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An Evaluation of the Effects of Dredging Within the Arkansas River Navigation System: Volume I - Introduction, Summary and Conclusions, and Recommendations

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AN EVALUATION OF THE EFFECTS OF DREDGING WITHIN THE ARKANSAS RIVER NAVIGATION SYSTEM

VOLUME I

INTRODUCTION, SUMMARY AND CONCLUSIONS, AND RECOMMENDATIONS

edited by

Myra McNutt

43

AN EVALUATION OF THE EFFECTS OF DREDGING WITHIN THE ARKANSAS RIVER NAVIGATION SYSTEM

VOLUME I

INTRODUCTION, SUMMARY AND CONCLUSIONS, AND RECOMMENDATIONS

THE FINAL REPORT TO THE
UNITED STATES CORPS OF ENGINEERS
CONTRACT NO. DACW 03-74-C-914C
1976

BY

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ACKNOWLEDGEMENTS

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The principal investigators wish to extend their deep appreciation to Ms. Myra McNutt for her numerous contributions to the entire project. We especially thank her for the adroit handling of the supervision and coordination of the many people and inputs necessary for the completion of this project.

TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

Figure Page

LIST OF TABLES

LIST OF APPENDIX TABLES

INTRODUCTION

The Arkansas River originates in the eastern slopes of the Rocky Mountains near Leadville, Colorado, and extends through Kansas, Oklahoma, and Arkansas, where it flows into the Mississippi River. The Arkansas River is approximately 1,450 miles in length and drains a total area of 160,500 square miles. The river and its tributaries have been developed for navigation, flood control, and hydro-electric power, as well as recreational purposes under the River and Harbor Act of July 24, 1946. The development of the Arkansas River for recreational use will be completed in the near future. The McClellan-Kerr Arkansas River Navigation System was completed from its confluence with the Mississippi River to Little Rock in 1969 and subsequently to Fort Smith by 1970. Lock and dam construction, channel realignment and other activities have resulted in many changes in the river's natural characteristics.

Frequent dredging of sand bars and shoals is required at various locations along the system in order to maintain a navigable channel. The natural occurrence of shoaling along with periodic flooding necessitates dredging. The dredging activities result in the movement of large quantities of sediment each year. Dredging may influence major ecological disruptions as its effects contribute to current changes, increased water turbidity, release of toxic substances from sediments, erosion and others.

Although a base-line study of the biota of the Arkansas River has not been carried out previously, a few isolated studies of various points along the river have been investigated. These few studies focused exclusively on the plankton and fish communities without reference to benthos.

A limited number of prior studies addressed to the water quality of the Arkansas River was based on diatom abundances and distribution. Williams (1964) analyzed the trophic structure of the Arkansas River according to the frequency of the most abundant diatom species. He concluded that the Arkansas River near Ponca City, Oklahoma, exhibited the least diversity and therefore was the most enriched of the sites studied. He attributed this to low population levels of consumer organisms brought about by high chloride concentrations at this particular location. The "trophic index" at Pendelton Ferry, Arkansas, also was found to be high. The occurrence of the four most abundant diatom species of the Arkansas River has been listed in a guide of water quality by Weber (1971). Additional studies by Williams (1966) reported low rotifer densities due to high silt concentrations at Coolidge, Kansas, while low densities of rotifers were reported at Pendelton Ferry, Arkansas.

Kochsiek, Wilm, and Morrison (1971) reported high values for the turbidity, alkalinity, and zooplankton density in the Arkansas River arm of Keystone Reservoir, Oklahoma.

Palko (1974) listed 21 genera of Rotatoria, two Cladocera, and two Copeoda occurring in Lake Dardanelle on the mainstream of the Arkansas River. In this same study, Palko reported low levels of primary productivity which were determined through chlorophyll analysis of net plankton samples only.

The first scientific collection of fishes from the mainstream of the Arkansas River was made in 1856 at Fort Smith by Charles Girard (1856, 1958). Additional seine collections were taken near Fort Smith by Jordan and Gilbert in 1884 (Jordan and Gilbert, 1886), Meek during the early 1890's (Meek, 1894, 1896), and by John D. Black in the late 1930's (Black, 1940). Almost no information has been published on Arkansas River fishes in over 35 years.

Dredging activities on the Arkansas River have not, in terms of impact or potential impact on the aquatic environment and ichthyofauna, previously been assessed. For the present project a coordinated study was conducted to evaluate the effects of dredging activities on the major divisions of the biotic trophic pyramid in the aquatic system of the Arkansas River. The four divisions, phytoplankton, zooplankton, benthos, and fish, have been treated as individual studies in Volumes II, III, IV, and V, respectively. Emphasis was placed on community structure of the biota in terms of composition, abundance, stability, and spatial and temporal distributions throughout the study reach. Since there has been no systematic effort to characterize the biota of the Arkansas River, it is hoped that this report will serve as a base line for monitoring future changes in the distribution and composition of the biota. The data collected and interpreted hopefully will serve to assist in the planning and operation of dredging activities on the Arkansas River.

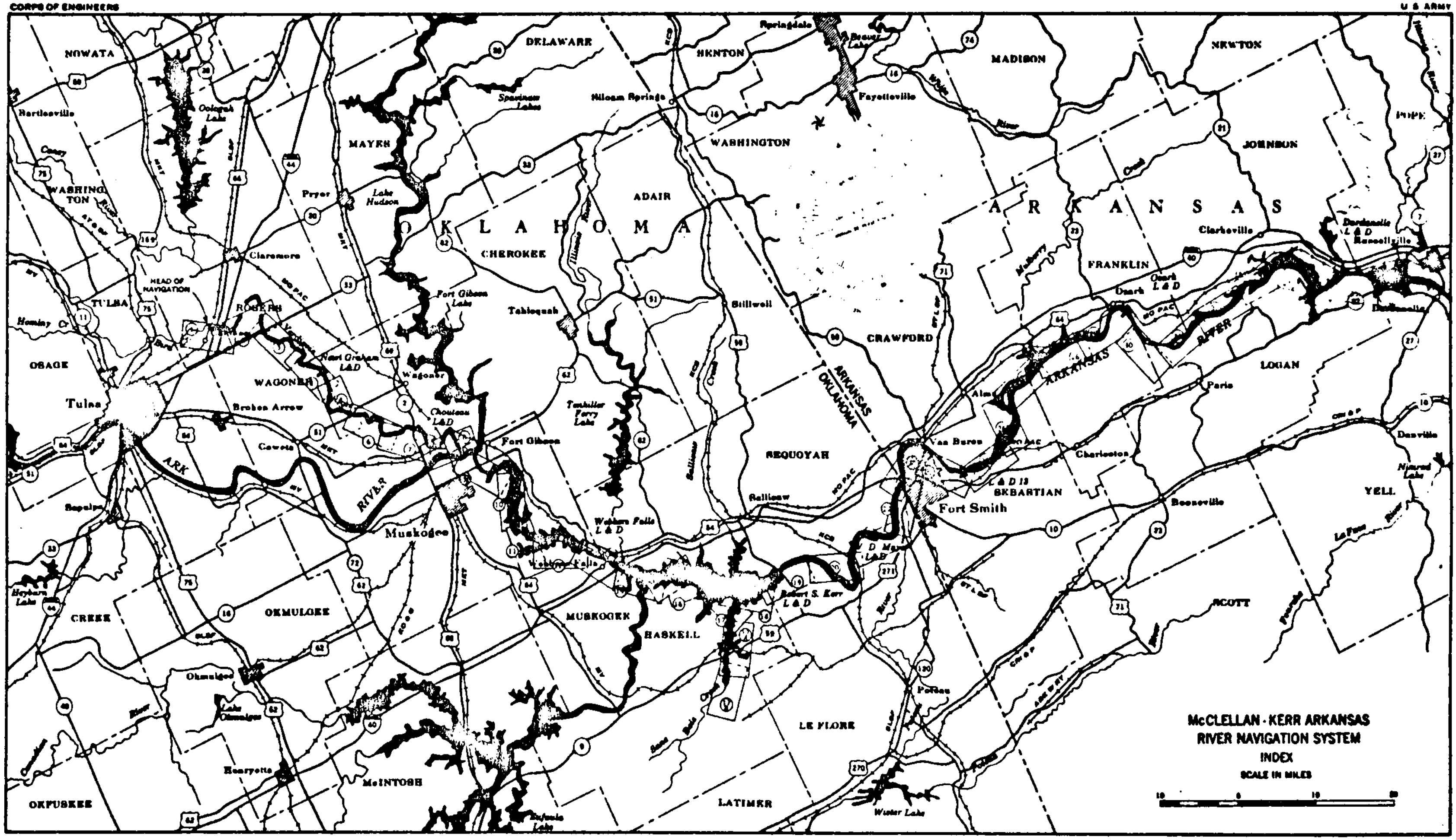
SAMPLING STATIONS AND SITES

This study includes that portion of the Arkansas River between river mile (RM) 308.0 and the mouth (Fig. 1). The actual study reach, covering approximately 240 miles, was confined to between RM 283 and RM 43. The study was based on an annual survey with phytoplankton, zooplankton, and benthic samples collected during each of four sampling periods in July 1974, October 1974, January 1975, and April 1975. Fish samples were taken during a different and abbreviated time span (see Volume V). Collection dates were adjusted to accommodate work schedules and dangerously high water. The biotic sampling techniques were arranged between the boat crew (U. S. Army Corps personnel, Little Rock District) and the principal investigators after testing various pieces of equipment under field conditions. The final decision on equipment selection was made after on-site evaluations. The specific sampling materials and methods for each division of the biotic community studied are listed in the appropriate sections of each volume. Unforeseen circumstances involving equipment failure terminated the July sampling period before the entire study reach was sampled. Samples from the abbreviated sampling period were used for qualitative analyses. The samples were collected by the Corps of Engineers (Little Rock District) at 13 stations along the reach. Figure 2 shows the location of these stations both along the study reach

Figure 1a. The McClellan-Kerr Arkansas River Navigation System extending from Catoosa, Oklahoma, to the mouth of the White River (Catoosa, Oklahoma, to Russellville, Arkansas).

CORPS OF ENGINEERS

U S ARMY

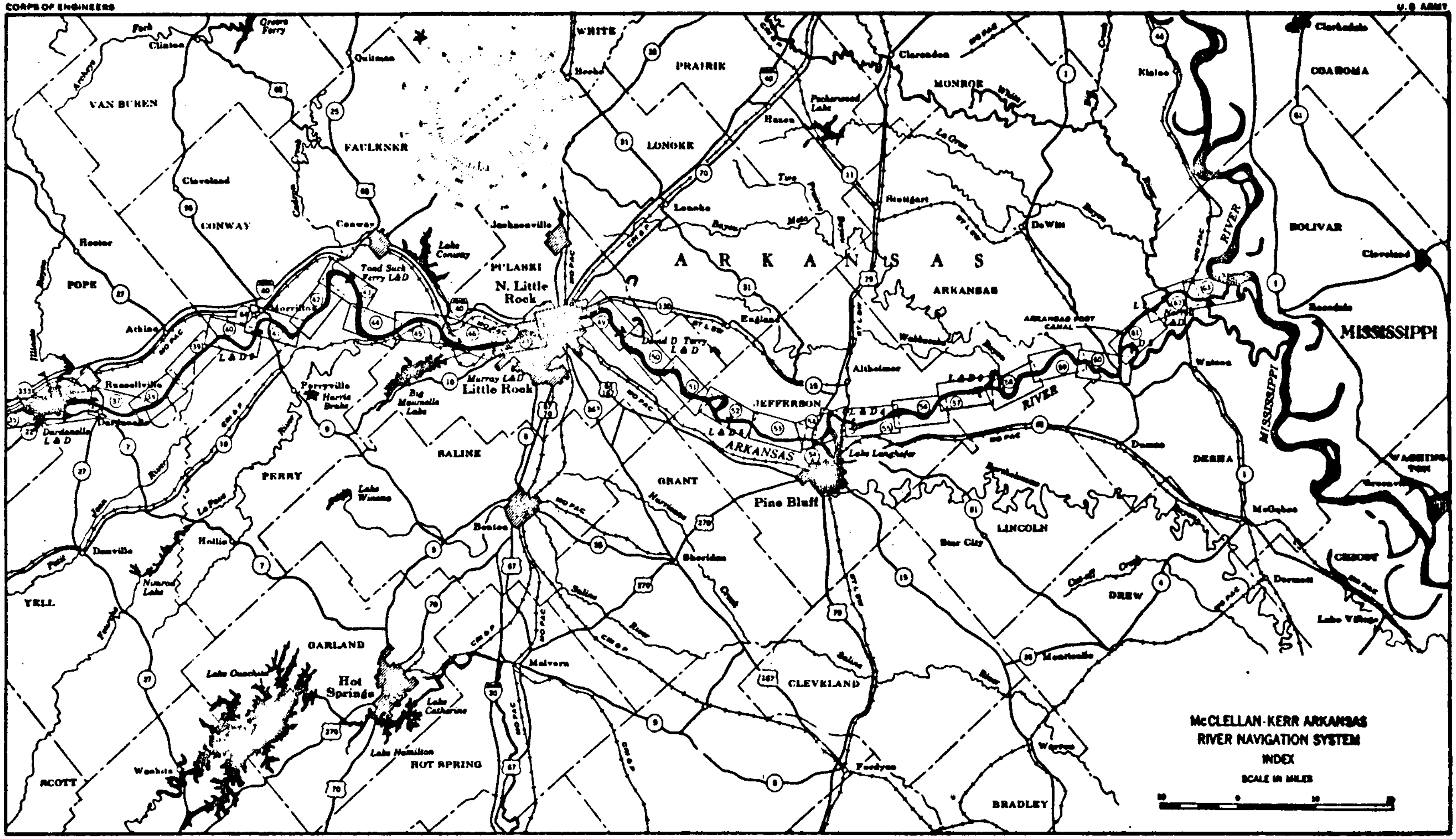


SHEET NO. 11

Figure 1b. The McClellan-Kerr Arkansas River Navigation System extending from Catoosa, Oklahoma, to the mouth of the White River (Russellville, Arkansas, to confluence with Mississippi River).

CORPS OF ENGINEERS

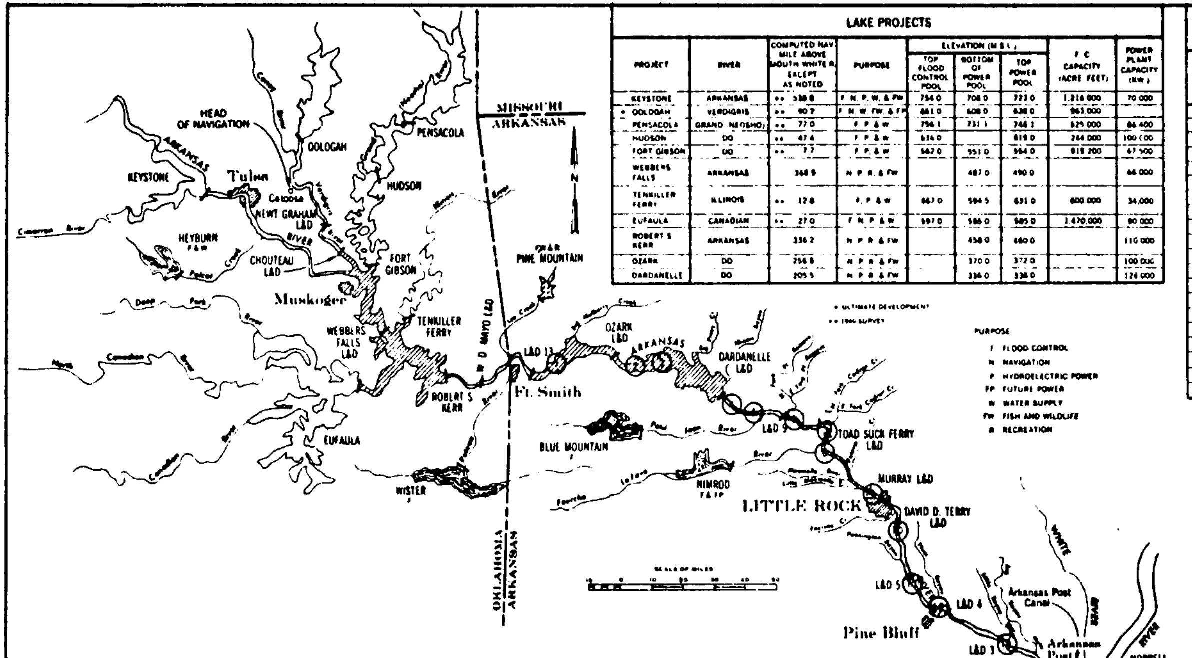
U.S. ARMY



McCLELLAN-KERR ARKANSAS
RIVER NAVIGATION SYSTEM
INDEX
SCALE IN MILES

SHEET NO. 12

Figure 2. Sampling Stations both along the study reach and in profile.



LAKE PROJECTS

PROJECT	RIVER	COMPUTED NAV MILE ABOVE MOUTH WHITE R. EXCEPT AS NOTED	PURPOSE	ELEVATION (M.S.L.) TOP FLOOD CONTROL POOL	BOTTOM OF POWER POOL	TOP POWER POOL	F. C. CAPACITY (ACRE FEET)	POWER PLANT CAPACITY (KW)
KEYSTONE	ARKANSAS	** 538.8	F, N, P, W, & FW	754.0	706.0	723.0	1,216,000	70,000
* OOLOGAH	VERDIGRIS	** 90.2	F, N, W, FW, & FP	661.0	608.0	638.0	963,000	
PENSACOLA	GRAND (NEOSHO)	** 77.0	F, P & W	756.1	731.1	746.1	525,000	86,400
HUDSON	DO	** 47.4	F, P, & W	636.0		619.0	244,000	100,000
FORT GIBSON	DO	** 7.7	F, P, & W	582.0	551.0	554.0	919,200	67,500
WEBBERS FALLS	ARKANSAS	368.9	N, P, R, & FW		487.0	490.0		60,000
TENKILLER FERRY	ILLINOIS	** 12.8	F, P & W	667.0	594.5	632.0	600,000	34,000
EUFAULA	CANADIAN	** 27.0	F, N, P & W	597.0	565.0	585.0	1,470,000	90,000
ROBERT S. KERR	ARKANSAS	336.2	N, P, R & FW		458.0	460.0		110,000
OZARK	DO	256.8	N, P, R & FW		370.0	372.0		100,000
DARDANELLE	DO	205.5	N, P, R & FW		336.0	338.0		124,000

* ULTIMATE DEVELOPMENT

** 1966 SURVEY

PURPOSE

F	FLOOD CONTROL
N	NAVIGATION
P	HYDROELECTRIC POWER
FP	FUTURE POWER
W	WATER SUPPLY
FW	FISH AND WILDLIFE
R	RECREATION

NAVIGATION PROJECTS
(River and Harbor)

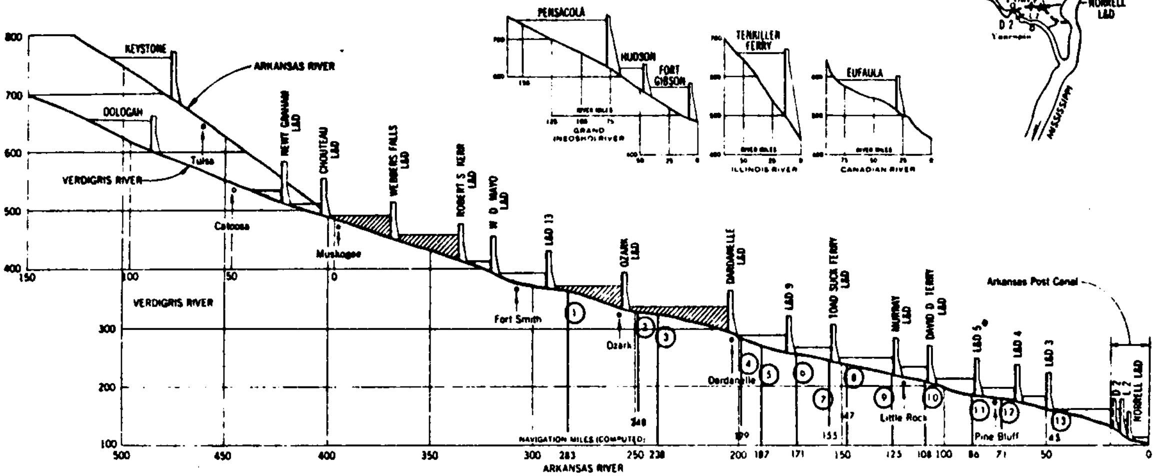
STRUCTURE	NAVIGATION MILE (COMPUTED)	UPPER POOL ELEVATION (FEET M.S.L.)	LOWER POOL ELEVATION (FEET M.S.L.)
NEWT GRAHAM L&D	(2) 26.7 VERDIGRIS R.	532.0	511.0
CHOUTEAU DAM	(2) ● 8.2 DO	511.0	490.0
CHOUTEAU LOCK	(2) 6.5 DO	511.0	490.0
WEBBERS FALLS L&D (1)	368.9 ARKANSAS R.	490.0	460.0
ROBERT S. KERR L&D (1)	336.2 DO	460.0	412.0
W. D. MAYO L&D	319.6 DO	412.0	392.0
L&D NO. 13	297.8 DO	392.0	372.0
OZARK L&D (1)	256.8 DO	372.0	338.0
L&D NO. 11	(DELETED)		
DARDANELLE L&D (1)	205.5 DO	338.0	284.0 287.0
L&D NO. 9	176.9 DO	284.0 287.0	265.0
TOAD SUCK FERRY L&D	155.9 DO	265.0	249.0
MURRAY L&D	125.4 DO	249.0	231.0
DAVID D. TERRY L&D	108.1 DO	231.0	213.0
L&D NO. 5	86.3 DO	213.0	196.0
L&D NO. 4	66.0 DO	196.0	182.0
L&D NO. 3	50.2 DO	182.0	162.0
DAM NO. 2	(3) 40.5 DO	162.0	ARKANSAS R.
LOCK NO. 2	13.3	162.0	142.0
NORRELL L&D	10.3	142.0	112 (WHITE R.)

(1) MULTIPLE PURPOSE

(2) MILES ABOVE MOUTH OF VERDIGRIS RIVER

(3) LOCATED ON ARKANSAS RIVER 2.2 MILES BELOW UPSTREAM END OF ARKANSAS POST CANAL

● LOCATED ON OLD RIVER CHANNEL 0.2 MILE DOWNSTREAM OF JUNCTION WITH NAVIGATION CHANNEL



LEGEND

- Canalization approved
- Navigation lock & dam
- Navigation - Power lake
- Lake included in multiple - purpose plan
- Lake in operation (not included in multiple - purpose plan)
- Lake approved (not included in multiple - purpose plan)

ARKANSAS RIVER AND TRIBUTARIES
ARKANSAS AND OKLAHOMA

NAVIGATION FEATURES

GENERAL PLAN AND PROFILE

SCALE AS SHOWN

LITTLE ROCK DISTRICT CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, MARCH 1973

DRAWN
TRACED
CHECKED

and in profile. These stations were designated in accordance with dredging operations as to intake locations, points of discharge and return of effluent to the river. The proposed study was designated to evaluate changes, if any, among the biota from samples taken above the sites of dredging, at the sites of dredging, and below the sites of dredging. Unforeseen inconsistencies in the concurrence of dredging activities with the proposed sampling procedures limited this aspect of the actual study to only three of the 13 sampling stations.

The 13 sampling stations were subdivided into a variable number of sites totaling 56. Descriptions of the stations and sites are indicated in Table 1. The figure numbers of the respective map showing the location of specific stations, sites, and dredging status also are indicated. The number of collection sites at each station ranged from one site at Station 3 (RM 283) to 10 sites at Station 13 (RM 46 and RM 43). Station length varied from relatively short distances to three miles (for Station 13). Thirty-seven of the 56 sites were located very near or behind dikes or revetments. Six of the sites were at confluences of tributaries. Two sites were in backwaters (both at Station 13). Nineteen of the sites were located near the left bank of the river, facing downstream (L), and 29 sites were near the right bank (R). There were only two mid-channel sites, one at Station 1 and one at Station 13.

TABLE 1

Study stations and designated sites used for collection of October 1974, January 1975, and April 1975 samples

FIGURE	STATION	STATION NAME	STATION SITE	RM	LOCATION	OTHER
3	1	Ozark	1	283	R(R)	(sites in a line from right bank to midchannel at this station)
			2	283	R(R)	
			3	283	R(R)	
			4	283	MC	
						35 mi.
4	2	Dardanelle	1	248	R(R)	
			2	248	R(R)	
			3	247.5	R(R)	
			4	247	R(R)	
						9 mi.
5	3	Dardanelle	1	238	L	
						38 mi.
6	4	Dardanelle	1	200	L	
			2	199	L	
			3	199	L	
			4	198.5	L	
						9 mi.
7	5	Pool 9	4	189	R(R)	
			3	188.5	R(R)	
			2	188	R(R)	
			1	188	R(R)	
						17 mi.

TABLE 1--continued

FIGURE	STATION	STATION NAME	STATION SITE	RM	LOCATION	OTHER
8	6	Pool 8	1	171	L(R)	
			2	170.5	L	
			3	170.5	L	
			4	170	L	
						15 mi.
9	7	Pool 8	1	155	R(R)	
			2	155	R(R)	
			3	154.5	R(R)	
			4	154.5	R(R)	
						7 mi.
10	8	Murray	1	147	L(R)	
			2	146.5	R(Ri)	
			3	146	L(R)	
						22 mi.
11	9	Murray	1	124.5	R(R)	
			2	124.5	R(R)	
			3	124	R(R)	
			4	124	R(R)	
						17 mi.
12	10	D. D. Terry	1	107.5	R(R)	
12a			2	107.5	R(R)	
			3	107	R(R)	
						22 mi.

TABLE 1--continued

FIGURE	STATION	STATION NAME	STATION SITE	RM	LOCATION	OTHER
13	11	Pool 5	1	85.5	R(R)	
			2	85.5	R(R)	
			3	85	R(R)	
			4	85	R(R)	
						14 mi.
14	12	Pool 4 (Yell Bend)	1	71	R(Ri)	
			2	71	R(Ri)	all sites at inlet of Yell Bend
			3	70.5	R(Ri)	
			4	70	R(Ri)	
						14 mi.
15	13	Pool 2	1	46	R	
			2	45.5	R	
			3	45.5	R	
			4	44	L(Ri)	
			5	43	L(R)	
			6	43	L(R)	
			7	43	L(R)	
			8	45	B	
			9	45	B	
			10	43	MC	

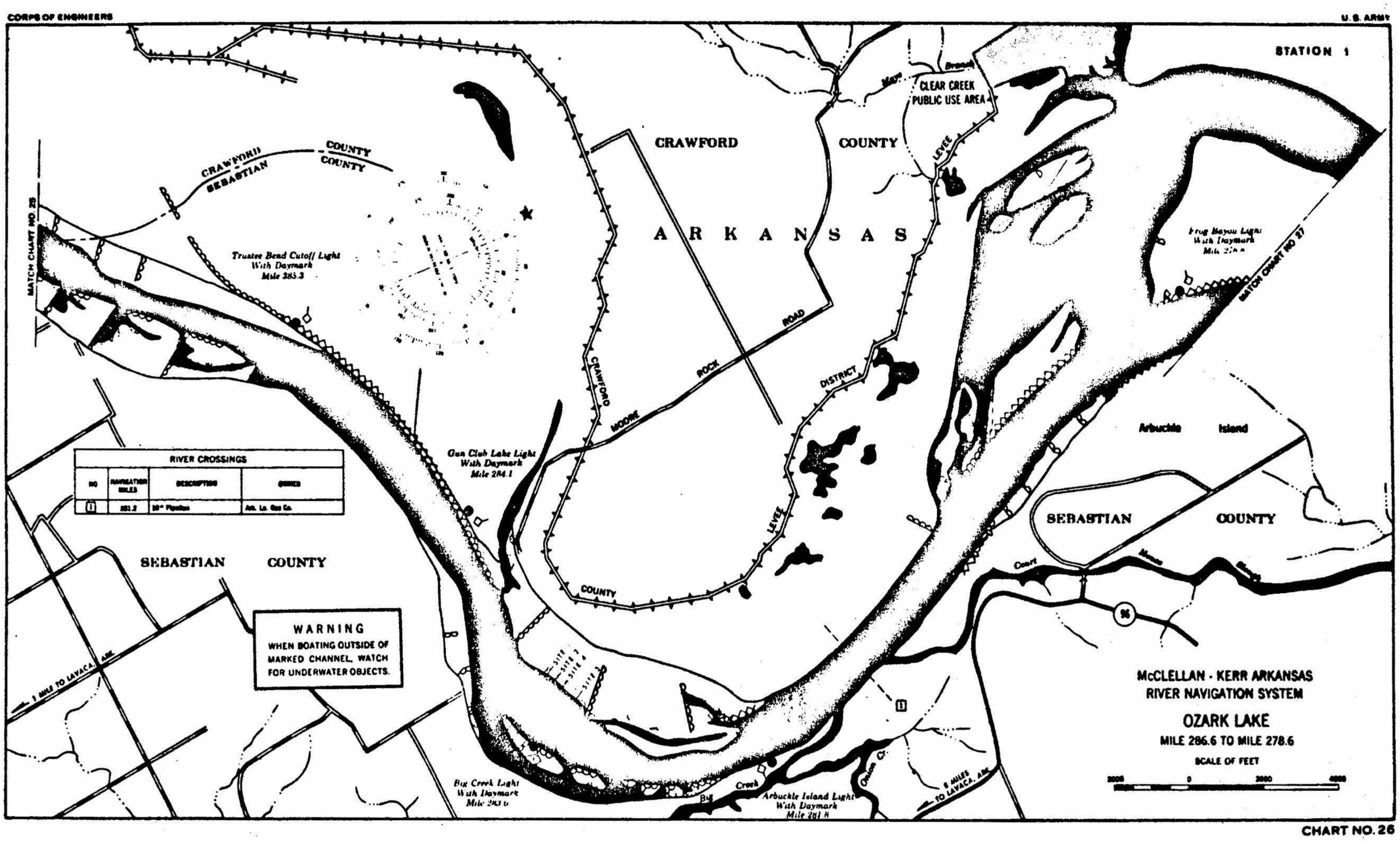
L = left bank (facing downstream)
R = right bank (facing downstream)
B = backwater
B(R) = backwater, behind revetment
(R) = revetment
i = at inlet
MC = midchannel

Quantitative and qualitative descriptions, analyses, and evaluations of phytoplankotn, zooplankton, benthos, and fish data are given in Volumes II, III, IV, and Volume V, respectively. With the exception of data on substrate particle size, flow rates, and turbidity, the physico-chemical data for this study were obtained by U. S. Army Corps of Engineers personnel (Little Rock District) along with the phytoplankton, zooplankton, and benthic samples. Flow water at the collection sites were calculated from Corps of Engineer powerhouse release information and river subsection velocity data. Physical and chemical charactistics with the exception of flow rate and substrate data (listed in Appendix, Tables 1 and 2) are described below. The flow rate and substrate data obtained during this project were specifically studied in connection with benthos. Therefore, the reader is referred to the benthic study, Volume IV, for the discussion concerning the relationship of these two physico-chemical parameters with the benthic community within the Arkansas River Navigation System.

Figured 3 through 15

Maps of Sampling Stations 1 through 13

Figure 3. Station 1 (RM 283) with four sampling sites.



RIVER CROSSINGS			
NO	NAVIGATION MILES	DESCRIPTION	OWNER
1	281.2	16" Pipeline	Ark. La. Gas Co.

WARNING

WHEN BOATING OUTSIDE OF MARKED CHANNEL, WATCH FOR UNDERWATER OBJECTS.

Figure 4. Station 2 (RM 248) with four sampling sites.

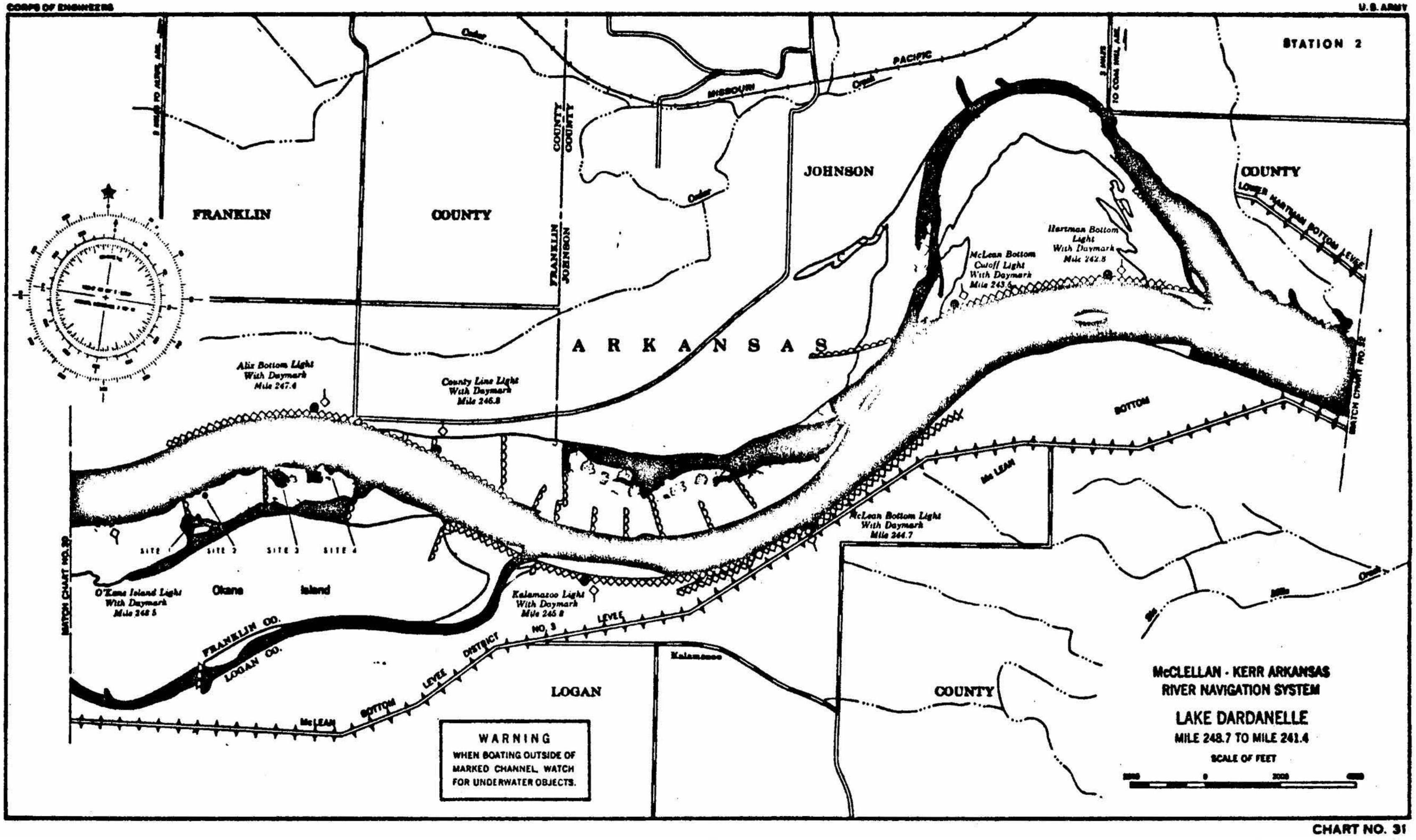
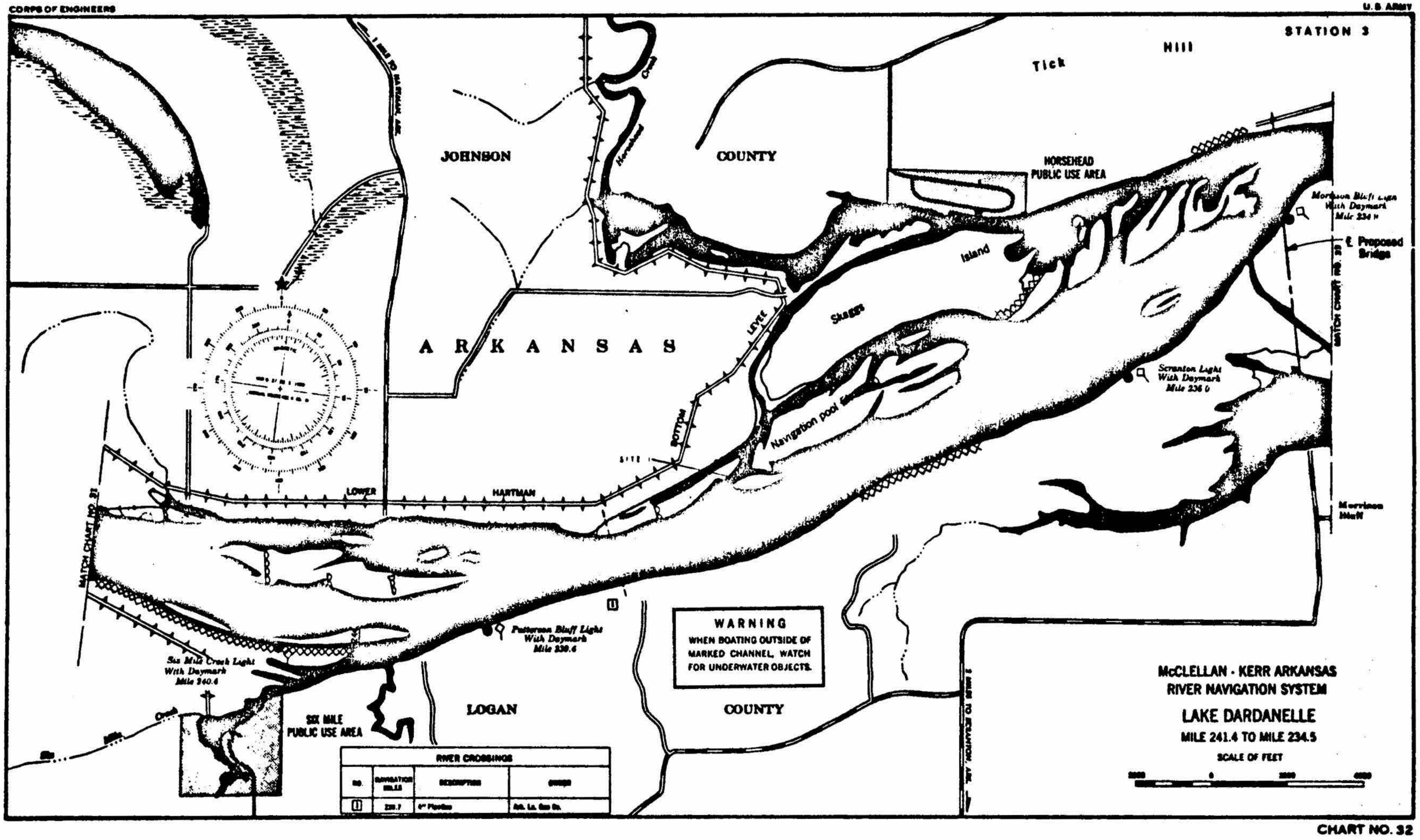

CORPS OF ENGINEERS
U.S. ARMY
STATION 2
3 MILES TO ALTUS, ARK.
3 MILES TO COAL HILL, ARK.
Cedar
Cedar
MISSOURI
PACIFIC
Creek
FRANKLIN
COUNTY
COUNTY
COUNTY
FRANKLIN
JOHNSON
JOHNSON
COUNTY
ARKANSAS
LOWER HARTMAN BOTTOM LEVEE
Hartman Bottom Light With Daymark Mile 242.8
McLean Bottom Cutoff Light With Daymark Mile 243.6
Alix Bottom Light With Daymark Mile 247.4
County Line Light With Daymark Mile 246.8
BOTTOM
MATCH CHART NO. 32
McLEAN
McLean Bottom Light With Daymark Mile 244.7
SITE 1
SITE 2
SITE 3
SITE 4
MATCH CHART NO. 30
O'Kane Island Light With Daymark Mile 248.5
Okane
Island
Kalamazoo Light With Daymark Mile 245.8
FRANKLIN CO.
LOGAN CO.
LEVEE
DISTRICT
NO. 3
LEVEE
Kalamazoo
LOGAN
COUNTY
Mills
Creek
McLEAN
BOTTOM
LEVEE
WARNING
WHEN BOATING OUTSIDE OF MARKED CHANNEL, WATCH FOR UNDERWATER OBJECTS.
McCLELLAN - KERR ARKANSAS RIVER NAVIGATION SYSTEM
LAKE DARDANELLE
MILE 248.7 TO MILE 241.4
SCALE OF FEET
0
2000
CHART NO. 31

Figure 5. Station 3 (RM 238) with one sampling site.



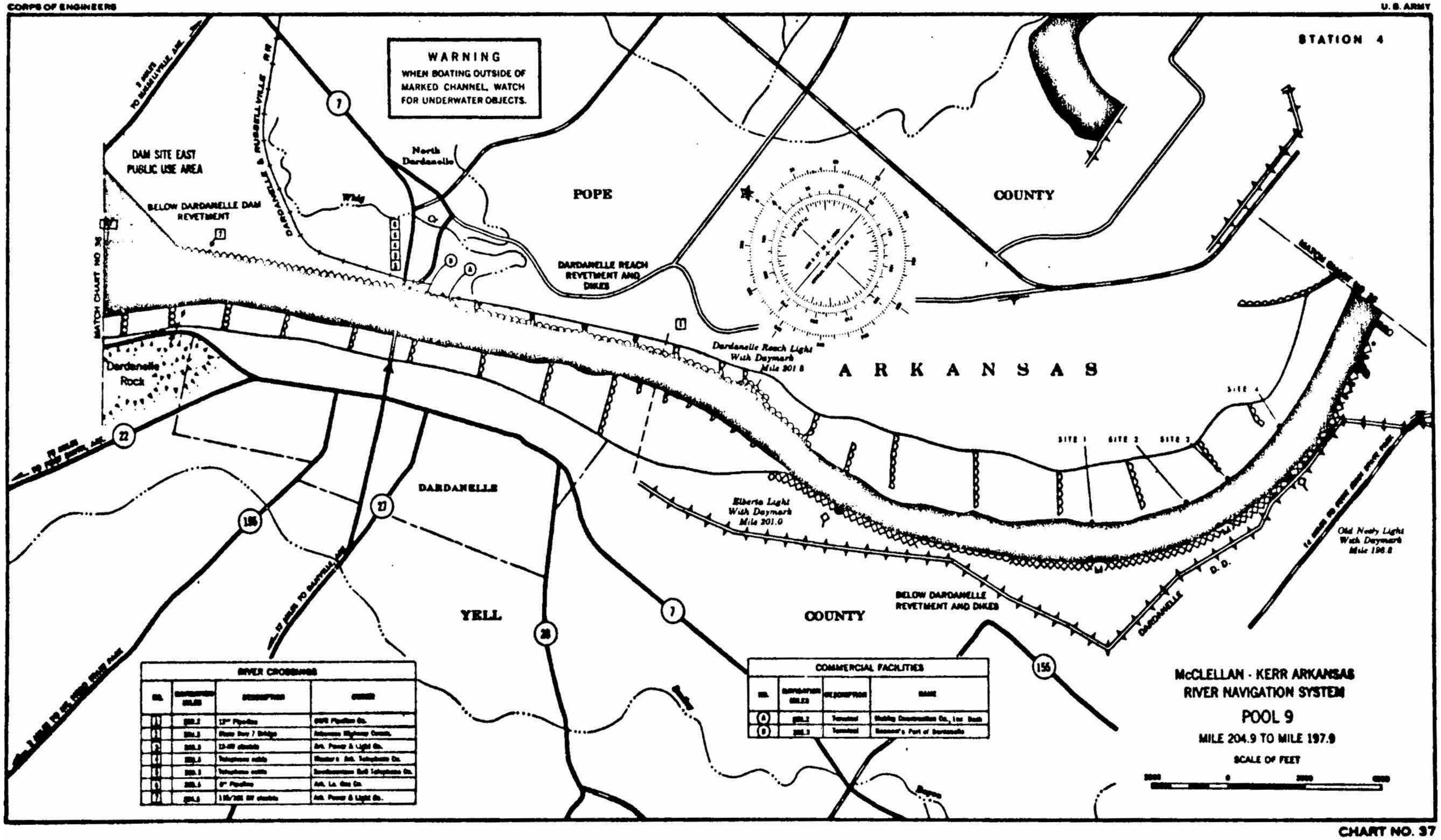
McCLELLAN - KERR ARKANSAS
RIVER NAVIGATION SYSTEM

LAKE DARDANELLE

MILE 241.4 TO MILE 234.5

CHART NO. 32

Figure 6. Station 4 (RM 199) with four sampling sites.



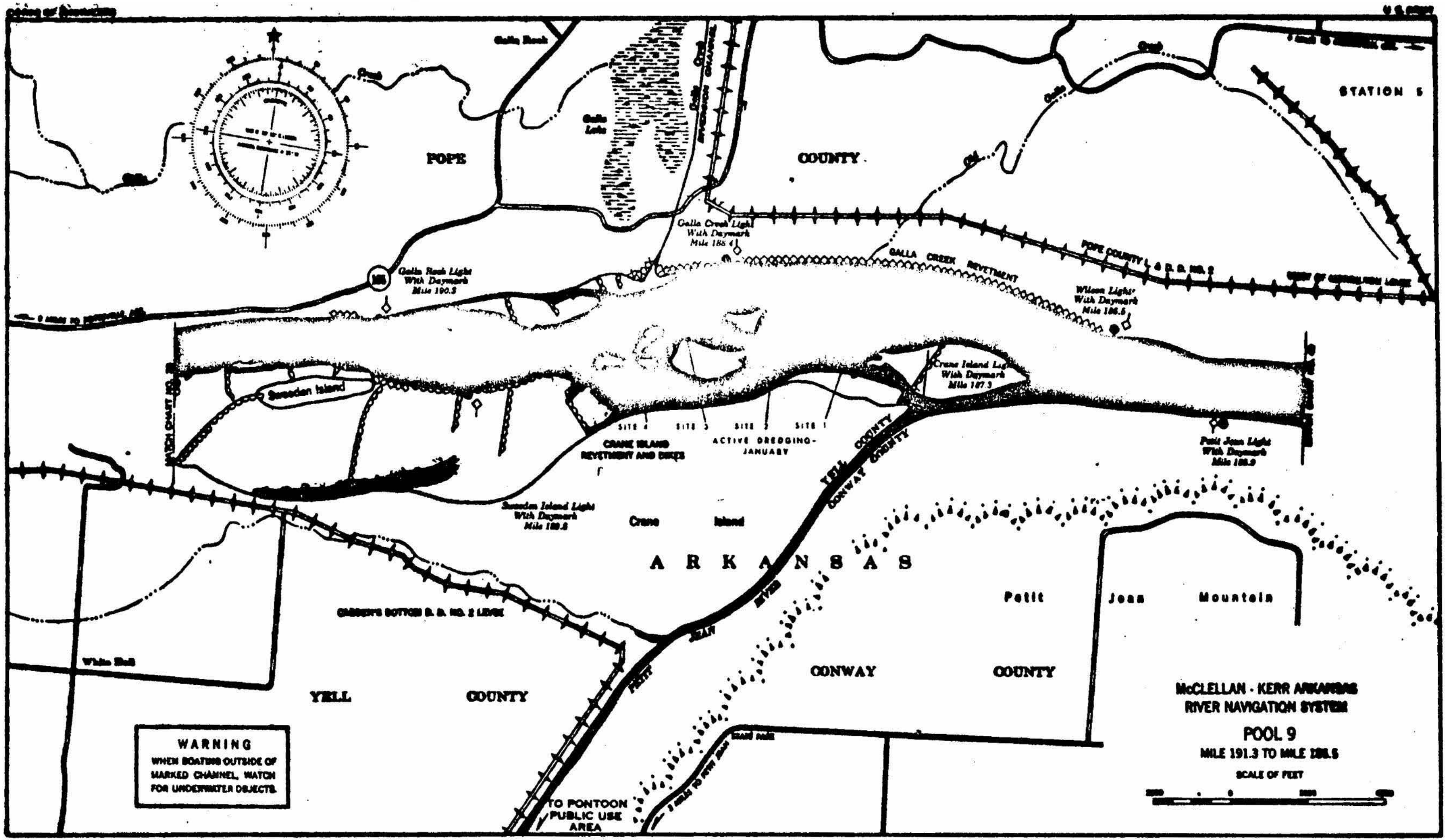
NO.	NAVIGATION MILES	DESCRIPTION	OWNER
1	[illegible]	12" Pipeline	[illegible] Pipeline Co.
2	[illegible]	State Hwy 7 Bridge	Arkansas Highway Comm.
3	[illegible]	[illegible] circuits	Ark. Power & Light Co.
4	[illegible]	Telephone cable	Western Ark. Telephone Co.
5	[illegible]	Telephone cable	Southwestern Bell Telephone Co.
6	[illegible]	6" Pipeline	Ark. La. Gas Co.
7	[illegible]	[illegible] circuits	Ark. Power & Light Co.

NO.	NAVIGATION MILES	DESCRIPTION	NAME
A	[illegible]	Terminal	[illegible] Construction Co., Inc. [illegible]
B	[illegible]	Terminal	[illegible] Port of Dardanelle

McCLELLAN - KERR ARKANSAS
RIVER NAVIGATION SYSTEM
POOL 9
MILE 204.9 TO MILE 197.9
SCALE OF FEET

CHART NO. 37

Figure 7. Station 5 (RM 189) with four sampling sites. Active dredging occurred at site 1 during January 1975 of this study period.



McCLELLAN - KERR ARKANSAS
RIVER NAVIGATION SYSTEM

POOL 9

MILE 191.3 TO MILE 185.5

CHART NO. 39

Figure 8. Station 6 (RM 171) with four sampling sites. Active dredging occurred at all four sites during January 1975 of this study period.

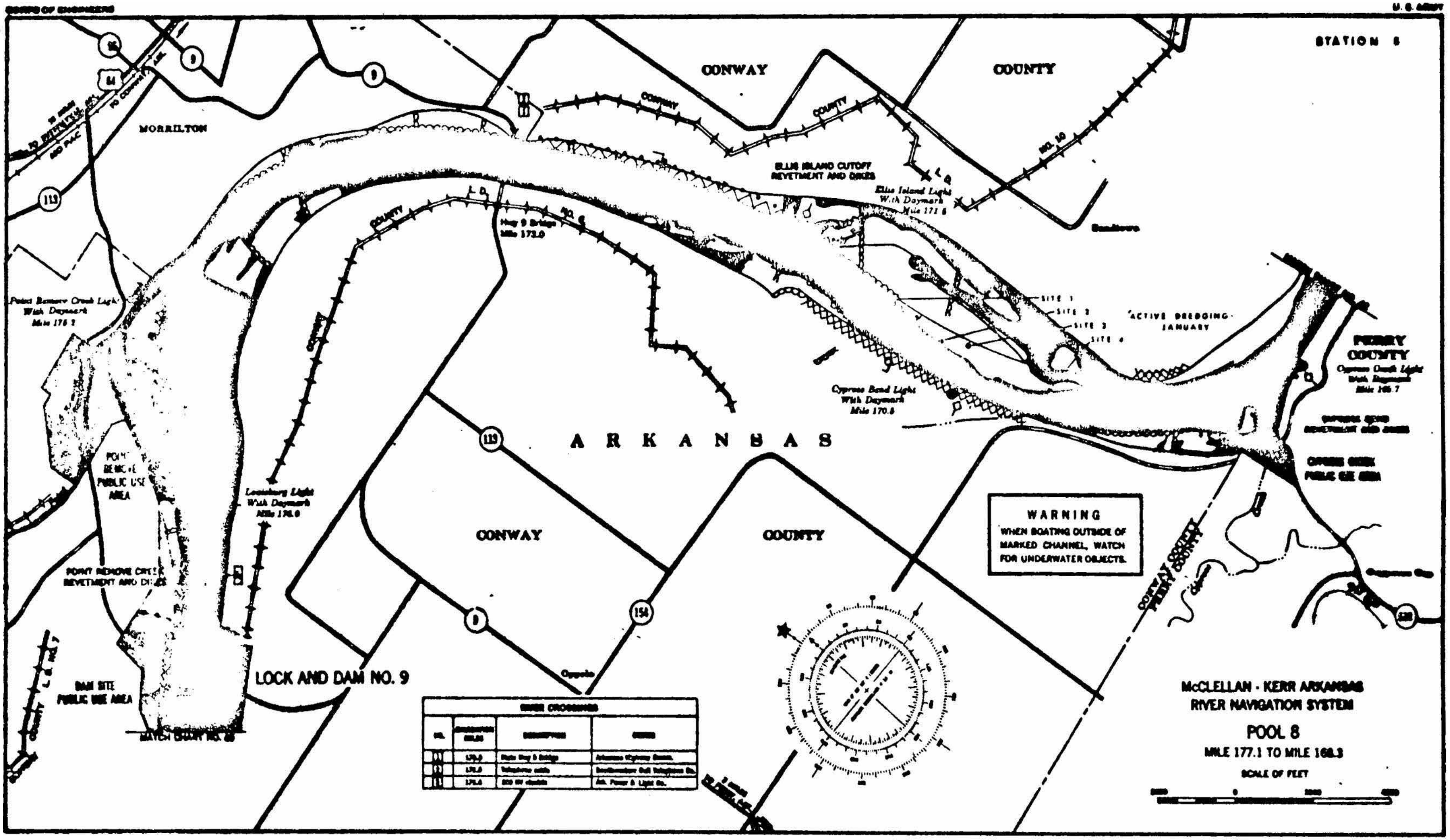

CORPS OF ENGINEERS
U. S. ARMY
STATION 8
CONWAY
COUNTY
MORRILTON
ELLIS ISLAND CUTOFF
REVETMENT AND DIKES
Ellis Island Light
With Daymark
Mile 171.6
Hwy 9 Bridge
Mile 173.0
Point Remove Creek Light
With Daymark
Mile 175.2
SITE 1
SITE 2
SITE 3
SITE 4
ACTIVE DREDGING
JANUARY
PERRY
COUNTY
Cypress Creek Light
With Daymark
Mile 168.7
Cypress Bend Light
With Daymark
Mile 170.8
A R K A N S A S
POINT
REMOVE
PUBLIC USE
AREA
Lewisburg Light
With Daymark
Mile 176.0
CONWAY
COUNTY
POINT REMOVE CREEK
REVETMENT AND DIKES
WARNING
WHEN BOATING OUTSIDE OF
MARKED CHANNEL, WATCH
FOR UNDERWATER OBJECTS.
CONWAY COUNTY
PERRY COUNTY
DAM SITE
PUBLIC USE AREA
LOCK AND DAM NO. 9
MATCH CHART NO. 40
RIVER CROSSINGS
Oppelo
113
9
154
64
CYPRESS CREEK
PUBLIC USE AREA
McCLELLAN - KERR ARKANSAS
RIVER NAVIGATION SYSTEM
POOL 8
MILE 177.1 TO MILE 168.3
SCALE OF FEET
0

CHART NO. 41

Figure 9. Station 7 (RM 155) with four sampling sites.

CORPS OF ENGINEERS

U.S. ARMY

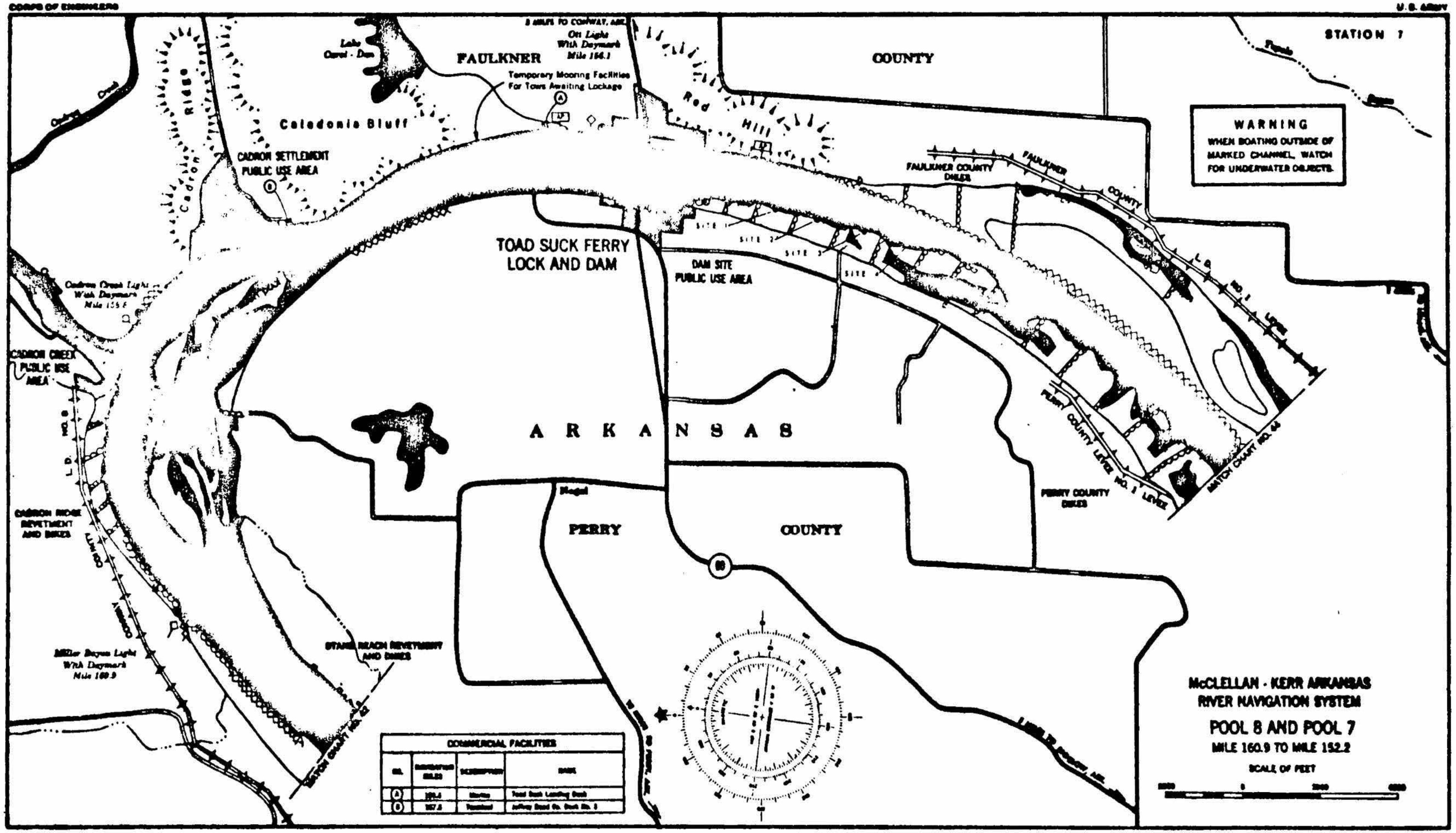


CHART NO. 43

Figure 10. Station 8 (RM 147) with three sampling sites.

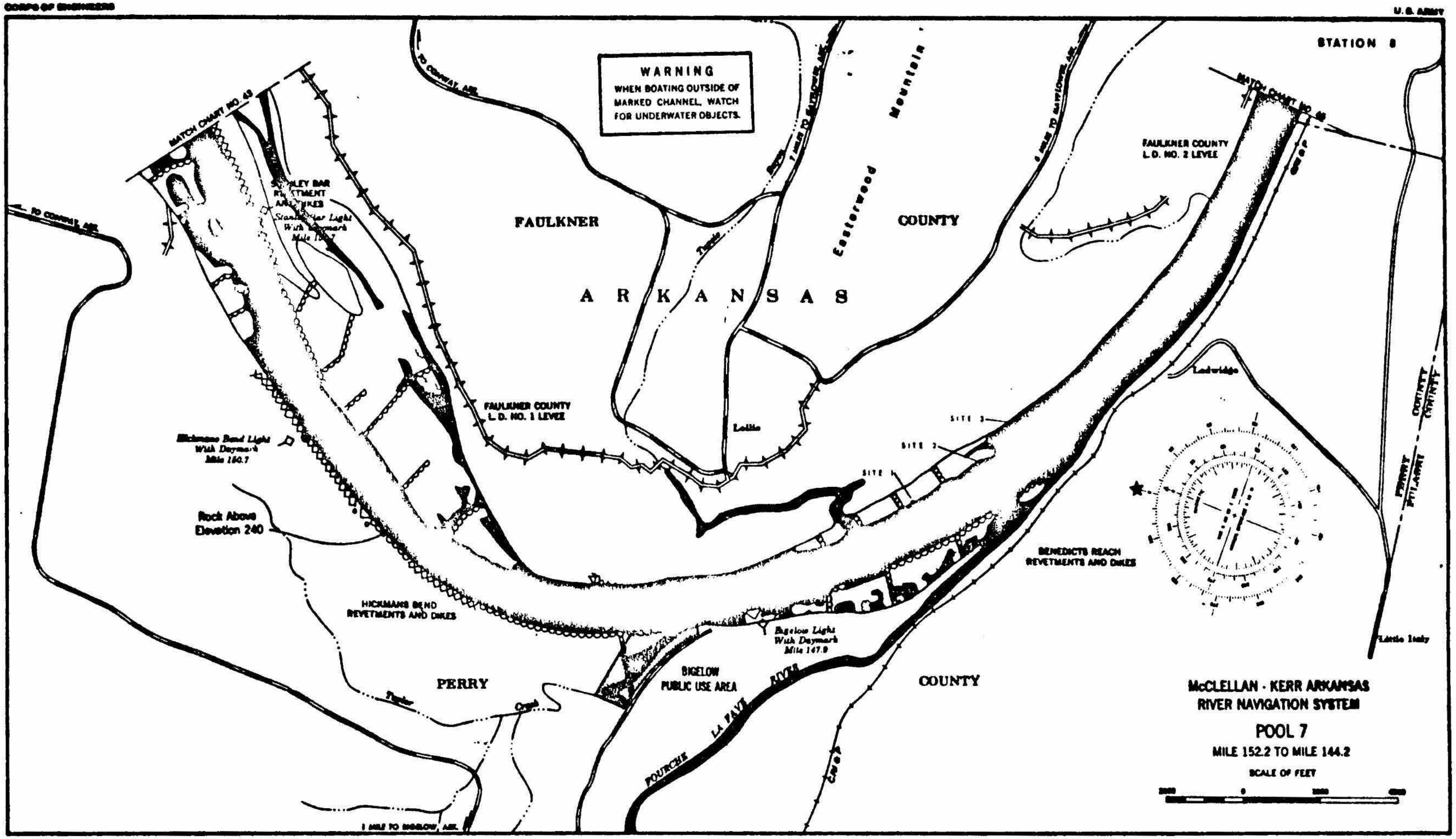
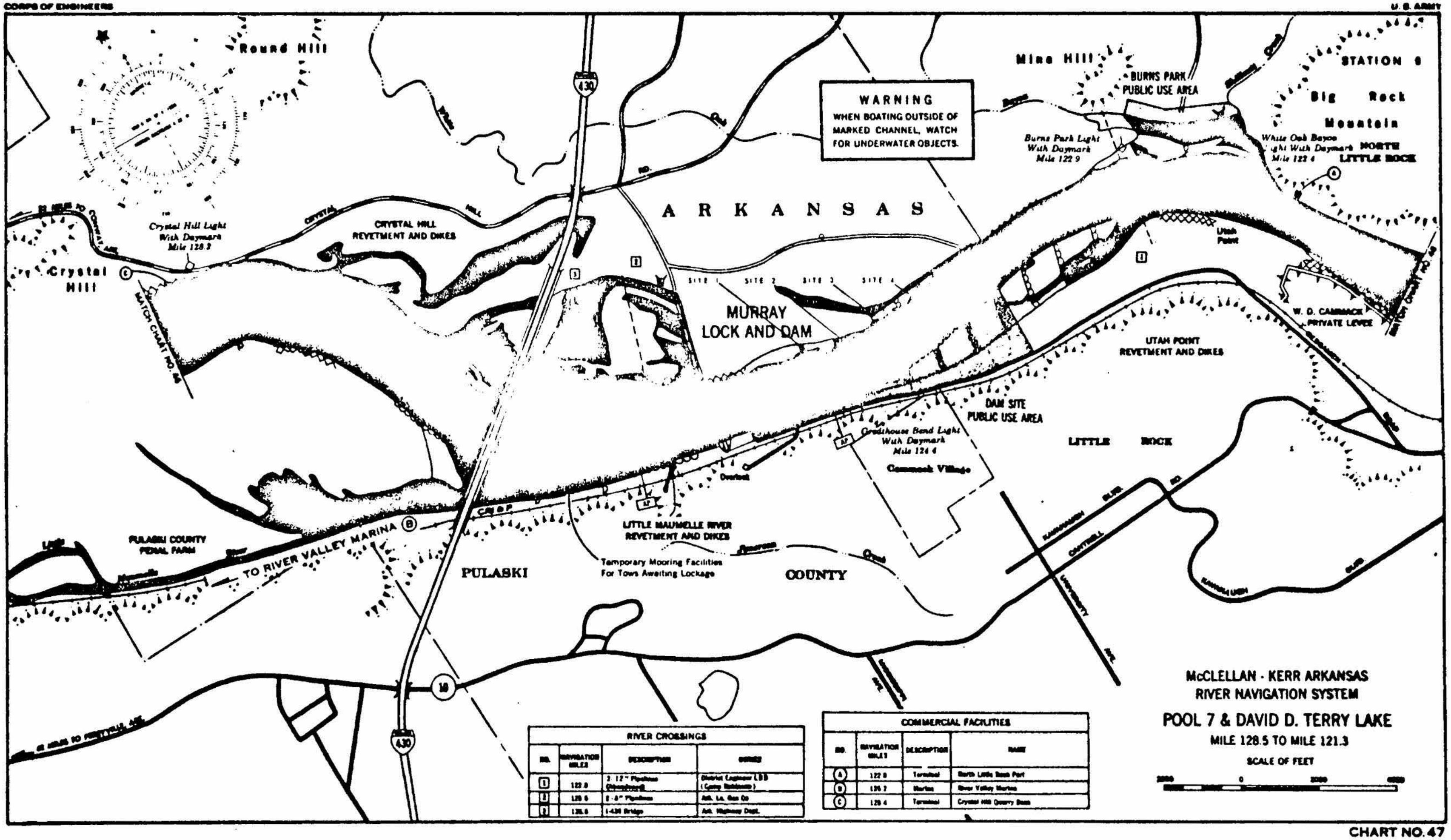

CORPS OF ENGINEERS
U.S. ARMY
STATION 8
WARNING
WHEN BOATING OUTSIDE OF MARKED CHANNEL, WATCH FOR UNDERWATER OBJECTS.
TO CONWAY, ARK.
TO CONWAY, ARK.
MATCH CHART NO. 43
MATCH CHART NO. 45
FAULKNER
COUNTY
A R K A N S A S
Easterwood Mountain
Taylor Creek
1 MILE TO MAYFLOWER, ARK.
STANLEY BAR REVETMENT AND DIKES
Stanley Bar Light With Daymark Mile 150.7
FAULKNER COUNTY L.D. NO. 1 LEVEE
FAULKNER COUNTY L.D. NO. 2 LEVEE
Ladwidge
Lollie
SITE 1
SITE 2
SITE 3
Hickmans Bend Light With Daymark Mile 150.7
Rock Above Elevation 240
HICKMANS BEND REVETMENTS AND DIKES
BENEDICTS REACH REVETMENTS AND DIKES
Bigelow Light With Daymark Mile 147.9
BIGELOW PUBLIC USE AREA
FOURCHE LA FAVE RIVER
PERRY
COUNTY
Taylor Creek
Cove Creek
1 MILE TO BIGELOW, ARK.
Little Italy
PERRY COUNTY
PULASKI COUNTY
McCLELLAN - KERR ARKANSAS RIVER NAVIGATION SYSTEM
POOL 7
MILE 152.2 TO MILE 144.2
SCALE OF FEET

CHART NO. 44

Figure 11. Station 9 (RM 125) with four sampling sites.

CORPS OF ENGINEERS

U.S. ARMY



MCCLELLAN - KERR ARKANSAS RIVER NAVIGATION SYSTEM

POOL 7 & DAVID D. TERRY LAKE

MILE 128.5 TO MILE 121.3

SCALE OF FEET

2000 0 2000 4000

RIVER CROSSINGS

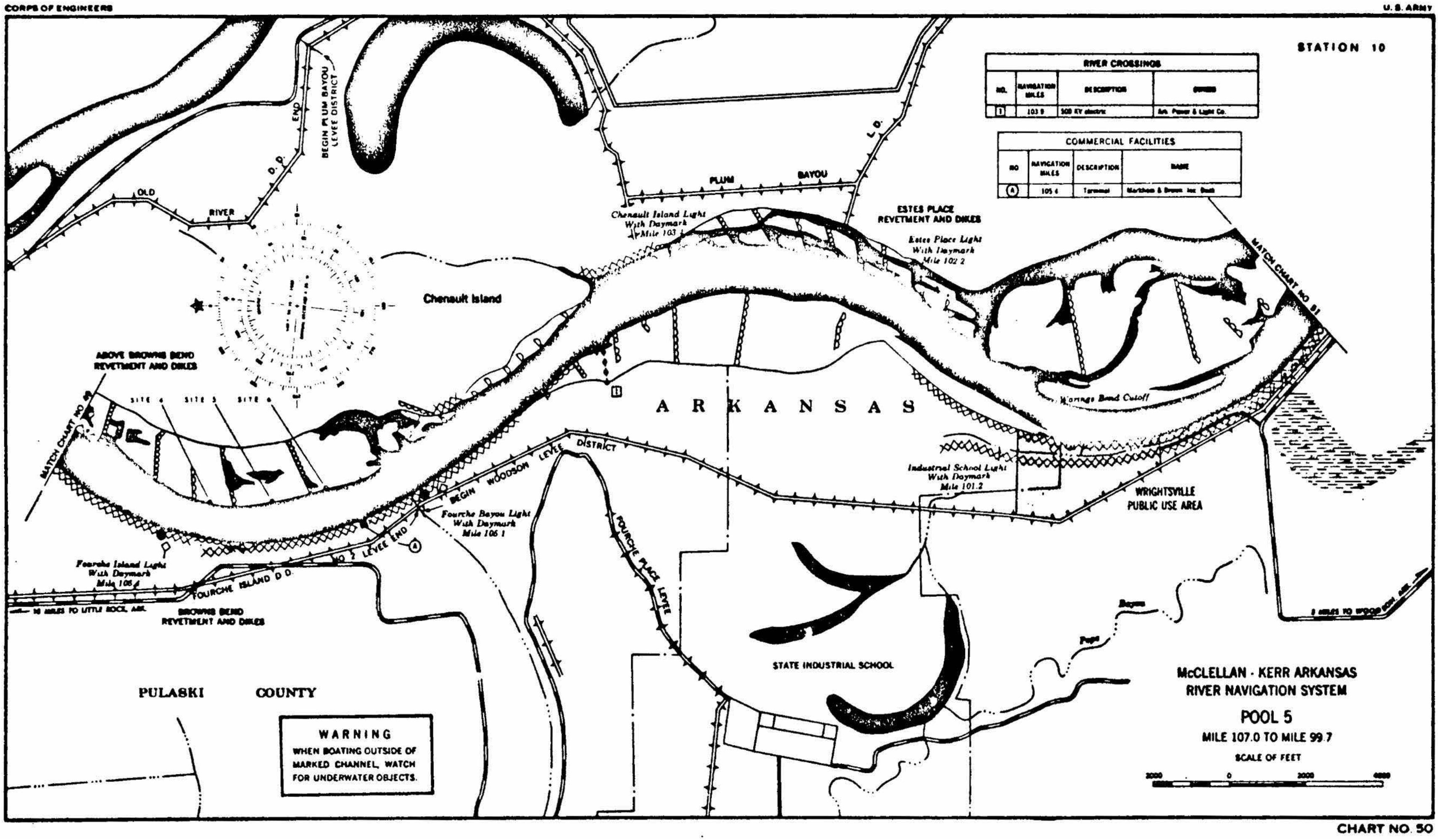
NO.	NAVIGATION MILES	DESCRIPTION	OWNER
1	122.8	2-12" Pipelines (Abandoned)	District Engineer LRD (Camp Robinson)
2	125.6	2-8" Pipelines	Ark. La. Gas Co.
3	126.6	I-430 Bridge	Ark. Highway Dept.

COMMERCIAL FACILITIES

NO.	NAVIGATION MILES	DESCRIPTION	NAME
Ⓐ	122.8	Terminal	North Little Rock Port
Ⓑ	126.2	Marina	River Valley Marina
Ⓒ	128.4	Terminal	Crystal Hill Quarry Dock

CHART NO. 47

Figure 12a. Station 10 (RM 106-108) with six sampling sites; sites 1, 2 and 3.



RIVER CROSSINGS			
NO.	NAVIGATION MILES	DESCRIPTION	OWNER
1	103.9	500 KV electric	Ark. Power & Light Co.

COMMERCIAL FACILITIES			
NO	NAVIGATION MILES	DESCRIPTION	NAME
(A)	105.4	Terminal	Markham & Brown Inc. Dock

Figure 13. Station 11 (RM 68) with four sampling sites.

CORPS OF ENGINEERS U S ARMY

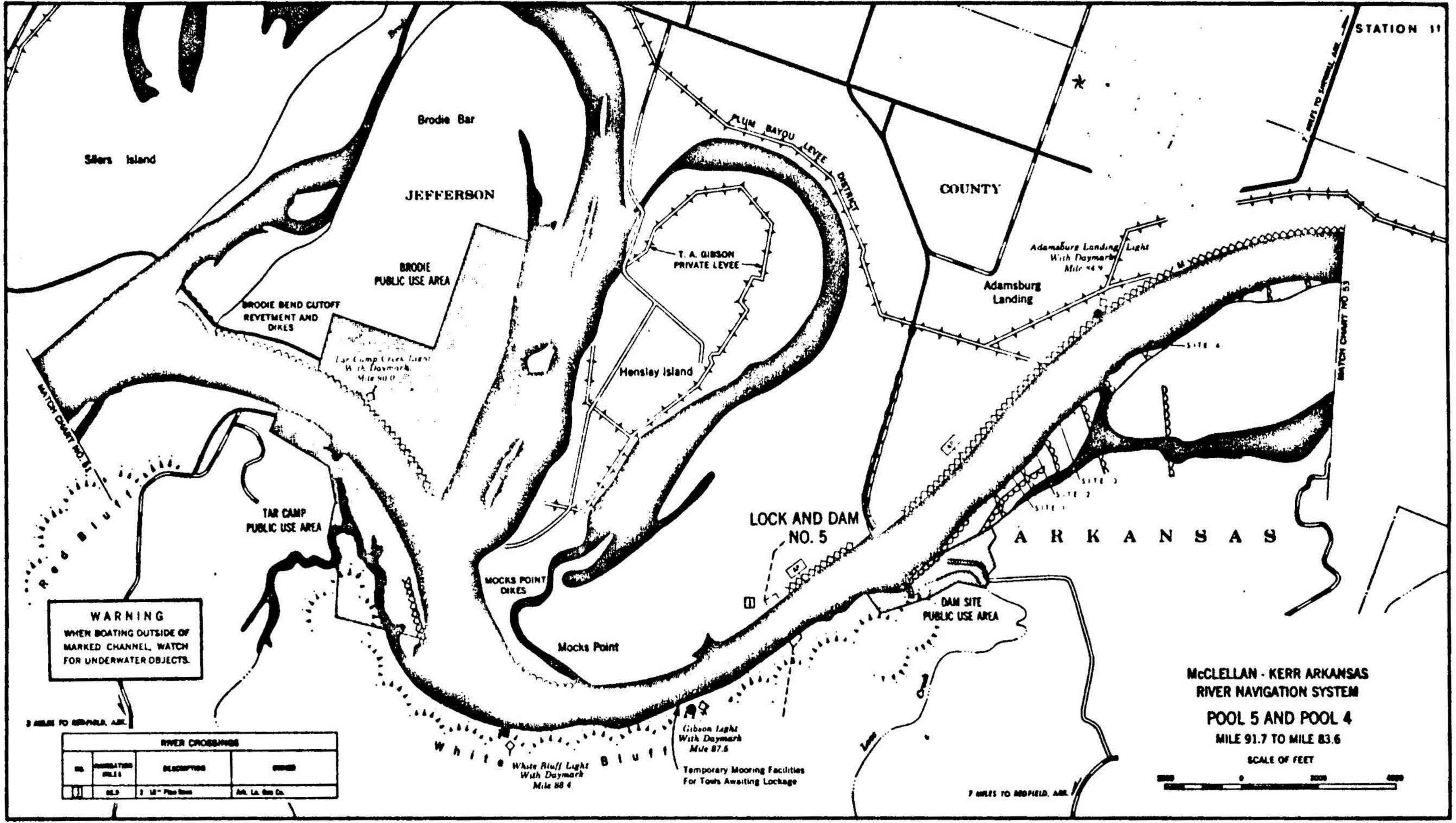
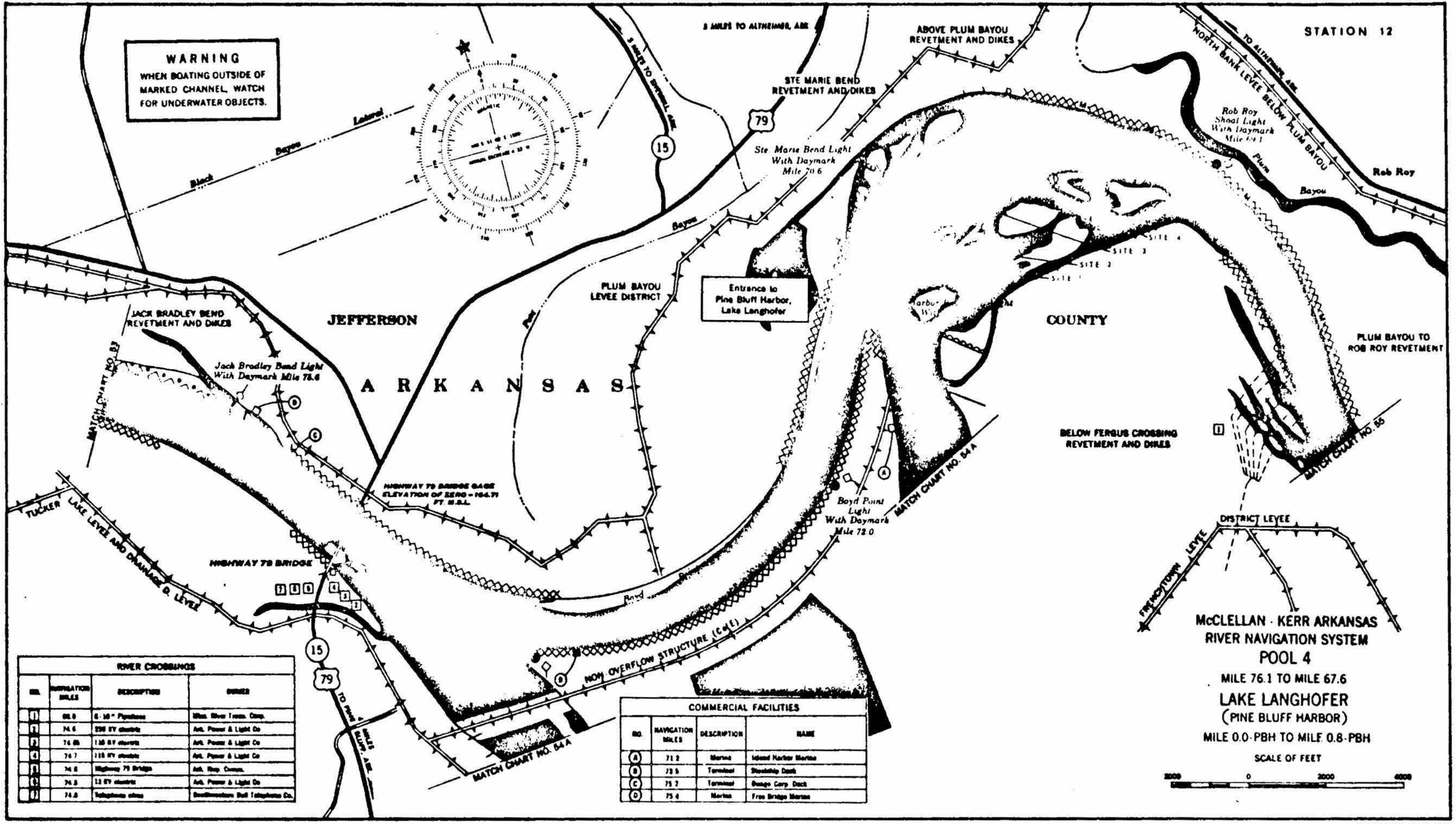


CHART NO. 52

Figure 14. Station 12 (RM 71) with four sampling sites.

CORPS OF ENGINEERS

U. S. ARMY



McCLELLAN - KERR ARKANSAS
RIVER NAVIGATION SYSTEM
POOL 4
MILE 76.1 TO MILE 67.6
LAKE LANGHOFER
(PINE BLUFF HARBOR)
MILE 0.0-PBH TO MILE 0.8-PBH

RIVER CROSSINGS

NO.	NAVIGATION MILES	DESCRIPTION	OWNER
1	68.0	6 - 10" Pipelines	Miss. River Trans. Corp.
2	74.6	230 KV electric	Ark. Power & Light Co
3	74.66	138 KV electric	Ark. Power & Light Co
4	74.7	115 KV electric	Ark. Power & Light Co
5	74.8	Highway 79 Bridge	Ark. Hwy. Comm.
6	74.8	13 KV electric	Ark. Power & Light Co
7	74.8	Telephone wires	Southwestern Bell Telephone Co.

COMMERCIAL FACILITIES

NO.	NAVIGATION MILES	DESCRIPTION	NAME
Ⓐ	71.2	Marina	Island Harbor Marina
Ⓑ	73.5	Terminal	Steamship Dock
Ⓒ	75.2	Terminal	Bunge Corp. Dock
Ⓓ	75.4	Marina	Free Bridge Marina

CHART NO. 54

Figure 15. Station 13 (RM 46-42.6) with ten sampling sites. Active dredging occurred at site 1 during January 1975 of this study period.

CORPS OF ENGINEERS U.S. ARMY

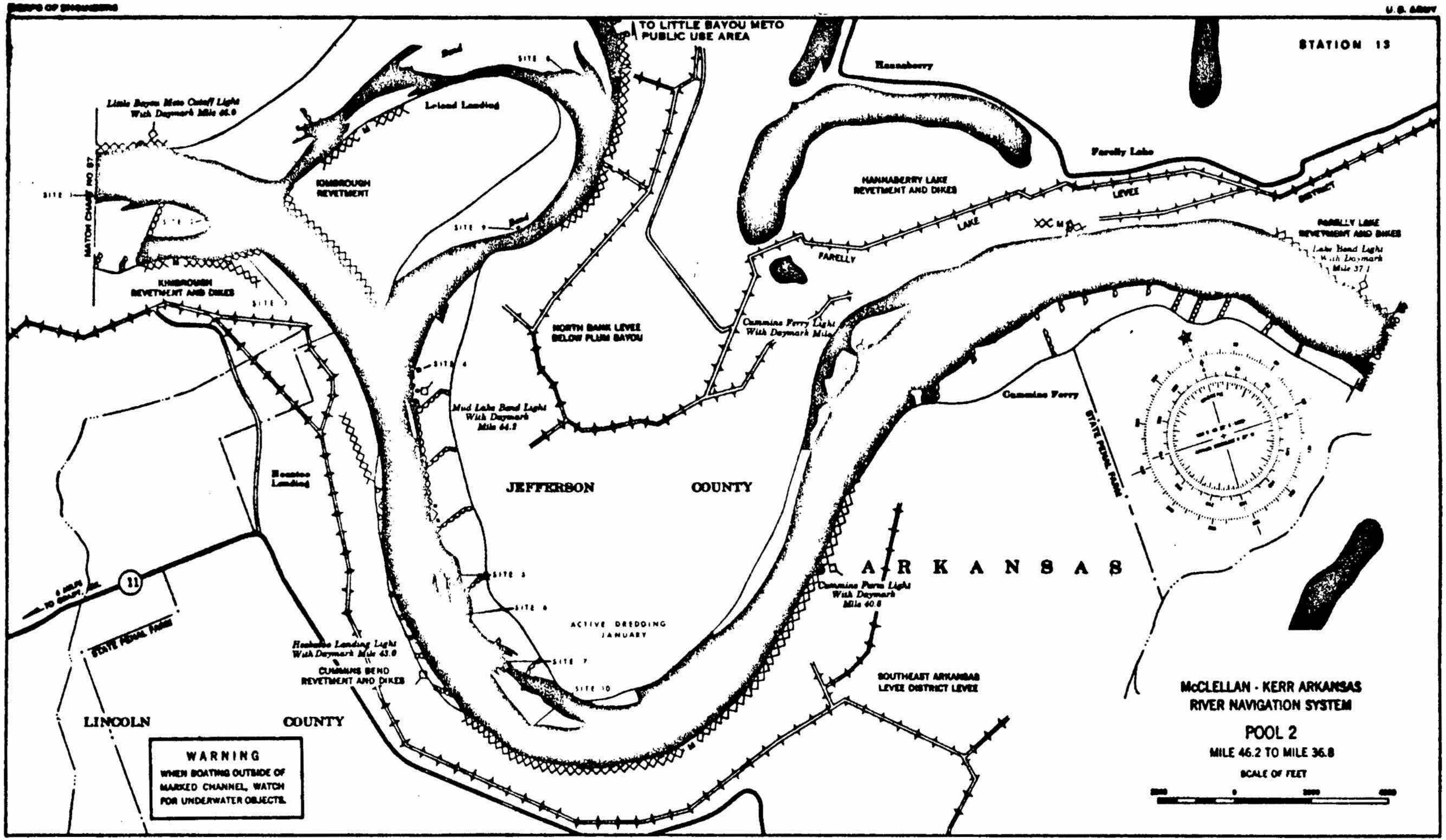


CHART NO. 58

PHYSICAL AND CHEMICAL CHARACTERISTICS

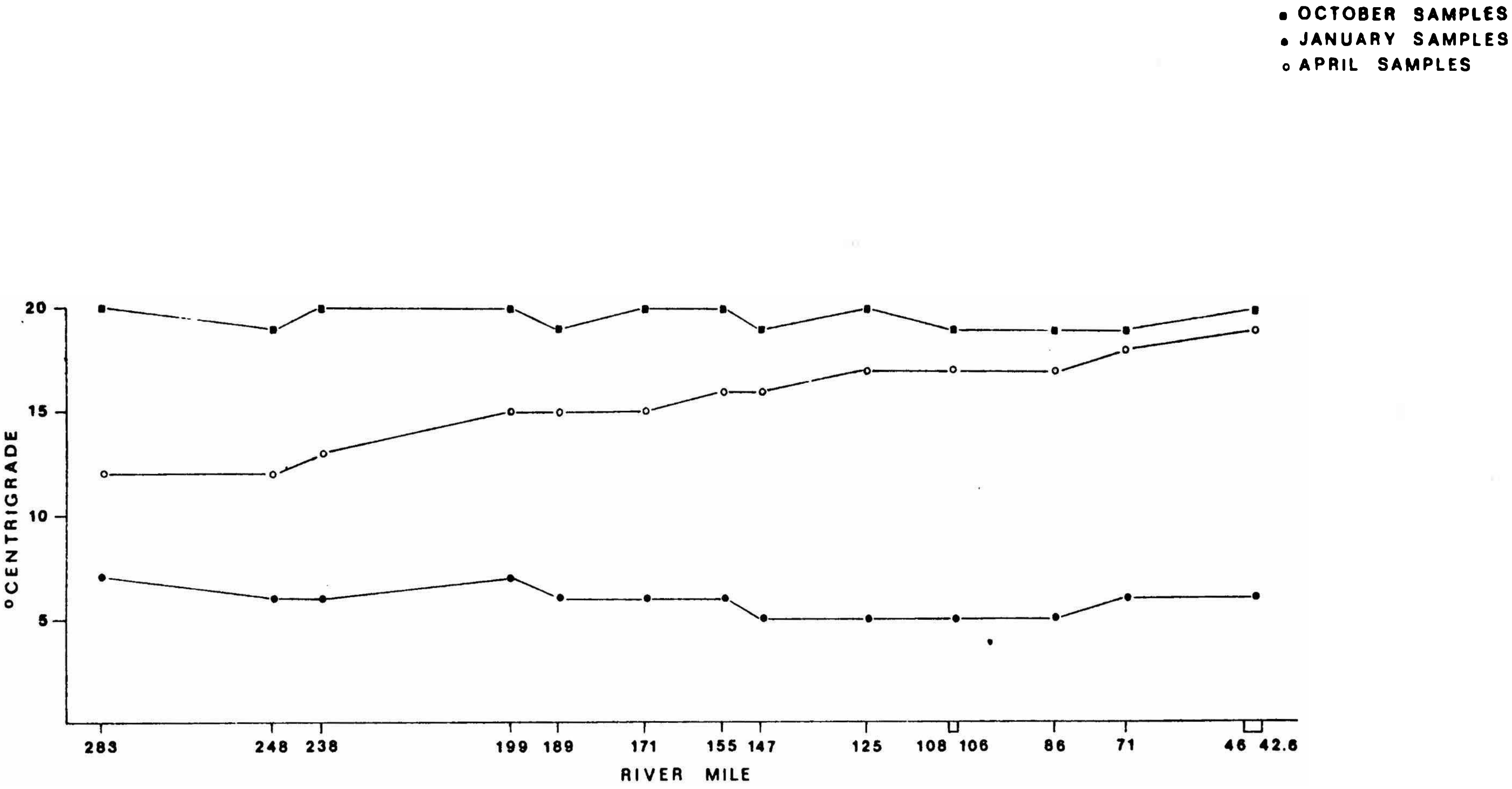
Temperature

Water temperatures were recorded at each station during each period of sampling (Appendix, Table 1). In October, mean temperatures were relatively stable longitudinally from Station 1 through Station 13 showing a range from 18.3°C (65°F) at RM 108 to 20.0°C (68°F) at RM 125 (Fig. 16). The mean temperature for the October samples was 19.1°C (66°F). The temperature never fluctuated more than 2°C throughout the study research during October. In January the waters were cool and relatively constant. They ranged from a mean of 5.1°C (41°F) to 6.8°C (43°F). During April, water temperatures increased gradually downriver with a maximum of 20.1°C (69°F) recorded at RM 45. The mean temperature during April was 15.4°C (59°F). The longitudinal trend of increase in temperatures downstream from Station 1 is noteworthy. This phenomenon seems to support the conclusion that the river begins to warm in an upstream direction (Fig. 16).

Thermograph records (U.S. Army Corps of Engineers) from previous years indicate that the Arkansas River reaches maximum temperatures in July and begins to cool by late August. Minimum temperatures were recorded in January and February and waters began to show slight warming by mid-March. The warming process usually nears its maximum by late June or early July.

Figure 16. Mean River Temperatures at each station by river mile; temperature expressed in degree centrigrade (°C).

MEAN RIVER TEMPERATURE
AT EACH STATION
BY RIVER MILE



Turbidity

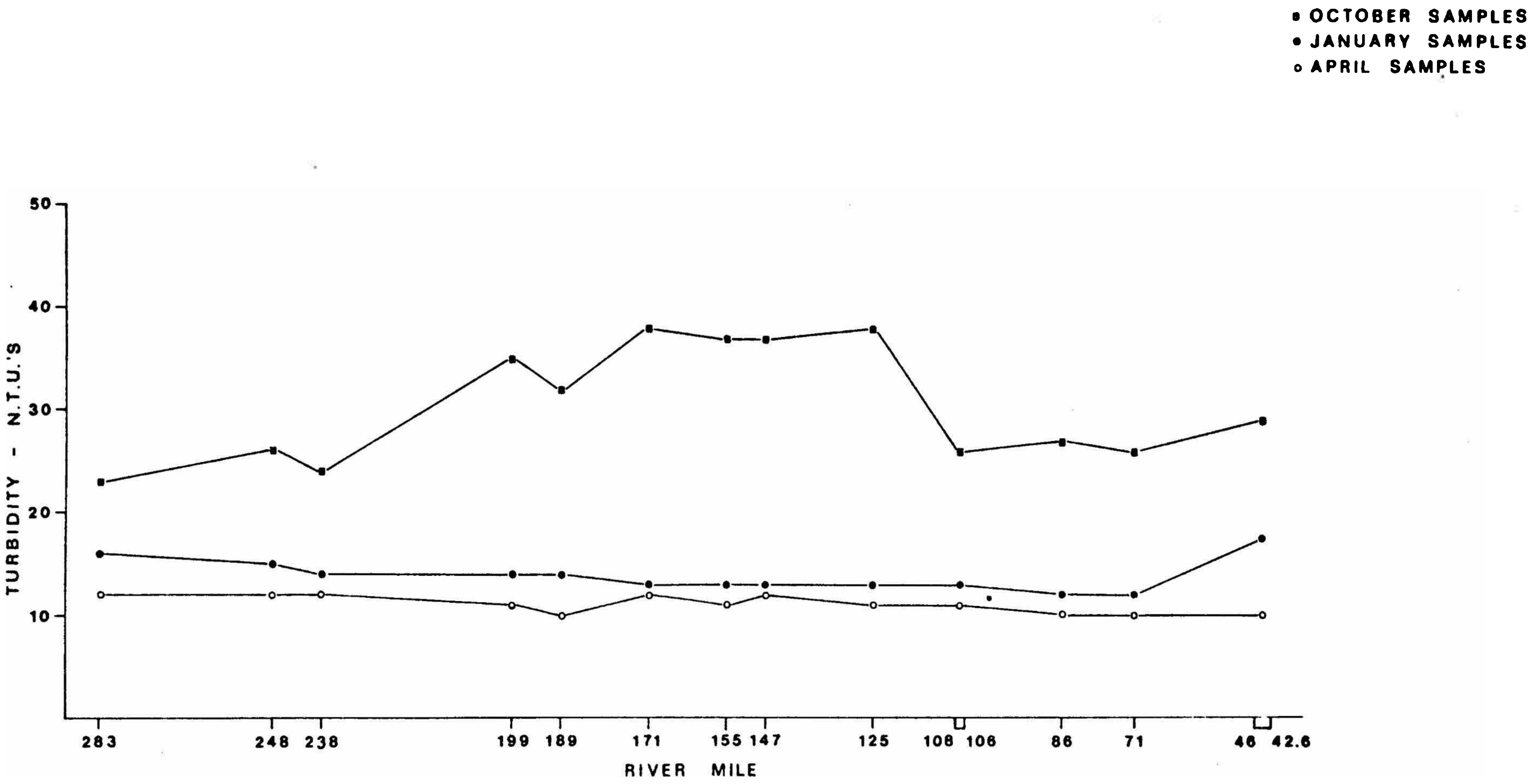
Turbidity values were determined for each sampling period (Appendix, Table 1). The method of turbidity analysis is described in Volume II. Measurements were obtained from the phytoplankton samples taken in October, January, and April. The mean turbidity values of combined sites at each station are presented in Figure 17 by river mile. Of the sampling periods, October showed the greatest changes in turbidity in a downstream direction. The lowest mean turbidity reading of 23 NTU's (Nephelometric Turbidity Units) for October occurred at RM 283. A zone of increased turbidities ranging from 32 to 38 NTU's occurred from RM 199 to RM 125. From RM 108 to RM 45 the turbidity returned to a level similar to that upstream. By January, values decreased and were relatively constant from RM 283 through RM 71 to range from 16 to 12 NTU's, respectively. A noticeable increase to 18 NTU's occurred at RM 45. Turbidity of the April samples ranged from 10 to 12 NTU's. Turbidity was relatively stable in a downstream direction with a slight fluctuation occurring from RM 189 to RM 147 (Fig. 17).

Transparency

During the investigation Secchi disc transparencies for the Arkansas River reached a maximum of two feet at Stations 1 (RM283) through 3 (RM 238) in July 1974 (Figure 18). Secchi disc transparencies were most consistent during April ranging from 0.9 to

Figure 17. Mean turbidity of combined samples at each station by river mile; turbidity expressed as Nephelometric Turbidity Units (NTU's).

MEAN TURBIDITY (N.T.U.'S) OF COMBINED SAMPLES AT EACH STATION BY RIVER MILE



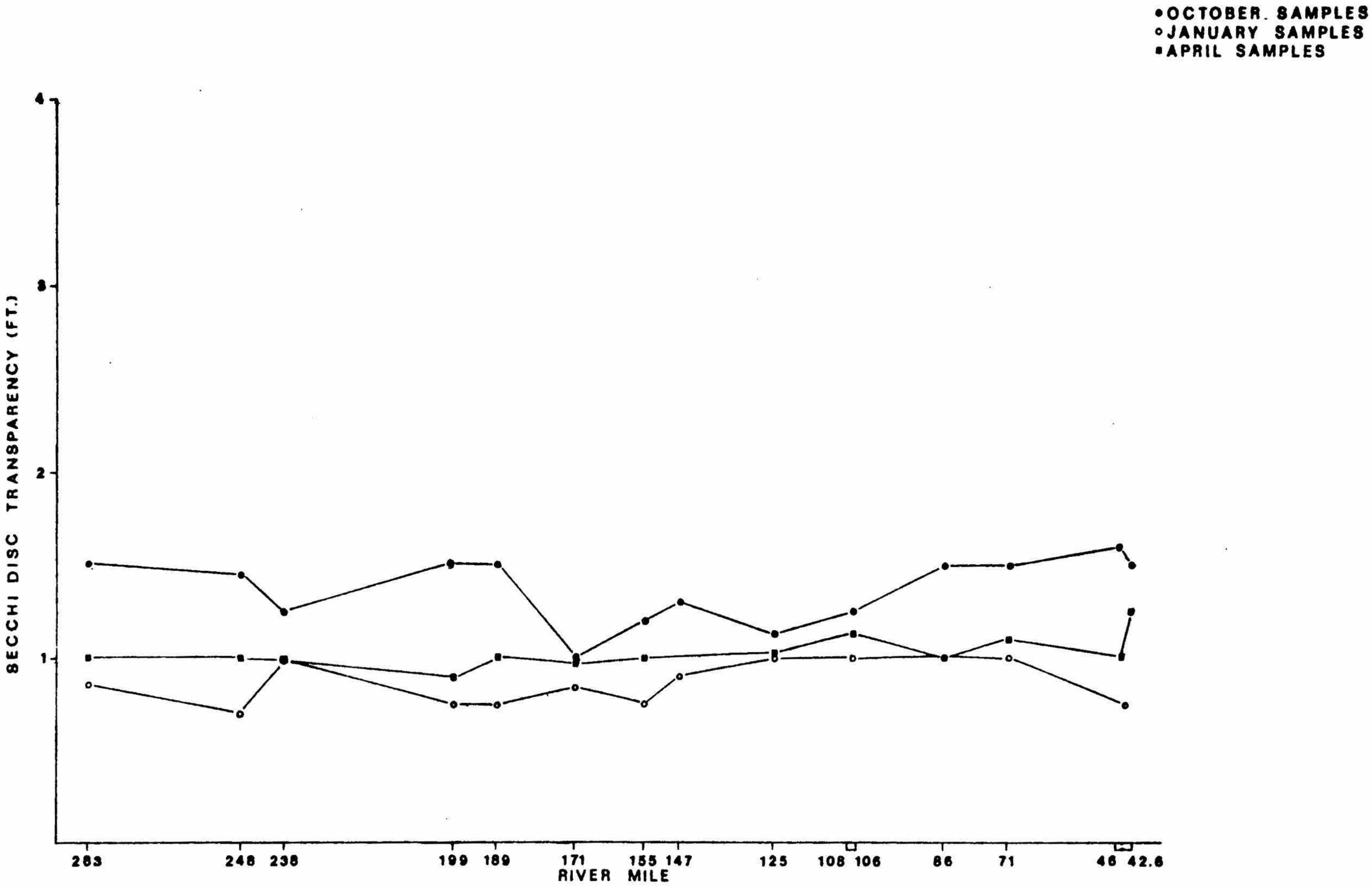
1.2 feet but showed more variation in October with readings from 1.0 to 1.6 feet. The overall Secchi disc transparencies decreased in January reaching a minimum of about 8.4 inches at Station 2 (RM 248) and a maximum of 1.0 foot at Stations 3 (RM 238), 9 (RM 125), 10 (RM 108), 11 (RM 86), and 12 (RM 71). The Secchi disc transparencies ranged from 0.5 to 2.0 feet at individual sites during the study. These data for October, January, and April are listed in Appendix, Table 2 and displayed in Figure 18.

Dissolved Oxygen

Dissolved oxygen levels were relatively high during the sampling intervals in October, January, and April (Appendix, Table 2). For example, the dissolved oxygen content ranged from 8.0 to 13.3 ppm during the above mentioned sampling intervals. However, dissolved oxygen content decreased significantly at individual sites during the July 1974 sampling interval and available data suggest the occurrence of stratification in slow flowing areas. The dissolved oxygen content among individual sites (Stations 1-3 (RM 283-238), July) ranged from 3.3 to 13.1 ppm, both readings occurring at sites within Station 1 (RM 283). Dissolved oxygen content often reached supersaturation during the study, particularly during the winter and early spring (January and April 1975). Longitudinal variations in dissolved oxygen content could not be discerned for July. However, mean dissolved oxygen values for October 1974 (Figure 19) show a sag or decrease from Station 1 to

Figure 18. The mean Secchi disc transparencies of combined sites: transparencies expressed in feet (ft.).

MEAN SECCHI DISC TRANSPARENCIES OF COMBINED SITES



7 (RM 283 to 155) and a gradual increase in dissolved oxygen content from Station 8 to 13 (RM 147-45). Dissolved oxygen content was relatively constant and high during January and station averages ranged from 12.0 to 13.3 ppm. By April the dissolved oxygen content exhibited a decrease moving longitudinally downstream. The station averages ranged from 11.8 ppm at Station 1 (RM 283) to 8.7 ppm at Station 13 (RM 45) (Fig. 19).

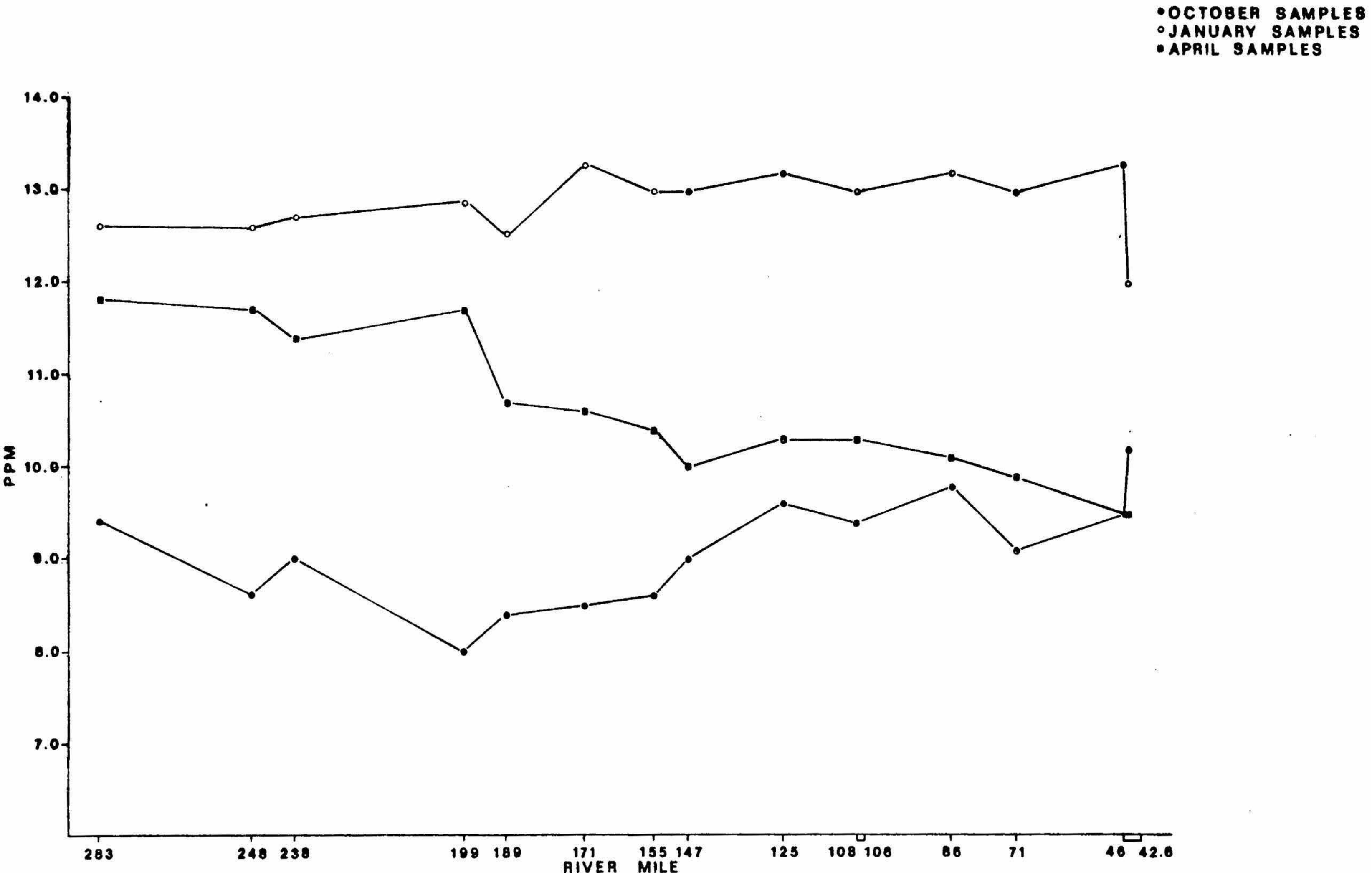
Hydrogen-ion concentrations (pH)

Hydrogen-ion concentration as expressed in pH values at the designated stations (1-13) ranged from pH 5.1 at site 4 within Station 1 in April 1975 to pH 9.2 at site 1 within Station 12 in October 1974 (Appendix, Table 2). Mean values ranged from a pH 6.2 to pH 9.2 in October, 6.4 to 7.4 in January, and 5.1 to 8.1 in April. Data taken at the three upper stations (1-3) during July ranged from pH 7.3 to pH 7.8.

Hydrogen-ion concentrations of inland streams and rivers usually fall within the range of pH 6.3 to pH 9.0 (Ellis, 1937). Ranges considered favorable for fish and animal life fall within pH 6.0 to pH 8.7. However, there is evidence that different species of a taxonomic group may each have an individual range of tolerance (Welch, 1952). Therefore, many organisms survive both lower and higher ranges than pH 6.0 to pH 8.7. On the other hand, many organisms require a much narrower range than mentioned above.

Figure 19. The mean dissolved oxygen values of combined sites: oxygen values expressed in parts per million (ppm).

MEAN DISSOLVED OXYGEN VALUES OF COMBINED SITES



Specific Conductance

In general, the range of specific conductance (conductivity) of natural waters should approximate that of total dissolved solids (Reid, 1961), Specific conductance is a measure of a water's capacity to conduct an electric current (Lind, 1974). In "low-conductivity" natural waters, such as the lower Arkansas River, the units are expressed in micromhos per centimeter (μmhos).

The specific conductance of the waters in the Arkansas River study ranged from less than 50 μmhos at site 2 within Station 8 to 1400 μmhos at the same site during October and April, respectively (Appendix, Table 2). In October, the specific conductance varied from 300 to 1400 μmhos at Stations 1 (site 1 and 2) and 8 (site 2), respectively. The overall specific conductance decreased during January and showed less variation ranging from 290-560 μmhos. Variation in specific conductance again increased by mid-April exhibiting readings of 50 to 545 μmhos. Available data for July indicate that specific conductance may have been least variable in as much as values ranged from 285 to 425 μmhos from Stations 1 through 3.

Alkalinity (Phenolphthalein and Total)

Alkalinity of water is another factor affecting the density of standing crops of plankton. The alkalinity of water is its capacity to accept protons; stated another way, it is the quality and kinds of compounds present that collectively shift the pH to the alkaline side of neutrality (Lind, 1974). Expected total alkalinities in nature usually range from 45 to 200 mg/l (Lind, 1974). The phenolphthalein alkalinity readings were consistently zero at all stations during the study except at Station 1 (site 3) in July 1974 (20 mg/l). During the study, total alkalinity ranged from 12 mg/l (Station 8 site 2) in April, 1975 to 200 mg/l (Station 5, site 3) in October 1974 (Appendix, Table 2). In July (data incomplete) the total alkalinity varied from 95 to 140 mg/l but ranged from 70 to 200 mg/l in October. Total alkalinity was more consistent during January and April of 1975 exhibiting ranges from 80 to 130 mg/l and 76 to 96 mg/l, respectively. The 12 mg/l recorded during April was a single observation below 76 mg/l.

LITERATURE REVIEW

By contrast with numerous studies concerning the biota in lacustrine systems, few studies have been conducted on the biota of lotic systems. This limited number of investigations reflects the difficulties encountered with sampling procedures and with the interpretation of data from riverine systems. Velocity of current, wide fluctuations in water volume, and high turbidity levels are some of the natural features of rivers that contribute to their complexity. Several of these characteristics and their consequent influence on the biota have been reviewed by Blum (1956), Greenburg (1964), and Hynes (1970a).

Pennak (1943), Lacky, et al. (1943) were among the first investigators to describe the existence of plankton in streams. Lacky et al. (1943) felt that the greatest potential modifying factor in unpolluted streams was the entrance of sewage. In a preliminary study of the Illinois River, Arkansas, Rice and Short in Kittle, et al. (1974) reported that diatoms and other algae dominated the plankton populations while zooplankton communities remained quantitatively insignificant.

Kofoid's (1903, 1908) work on the Illinois River, Illinois, formed the basic foundation for plankton ecology of rivers in North America. Many biological and chemical studies have been carried out on the Illinois River since the late 1800's.

Studies show that extremely high phyplankton counts exist in the Illinois River due to enrichment and high calcium hardness (Williams, 1964). It was suggested that the plankton of the entire river may be limited by turbidity and the synergistic effects of toxic metals (Starrett, 1971). Williams (1966) found that the Illinois River exhibited one of the highest densities of both phytoplankton and rotifers.

In a study of the San Joaquin River, California, Allen (1921) noted that temperature, within limits, determined seasonal distribution and that water currents above a very moderate rate were distinctly inimical to plankton development. Galtsoff (1924) listed 36 phytoplankton taxa and 80 zooplankters from the upper Mississippi River. He stated that the plankton of the upper Mississippi River was subject to great fluctuations depending upon the stage of the water. During an increase of water level the plankton was replaced almost entirely by detritus. The composition of the plankton was described as monotonous being dominated by rotifers, diatoms, and blue-greens. Wiebe (1927) found that no correlation existed between the total number of plankton individuals and the degree of pollution in the upper Mississippi River system, and therefore, that the abundance of plankton could not be employed as a criterion of the degree of pollution. Reinhard (1931) also stated that no definite correlation could be detected between chemical features of the Mississippi River and plankton. Phytoplankters were dominant and Rotatoria dominated the zooplankton communities. Reinhard concluded that the age of water, slope of the river, and hydrographic stability were all important to plankton production in lotic systems. He stated that current was the most important physical limiting factor.

Roach (1932) investigated the plankton of the Hocking River and cited floods as being most detrimental to river plankton because of current and "wash in acids." Several studies have shown an increase in the amount of plankton collected at successive points down a single stream and some workers considered age of the water to be important in plankton production. Hutchinson (1939) found that a combination of retarded flow, higher temperature, and senescence of the water at a given point increased plankton productivity in the Hocking River. Stability of hydrographic conditions and high temperatures were important factors in determining the monthly and seasonal distributions.

It was shown by Ellis (1936) that erosion silt alters aquatic environments, chiefly by screening out light, changing heat radiation, blanketing the stream bottom, and by retaining organic material as well as other substances which create unfavorable conditions. Sabaneef (1956, cited by Hynes 1970a) suggested that turbidity and silt may interfere with the feeding mechanisms of zooplankton. Berner (1951) recorded turbidity values over 3,000 ppm which affected almost every characteristic of the lower Mississippi River. The water temperature rose to a maximum of

82° F and the turbidity may have been partially responsible for the mid-summer dissolved oxygen saturation values of less than 50%. Usually, because of turbidity the phytoplankters were less common than the zooplankters. Rapid current and high silt content were considered by Hartman and Himes (1961) to be important factors in the decrease of numbers of organisms in the Shenango River.

The effects of turbidity on phytoplankton have been reported many times. The 19% reduction in phytoplankton in Lake Erie from 1941 to 1942 was attributed to high turbidities (Chandler and Weeks, 1945). Chandler (1942) reported that turbidity affected the composition, size, duration and time of occurrence of phytoplankton pulses. The increased growth of algae in the Missouri River is attributed to the reduction of turbidity by the construction of dams on the river (Bartsch, 1959). According to Plumb's (1973) summation, the effects of suspended solids on algae are: (1) solids create turbid suspensions that reduce light penetration and reduce photosynthesis; (2) silt can encrust algae and smother them or remove them from the water by flocculation and precipitation; and (3) suspended solids could contribute essential nutrients as the result of dissolution and therefore, stimulate the growth of algae. Also the abrasive action of inorganic particles may damage algae cells (Hollis et al., 1964). Variation in the composition of phytoplankton due to turbidity also has been suggested by Hutchinson (1967). In a study of the effects of turbidity on plankton in four flood control reservoirs of Mississippi, high turbidities were found to be deleterious to green and blue-green algae (McGaha and Steen, 1974). The increase in diatoms, especially Melosira, during the periods of high turbidity, was associated with an increase in silica.

Plankton may decrease along the course of a river but may be influenced by many environmental factors. Certain streams exhibit headwater areas low in plankton, a middle region rich in plankton, followed by a consistent decline in plankton in the lower course (Kofoid (1903, 1908); Forbes (1928); Eddy (1932); Chandler (1937); Beach (1960) and others). Yet other investigations have shown increases in plankton collected at successive points down a single stream; Eddy (1934); Hutchinson (1939), Sabaneeff (1952, cited by Hynes 1970a), Greenburg (1964), and others. Greenburg (1964) reported a gradual increase in phytoplankton along the reach of the Sacramento River. Through a statistical evaluation of the number of plankters and chemical and physical parameters of water quality and movement, he concluded that water temperature was the single most important factor affecting plankton development.

Eddy (1932) reported a decline in the plankton in the lower course of the Sangamon River durin the summer of 1929. Lakes on the course of the river supplied plankton to the lower reaches although selective elimination changed the composition. Eddy (1934) published a monograph based on more than 2,000 collections of plankton from streams, lakes, and ponds mainly in the United

States. Eddy believed that the most important factors influencing the development of plankton include age of water, temperature, and turbidity. In the streams studied, other factors such as light, dissolved oxygen, and hydrogen ion concentration seemed always adquate for plankton production.

One of the main emphases on river systems has been the effects of impoundments on the aquatic environment. Various rivers have been studied to assess the ecological impact of impoundments on phytoplankton. There seems to be a general agreement that impoundments by way of reducing the flow rates, increasing the depth, reducing turbidity and increasing the concentration of available nutrients, favor the development and reproduction of phytoplankton. These impounded areas create lacustrine conditions which result in the development of typical lake plankters (Cole, 1975). The study by Brook and Rzoska (1954) determined the influence of the Bebel Aulyia Dam on the development of plankton in the Nile River. A 100-fold increase was observed in the phytoplankton from samples taken farthest from the dam to the dam itself. Changes in composition also were observed with a tendency for the dominant component to change from diatoms to blue-greens. Cushing's (1964) study of the Montreal River attributed the increased abundances downstream to the series of lake-like conditions in the upstream portions. In a study of the Ohio River, Hartman (1965) concluded that the increased downstream population probably was attributed to the effects of local conditions rather than impoundments. He concluded also that navigational dams caused reductions in the phytoplankton.

Galtsoff (1924) expressed the importance of lakes, "river lakes," and the hydrographic conditions upon the amount of plankton in the upper parts of the Mississippi River. Galtsoff concluded that "...obviously the complete cycle of life in the 'river lakes,' the plankton pulses, the appearance and disappearance of plankton forms, the seasonal fluctuations in the amount and composition of plankton and even the distribution of plankton and bottom organisms is different from that in lakes...." He was making reference to the lakes formed by dams on the upper Mississippi River and its tributaries.

Eddy (1934) also made observations on the plankton of streams after impoundment and showed that the impounded water becomes biologically mature. In the many pools on the Rock River which were created by power dams, each duplicating the hydrographic conditions of a mature stream, the same species of plankton organisms were found to occur as elsewhere in the river, but much more abundantly. An 18-month study of the Huron River has shown that plankton derived from lakes undergoes a quantitative decrease at it flows down-stream, irrespective of season (Chandler, 1937). Chandler's results showed that a quantitative decrease in total net plankton and certain predominant individual plankters occurred in three lake-fed streams in Michigan.

Beach (1960) discussed the importance of lakes and artificial impoundments in a study of the planktonic rotifers of the Ocquec River system in Michigan. Lakes and artificial impoundments of the Ocquec River system were the major locations of plankton development. Lotic systems did not possess a planktonic rotifer fauna distinct from the lakes. However, most of the plankton was derived from lakes but decreased in quantity downstream and eventually disappeared. The length of each continuing stream segment, current, depth of water, turbulence and amount of vegetation or other objects contributed to the plankton decrease. The importance of backwaters and reservoirs in plankton production, particularly zooplankton, in rivers was noted as early as 1903 by Kofoid (1903).

The impact of damming streams was reviewed and studied by Neel (1963) with the purpose of discussing the effects of discharge, turbidity, temperature, water chemistry and biological features. The development of lentic conditions, which eventually follows impoundment where draw-down and other practices permit, brings about changes in benthos, nekton, plankton, chemical conditions, etc., within the reservoir area, but usually only the plankton reflects much direct effect beyond the impoundment (Neel, 1963). Reservoir plankters suffer varied fates below dams, and generally will slowly or rapidly decline depending upon stream conditions and volume of reservoir releases. On the other hand, a few workers have shown that plankton does increase downstream in particular rivers (Hutchinson, 1939; Sabaneeff, 1052; Greenburg, 1964). Obviously, the phenomenon depends much upon local conditions. Reservoirs often affect turbidity, removing silt, debris and other suspended particles by slowing the current. Temperature changes that normally occur in the spring and autumn are, in general, delayed by the great volume of water held by reservoirs, and modifications of water chemistry vary with the age of impoundment (Neel, 1963).

In studying the aquatic environment of lakes and streams many researchers have stressed the importance of studying benthos. Many biologists (e.g. Ward, 1919; Wurtz, 1969; Hilsenhoff, 1971; Dickson and Cairns, 1972; Fisher and Beeton, 1973) have been well aware that when the biota of a lake or stream have been decimated or eradicated through severe environmental ("pollutional") stress repopulation begins with the benthos.

Several studies have been made concerning the benthos of streams. Hynes (1970b) made an extensive study of stream insects which covered various geographic regions, chemical and physical parameters, food habits, and life histories including drift and flooding. Other investigators have studied food habits (Koslucher and Minshall, 1973); the influence of various stream sediments on benthos (Idyll, 1943; Curry, 1954; Brusven and Prather, 1974; Crisp and Crisp, 1974); movements (Bishop and Hynes, 1969) and physico-chemical relationships (Armitage, 1958; Mathis and Dorris, 1968; Robison, 1971; McGary and Harp, 1972; Coutant and Pfunderer, 1974; Gaufin et al., 1974).

Aggus and Warren (1967) compared the distributional patterns of bottom organisms with stream size and seasonal pattern of flow. The results showed that small spring-fed streams produced the most bottom organisms per unit area, large tributaries produced less, and small streams subject to surface drying least. Riffles were much more productive than pools in streams subject to surface drying, and pools produced almost twice as much as did riffles.

Seasonal fluctuations in the benthos populations also have been considered. Bishop and Hynes (1969) discovered that during the winter, statistically greater movement occurred in areas adjacent to the banks than in midstream, but in summer the midstream areas contributed most of the migrants. The upstream movement was of sufficient quantity and species diversity to account for recolonization of dried-out or erosion-denuded areas. In a study of the benthos of Oakwood Bottoms Greentree Reservoir, Hubert and Krull (1973) found that a large variety of macroinvertebrates occurred at Oakwood with populations in permanent water areas distinctly different from populations in areas with temporary water conditions. The greatest number and biomass of invertebrates occurred from November to April with fingernail clams, amphipods, isopods, and pulmonate snails predominating. Sublette (1956) studies the seasonal changes in bottom fauna of Clear Creek, a headwater stream in Northwestern Arkansas. He determined that insects dominated the bottom fauna. The rather low fall standing crop gradually increased until late winter at which time the maximum occurred. The large standing crop was then abruptly reduced by the erosional effects of flood waters. Following flooding, the relative composition of the standing crop was altered, apparently as a direct result of certain members being able to better withstand conditions of erosion.

Another account of the influence of flooding on benthic communities has been supplied by Hoopes (1974). He studied the effects of flood conditions from Hurricane Agnes in June 1972 on benthos. He found that a 22.7 $m^3/sec.$ peak discharge severely depressed the benthic community, which had, however; recovered by October 1972.

Studying the ecology of riffle insects of the Firehole River, Wyoming, Armitage (1958) postulated that alkalinity might be the chief factor that determines the level of standing crop in a stream, but that the level can be highly modified by the action of temperature and current and by the physical composition of the stream bottom. He found that rubble bottom had an average of 2.48 times the weight of organisms fauna on bedrock.

Cole (1973) determined that nutrient enrichment of streams reduced the number of species by about one-half in pool edges and riffles. Macroinvertebrates were most abundant in the sediment of pool edges. Species that normally were associated with pool edges appeared in riffles where many of the aquatic insects had been eliminated. He attributed this to change in species composition of "grossly enriched streams" to decreased oxygen and increased sedimentation.

Evaluating the effects of a paper mill effluent on bottom fauna, Hendricks et al. (1974) suggested that the natural environment was the probable cause of reduced diversity of the bottom fauna because of high and low periodic flows, heavy organic loads, intermittent inundation by salt water, coarse sandy bottoms, periodic decreased oxygen levels and lack of diverse habitat.

As with plankton, much concern has been placed on the effects of impoundments on benthic communities. Spence and Hynes (1971) found pronounced differences in the macroinvertebrate riffle fauna upstream and downstream of a flood control impoundment. Downstream differences were comparable with those occurring after mild organic enrichment. Spence and Hynes associated these changes with downstream increases in the availability of detritus, a lag of about four weeks in the early summer, rise in water temperature and a maximum temperature more than 6° C lower than upstream, and alteration of other environmental factors. Iehmkuhel (1972) attributed reduced benthic fauna downstream of a reservoir to changes in river temperature caused by the reservoir. Trotsky and Gregory (1974) also investigated the effects of severe fluctuation in flow on the distribution of bottom fauna of the upper Kennebec River. Slow currents resulting from low floods appeared to limit the diversity and abundance of swift-water aquatic insects on the river bottom below the dam. Sampling stations above the impoundment averaged

19 aquatic insect genera, while those below the dam averaged 11. Aquatic insects adapted for swift water were more abundant above the impoundments than below, and were absent from those stations below the impoundment with the lowest current velocity.

Several benthic studies have focused on the problem of determining adequate sampling procedures and methods. Hughes (1975) compared four methods of taking quantitative samples of benthic invertebrates. The four sampling methods (Surber sampler, box sampler, electric shock sampler, and artificial substrate sampler) gave different results with regard to population density, species density, community structure, and intersample variability. Samples taken by the artificial substrate samples contained the most animals, the most species, and gave the most consistent results; those taken by the electric shock sampler contained fewer animals and species, and gave the least consistent results. Wiggins (1966) noted that the standard dredges and sieving procedures aid in the collection of organisms, but sacrifice data on the physical habitat. He also concluded that a single sampling procedure for all stream habitats is not possible.

The literature contains many other studies which describe benthic populations and distributional patterns. Among these studies are: Blanz, et al (1969); Carlander, et al. (1967); Carlson (1968); Gale (1975); Langford (1971); and Stanford and Gaufin (1974).

EFFECTS OF DREDGING ON BIOTA

During the last few years more attention has been directed toward the environmental impact of dredging on biota. Even though there seems to be a great concern over this matter, very little research has been conducted. The Illinois River of Illinois has become one of the important rivers in America for man and development of some of his cultural activities (Starrett, 1972). Some of these activities have had adverse effects on the biota of the river. Among these activities are navigation and dredging. Dredging has been conducted on the Illinois River since 1852 (Barrow, 1910; Starrett, 1972). Through the years the channel benthic community probably has been affected by the construction of locks and dams. The changes which have occurred in the fish fauna of the Illinois River also reflect some of the drastic effects modern man has had upon the ecology of the river.

It has been shown by Jeane and Pine (1975) in a study concerned with environmental effects of dredging and spoil disposal in a bay that dredging can cause changes in the chemical properties of water, especially in the vicinity of the dredge. They found that the water surrounding the dredging area increased in conductivity, turbidity, and temperature. Secchi disc measurements decreased, as did dissolved oxygen. Hydrogen ion concentration remained about the same throughout the study. The dredging activity did not cause significant mortalities to juvenile chinook salmon, but it did cause a change in the species composition of benthic macroinvertebrates as well as a reduction in the number of species present in the area. Forshage and Carter (1973) studied the effects of gravel dredging on the Brazos River, Texas, and found that such perturbation caused increased turbidity several miles below the operations. The dredging also had a detrimental effect upon the fishes and benthic organisms. Stickney and Perlmutter (1975) investigated the effects of hydraulic dredging on the benthic fauna in Georgia in the Atlantic Intracoastal Waterway. The authors found a complete displacement of the benthic community due to dredging activities. They noted that within several months recolonization of the area had occurred.

Previous studies cited in a literature review by Lee and Plumb (1974) have been concerned mainly with the effects of turbidity and the possible release of nutrients and toxic chemicals from the dredged material on phytoplankton. Even though the influence of suspended material on phytoplankton can be detrimental as shown in studies by Plumb (1973) and Hollis et al. (1964), it is still questionable whether increased turbibidy is an objectional condition resulting from dredging activities (Harrison and Chisholm 1974).

In studying the influence of sediments on aquatic life, Cordone and Kelly (1961) state "... short term discharge of sediments may do little visible damage to fish, bottom fauna or fish eggs, but may interrupt the entire biological complex through effects on algae...".

In a literature review by May (1973), a study was cited concerning the dredging activities in upper Chesapeake Bay. Dredging increased the turbidity over an area of 1.5 to 1.9 square miles around the disposal site and the turbidity plume reached a maximum distance of 3.1 miles. No gross effects on the phytoplankton were observed. Turbidity plumes are reported to be temporary (lasting a few hours) and to generally extend within 2,000 ft. of discharge (Lee and Plumb, 1974).

One of the problems encountered in evaluating turbidity influences is determining what turbidity levels constitute an objectional condition (Harrison and Chisholm, 1974). The use of turbidity measurements in evaluating the environmetnal impact of dredging has even been questioned. May (1973) believes that turbidity measurements have little use in the dredging program since they are not quantitative. He advocated measuring the amount of suspended solids in the water. According to May, the suspended solids measurement is the only way to meaningfully evaluate the effects of dredging on sediment.

Because of the biological changes that could be influenced by the concentration of suspended solids, the type of suspended solids, the length of exposure, the presence of toxic materials, the conditions of the exposed organisms, and the phases of the life-cycles of the organisms, it has been suggested that rigid turbidity standards not be set (Lee and Plumb, 1974).

A theoretical model used to calculate the potential changes in photosynthesis and productivity showed a 50% reduction with a 0.5 mg/l increase in suspended solids (Plumb, 1973). As pointed out by Plumb, these results are questionable since other conditions that could limit algal growth and the adaptability of the organisms were not taken into consideration.

Gannon and Beeton (1969) used laboratory bioassays to study the effect of dredged sediments from five locations in the Great Lakes area on phytoplankton. The results of this study based on optical density readings suggested that a decrease in the abundance of phytoplankton occurred, but that it was probably temporary. Gannon also concluded through a carbon-14 study with bioassays that extracts from harbor sediments actually stimulated productivity. Due to a possible error in interpreting the results, the validity of this study has been questioned by Lee and Plumb (1974).

Studies have shown that one environmental impact of dredging is the release of aquatic plant nutrients. In studies reviewed by Slotta (1973) an increase from 50 to 1,000 times ambient total phosphorus and nitrogen levels occurred near a discharge plume. No increase in phytoplankton was observed. By contrast, another study showed stimulation of algal growths when dredged spoils were placed with the receiving waters in closed bottle experiments. Light-dark bottle experiments at the dredging site also reported significant algal growths.

Chruchhill and Brashier (1972) studied the effects of dredging on Lake Herman, North Dakota. The results showed a 300% increase in both orthophosphates and total phosphorus with no apparent changes in abundance or genera of the phytoplankton production.

The possible release of contaminants from dredged sediments is presently under investigation. The "Elutriate Test", which was designed to detect any significant release of chemical contaminants, is being evaluated, tested, and modified to assure reliability in the assessment of dredging effects in many of the various dredging locations across the United States (Lee, 1975).

In some dredging locations the release and availability of organic and inorganic constituents of dredged sediments to phytoplankton is unexpected. Both of these constituents remain largely absorbed or insoluable in sediments (May, 1973; Lee, 1975). The heavy metal content in sediments also has been shown to have little or no effect on the aquatic environment. Many of the metals are in a form unavailable to aquatic organisms (Lee, 1975).

SUMMARY AND CONCLUSIONS

The results of this coordinated study characterize through both seasonal and biogeographical aspects, the basic structure of the biotic communities within the aquatic system of the Arkansas River. An evaluation of the probable environmental impact of dredging operations on the biota is considered. The results of each phase are summarized as follows:

Phytoplankton

1. Eight taxa of phytoplankton with a total of 243 species were observed from the designated sampling stations along the study reach. Five of these eight taxa (coccoid greens, green flagellates, blue-greens, diatoms, and cryptomonads) comprised the bulk of the population. Although these taxa were widely distributed along the reach, the concentration of cells in each taxon varied during the sampling periods.

2. Based on the number of species of phytoplankton, the Arkansas River is structurally more diverse and complex than many previously studied river systems.

3. The blue-greens constituted the major portion (76%) of the total population during October, with coccoid greens and diatoms being subdominants. The coccoid greens became the most important taxon of the population in January with 34%, Thus indicating a seasonal change in the composition of the phyto-

plankton community. During January the diatoms and blue-greens were of secondary importance. In April the diatoms (33%) formed the largest percentage of the population with the coccoid greens and blue-greens being of secondary importance.

4. The gross changes in the abundance of each taxon are a reflection of the transitions in dominance at the generic level. For most of the taxa, transitions occurred throughout the study reach, indicating the possible interaction of certain local environmental factors.

5. The lowest abundance for the three sampling periods was recorded for the winter population (January). This low abundance was attributed to a 95% decrease in blue-greens from the previous sampling period.

6. The abundance of the spring population (April) resulted from greater-than-a-100% increase in the diatoms over the winter population with lesser increases in the other taxa excluding crytomonads and dinoflagellates.

7. The abundance of phytoplankton generally increased from upstream to downstream, with fluctuations in the total population occurring along the study reach.

8. Our data suggest that higher concentrations of phytoplankton occur in the open stream and reduced populations occur along the dikes and revetments.

9. The population during October showed the greatest range

and instability of the three sampling periods with the total population deviating approximately 49% from the mean number of cells. The January population was the most stable of the populations. The April population showed a slightly lesser degree of stability throughout the reach than in January but was more stable than in October.

10. The seasonal differences in light and temperature parameters are, in addition, modified by stream flow characteristics. These variations resulted in the irregular fluctuations of the total abundance of phytoplankton with each river mile.

11. The unstable population during October possibly reflects the influence of high turbidities resulting from flooding conditions during this sampling period. Light and temperature were considered to be the major "controlling" factors during October. Regions of maximum change in the total population possibly could be attributed to the fluctuation in turbidities and/or chemical or nutrient imputs. There appear to be three distinct zones showing major differences in the abundances of the standing crop of phytoplankton. The first zone occurred from RM 283 to 238 where the majority of the taxa decreased in abundance; the second zone from RM238 to 147 where the major fluctuations were prevalent; and the third zone from RM 147 to 45 where all of the taxa increased in abundance.

12. A reduction in temperature and light probably contributed

to the low abundance of phytoplankton during January. Two regions showed major changes in the total population abundances. The decline from RM 199 to 171 was attributed to decreases in cryptomonads, green flagellates and blue-greens. RM 86 to 45 was characterized by a peak abundance at RM 71 followed by a major decline at RM 45. The fluctuating pattern in this region was attributed to major shifts in abundance of the blue-greens and diatoms.

13. The increased population during April occurred along with increases in temperature and illumination. Varying abundances in the blue-greens, green flagellates, and cryptomonads contributed to the erratic fluctuations of the total population along the reach. The maximum peak at RM 71 was due to an increase primarily in the blue-greens.

14. Turbidity of the river samples during each collection period seems to be related to many of the erratic fluctuations in the phytoplankton abundances. The decrease in abundance of the blue-greens: *Merismopedia, Gomphoxphaeria, Oscillatoria,* and possibly *Microcystis,* seems to be associated with high turbidities. *Melosira* showed drastic decreases in association with the high turbidities. Since factors affecting or limiting the expression of phytoplankton might vary from system to system, the transfer and application of cause-and-effect relationships must be employed with caution.

15. In evaluating the effects of dredging on phytoplankton, the potential effect of increased turbidities in the immediate vicinity, as well as in the vicinity downstream from the dredging site, was considered. Turbidity data for samples from the active dredging sites revealed no anomalies.

16. Station 5 at RM 189 was dredged only at site 1. Since this site was the distal downstream site of the four sites, the dredging effects could not be adequately assessed.

17. RM 171 was dredged at all four of the designated sites. Fluctuations were observed in the population at this river mile in comparison to the populations at the preceding and succeeding river miles. Factors other than dredging are more likely to account for these changes.

18. Site 1 of RM 45 was actively dredged in January. A comparison of phytoplankton data from site 1 with the next two downstream sites revealed no significant changes in the phytoplankton populations. The abundances and percentages remained relatively stable, The other sites at the station were influenced by the outflow from the Mud Lake Bend area and were, therefore, considered not to be applicable in assessing the effects of dredging activities at site 1.

Zooplankton

1. The Arkansas River can be separted biologically and

and physically into two major longitudinal sections: the section above Dardanelle Lock and Dam (RM 200 and above) and the section below Dardanelle Lock and Dam.

2. The seasonal abundance patterns indicate that zooplankton densities are minimal during the winter and maximal during the summer and fall. The mean densities for the Arkansas River show that the overall production of zooplankton is relatively high as compared to other well-known rivers.

3. In general, the overall abundance of zooplankton decreases downstream from the upper reaches to the lower.

4. Clearly, the Rotatoria are the most important zooplankters in terms of numbers and diversity. The Copepoda are the most significant among the entomostracans.

5. The most important zooplankters observed throughout the study were: nauplii, *Polyarthra vulgaris*, *Keratella cochlearis*, *Conochilus unicornis*, *Pedipartia sp.*, *Brachionus calyciflorus*, *Hexarthra mira*, *Brachionus angularis*, *Keratella earlinae*, *Synchaeta pectinata*, *Keratella valga*, *Kellicottia bostoniensis*, *Synchaeta oblonga*, *Branchionus urceolaris*, *Bosmina longirostris*, *Diaphansoma leuchtenbergianum*, *Ceriodaphnia lacustris*, *Caphnia parvula*, and *Holopedium amazonicum*. All of these occur throughout North America, and the list is in agreement with other workers except for the genus *Pedipartia*. *Pedipartia spp.* are considered psammolittoral forms, but even so the genus dominated the zooplankton associations

during January 1975.

6. The Arkansas River exhibited a diverse zooplankton fauna during the 1974-75 study period; five Copepoda, 23 Cladocers, and 88 Rotatoria were identified.

7. There were significant differences found in the number of taxa recovered at each station during the respective sampling periods. However, these differences cannot be traced to any specific factor based upon the available data.

8. Temperature seems to be a controlling factor affecting the seasonal productivity of zooplankton in the Arkansas River. The production of zooplankton increased sooner in the lower reaches of the Arkansas River as the water began to warm in an upstream direction.

9. The chemical characteristics of the Arkansas River (e.g. dissolved oxygen, hydrogen ion concentration, and alkalinity) seem to be adequate and capable of sustaining a rich plankton population. However, the available physical-chemical data is not adequate to show any specific correlations.

10. Comparative analysis of the historical review and the summary of the present study show that the construction of the locks and dams, and subsequently the impoundments, have profoundly affected zooplankton production in the Arkansas River. The "river lakes" (fast turnover impoundments), especially in upper regions, have increased the density and production of zooplankton

to a significant degree. The overall seasonal abundance patterns of zooplankton probably have not been affected by the construction of the "river lakes" or a navigation system in the Arkansas River. The longitudinal decrease in abundance of zooplankton is amplified by the decrease in backwater areas, and the increase in water current and silt load within a portion of the lower section of the Arkansas River (RM 201-210.3). The qualitative composition of zooplankton has not been affected, but the community structure and diversity have changed as a consequence of increased production of certain dominant species due to changes in the habitat within the river.

11. Dredging may affect zooplankton via turbidity, stream flow, habitat destruction, mechanical destruction, chemical change, and toxic substances. To measure and monitor such effects, many stations must be established above, within, and below the dredging operation areas. This is necessary to gain adequate insight into the longitudinal effects of dredging on water quality and biological conditions. To measure the effects of dredge spoils upon the deposition area, a similar type of monitoring program must be conducted during this study. Therefore, it is nearly impossible to evaluate the effects of dredging upon the physical-chemical characteristics or zooplankton associations within specific local sites on the Arkansas River.

Benthos

1. Eight benthic groups appeared to be the most abundant and the most widely distributed in the 240-mile long study reach. These groups are: Nematoda, Oligochaeta, Crustacea, Trichoptera, Ephemeroptera, Chironomidae, other insects, and Mollusca.

2. Some groups were more abundant in the fall and tapered off in the spring (e.g. the bivalved mollusk, *Corbicula*). Some groups were remarkably constant in abundance through the sampling periods (e.g. Chironomidae). Some were more abundant in April than in October (e.g. Oligochaeta).

3. Biologically the most significant finding of the benthic study was the prevalence of an introduced bivalve, *Corbicula*, throughout the study reach.

4. *Corbicula* and chironomid larvae were the most abundant groups and the most widely distributed groups in the river during all collecting seasons.

5. Oligochaetes, although numerically abundant, were the most limited of the larger groups in their distribution in the river.

6. With regard to the longitudinal distribution of the benthic fauna in the Arkansas River, there appear to be at least three regions: (1) the region above Lake Dardanelle, characterized by boulders in the substrate with gastropods and mayfly larvae; (2) the region below Lake Dardanelle and on through the long

mid-region of the study reach, characterized by much sandy substrate and a fauna comprised essentially of *Corbicula* and chironomid midge larvae; and (3) the region at the lower end of the study reach near Mud Lake, characterized by pollution-tolerant organisms such as the oligochaetes, *Tubifex tubifex* and *Limnodrilus uedekiamus*.

7. Dissolved oxygen concentrations did not appear to effect the abundance and distribution of benthic fauna except in the lower reaches where the dominant organisms were pollution tolerant forms.

8. Of the physical parameters considered, substrate and substrate particle size seem to be the most important for the Arkansas River benthic fauna. Characteristic fauna were associated with samples containing various kinds of particles. It was noted that prevalence of sandy substrate in the long mid-region of the study reach coincided with the almost exclusive habitat of chironomid larvae and the bivalve, *Corbicula.* Samples containing only very fine, fine, and medium sand were invariably the most barren of all.

9. The benthic fauna of the Arkansas River was more abundant and diverse than anticipated at the outset of the study. The benthic communities as a whole do not show the stability one would expect from a "natural " river; nor do they show the characteristic composition or diversity of such streams.

10. It may be that a combination of the peculiar habits of *Corbicula* and the sediment-moving practices of river management on the Arkansas River have brought about the wide distribution of *Corbicula* in the benthos of the river.

Fish

1. The total assemblage of fishes present in the system indicates that the system currently supports a rich, diverse fish fauna with good populations of most native forms.

2. The present study produced 51 species previously reported from the river; five species previously reported from the river have not been collected since the construction of the navigation system. A few species such as the shovelnose sturgeon paddlefish and alligator gar appear to have declined somewhat in abundance. The decline or absence of these species cannot be definitely attributed to the construction of the system, because of a lack of preconstruction data.

3. Of the 106 species collected during the present investigation, 46 (43%) probably represent stragglers that are accidental to the navigation system. These are mainly from the lowland tributaries and are not believed to maintain populations in the main channel itself. Their occasional presence in the system indicates the value of this large river as a dispersal route.

4. The accidental species, as well as the 20 fishes that apparently do maintain only small populations in the system, are useful as indicators of ecological conditions in the river.

5. Forty species were common or abundant throughout most of the navigation system. Many of these species are of sport or commercial significance.

6. Of the 106 species of fishes collected from the navigation system, 63 were found in the Arkansas River Physiographic Region and the Gulf Coastal Plain Physiographic Region, 17 were found only in the Arkansas Valley Physiographic Region, and 26 were found only in the portion of the system flowing through the Gulf Coastal Plain Physiographic Region. It appears that the differences in physiographic regions have little impact on the distributional patterns of most species which maintain permanent, stable populations in the navigation system, especially those species of commercial or sport significance.

7. Most species of fishes in the navigation system exhibit at least some sort of seasonal variation in distributional patterns. The most commonly observed seasonal changes involve spawning migrations of various types.

8. Many species show marked feeding migrations over a 24-hour period. Night seining and electro-fishing, particularly in the areas of dredge deposits, resulted in the collection of large numbers of fishes that were rarely or never collected by these methods during daylight hours.

9. Although the fish communities of the Arkansas System are presently in good condition, the potential for a rapid change in

this status definitely exists.

10. Dredged material disposal areas were highly variable in their construction, physical features, and suitability for fish populations. No two disposal areas were alike with respect to all of these features, and it was not possible to make generalizations about the fish populations of dredged material disposal sites as compared with non-dredged material disposal areas. Just as in the non-dredged material disposal areas, some disposal sites supported diverse fish populations with many desirable gamefish, whereas other disposal sites exhibited very poor fish habitat and few desirable gamefish. All species which were common throughout the navigation system, including the important game and commercial fishes, were well-represented in both dredged material disposal and non-dredged material disposal samples.

RECOMMENDATIONS

Based on the information obtained through this study of the various segments composing the biotic communities of the Arkansas River, several recommendations are made that will, hopefully, aid in the present and future assessment of dredging activities on the Arkansas River.

1. Limit dredging activities to those necessary to maintain the navigation system.
2. Minimize grand scale dredging activities; i.e., simultaneous dredging from the upper reaches of the Arkansas River to the lower, if at all possible.
3. Minimize dredging activities in backwater areas, mouths of tributaries, and any slower flowing waters suitable for feeding and breeding ground for biota.
4. If dredging is necessary near the mouths of tributaries, the materials removed should be placed well upon the banks out of the water.
5. In order to make a better assessment of the effects of dredging, the study area should be confined to a particular zone of dredging that is under the least influence of local conditions, such as sewage outflows, navigational locks and dams, etc.
6. Passageways from the upper reaches to the lower, and

between dredge spoil backwaters should be maintained.

7. The backwater cover (vegetation, brush, etc.) should not be removed from shallow areas or from the banks. It should also not be covered with dredged materials.
8. Dredged material disposal areas should not be deposited in old river cutoffs or existing bends.
9. Dredged material disposal areas should be constructed with extensive areas of deep and shallow backwaters wherever possible.
10. Dredged material should not be placed in backwater habitats, since such would obliterate entire assemblages of zooplankton. Place dredged materials in areas in such a way as to minimize the turbidity and mixing factors.
11. It would be better to dredge when light and temperature are limiting in order to minimize mass destruction of the phytoplankton populations. Time of dredging is important since the abundance of phytoplankton during dredging in one particular season does not necessarily reflect what will happen to the populations in other seasons.
12. A stable, diversified abundant river benthic fauna is characteristically associated with a variety of substrate types, particularly coarse particles with sizeable "interstices", and with detritus. Therefore, any river management practices which would develop or maintain such

a diverse substrate is recommended.

13. To adequately evaluate long-term effects of dredging in the Arkansas River, information is needed on the composition of the substrate above, at, and below specific sites where dredging operations occur.

14. The composition of the dredged sediments should be monitored for toxic substances. Examination of such soils for benthic fauna (tolerant and/or non-tolerant organisms) would provide immediate clues about the "health" of the benthic habitat.

15. With regard to the "thread" artifact found in many benthic samples of the present study, it is suggested that appropriate engineering personnel inquire into the source and/or potential long-term effect of the artifact, as it relates to the Arkansas River habitat.

16. It is suggested that regular long-term biomonitoring of the river substrate and benthic biota be conducted in connection with the regular, routine duties now employed in substrate sampling (Corps of Engineers, Hydraulic Division, Little Rock District).

17. The *Corbicula* population in the Arkansas River should be monitored throughout the year. *Corbicula* is so widely distributed and so abundant in the river, that the other groups of organisms with much more limited abundance and

distribution can be expected to be more readily, adversely affected than *Corbicula* by any changes in the river's environment. Yet it is the other groups of organisms which are known to possess the capacity for producing stable, diverse benthic communities in the river benthos.

18. Spawning habitats during periods of high water should be improved. The planting of some type of fast-growing cover crop on the dredged material disposal areas when they are exposed during low water periods would stabilize these areas and provide much more suitable spawning habitats when high spring waters occur. This would have the additional function of providing food for wildlife during normal flows. Extensive plantings of grasses, legumes, or other suitable vegetation along the navigation system would do much to offset the adverse effects of the dredging process itself and the reduction in environment heterogeneity associated with many of the dredged material disposal areas.
19. For long-term scientific studies of the biota of the Arkansas River, it is recommended that at least a substantial proportion of the organisms from the present and/or future studies of the river, be housed in an appropriate, accessible manner.
20. It is a well-known fact that fish feed upon zooplankton, especially during larval stages. Macroinvertebrates also

feed upon plankton, and it has been suggested that a trophic relationship exists between zooplankton and phytoplankton. Therefore, dredging activities, dredged material deposition, and other activities within the Arkansas River aquatic system must be directed with the "whole" biotic community in mind.

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APPENDIX

TABLE 1

TEMPERATURE AND TURBIDITY DATA OCTOBER

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	*NTU's	MEAN NTU's/STA
283	1	1	0	20.6	19.9	19	23
283	1	1	4	20.6	(67.7°F)	22	
283	1	2	0	19.5		19	
283	1	2	4	19.5		23	
283	1	3	0	19.5		30	
283	1	3	5	19.5		26	
248	2	1	0	19.0	19.3	22	26
248	2	1	3.5	19.0	(66.5°F)	22	
248	2	2	0	19.0		29	
248	2	2	2.5	19.0		27	
248	2	3	0	19.5		28	
248	2	3	2.5	19.5		30	
248	2	4	0	19.5		27	
248	2	4	2.5	19.5		28	
238	3	1	0	19.5	19.5	25	24
238	3	1	2.0	19.5	(67.0°F)	24	
199	4	1	0	19.8	19.8	41	35
199	4	1	2.5	19.8	(67.5°F)	39	
199	4	2	0	19.8		34	
199	4	2	2.5	19.8		41	
199	4	3	0	19.8		27	
199	4	3	2.5	19.8		30	
199	4	4	0	19.8		36	
199	4	4	2.5	19.8		33	
189	5	1	0	19.0	19.0	30	32
189	5	1	2.5	19.0	(66.0)	30	
189	5	2	0	19.0		30	
189	5	2	2.5	19.0		33	
189	5	3	0	19.0		32	
189	5	3	2.5	19.0		32	
189	5	4	0	19.0		33	
189	5	4	2.5	19.0		36	

*Nephelometric Turbidity Units

TEMPERATURE AND TURBIDITY DATA (CONT.)

OCTOBER

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
171	6	1	0	19.5	19.5	50	38
171	6	1	2.5	19.5	(67.0°F)	41	
171	6	2	0	19.5		41	
171	6	2	2.5	19.5		38	
171	6	3	0	19.5		41	
171	6	3	2.5	19.5		31	
171	6	4	0	19.5		27	
171	6	4	3.0	19.5		41	
155	7	1	0	19.5	19.5	39	37
155	7	1	3.5	19.5	(67.0°F)	41	
155	7	2	0	19.5		31	
155	7	2	3.0	19.5		39	
155	7	3	0	19.5		41	
155	7	3	3.0	19.5		38	
155	7	4	0	19.5		27	
155	7	4	3.0	19.5		41	
147	8	1	0	19.2	19.3	38	37
147	8	1	2.5	19.2	(66.6°F)	32	
147	8	2	0	19.3		33	
147	8	2	2.5	19.3		41	
147	8	3	0	19.5		43	
147	8	3	2.5	19.5		38	
125	9	1	0	20.1	20.1	38	38
125	9	1	3.5	20.1	(68.0°F)	42	
125	9	2	0	20.1		38	
125	9	2	2.5	20.1		39	
125	9	3	0	20.1		35	
125	9	3	2.5	20.1		35	
125	9	4	0	20.1		40	
125	9	4	2.5	20.1		41	
108	10	1	0	18.5	18.5	32	26
108	10	1	2.5	18.5	(65.0°F)	29	
108	10	2	0	18.5		28	
108	10	2	2.5	18.5		29	
108	10	3	0	18.5		30	
108	10	3	2.5	18.5		30	

TEMPERATURE AND TURBIDITY DATA (CONT.) OCTOBER

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
106	10	4	0	18.5	18.5	30	26
106	10	4	2.0	18.5	(65.0°F)	29	
106	10	5	0	18.5		24	
106	10	5	2.5	18.5		27	
106	10	6	0	18.5		27	
106	10	6	2.5	18.5		28	
86	11	1	0	19.0	19.0	27	27
86	11	1	2.3	19.0	(66.0°F)	26	
86	11	2	0	19.0		29	
86	11	2	2.5	19.0		24	
86	11	3	0	19.0		26	
86	11	3	2.0	19.0		27	
86	11	4	0	19.0		26	
86	11	4	2.5	19.0		31	
71	12	1	0	18.5	18.6	29	26
71	12	1	2.5	18.5	(65.5°F)	26	
71	12	2	0	18.5		25	
71	12	2	2.5	18.5		23	
71	12	3	0	19.0		17	
71	12	3	2.5	19.0		29	
71	12	4	0	19.0		30	
71	12	4	2.0	19.0		29	
46	13	1	0	19.0	19.8	31	29
46	13	1	2.8	19.0	(67.4°F)	28	
46	13	2	0	19.8		25	
46	13	2	2.0	19.8		26	
46	13	3	0	19.8		27	
46	13	3	2.3	19.8		29	
45	13	4	0	19.5		35	
45	13	4	2.5	19.5		39	
43	13	5	0	19.8		27	
43	13	5	2.5	19.8		31	
43	13	6	0	20.1		31	
43	13	6	2.5	20.1		31	
43	13	7	0	20.5		54	
43	13	7	1.8	20.5		29	
45	13	8	0	20.1		24	
45	13	8	2.5	20.1		29	
45	13	9	0	19.5		27	
45	13	9	2.3	19.5		14	

TABLE 1 (CONT.)

TEMPERATURE AND TURBIDITY DATA JANUARY

RM	STA.	SITE	DEPTH (FT.)	TEMP ^{o}C	MEAN TEMP/STA	*NTU's	MEAN NTU's/STA
283	1	1	0	6.8	6.8	16	16
283	1	1	5	6.8	(44.0^{o}F)	20	
283	1	2	0	6.8		16	
283	1	2	6	6.8		17	
283	1	3	0	6.8		15	
283	1	3	2.5	6.8		16	
283	1	4	0	6.8		17	
283	1	4	3	6.8		15	
248	2	1	0	5.7	5.7	18	15
248	2	1	3	5.7	(42.0^{o}F)	11	
248	2	2	0	5.7		19	
248	2	2	5	5.7		16	
248	2	3	0	5.7		16	
248	2	3	4	5.7		14	
248	2	4	0	5.7		16	
248	2	4	3	5.7		12	
238	3	1	0	6.2	6.2	14	14
238	3	1	2.5	6.2	(43.0^{o}F)	15	
199	4	1	0	6.8	6.5	14	14
199	4	1	2.5	6.8	(43.5^{o}F)	15	
199	4	2	0	6.8		14	
199	4	2	3	6.8		16	
199	4	3	0	6.2		15	
199	4	3	3	6.2		14	
199	4	4	0	6.2		15	
199	4	4	3	6.2		15	
189	5	1	0	6.2	6.2	15	14
189	5	1	3	6.2	(43.0^{o}F)	14	
189	5	2	0	6.2		15	
189	5	2	3	6.2		14	
189	5	3	0	6.2		14	
189	5	3	3	6.2		15	
189	5	4	0	6.2		15	
189	5	4	3	6.2		15	

*Nephelometric Turbidity Units

TEMPERATURE AND TURBIDITY DATA (CONT.)

JANUARY

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
171	6	1	0	5.7	5.7	13	13
171	6	1	2.5	5.7	(42.0°F)	13	
171	6	2	0	5.7		13	
171	6	2	4	5.7		13	
171	6	3	0	5.7		13	
171	6	3	4	5.7		13	
171	6	4	0	5.7		13	
171	6	4	4	5.7		13	
155	7	1	0	5.7	5.7	13	13
155	7	1	3.5	5.7	(42.0°F)	14	
155	7	2	0	5.7		13	
155	7	2	2.5	5.7		13	
155	7	3	0	5.7		13	
155	7	3	6	5.7		13	
155	7	4	0	5.7		13	
155	7	4	5	5.7		13	
147	8	1	0	5.1	5.1	14	13
147	8	1	3	5.1	(41.0°F)	13	
147	8	2	0	5.1		13	
147	8	2	5	5.1		12	
147	8	3	0	5.1		13	
147	8	3	3	5.1		13	
125	9	1	0	5.1	5.1	13	13
125	9	1	5	5.1	(41.0°F)	13	
125	9	2	0	5.1		13	
125	9	2	4	5.1		13	
125	9	3	0	5.1		13	
125	9	3	4	5.1		13	
125	9	4	0	5.1		13	
125	9	4	4.5	5.1		13	
108	10	1	0	5.7	5.4	13	13
108	10	1	4	5.7	(41.4°F)	13	
108	10	2	0	5.7		13	
108	10	2	3	5.7		13	
108	10	3	0	5.7		13	
108	10	3	4	5.7		13	
108	10	4	0	5.7		13	
108	10	4	3	5.7		13	
108	10	5	0	5.1		13	
108	10	5	3	5.1		13	
108	10	6	0	4.5		13	
108	10	6	4	4.5		13	

TEMPERATURE AND TURBIDITY DATA (CONT.) JANUARY

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
86	11	1	0	5.1	5.1	13	12
86	11	1	5	5.1	(41.0°F)	13	
86	11	2	0	5.1		13	
86	11	2	4.5	5.1		12	
86	11	3	0	5.1		13	
86	11	3	5	5.1		13	
86	11	4	0	5.1		12	
86	11	4	5	5.1		13	
71	12	1	0	5.1	5.6	13	12
71	12	1	4	5.1	(41.8°F)	13	
71	12	2	0	5.7		13	
71	12	2	4	5.7		13	
71	12	3	0	5.7		12	
71	12	3	4	5.7		12	
71	12	4	0	5.7		13	
71	12	4	5	5.7		13	
45	13	1	0	5.7	5.8	13	18
45	13	1	3.5	5.7	(42.2°F)	13	
45	13	2	0	5.7		14	
45	13	2	3	5.7		13	
45	13	3	0	5.7		13	
45	13	3	3	5.7		13	
45	13	4	0	5.7		13	
45	13	4	3	5.7		14	
45	13	5	0	5.7		12	
45	13	5	5	5.7		15	
45	13	6	0	5.7		13	
45	13	6	5	5.7		14	
45	13	7	0	5.7		14	
45	13	7	2	5.7		14	
45	13	8	0	6.2		42	
45	13	8	4	6.2		43	
45	13	9	0	6.2		32	
45	13	9	3	6.2		32	
42.6	13	10	0	5.7		13	
42.6	13	10	6	5.7		14	

TABLE 1 (CONT.)

TEMPERATURE AND TURBIDITY DATA APRIL

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	*NTU's	MEAN NTU's/STA
283	1	1	0	12.2	12.2	13	12
283	1	1	7.0	12.2	(54.0°F)	14	
283	1	2	0	12.2		13	
283	1	2	6.0	12.2		14	
283	1	3	0	12.2		13	
283	1	3	2.5	12.2		13	
283	1	4	0	12.2		11	
283	1	4	3.0	12.2		12	
248	2	1	0	12.2	12.2	12	12
248	2	1	5.0	12.2	(54.0°F)	13	
248	2	2	0	12.2		13	
248	2	2	6.0	12.2		12	
248	2	3	0	12.2		12	
248	2	3	5.0	12.2		13	
248	2	4	0	12.2		13	
248	2	4	5.0	12.2		14	
238	3	1	0	13.2	13.2	12	12
238	3	1	3	13.2	(56.0°F)	12	
199	4	1	0	14.0	14.4	11	11
199	4	1	2.5	14.0	(57.8°F)	11	
199	4	2	0	14.5		11	
199	4	2	4	14.5		12	
199	4	3	0	14.5		12	
199	4	3	4	14.5		12	
199	4	4	0	14.5		11	
199	4	4	3	14.5		12	
189	5	1	0	15.1	14.7	11	10
189	5	1	2	15.1	(58.3°F)	11	
189	5	2	0	14.5		11	
189	5	2	2.5	14.5		11	
189	5	3	0	14.5		9	
189	5	3	4.0	14.5		11	
189	5	4	0	14.5		11	
189	5	4	4.0	14.5		12	

TEMPERATURE AND TURBIDITY DATA (CONT.)

APRIL

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
171	6	1	0	15.1	15.1	12	12
171	6	1	4	15.1	(59.0°F)	12	
171	6	2	0	15.1		12	
171	6	2	4	15.1		13	
171	6	3	0	15.1		13	
171	6	3	2	15.1		12	
171	6	4	0	15.1		11	
171	6	4	4	15.1		13	
155	7	1	0	15.6	15.6	13	11
155	7	1	2	15.6	(60.0°F)	13	
155	7	2	0	15.6		11	
155	7	2	3.5	15.6		11	
155	7	3	0	15.6		11	
155	7	3	6.0	15.6		12	
155	7	4	0	15.6		11	
155	7	4	5.0	15.6		11	
147	8	1	0	15.6	15.6	13	12
147	8	1	3.0	15.6	(60.0°F)	12	
147	8	2	0	15.6		13	
147	8	2	3.0	15.6		13	
147	8	3	0	15.6		12	
147	8	3	4.0	15.6		12	
125	9	1	0	16.8	16.8	11	11
125	9	1	2.5	16.8	(62.0°F)	11	
125	9	2	0	16.8		12	
125	9	2	2.5	16.8		12	
125	9	3	0	16.8		12	
125	9	3	3.5	16.8		13	
125	9	4	0	16.8		11	
125	9	4	3.5	16.8		11	
108	10	1	0	16.8	16.8	11	11
108	10	1	3.0	16.8	(62.0°F)	11	
108	10	2	0	16.8		12	
108	10	2	2.5	16.8		12	
108	10	3	0	16.8		13	
108	10	3	3.0	16.8		12	
108	10	4	0	16.8		10	
108	10	4	2.5	16.8		11	
108	10	5	0	16.8		11	
108	10	5	3.5	16.8		11	
108	10	6	0	16.8		11	
108	10	6	3.0	16.8		10	

TEMPERATURE AND TURBIDITY DATA (CONT.) APRIL

RM	STA.	SITE	DEPTH (FT.)	TEMP °C	MEAN TEMP/STA	NTU's	MEAN NTU's/STA
86	11	1	0	17.2	17.2	11	10
86	11	1	5.0	17.2	(63.0°F)	12	
86	11	2	0	17.2		11	
86	11	2	3.0	17.2		11	
86	11	3	0	17.2		10	
86	11	3	4.0	17.2		10	
86	11	4	0	17.2		10	
86	11	4	3.5	17.2		11	
71	12	1	0	17.2	17.9	10	10
71	12	1	4	17.2	(64.0°F)	10	
71	12	2	0	17.2		10	
71	12	2	3.5	17.2		11	
71	12	3	0	18.5		9	
71	12	3	3.5	18.5		10	
71	12	4	0	18.5		9	
71	12	4	4.0	18.5		10	
45	13	1	0	18.5	19.0	10	10
45	13	1	4	18.5	(66.0°F)	11	
45	13	2	0	18.5		11	
45	13	2	3	18.5		9	
45	13	3	0	18.5		10	
45	13	3	3	18.5		9	
45	13	4	0	20.1		11	
45	13	4	4	20.1		8	
45	13	5	0	18.5		12	
45	13	5	4	18.5		11	
45	13	6	0	18.5		12	
45	13	6	3.5	18.5		11	
45	13	7	0	18.5		12	
45	13	7	3	18.5		11	
45	13	8	0	20.1		11	
45	13	8	4.5	20.1		12	
45	13	9	0	20.1		12	
45	13	9	3.5	20.1		12	
45	13	10	0	19.0		10	
45	13	10	10.0	19.0		11	

TABLE 2

SAS RIVER PHYSICO-CHEMICAL DATA

Y DATE 10-14-74 THRU 10-23-74

SITE	RMILE	BOTDEP	SAM.DEP	SP.CON	TEMP	PH	DO	ALK	SECCHI
1	283.0	9.0	5.0	300	69.0	6.40	9.8	100	1.50
2	283.0	7.0	4.0	300	67.0	7.10	9.5	110	1.50
3	283.0	6.0	5.0	700	67.0	6.50	9.0	90	1.50
1	248.0	5.0	2.5	675	66.0	6.50	7.7	90	1.50
2	248.0	5.0	2.5	700	66.0	6.50	8.9	110	1.50
3	248.0	5.0	2.5	580	67.0	6.40	8.8	90	1.50
4	248.0	5.0	2.5	750	67.0	6.20	9.0	80	1.25
1	238.0	3.0	2.0	725	67.0	6.70	6.7	85	1.25
1	199.0	5.0	2.5	475	67.5	6.60	8.1	90	1.50
2	199.0	5.0	2.5	480	67.5	6.60	8.1	110	1.50
3	199.0	5.0	2.5	420	67.5	6.80	7.9	90	1.50
4	199.0	5.0	2.5	420	67.5	7.08	8.1	80	1.50
4	189.0	5.0	2.5	480	66.0	6.80	8.4	80	1.50
3	189.0	5.0	2.5	480	66.0	7.20	8.6	200	1.50
2	189.0	5.0	2.5	480	66.0	7.20	8.5	90	1.50
1	189.0	5.0	2.5	480	66.0	7.10	8.2	70	1.50
1	171.0	5.0	2.5	385	67.0	8.20	8.3	95	1.00
2	171.0	5.0	2.5		67.0	8.20	8.7	90	1.00
3	171.0	5.0	2.5	480	67.0	8.20	8.4	100	1.00
4	171.0	6.0	3.0	440	67.0	7.65	8.6	85	1.00
1	155.0	7.0	3.5	480	67.0	7.50	8.6	100	1.25
2	155.0	6.0	3.0	440	67.0	6.10	8.7	95	1.30
3	155.0	6.0	3.0	440	67.0	6.80	8.7	90	1.00
4	155.0	6.0	3.0	450	66.0	8.20	8.6	95	1.25
1	147.0	5.0	2.5	420	66.0	8.00	9.0	80	1.50
2	147.0	4.0	2.0	1400	67.0	0.00	8.8	80	1.00
3	147.0	5.0	2.5	690	67.0	0.00	9.2	0	1.40
1	125.0	7.0	3.5	420	68.0	7.70	10.8	105	1.30
2	125.0	5.0	2.5	460	68.0	8.10	9.4	90	1.30
3	125.0	5.0	2.5	480	68.0	7.70	9.2	90	1.00
4	125.0	5.0	2.5	440	68.0	7.70	9.2	85	1.00
1	108.0	5.0	2.5	1100	65.0	8.30	9.5	100	1.25
2	108.0	5.0	2.5	975	65.0	8.40	9.2	97	1.25
3	108.0	5.0	2.5	390	65.0	8.30	9.2	100	1.20
4	105.0	4.0	2.0	1050	65.0	8.60	9.4	77	1.20
5	106.0	5.0	2.5	500	66.0	8.70	9.8	100	1.20
6	106.0	5.0	2.5	460	65.0	8.60	9.5	100	1.25
1	86.0	4.5	2.3	420	66.0	8.20	10.1	100	1.50
2	86.0	5.0	2.5	460	66.0	8.30	9.5	80	1.50
3	86.0	4.0	2.0	450	66.0	8.30	9.8	75	1.50
4	85.0	5.0	2.5	460	66.0	8.40	9.0	90	1.50
1	71.0	5.0	2.5	420	65.0	9.20	9.0	80	1.50
2	71.0	5.0	2.5	460	66.0	8.60	9.3	75	1.50
3	71.0	5.0	2.5	400	66.0	8.30	9.2	90	1.50
4	71.0	4.0	2.0	400	66.0	8.70	9.1	90	1.75
9	45.0	4.5	2.3	440	67.0	8.30	9.6	110	1.75
8	45.0	5.0	2.5	440	68.0	8.30	11.4	160	1.75
4	45.0	5.0	2.5	475	67.0	8.30	9.6	120	1.50
1	46.0	5.5	2.8	475	66.0	9.10	9.6	90	1.50
2	46.0	4.0	2.0	380	67.0	9.10	9.4	85	1.50
3	46.0	4.5	4.3	435	67.0	8.30	9.6	75	1.50
5	43.0	5.0	2.5	400	68.0	8.20	9.9	80	1.50
6	43.0	5.0	2.5	500	68.0	8.30	9.8	80	1.50
7	43.0	3.5	1.8	540	69.0	8.10	10.1	70	1.25

OM DEPTH AND SAMPLE DEPTH IN FEET
IFIC CONDUCTIVITY IN MICRO-MHOS
ERATURE IN DEGREES FAHRENHEIT
AND ALKALINITY IN MILLIGRAMS PER LITER
HI IN FEET

TABLE 2 (CONT.)

ANSAS RIVER PHYSICO-CHEMICAL DATA

VEY DATE 01-14-74 THRU 01-24-74

AT	SITE	RMILE	BOTDEP	SAM.DEP	SP.CON	TEMP	PH	DO	ALK	SECCHI
	1	283.0	10.0	5.0		44.0	7.31	12.4	130	0.80
	2	283.0	12.0	6.0		44.0	6.90	12.2	100	0.90
	3	283.0	5.0	2.5		44.0	6.90	12.6	100	0.80
	4	283.0	6.0	3.0		44.0	6.80	13.2	100	0.75
	1	248.0	6.0	3.0		42.0	6.80	12.4	100	0.75
	2	248.0	10.0	5.0		42.0	5.90	12.7	120	0.75
	3	248.0	8.0	4.0		42.0	6.90	12.8	110	0.75
	4	248.0	6.0	3.0			6.60	12.6	110	0.60
	1	238.0	5.0	2.5	440	43.0	6.90	12.7	110	1.00
	1	199.0	5.0	2.5	500	43.0	7.15	13.2	120	0.75
	2	199.0	6.0	3.0	490	43.0	6.50	13.0	90	0.75
	3	199.0	6.0	3.0	490	43.0	6.50	12.8	100	0.75
	4	199.0	6.0	3.0	530	43.0	6.50	12.8	100	0.75
	1	189.0	6.0	3.0	530	43.0	6.50	12.8	110	0.75
	2	189.0	6.0	3.0	500	43.0	6.60	12.5	110	0.75
	3	189.0	6.0	3.0	510	43.0	6.60	12.4	110	0.75
	4	189.0	6.0	3.0	510	43.0	6.60	12.4	110	0.75
	1	171.0	5.0	2.5	550	42.0	6.80	13.0	90	0.75
	2	171.0	8.0	4.0	525	42.0	6.40	13.1	100	0.75
	3	171.0	8.0	4.0	420	42.0	6.80	13.1	110	0.75
	4	171.0	8.0	4.0	480	42.0	6.80	14.0	120	1.00
	1	155.0	7.0	3.1	500	42.0	6.70	12.9	100	0.75
	2	155.0	7.0	3.5	420	42.0	6.40	13.0	100	0.75
	3	155.0	12.0	6.0	460	42.0	6.60	13.0	100	0.75
	4	155.0	10.0	5.0	420	42.0	5.70	13.1	110	0.75
	1	147.0	8.0	4.0	400	41.0	6.60	13.0	110	0.75
	2	147.0	10.0	5.0	380	41.0	6.70	13.0	100	1.00
	3	147.0	6.0	3.0	480	41.0	6.40	13.0	100	1.00
	1	125.0	10.0	5.0	380	41.0	6.70	13.0	100	1.00
	2	125.0	8.0	4.0	420	41.0	6.70	13.1	100	1.00
	3	125.0	8.0	4.0	440	41.0	6.90	13.1	100	1.00
	4	125.0	9.0	4.5	540	41.0	6.90	13.6	110	1.00
	1	108.0	8.0	4.0	420	42.0	6.70	13.1	90	1.00
	2	108.0	6.0	3.0	490	42.0	6.80	13.1	100	1.00
	3	108.0	8.0	4.0	480	42.0	6.90	13.1	110	1.00
	4	108.0	6.0	3.0	425	41.0	6.60	13.0	100	1.00
	5	108.0	6.0	3.0	420	41.0	6.60	13.0	100	1.00
	6	108.0	8.0	4.0	400	40.0	6.50	13.2	110	1.00
	1	86.0	10.0	5.0	420	41.0	7.30	13.2	100	1.00
	2	86.0	9.0	4.5	410	41.0	6.60	13.2	110	1.00
	3	86.0	10.0	5.0	410	41.0	6.70	13.2	90	1.00
	4	85.0	10.0	5.0	410	41.0	3.20	13.2	100	1.00
	1	71.0	8.0	4.0	525	42.0	7.30	13.2	90	1.00
	2	71.0	8.0	4.0	425	42.0	7.40	12.9	100	1.00
	3	71.0	8.0	4.0	410	42.0	7.30	13.0	100	1.10
	4	71.0	10.0	5.0	490	42.0	7.25	13.0	110	1.10
	1	45.0	7.0	3.5	500	42.0	7.41	13.3	90	0.75
	2	45.0	6.0	3.0	500	42.0	7.40	13.3	100	0.75
	3	45.0	6.0	3.0	425	42.0	7.40	13.3	100	0.75
	4	45.0	6.0	3.0	405	42.0	7.10	13.3	110	0.75
	5	45.0	10.0	5.0	520	42.0	7.50	13.3	100	0.75
	6	45.0	10.0	5.0	520	42.0	7.40	13.3	110	0.75
	7	45.0	4.0	2.0	510	42.0	7.30	13.3	100	0.75
	8	45.0	8.0	4.0	280	43.0	7.10	11.4	80	0.50
	9	45.0	6.0	3.0	410	43.0	7.10	11.0	120	0.50
	10	45.0	12.0	6.0	410	42.0	7.40	13.7	100	1.00

OTTOM DEPTH AND SAMPLE DEPTH IN FEET
ECIFIC CONDUCTIVITY IN MICRO-MHOS
MPERATURE IN DEGREES FAHRENHEIT
O. AND ALKALINITY IN MILLIGRAMS PER LITER
CCHI IN FEET

TABLE 2 (CONT.)

AS RIVER PHYSICO-CHEMICAL DATA

DATE 04-14-75 THRU 04-24-75

SITE	RMILE	BOTDEP	SAM.DEP	SP.CON	TEMP	PH	DO	ALK	SECCHI
1	283.0	15.0	7.0	425	54.0	6.90	11.8	92	1.00
2	283.0	12.0	6.0	365	54.0	7.55	12.1	96	1.00
3	283.0	6.0	2.5	365	54.0	8.10	11.4	88	1.00
4	283.0	7.0	3.0	410	54.0	5.10	12.1	96	1.00
1	248.0	10.0	5.0	380	54.0	6.90	11.8	92	1.00
2	248.0	13.0	6.0	375	54.0	7.30	11.6	88	1.00
3	248.0	10.0	5.0	380	54.0	7.20	11.9	96	1.00
4	248.0	10.0	5.0	380	54.0	7.40	11.3	92	1.00
1	238.0	6.5	3.0	500	56.0	7.20	11.4	96	1.25
1	199.0	5.0	2.5	355	57.0	6.90	11.6	96	1.00
2	199.0	10.0	5.0	520	58.0	6.80	11.9	80	0.75
3	199.0	8.0	4.0	545	58.0	6.90	11.6	95	0.80
4	199.0	6.0	3.0	405	58.0	7.00	11.6	96	1.00
1	189.0	4.0	2.0	395	59.0	7.20	10.7	92	1.00
2	189.0	5.0	2.5	505	59.0	7.10	10.6	92	1.00
3	189.0	8.0	4.0	495	59.0	7.15	10.7	90	1.00
4	189.0	8.0	4.0	520	59.0	7.20	10.6	92	1.00
1	171.0	8.0	4.0	450	59.0	7.10	10.8	84	0.80
2	171.0	8.0	4.0	445	59.0	7.20	10.6	80	1.00
3	171.0	4.0	2.0	355	59.0	7.20	10.6	80	1.00
4	171.0	8.0	4.0	400	59.0	7.20	10.4	84	1.00
1	155.0	4.0	2.0	420	60.0	7.10	10.3	88	1.00
2	155.0	7.0	3.5	470	60.0	7.05	10.4	88	1.00
3	155.0	12.0	6.0	445	60.0	7.10	10.5	84	1.00
4	155.0	10.0	5.0	365	60.0	7.00	10.4	88	1.00
1	147.0	6.0	3.0	445		7.50	10.4	88	1.00
2	147.0	6.0	3.0	50	60.0	8.00	9.4	12	1.00
3	147.0	8.0	4.0	345	60.0	7.50	10.3	95	1.00
1	125.0	5.0	2.5	430	62.0	8.00	10.2	76	1.25
2	125.0	5.0	2.5	420	62.0	6.20	10.3	88	1.00
3	125.0	7.0	3.5	340	62.0	6.20	10.2	80	1.00
4	125.0	7.0	3.5	460	62.0	6.60	10.4	84	1.00
1	108.0	6.0	3.0	310	62.0	7.20	10.3	76	1.25
2	108.0	5.0	2.5	415	62.0	7.10	10.1	76	1.20
3	108.0	6.0	3.0	415	62.0	0.00	10.2	80	1.00
4	108.0	5.0	2.5	395	62.0	6.40	10.4	84	1.25
5	108.0	7.0	3.5	395	62.0	6.60	10.4	84	1.10
6	108.0	6.0	3.0	455	62.0	6.50	10.4	88	1.10
1	86.0	10.0	5.0	420	63.0	7.10	10.1	75	1.00
2	86.0	5.0	2.5	450	63.0	7.10	10.2	84	1.00
3	86.0	8.0	4.0	420	63.0	7.00	10.1	84	1.00
4	86.0	7.0	3.5	405	63.0	7.10	9.9	80	1.00
1	71.0	8.0	4.0	380	63.0	6.90	10.0	60	1.00
2	71.0	7.0	3.5	415	65.0	6.95	10.1	82	1.00
3	71.0	7.0	3.5	375	65.0	6.40	9.8	84	1.00
4	71.0	8.0	4.0	395	65.0	6.50	9.7	76	1.25
1	45.0	8.0	4.0	410	65.0	5.70	9.9	80	1.00
2	45.0	6.0	3.0	405	65.0	6.70	9.8	80	1.00
3	45.0	6.0	3.0	380	65.0	6.80	9.5	80	1.00
4	45.0	8.0	4.0	320	68.0	7.20	8.7	80	1.00
5	45.0	8.0	4.0	400	65.0	6.70	10.0	100	1.25
6	45.0	7.0	3.5	405	65.0	6.90	9.4	82	1.25
7	45.0	6.0	3.0	375	65.0	7.00	9.4	84	1.25
8	45.0	9.0	4.5	405	68.0	6.50	8.7	88	0.75
9	45.0	7.0	3.5	320	68.0	5.80	8.6	84	1.00
10	45.0	20.0	0.0	335	66.0	7.10	9.9	92	1.25

TOM DEPTH AND SAMPLE DEPTH IN FEET
IFIC CONDUCTIVITY IN MICRO-MHOS
ERATURE IN DEGREES FAHRENHEIT
AND ALKALINITY IN MILLIGRAMS PER LITER
HI IN FEET