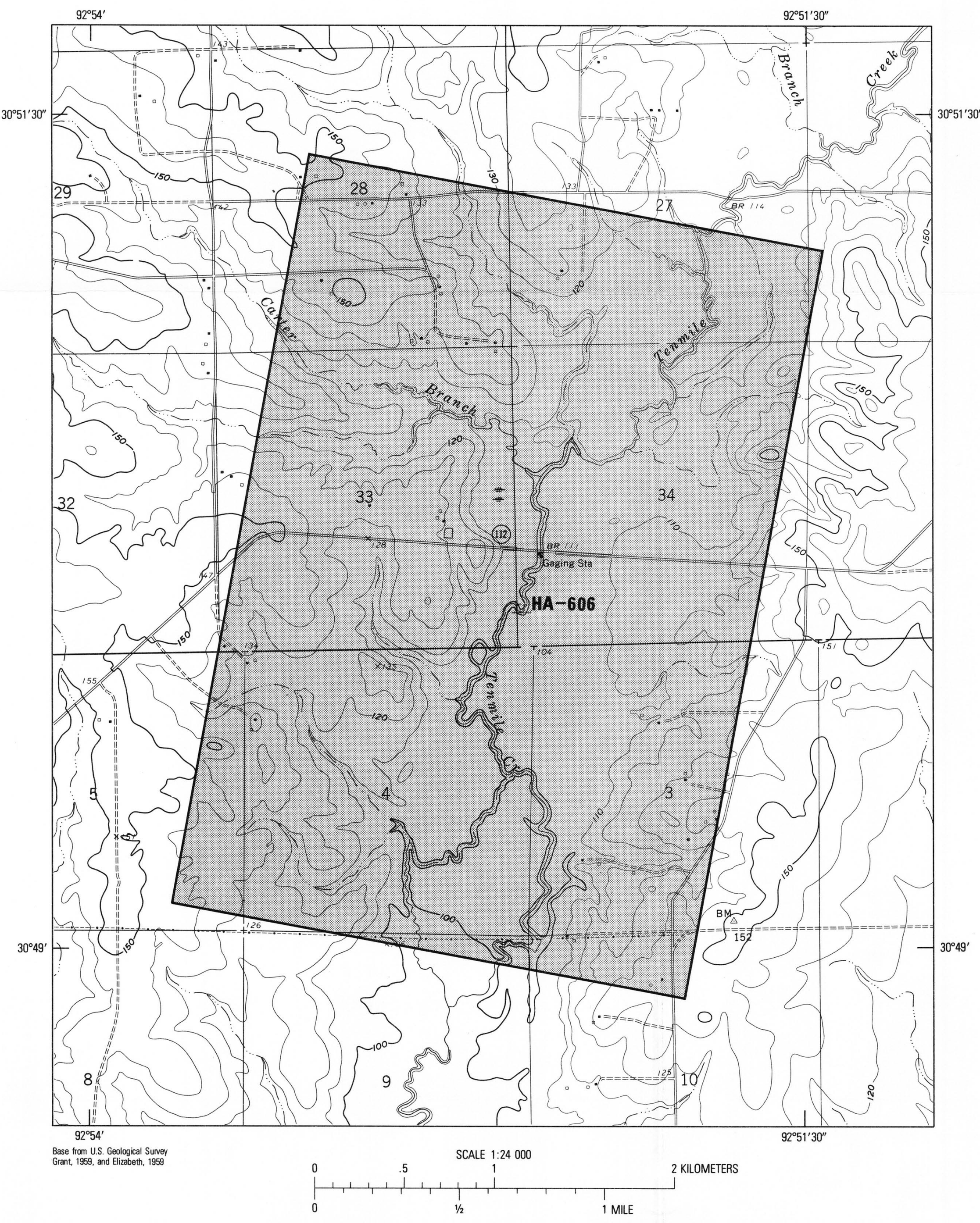

FIGURE 2—INDEX MAP OF STUDY REACH, TENMILE CREEK NEAR ELIZABETH, LOUISIANA.

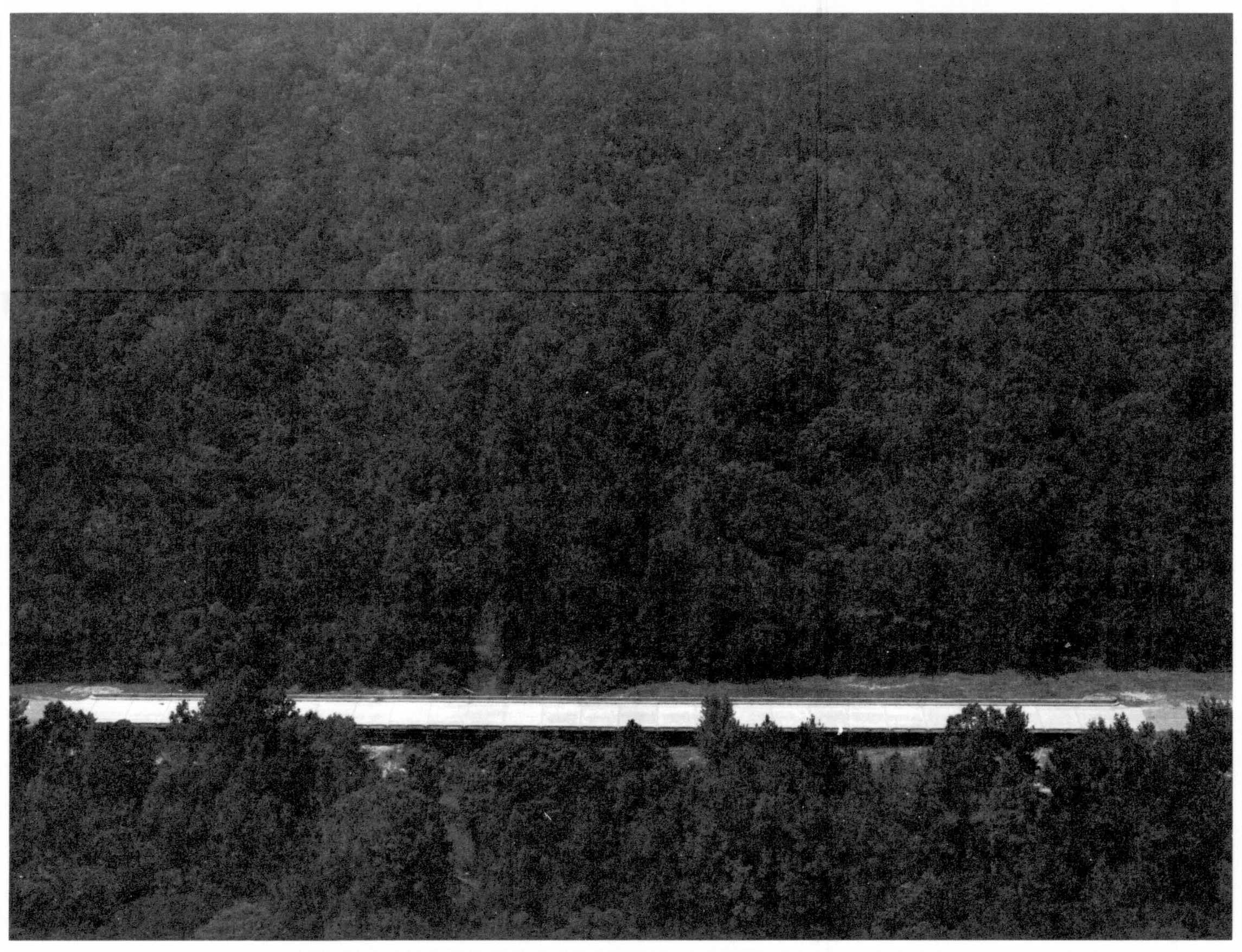

FIGURE 3—AERIAL VIEW LOOKING UPSTREAM AT BRIDGE ON STATE HIGHWAY 112, TENMILE CREEK NEAR ELIZABETH, LOUISIANA.

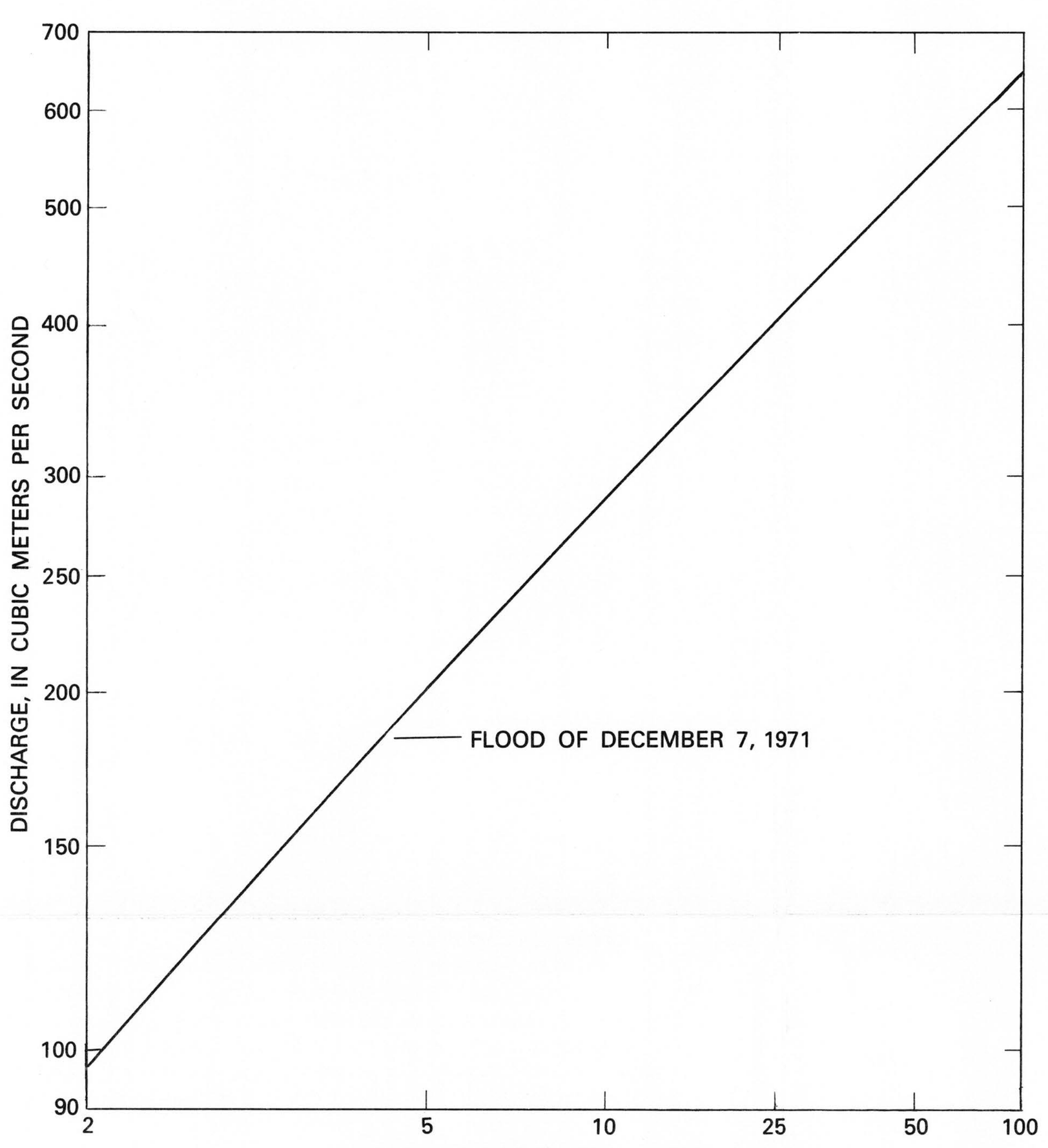

FIGURE 4—FREQUENCY OF FLOODS, TENMILE CREEK NEAR ELIZABETH, LOUISIANA

BACKWATER AT BRIDGES AND DENSELY WOODED FLOOD PLAINS TENMILE CREEK NEAR ELIZABETH, LOUISIANA

INTRODUCTION

New techniques for predicting water-surface profiles, needed in the design of economical, structurally sound, and environmentally compatible stream crossings, are under investigation. The investigation has accelerated with the advent of digital computers capable of analyzing large quantities of data. Among the techniques is the development of two-dimensional (2–D) digital models. Field data are essential for development and evaluation of these techniques for predicting water-surface profiles. This atlas is one of a series that provide a wide range of field data.

Since 1969 the U.S. Geological Survey has been collecting backwater data where wide, densely vegetated flood plains are crossed by highway embankments and single-opening bridges. This work was done in cooperation with the Federal Highway Administration Department of Transportation, the Alabama State Highway Department, the Louisiana Department of Transportation and Development, and the Mississippi State Highway Department. The objective of this cooperative project is to present the data in a format conducive to the development of improved models for predicting hydraulic responses of flow at highway crossings of streams in complex hydrologic and geographic settings.

Backwater data were obtained at 22 sites for 35 floods; that is, 11 sites had 1 flood each; 9 sites, 2 floods each; and 2 sites, 3 floods each. Analysis of data (Schneider and others, 1976) showed that backwater and discharge at these sites computed by methods presently in use, would be inaccurate. The floodflow data are unique in the range and detail in which information was collected and provide a base for evaluating digital models relating to open-channel flow.

The data sites (fig. 1) are listed below. This atlas shows flood data obtained on Tenmile Creek near Elizabeth, Louisiana, one of the 22 sites.

HYDROLOGIC INVESTIGATIONS ATLAS NUMBER

ALABAMA

- Buckhorn Creek near Shiloh HA–607
- Pea Creek near Louisville 608
- Poley Creek near Sanford 609
- Yellow River near Sanford 610
- Whitewater Creek near Tarentum 611

LOUISIANA

- Alexander Creek near St. Francisville HA–600*
- Beaver Creek near Kentwood 601
- Comite River near Olive Branch 602
- Cypress Creek near Downsville 603*
- Flagon Bayou near Libuse 604
- Little Bayou de Loutre near Truxno 605*
- Tenmile Creek near Elizabeth 606

MISSISSIPPI

- Bogue Chitto near Johnston Station HA–591
- Bogue Chitto near Summit 592
- Coldwater River near Red Banks 593*
- Lobutcha Creek at Zama 594
- Okatoma Creek east of Magee 595
- Okatoma Creek near Magee 596
- Tallahala Creek at Waldrup 590
- Thompson Creek near Clara 597*
- West Fork Amite River near Liberty 598*
- Yockanookany River near Thomastown 599*

*In press

DESCRIPTION OF DATA

TYPE OF DATA

Data collected at all study sites consist of (1) depths, velocities, and discharges measured through the bridge openings, and (2) peak water-surface elevations along the highway embankment and along cross sections. A minimum of eight valley cross sections were surveyed at approximately one valley-width intervals in the vicinity of the bridge at each site. Locations of the cross sections were alined perpendicularly to the assumed direction of flow. Cross sections were extended to intersect the edge of the valley at equal water-surface elevations. Surveying procedures described in the U.S. Geological Survey Techniques of Water-Resources Investigations series (Matthai, 1967; Benson and Dalrymple, 1967) were followed.

HIGH-WATER MARKS

Water-surface elevations were determined from high-water marks identified along the cross sections and the edges of the valley after each flood. During peak discharge measurements, water-surface elevations were marked with standard surveying stakes along the upstream and downstreams sides of the highway embankment. For some floods additional high-water marks were identified in the valley adjacent to the bridge to define in detail the water surface in the approach and exit reaches.

BRIDGE GEOMETRY

Detailed bridge geometry was obtained at each site. The bridge cross section was surveyed at the most contracted section. Piers, spur dikes, wingwalls, abutment slopes, and other pertinent geometry were measured.

MANNING'S ROUGHNESS COEFFICIENT

Schneider and others (1976) used composite Manning's roughness coefficient values *n* where frequent changes in roughness occurred. In their study, composite values of *n* were verified by matching step backwater computations of the water surface with actual water-surface profiles for measured discharges. The range of *n* values used in this report is based on values used by Schneider and others (1976). Roughness varies from open fields to dense forests.

Roughness values or ranges of roughness values in different parts of the flood plain are shown on the maps. The values shown are based on water depth. The high value is the value where water depth is less than 0.6 meter and the low value applies where water depth is greater than 1.0 meter. A linear relation of roughness to water depth is assumed for water depths between 0.6 and 1.0 meter.

PRESENTATION OF DATA

The data are presented on topographic maps enlarged from standard 1:24,000 or 1:62,500 scale U.S. Geological Survey topographic maps which comply with National Map Accuracy Standards. Accuracy limitations of the base maps are retained in the enlargements. Although positions may be scaled closely on the enlargements, they are not defined with greater accuracy than positions on the base maps.

Ground elevations are placed adjacent to solid squares. Elevations of floodmarks are indicated by numerical values adjacent to solid triangles. Floodmark elevations for separate floods are shown on separate sheets. Bridge geometry and road-embankment dimensions are shown with brief notations of pier spacing and configuration.

In addition to the data points shown on the maps, discharge measurements of selected floods, plots of cross sections, and velocity distribution diagrams are shown. Cross-section elevations are tabulated to define stream channels and flood-plain features in greater detail. Each cross section is referred to a zero station established at the extreme left edge (facing downstream) of the valley.

DATUM

All elevations presented in this report are referred to National Geodetic Vertical Datum of 1929 (NGVD).

FLOOD FREQUENCY

Flood-frequency relations are presented graphically. Techniques for deriving flood-frequency relations are those described by the U.S. Water Resources Council (1977), and by Neely (1976).

INTERNATIONAL SYSTEM OF UNITS (SI)

The International System of Units (SI) is used throughout this report. All data were measured in the U.S. customary units and converted to SI units. Ground elevations which were originally determined to the nearest tenth of a foot are rounded to the nearest 0.01 meter. Water-surface elevations which were surveyed to hundredths of a foot are rounded to millimeters. The same criteria apply to all other dimensions, except contour elevations which are shown to the nearest tenth of a meter.

The following factors may be used to convert SI units to the U.S. customary units:

MULTIPLY SI UNITS	*BY*	*TO OBTAIN U.S. CUSTOMARY UNITS*
	LENGTH	
Meter (m)	3.281	Feet (ft)
	AREA	
Square meter (m^2)	10.76	Square feet (ft^2)
	VOLUME	
Cubic meter (m^3)	35.31	Cubic feet (ft^3)
	VELOCITY	
Meter per second (m/s)	3.281	Feet per second (ft/s)
	FLOW RATE	
Cubic meter per second (m^3/s)	35.31	Cubic feet per second (ft^3/s)

DATA FOR TENMILE CREEK NEAR ELIZABETH, LOUISIANA

Data for Tenmile Creek near Elizabeth, La., obtained in a 4-kilometer reach crossed about midway by State Highway 112, are presented on three sheets (fig. 2). Sheet 1 contains tables showing cross-section data (table 1) and discharge data (table 2). An aerial view of the reach in the vicinity of the bridge is shown in figure 3. Relative magnitude of floods is shown on the frequency curve (fig. 4).

The locations of representative ground elevations are shown on sheet 2. These are points of significant changes in cross-section elevations and alinement of axis. Stationing along cross sections was projected along straight lines perpendicular to the flow. Plots of the cross sections are graphic presentations of the tabular data.

Bridge geometry and road embankments are shown on sheet 2 as they existed at the time of the flood. The cross section surveyed at the downstream side of the bridge is tabulated on sheet 1. The cross section shown for velocity distribution was obtained by sounding from the downstream side of the bridge during the discharge measurement.

Data for the flood of December 7, 1971, are presented. Nine valley cross sections were surveyed after this flood and additional ground elevations were surveyed in the vicinity of the bridge (sheet 2). Cross section 3 is located along an old railroad spurline.

Manning's roughness coefficient values and the 1971 flood boundaries are shown on sheets 2 and 3.

FLOOD OF DECEMBER 7, 1971

Peak water-surface elevations, measured cross section, and velocities for the flood of December 7, 1971, are shown on sheet 3. The flood crested at an elevation of 33.607 meters at the reference point located on the downstream quardrail near the middle of the downstream side of the bridge. The peak discharge was 181 cubic meters per second, from a stage-discharge relation developed for the site. Two discharge measurements were made during the flood. A discharge of 115 cubic meters per second was measured at an elevation of 33.232 meters at the reference point and a discharge of 146 cubic meters per second was measured at an elevation of 33.461 meters.

The recurrence interval of the peak discharge is 4 years (Neely, 1976). See figure 4.

SUMMARY

Floodflow data that will provide a base for evaluating digital models relating to open-channel flow were obtained at 22 sites on streams in Alabama, Louisiana, and Mississippi. Thirty-five floods were measured. Analysis of the data indicated that backwater and discharges computed by standard indirect methods currently in use would be inaccurate where densely vegetated flood plains are crossed by highway embankments and single-opening bridges. This atlas presents flood information at the site on Tenmile Creek near Elizabeth, La. Water depths, velocities, and discharges through the bridge openings for the flood of December 7, 1971, on Tenmile Creek near Elizabeth were measured, together with peak water-surface elevations along embankments and along cross sections. Manning's roughness coefficients in different parts of the flood plain are shown on maps, and flood-frequency relations are shown on a graph.

ADDITIONAL INFORMATION

Other information pertaining to floods in Alabama, Louisiana, and Mississippi may be obtained at the offices of the U.S. Geological Survey listed below:

U.S. Geological Survey
Room 202, Oil and Gas Board Building (P. O. Box V)
University, Alabama 35486

U.S. Geological Survey
6554 Florida Boulevard (P. O. Box 66492)
Baton Rouge, Louisiana 70896

U.S. Geological Survey
430 Bounds Street
Jackson, Mississippi 39206

SELECTED REFERENCES

Barnes, H. H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geol. Survey Water Supply Paper 1849, 213 p.

Benson, M. A., and Dalrymple, T., 1967, General field and office procedures for indirect discharge measurements: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, Chap. A1, 30 p.

Bradley, J. N., 1970, Hydraulics of bridge waterways: Federal Highway Admin., Hydraulic Design Ser. No. 1, 111 p.

Colson, B. E., and Hudson, J. W., 1976, Flood frequency of Mississippi streams: Mississippi State Highway Dept., 34 p.

Hains, C. F., 1973, Floods in Alabama, magnitude and frequency: Alabama Highway Dept., 37 p.

Hedman, E. R., 1964, Effects of spur dikes on flow through constrictions: Am. Soc. Civil Engineers Proc., Jour. Hydraulics Div., v. 91, no. HY4, July 1965, p. 155–165.

Matthai, H. F., 1967, Measurement of peak discharge at width contractions by indirect methods: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A4, 44 p.

Neely, B. L., Jr., 1976, Floods in Louisiana, magnitude and frequency, 3d ed.: Louisiana Dept. Highways, 340 p.

Schneider, V. R., Board, J. W., Colson, B. E., Lee, F. N., and Druffel, L., 1976, Computation of backwater and discharge at width constrictions of heavily vegetated flood plains: U.S. Geol. Survey Water-Resources Inv. 76–129, 64 p.

U.S. Water Resources Council, 1977, Guidelines for determining flood flow frequency: Washington, D.C., U.S. Water Resources Council Bull. 17A, 163 p.

TABLE 1—VALLEY CROSS-SECTION DATA FOR TENMILE CREEK NEAR ELIZABETH, LOUISIANA. ZERO STATION IS AT THE LEFT EDGE OF THE VALLEY (FACING DOWNSTREAM)

CROSS SECTION 1

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	31.63
14	30.63
32	30.39
39	29.81
59	28.77
84	29.74
88	30.81
140	30.24
158	30.57
216	30.63
236	30.23
256	30.57
286	30.08
308	30.33
328	30.18
357	30.18
378	30.33
402	30.29
425	29.99
436	29.99
437	29.77
452	30.08
472	30.08
494	30.57
527	30.36
546	30.33
567	30.14
584	29.93
623	30.30
639	30.87
677	30.87
686	30.24
701	30.02
716	29.87
738	29.96
768	29.75
774	29.04
782	30.02
853	31.24
855	31.64

CROSS SECTION 2

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	32.21
50	31.06
56	30.66
64	31.46
98	31.45
152	31.21
195	31.18
232	31.11
262	30.82
280	31.12
328	31.05
329	30.11
331	30.97
361	30.26
404	31.58
439	31.70
440	29.35
443	27.86
448	29.32
457	31.54
488	31.03
491	30.30
496	31.09
510	31.03
515	30.72
518	31.64
532	31.03
546	31.82
579	31.94
597	31.67
619	31.39
623	30.29
637	31.76
649	31.58
689	32.06
721	31.97
736	31.85
749	32.13
756	32.64

CROSS SECTION 3

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	32.79
89	32.80
91	31.21
104	30.85
106	31.49
107	32.82
213	32.77
218	32.43
222	33.06
264	31.06
281	30.82
288	30.60
290	30.35
300	32.82
325	31.64
334	30.91
337	28.83
367	30.60
431	31.24
442	31.85
471	31.52
515	31.46
549	31.48
584	32.46
586	32.58

CROSS SECTION 4

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	33.28
15	32.74
30	32.71
40	32.19
50	31.94
76	31.69
104	32.16
124	32.82
137	32.52
158	32.83
168	32.71
181	32.79
189	32.37
198	32.25
213	32.61
238	31.85
256	33.16
259	32.40
262	32.52
268	32.71
279	31.97
297	32.76
326	32.13
340	31.27
361	31.78
378	31.06
389	32.13
396	31.18
430	32.03
459	32.19
471	32.10
485	32.22
503	31.91
564	32.19
579	31.30
594	31.94
604	31.33
610	31.97
631	31.54
646	32.19
674	32.77
686	33.67

CROSS SECTION 5

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	33.10
24	32.79
45	32.67
53	32.52
71	32.46
76	32.49
96	32.80
124	32.82
143	32.71
283	32.58
317	32.43
357	32.28
357	31.94
358	31.21
361	30.88
365	30.88
368	30.78
371	29.75
374	28.77
377	29.11
380	29.26
383	30.69
386	31.52
387	31.97
398	32.64
419	32.24
454	32.10
475	32.06
506	32.13
529	32.52
571	33.16
573	33.65

CROSS SECTION 6

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	33.95
2	33.80
61	32.28
113	32.97
144	33.04
149	32.77

CROSS SECTION 6 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
176	32.79
183	33.19
192	33.04
194	33.74
201	33.16
216	33.16
221	33.35
228	33.25
240	33.16
251	32.61
258	32.40
262	32.43
266	32.22
268	32.06
270	32.19
276	32.55
288	32.37
299	31.73
302	31.39
305	31.39
311	32.25
316	32.19
322	32.27
327	32.06
330	31.58
337	31.18
339	30.63
343	31.09
345	32.16
361	32.34
365	32.55
370	32.28
372	31.18
383	29.08
393	31.18
395	32.28
407	31.88
411	31.97
416	32.64
432	32.52
438	32.58
444	32.25
450	32.13
456	31.88
462	31.73
471	31.76
475	31.49
483	31.42
490	32.10
505	32.58
522	32.46
550	32.27
570	32.03
576	32.34
582	32.06
596	31.94
616	32.28
643	32.06
650	31.85
684	31.91
707	31.91
738	32.52
745	33.95

CROSS SECTION 7

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	34.25
6	33.74
19	32.28
26	31.61
29	31.70
30	32.06
38	32.00
41	32.00
44	32.25
48	31.42
55	32.46
67	32.42
75	32.40
78	31.88
84	32.74
88	32.71
113	32.49
119	31.69
124	32.28
134	32.55
137	32.19
141	32.61
160	31.36
163	31.27
168	32.40
168	31.79
177	32.58
180	32.55
189	32.19
199	32.36
204	31.06
210	31.21
211	32.31
216	32.40
229	31.76
241	31.64
241	32.19
248	31.46
259	31.39
268	32.19
272	32.37
282	32.37
290	31.76
297	32.19
311	32.31
320	32.31
334	32.28
335	32.42
370	32.46
412	32.39
421	30.81
430	31.70
437	32.25
448	32.64
454	31.55
460	32.16
463	31.18
482	31.18
483	32.52
518	32.74
527	32.22
532	30.91
539	32.36
556	32.52
558	32.46
568	31.39
613	33.77
614	33.74
619	33.80
643	33.83
671	34.17

CROSS SECTION 8

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	34.32
21	34.11
26	33.83
38	33.41
47	32.52
58	32.15
77	32.25
93	32.49
126	32.31
140	33.01
161	33.28
173	33.43
196	32.61
208	32.77
221	32.43
228	32.52
234	33.35
256	32.67
269	32.37
282	32.43
300	32.74
314	32.88
358	33.04
367	33.10
373	32.92
391	33.07
396	32.95
402	32.46
408	33.01
440	33.41
449	33.55
461	31.76
475	33.19
500	32.80
524	31.73
536	33.41
543	33.38
548	32.18
551	33.31
589	31.94
589	32.61
591	33.44
604	32.49
609	31.09
617	33.07
639	33.31
663	32.71
664	33.06
681	32.28
693	33.01
694	33.16
707	32.46
709	32.34
711	32.31
712	33.41
716	32.85
745	32.92
757	32.80
784	32.83
797	32.80
827	32.86
857	33.19
874	32.37
879	32.37
888	33.10
903	33.56
919	33.28
942	33.67
960	33.28
982	32.43

CROSS SECTION 8 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
987	32.25
989	33.01
994	32.22
1002	32.00
1009	31.61
1014	31.60
1015	32.64
1026	32.95
1036	33.07
1050	33.50
1059	34.31

CROSS SECTION 9

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	34.86
18	34.17
35	33.89
67	33.71
87	33.56
105	33.53
114	33.52
125	33.53
168	33.95
175	33.35
187	32.80
198	33.03
207	33.03
219	33.19
234	33.10
259	33.04
287	33.07
311	32.76
335	33.10
351	33.25
363	33.35
387	33.44
399	33.56
430	33.59
445	33.77
470	33.65
473	32.43
475	32.67
477	33.59
503	33.80
518	33.74
543	33.77
549	34.08
554	34.07
558	32.13
560	30.78
562	29.11
573	29.11
574	30.63
576	32.03
581	33.80
603	33.31
605	32.00
607	31.70
609	32.00
611	33.31
614	33.99
626	33.74
643	33.56
651	32.98
663	33.62
674	33.35
680	32.92
686	33.46
701	33.65
718	33.65
741	34.02
764	33.16
794	33.41
860	34.22
901	34.11

CROSS SECTION 9 (Cont.)

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
927	34.34
940	34.41
960	34.35
986	34.29
1021	34.44
1036	34.89

BRIDGE SECTION

STATION (METERS)	GROUND SURFACE ELEVATION (METERS)
0	34.53
0	34.17
2	34.08
2	33.53
3	33.38
6	32.86
9	32.67
12	32.16
15	32.28
18	32.22
21	32.34
24	32.22
27	32.37
30	32.19
34	32.13
37	32.00
40	31.94
43	31.94
46	31.94
49	31.94
52	31.91
55	31.94
58	31.97
61	31.97
64	31.97
67	32.00
70	31.91
73	31.94
76	31.76
79	31.65
82	31.58
84	31.94
85	31.21
88	30.75
91	30.88
94	30.78
98	29.75
101	28.74
104	29.11
107	29.26
110	30.69
113	31.52
114	31.97
116	31.64
119	31.36
120	32.13
122	32.22
125	31.67
128	32.10
131	32.00
134	32.13
137	32.06
140	32.19
143	32.10
146	32.16
149	32.06
152	32.22
155	32.10
158	32.37
159	32.40
162	33.41
162	33.53
163	34.08
165	34.14
165	34.53

TABLE 2—DISCHARGE MEASUREMENTS DECEMBER 6 AND 7, 1971, TENMILE CREEK NEAR LOUISVILLE, LOUISIANA. ZERO STATION IS AT THE EDGE OF THE LEFT ABUTMENT (FACING DOWNSTREAM)

DISCHARGE MEASUREMENT OF DECEMBER 7, 1971, (WATER-SURFACE ELEVATION=33.461 METERS) TOTAL DISCHARGE=146 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
3.0	0.0	0	0.0	0.0
6.1	0.55	23	0.6	1.158
12.2	1.13	0	0.6	0.762
18.3	1.10	0	0.6	0.625
24.4	1.16	0	0.6	0.469
30.5	1.22	0	0.6	0.421
48.8	1.40	0	0.6	0.171
54.9	1.46	0	0.6	0.338
61.0	1.37	0	0.6	0.256
73.2	1.49	0	0.6	0.283
79.2	1.49	0	0.6	0.244
85.3	1.83	0	0.6	0.323
91.4	2.56	0	0.2	0.597
			0.8	0.256
94.5	2.62	0	0.2	0.713
			0.8	0.728
97.5	3.96	0	0.2	0.890
			0.8	0.744
99.1	3.96	0	0.2	1.158
			0.8	1.113
100.6	4.39	0	0.2	1.332
			0.8	1.241
102.1	4.27	0	0.2	1.213
			0.8	1.067
103.6	4.24	0	0.2	1.186
			0.8	1.134
105.2	3.96	0	0.2	1.332
			0.8	0.820
106.7	4.08	0	0.2	1.268
			0.8	0.640
108.2	3.20	0	0.2	1.000
			0.8	0.460
109.7	2.26	0	0.2	0.308
			0.8	0.238
115.8	1.62	0	0.6	0.210
121.9	1.16	0	0.6	0.421
128.0	1.16	0	0.6	0.296
134.1	1.16	0	0.6	0.283
137.2	1.22	0	0.6	0.323
140.2	1.13	0	0.6	0.494
143.3	1.16	0	0.6	0.655
146.3	1.13	0	0.6	0.518
149.4	1.22	0	0.6	1.241
152.4	1.13	0	0.6	1.585
155.4	1.19	0	0.6	1.622
158.5	0.79	0	0.6	1.113
161.5	0.0	0	0.0	0.0

[1]Observation depth is the ratio of the velocity-observation depth to the total depth at the station

DISCHARGE MEASUREMENT OF DECEMBER 6, 1971. (WATER-SURFACE ELEVATION=33.232 METERS) TOTAL DISCHARGE=115 CUBIC METERS PER SECOND

STATION (METERS)	DEPTH (METERS)	ANGLE (DEGREES)	OBSERVATION DEPTH[1]	VELOCITY (METERS PER SECOND)
4.6	0.0	0	0.0	0.0
6.1	0.30	0	0.6	0.671
12.2	0.76	0	0.6	1.268
18.3	0.85	0	0.6	0.762
27.4	0.73	0	0.6	0.448
36.6	1.13	0	0.6	0.381
42.7	1.19	0	0.6	0.497
48.8	1.19	0	0.6	0.585
54.9	1.22	0	0.6	0.405
61.0	1.13	0	0.6	0.256
73.2	1.16	0	0.6	0.338
79.2	1.22	0	0.6	0.204
85.3	2.01	0	0.6	0.256
91.4	1.98	0	0.6	0.338
94.5	2.29	0	0.2	0.585
			0.8	0.536
97.5	2.59	0	0.2	0.640
			0.8	1.332
99.1	3.75	0	0.2	1.000
			0.8	0.911
100.6	4.02	0	0.2	1.088
			0.8	1.000
102.1	4.48	0	0.2	1.241
			0.8	0.835
103.6	3.96	0	0.2	1.000
			0.8	1.088
105.2	3.72	0	0.2	1.186
			0.8	0.954
106.7	3.87	0	0.2	1.158
			0.8	0.482
108.2	3.26	0	0.2	0.835
			0.8	0.280
109.7	2.29	0	0.2	0.280
			0.8	0.238
115.8	1.49	23	0.6	0.165
121.9	0.94	29	0.6	0.223
128.0	1.01	14	0.6	0.213
134.1	1.01	0	0.6	0.189
137.2	1.07	0	0.6	0.287
140.2	0.94	0	0.6	0.469
143.3	1.04	0	0.6	0.573
146.3	0.94	0	0.6	0.713
149.4	1.04	0	0.6	0.978
152.4	0.82	0	0.6	0.671
155.4	1.04	0	0.6	1.332
158.5	0.64	0	0.6	0.744
161.5	0.0	0	0.0	0.0

[1]Observation depth is the ratio of the velocity-observation depth to the total depth at the station

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1979—W79234

For sale by Branch of Distribution, U.S. Geological Survey 1200 South Eads Street, Arlington, VA 22202 and Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225