ASSESSMENT OF ARKANSAS' SIGNIFICANT PUBLICLY-OWNED LAKES

ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY
WATER DIVISION

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Introduction

Various estimates have been made concerning the size of the surface water resource in the state of Arkansas. Most of these estimate three-fourths of a million acres of flowing and impounded waters. Approximately one-third of the total is composed of streams and rivers. The remaining one-half million acres are about equally divided between the large Corps of Engineers multi-purpose reservoirs and the small, usually specific-purpose lakes (including private ponds).

In this document, primarily for convenience, the terms "lakes" and "reservoirs" are used synonymously without regard to size or whether they were naturally or artificially created.

The large Corps of Engineers constructed reservoirs are multi-use, but most were constructed primarily for hydropower and flood control; some were constructed primarily for flood control, others primarily for navigation. A few are presently used for municipal water supply. All receive substantial recreational uses such as fishing, swimming, boating, camping, and related uses. The smaller lakes in the state were normally constructed for a single purpose. Many of these lakes are used exclusively for municipal water supply, others were built for general recreation use and some were designed and managed for the primary purpose of public fishing. In the latter group other recreational uses are permitted, unless they conflict with fishing, e.g., water skiing. Multiple uses are allowed on very few of the municipal water supply lakes; however, numerous uses are allowed on the industrial water supply impoundments.

Water quality data from the majority of Arkansas' lakes is totally lacking although selected lakes have intensive, long-term data collection. Some have only specific-purpose data, e.g., fecal coliform sampling from swimming areas. A few lakes have been investigated as a short-term project when a specific problem or potential problem was identified. Such studies were associated with the Clean Lakes Section of the Water Quality Act or municipal water supply reservoirs with treatment problems. In contrast, the Corps lakes of the Little Rock District have a relatively large amount of multi-parameters and multi-site water quality data. Additionally, DeGray Reservoir probably has the most extensive water quality data base of any reservoir in this region of the country. The data extends from pre-impoundment to the current date.

Recent requirements of the Water Quality Act of 1987, relating to the Clean Lakes Section and Section 305(b) reporting, mandates the development of a public lakes assessment program. The primary objectives of the assessment are to (1) identify lakes which do not meet water quality standards, (2) identify degraded, impaired, or threatened lakes, and (3) identification of the trophic status of these lakes. Arkansas' project attempts to meet these requirements with a first-time, single-point-in-time data set from the majority of the state's significant publicly-owned lakes. The tremendous variability of lake water quality data annually, seasonally and daily as well as meteorological, operational and management influences must be considered when analyzing or basing decisions on this logistically limited data base from a large variety of lake types.

Methodology

Selection of the lakes to be assessed was determined by the definition developed for a "significant publicly-owned lake." Such lakes are defined as an impoundment of substantial size (approximately 100 acres or greater) which contains access designed to enhance public uses in and on the waters. Seventy-seven lakes ranging in size from 60 to over 45,000 acres and totalling 355,063 acres were identified. The lakes were categorized by (1) ecoregions in which they are located, (2) the primary purpose for which they were constructed, and (3) by lake type which includes certain morphometric features such as size and average depth (Table 1, Figure 1)

Lakes having a current water quality data base which was adequate to make an assessment were not resampled unless additional stations were deemed necessary on the larger lakes. Substantial data was available from the Little Rock and Vicksburg Districts Corps of Engineers for the reservoirs which they operate and maintain. All lakes approximately 2,000 acres or larger were sampled at a minimum of two sites, some lakes had three sample sites. A lower lake station (near the dam) was established for all lakes. The natural, oxbow lakes were sampled near the deepest and widest section which was often near mid-lake, but this was designated as the lower station since it was the only station sampled on these lakes.

All sampling was done between mid-July and the last of August 1989. It was anticipated that this would be the period of maximum stratification for most lakes. Two 2-day sampling trips were made each week during the sample period. Normally, three or four lakes were sampled each day and one overnight was required for several trips. Each trip was restricted to no more than two days so the samples could be returned to the lab and processed within the 48-hour maximum holding time for analysis of most parameters.

At each sample site a shore-to-shore transect was made with the boat to determine the maximum depth and establish the sample station. Along each transect, fecal coliform samples were taken approximately 50 feet from each shore, at the left and right quarter-points and at the mid-point. Also, at each of these points a standard size surface water sample was taken. All were mixed to provide a composite sample for chlorophyll-a determination. Depth of water along the transect was initially determined by an Eagle-60, flasher-type depth finder. The boat was anchored over the maximum water depth and a vertical dissolved

TABLE 1. ARKANSAS SIGNIFICANT PUBLICLY-OWNED LAKES

NO.	LAKES	COUNTY	ACRES	AVG DPTH	WTRSHD	W/A	ECORGN	PURPOSE	TYPE
1	WINONA	SALINE	1240	30.0	44.4	22.9	OM	W	A
2	DIERKS	HOWARD	1360	22.0	114.0	53.6	OM	F	A
3	GILLHAM	HOWARD	1370	21.0	271.0	126.6	OM	F	A
4	DEQUEEN	SEVIER	1680	21.0	169.0	64.4	OM	F	A
5	CATHERINE	HOT SPRING	1940	18.0	1516.0	500.1	OM	H	A
6	GREESON	PIKE	7200	38.7	237.0	21.1	OM	H	A
7	HAMILTON	GARLAND	7300	26.0	1441.0	126.3	OM	H	A
8	MAUMELLE	PULASKI	8900	23.0	137.0	9.9	OM	W	A
9	DEGRAY	CLARK	13200	48.8	453.0	22.0	OM	H	A
10	NORFORK	BAXTER	22000	57.0	1806.0	52.5	OH	H	A
11	BEAVER	BENTON	28200	58.0	1186.0	26.9	OH	H	A
12	GREERS FERRY	CLEBURNE	31500	60.0	1153.0	23.4	BM	H	A
13	OUACHITA	GARLAND	40100	51.0	1105.0	17.6	OM	H	A
14	BULL SHOALS	MARION	45440	67.0	6036.0	85.0	OH	H	A
15	CRYSTAL	BENTON	60	12.0	4.5	48.0	OH	A	B
16	SHORES	FRANKLIN	82	10.0	26.0	202.9	BM	R	B
17	SPRING	YELL	82	23.0	10.5	82.0	AV	R	B
18	HORSEHEAD	JOHNSON	100	16.0	17.3	110.7	BM	R	B
19	WEDDINGTON	WASHINGTON	102	16.0	3.0	18.8	OH	R	B
20	COVE	LOGAN	160	10.0	8.5	34.0	AV	R	B
21	ELMDALE	WASHINGTON	180	8.0	6.0	21.3	OH	A	B
22	FAYETTEVILLE	WASHINGTON	196	15.0	6.0	19.6	OH	R	B
23	BOBB KIDD	WASHINGTON	200	13.3	4.0	12.8	OH	A	B
24	WILHELMENA	POLK	200	10.0	13.5	43.2	OM	A	B
25	BARNETT	WHITE	245	27.0	37.5	98.0	AV	A	B
26	SUGARLOAF	SEBASTIAN	250	12.0	5.0	12.8	AV	A	B
27	FT. SMITH	CRAWFORD	416	28.0	73.0	112.3	BM	W	B
28	SEQUOYAH	WASHINGTON	500	8.0	275.0	352.0	OH	R	B
29	SWEPCO	BENTON	531	17.0	14.0	16.9	OH	W	B
30	SHEPHERD SPGS.	CRAWFORD	552	31.0	68.0	78.8	BM	W	B
31	CHARLES	LAWRENCE	562	8.0	18.0	20.5	OH	A	B
32	BEAVERFORK	FAULKNER	900	10.0	11.5	8.2	AV	R	B
33	HINKLE	SCOTT	965	15.0	27.5	18.2	AV	A	B
34	BREWER	CONWAY	1165	20.0	36.4	20.0	AV	W	B
35	JUNE	LAFAYETTE	60	5.0	4.0	42.7	GC	A	C
36	BAILEY	CONWAY	124	8.0	7.5	38.7	AV	R	C
37	TRICOUNTY	CALHOUN	280	7.0	11.5	26.3	GC	A	C
38	COX CREEK	GRANT	300	6.0	17.0	36.3	GC	A	C
39	HURRICANE	SALINE	300	8.0	24.9	53.1	OM	W	C
40	FRIERSON	GREENE	335	7.5	7.3	13.9	DL	A	C
41	STORM CREEK	PHILLIPS	420	7.0	8.0	12.2	DL	R	C
42	CALION	UNION	510	6.0	6.7	8.4	GC	A	C
43	POINSETT	POINSETT	550	7.0	4.5	5.2	DL	A	C
44	BEAR CREEK	LEE	625	10.0	6.0	6.1	DL	R	C
45	UP WHITE OAK	OUACHITA	630	8.0	20.7	21.0	GC	A	C
46	ATKINS	POPE	750	5.5	10.2	8.7	AV	A	C
47	OVERCUP	CONWAY	1025	4.0	17.2	10.7	AV	A	C
48	LO WHITE OAK	OUACHITA	1080	8.0	42.5	25.2	GC	A	C
49	HARRIS BRAKE	PERRY	1300	6.0	11.2	5.5	AV	A	C
50	CANE CREEK	LINCOLN	1620	6.0	24.0	9.5	GC	A	C
51	WILSON	ASHLEY	150	5.0	1.0	4.3	DL	A	D
52	ENTERPRISE	ASHLEY	200	5.0	2.0	6.4	DL	A	D
53	1ST OLD RIVER	MILLER	200	4.0	2.0	6.4	GC	A	D
54	HOGUE	POINSETT	280	4.4	2.0	4.6	DL	A	D
55	GREENLEE	MONROE	300	6.0	0.5	1.1	DL	A	D
56	MALLARD	MISSISSIPPI	300	6.0	0.5	1.1	DL	A	D
57	GRAMPUS	ASHLEY	334	6.0	2.0	3.8	DL	A	D
58	DESARC	PRAIRIE	350	6.0	1.0	1.8	DL	A	D
59	WALLACE	DREW	362	5.2	1.0	1.8	DL	A	D
60	PINE BLUFF	JEFFERSON	500	6.0	4.0	5.1	DL	A	D
61	ASHBAUGH	GREEN	500	5.0	1.0	1.3	DL	A	D
62	BOIS D'ARC	HEMPSTEAD	750	4.0	4.0	3.4	GC	A	D
63	OLD TOWN	PHILLIPS	900	3.5	23.0	16.4	DL	R	D
64	HORSESHOE	CRITTENDEN	1200	10.0	13.5	7.2	DL	R	E
65	UPPER CHICOT	CHICOT	1270	15.0	14.0	7.1	DL	R	E
66	GRAND	CHICOT	1400	7.0	5.5	2.5	DL	A	E
67	GA. PACIFIC	ASHLEY	1700	4.0	4.0	1.5	GC	W	E
68	BLUE MT.	LOGAN	2900	8.6	489.0	107.7	AV	F	E
69	COLUMBIA	COLUMBIA	2950	11.0	48.0	10.4	GC	W	E
70	NIMROD	YELL	3600	8.2	680.0	120.9	AV	F	E
71	LOWER CHICOT	CHICOT	4030	15.4	350.0	55.6	DL	R	E
72	CONWAY	FAULKNER	6700	5.0	136.0	13.0	AV	A	E
73	ERLING	LAFAYETTE	7000	7.0	400.0	36.6	GC	W	E
74	OZARK	FRANKLIN	10600	14.0	151801.0	9165.3	AV	N	E
75	FELSENTHAL	BRADLEY	14000	7.0	10852.0	496.1	GC	R	E
76	MILLWOOD	LITTLE RIVER	29500	5.2	4144.0	89.9	GC	F	E
77	DARDANELLE	POPE	34300	14.2	153666.0	2867.2	AV	N	E
	TOTAL		355063						

(Greenwood / Wright-) 350 Acres 9 3.1 sq. mil

Lee Creek 635 11 465 sq mil

Paris City
Greenwood
Big Johnson
Pinoza
Jones
Irons Lake
Wright
Lee Creek

Ecoregions: OM-Ouachita Mts.; BM-Boston Mts.; OH Ozark Highlands; AV-Arkansas River Valley; GC-Gulf Coastal; D-Delta

Purpose: W-Water supply; F-Flood Control; H-Hydropower; R-Recreation; A-Angling (public fishing); N-Navigation

Watershed - square miles W/A-Watershed (acres)/Area of lake

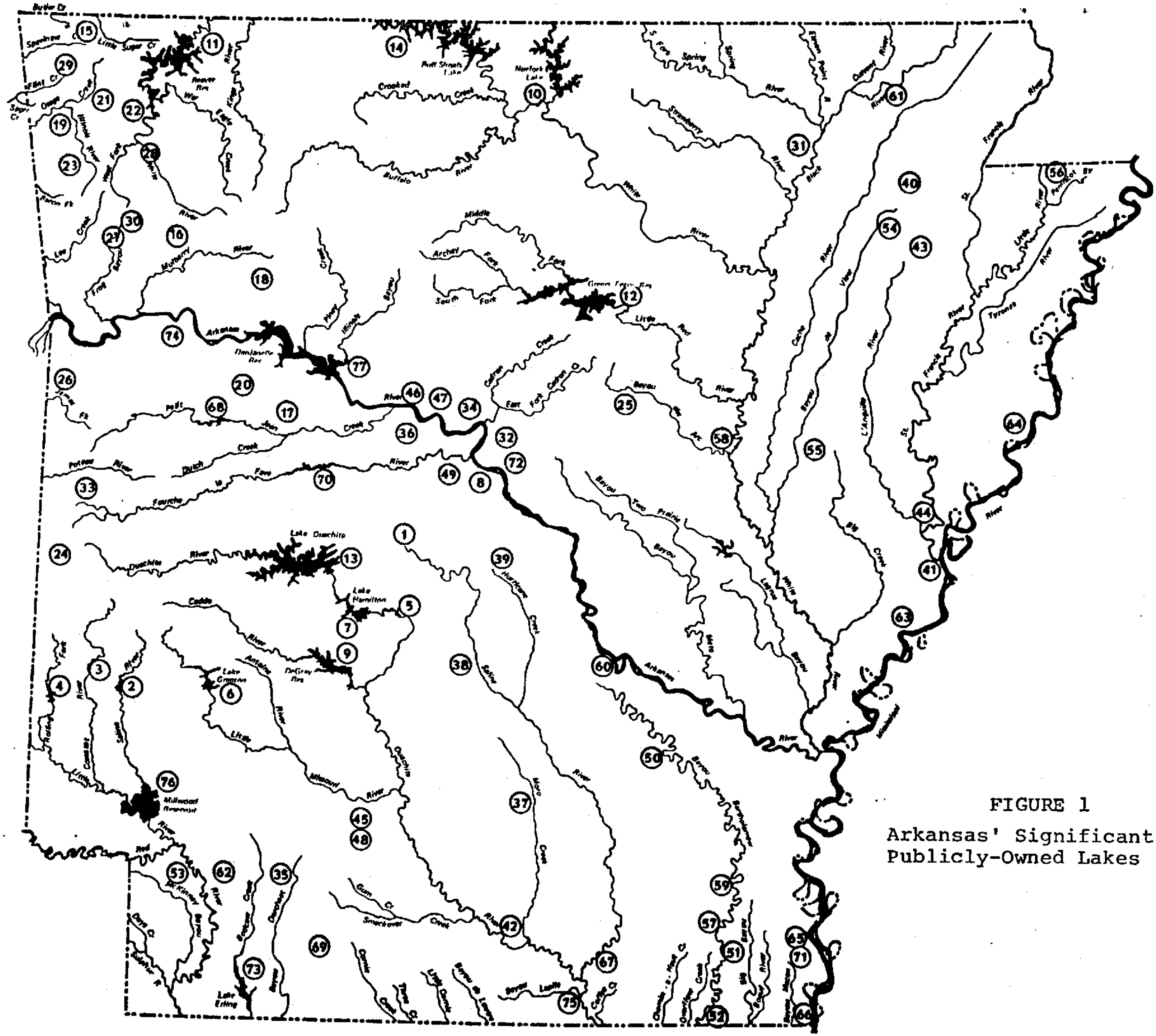


FIGURE 1
Arkansas' Significant Publicly-Owned Lakes

oxygen and temperature profile was taken from surface to bottom using a YSI Model 56 portable oxygen meter which was calibrated daily using the winkler-azide method. Readings were taken at one meter or one-half meter intervals through the epiliminion and the metaliminion. Larger intervals were sometimes taken through the hypoliminion. Accurate maximum depth was also determined by measuring the depth while taking the D.O.-Temp profile. Grab samples for multiple parameter analyses were taken with a Van Dorn sample bottle at one-meter depth and at a depth of 80 percent of the maximum depth. In situ pH readings were determined from each grab sample using an Orion Model 211 pH meter which was calibrated with a standard solution before each reading. Grab samples were labeled and iced immediately. One duplicate grab sample and chlorophyll-a sample were taken each day for quality assurance purposes of the lab. Secchi visibility reading using a standardized secchi disk was taken before leaving the sample site.

The parameters analyzed from each grab sample include: turbidity, alkalinity, conductivity, chlorides, sulfates, total dissolved solids, ammonia-nitrogen, nitrite and nitrate-nitrogen, total phosphorus, and total orthophosphate. Laboratory analyses were according to the 16th Edition of Standard Methods for the Examination of Water and Wastewater and/or EPA approved procedures.

Results

Morphometric data such as size, average depth, size of watershed, etc., of the lakes was determined from a variety of sources including various U.S. Army Corps of Engineers documents and files, engineering records from U.S. Department of Agriculture - Soil Conservation Service (P.L. 566 projects), Arkansas Game and Fish Commission records and files, records from corporate owners of certain lakes, Arkansas State Water Plan - "Lakes of Arkansas," and others. Some data discrepancies among the sources were noted. Resolution of differences noted was made; however, not all discrepancies may have been found and therefore may still exist.

Data for Dardanelle and Ozark reservoirs was not included since they are main stream impoundments on the Arkansas River and are essentially a flow through system on the main channel. They are included as part of the routine ambient monitoring network on the Arkansas River. Also, data was not collected from Cox Creek Lake or Lake Pine Bluff since they had been partially dewatered for renovation or maintenance work during the sample period. Lake Sequoyah had also been substantially dewatered when it was sampled; however, one grab sample, fecal coliform and chlorophyll-a samples were taken. Atypical values for most parameters resulted from the severe drawdown.

Substantially above average rainfall occurred throughout most of the state during late Spring and early Summer of this year. This resulted in high inflows and flushing of most lakes. This appeared to interrupt the normal stratification of several lakes early in the sample period.

Lakes Classification

Using size, average depth and ecoregion all lakes were placed into one of five different lake types.

Type A These are the larger lakes, usually of several thousand acres in size. They have average depths normally 30 to 60 feet. They are located in the montane areas of the state in the Ozark Highlands, Ouachita Mountains, and Boston Mountains. The watersheds of most are forest dominated. The primary purposes for construction of these lakes was hydropower and/or flood control. Most of these lakes are operated and maintained by the U.S. Army Corps of Engineers. Two were constructed by a private utility company for hydropower production but have developed intensive urbanization around the shoreline and immediate watershed and are used predominately for recreation. Two other lakes of this group were constructed for municipal water supply for the metropolitan center of the state. The watershed to lake area ratios (W/A) are normally large for these impoundments. They generally range from about 20 to 100 although the smallest is 9.9 and the largest is 500. The median value for all lakes of the group is 39.7. Although ratios of such magnitude generally indicate high flushing rates, the large storage volumes in most of these lakes partially abate excessive water exchanges. The theoretical hydraulic residence time in most of these lakes is about one year. However, the residence time in Lake Catherine is less than two weeks and Lake Hamilton is only twice that of Lake Catherine.

Water Quality data from the lakes of this type can be found in Appendix Table A-1. The waters in most of these lakes are very "soft" and weakly buffered, except for the lakes located in the Ozark Highlands which reflect their limestone-dolomite watersheds. Lakes Norfork and Bull Shoals have alkalinities generally between 100 and 150 mg/l; Beaver Lake, which drains both Boston Mountains and Ozark Highlands, has alkalinities around 50 mg/l. All other lakes of this type receive drainage from the Ouachita Mountains and have alkalinities of less than 20 mg/l. Total dissolved solids data was not available from most of these Corps lakes; however, TDS and conductivity values will reflect a similar pattern as shown by alkalinities. Values for pH are also noticably higher in the Ozark Highlands lakes although some slightly elevated values are seen in the epiliminion of some of the other lakes from photosynthesis activity. Secchi visibility in these lakes is usually greater than six feet although values of 10 feet are common and values of near 20 feet were recorded in Bull Shoals, Norfork, Beaver, and Ouachita. As might be expected, turbidity and chlorophyll-a values are very low in these lakes. However, of particular interest are the noticably higher turbidity values in the hypoliminion of the upper station of several lakes. Beaver and Bull Shoals Lakes show a distinctive pattern of increasing hypolimnetic turbidity in an up-lake direction. The turbidity value recorded for the hypoliminion in the upper station on Beaver Lake exceeded the water quality standards. Less distinctive but similar patterns are suggested in data from other lakes of this type. Hypolimnetic NO_2+NO_3 nitrogen was also noticably higher in Bull Shoals, Norfork, and Beaver than in other lakes of this type. Elevation of nitrogen values due to high nitrites and nitrates is an existing pattern for many of the streams in this section of the state. Phosphorus values in this type lake are low, although there are occasional, slightly elevated levels in the hypolimnetic depths of the up-lake stations. This is likely associated with the increased sedimentation in these areas.

Type B - This includes the smaller lakes of the uplands or steeper terrain. Most are around 500 acres or less in size, but probably are the most heterogenous group of lakes. Most are located in the Ozark Highlands, Ouachita Mountains, and Boston Mountains; however, several are located in the more mountainous areas of the Arkansas River Valley. Average depths are relatively deep and range generally from 10 to 25 feet. Watersheds are normally dominated by forest lands. Most lakes of this type were constructed for the primary purpose of multi-purpose recreation or specifically for public fishing. Two lakes are used as a public water supply and another is used as a cooling water supply for an electric power plant. The watersheds to lake area ratio is generally high with a range of 8.2 to 352 and a median value for these lakes of about 30. This results in a rather high flushing rate and low water retention time. Additionally, the watershed of most of these lakes is generally well timbered and of low productivity. These factors result in chlorophyll-a values of generally less than 10 ug/l, high secchi values and low turbidity. Water quality data collected for these lakes is listed in Appendix Table A-2. Conductivity, total dissolved solids, alkalinity and pH of these lakes reflect the geology of their watersheds with noticably higher values for all of these parameters in lakes located in the limestone-dolomite dominated Ozark Highlands Ecoregion. The chloride and sulfate levels in these lakes are very low except for SWEPCO Lake sulfates which exceed the water quality standards guidelines for that parameter. Turbidity values in Lake Sequoyah exceeded the water quality standard. This is apparently a result of the rather rapid and severe drawdown which had reduced the lake to less than one-fourth of its normal acreage. The abnormally high chlorophyll-a value in this lake also may have been a result of the drawdown. Other atypically high values found in this lake were surface NH_3-N values and surface total phosphorus.

Hypolimnetic NH_3-N and total phosphorus were atypically high in lakes Fayetteville, Wilhelmena, Bobb Kidd, and Barnett. Also hypolimnetic orthophosphate was noticably higher in all these lakes except Lake Fayetteville. These lakes, as most of this type, are distinctly stratified with a significant anoxic zone. Otherwise, there seems to be no common factor causing the high nutrient values in these four lakes. The watershed of Lake Fayetteville is highly developed with a combination of truck farm type agriculture, confined animal production, and suburban homes. Lake Wilhelmena has a commercial caged fish production facility near the dam, but its watershed is relatively undisturbed. Bobb Kidd Lake has a few confined animal production facilities in its watershed, and it is fertilized annually with commercial fertilizer for fisheries management purposes. Lake Barnett is a new reservoir in which there is an abundance of brush and timber that is in the process of dying and decomposing. The chlorophyll-a value in these lakes is low but typical of other lakes of this type. However, this condition may change during destratification.

Additionally, the nitrite, nitrate-nitrogen values in the hypoliminion of Lakes Fort Smith and Shepherd Springs was higher than normal. This is possibly a result of runoff from the poultry production facilities that are in the watershed.

Type C - This group is composed of the smaller lakes of the lowland or flat terrain areas. Sizes generally range from 300 to 1,000 acres with average depths of normally less than 10 feet. These lakes are located in the flatter terrain of the Arkansas River Valley, in the Gulf Coastal and in the Delta Ecoregions. The Delta lakes of this group are generally associated with the Crowley's Ridge region. Watersheds of these lakes include timberlands of both lowland hardwoods and pines, but some are broken by pasture land and small farms. Almost all lakes of this group were constructed specifically for public fishing with other types of recreation as secondary uses. However, a few of these lakes were developed for multiple recreation uses without emphasis on a specific recreational use. The watershed to lake area ratios are relatively small. The median value for these lakes is 13 although the range is from about 5 to over 50. As a result of the shallow average depth and relatively small storage volume, high flushing takes place on the lakes that have high W/A ratios. Table A-3 gives the water quality data collected for these lakes. The chlorophyll-a values are higher for this type lake than the two previous types. The median value was 21 ug/l with an average of 27.1 ug/l which was somewhat influenced by high values from two lakes. Watersheds range from low to moderately high in productivity. Alkalinity values and the buffering capacity of these lakes is generally low. Most alkalinities are below 20 mg/l.

Storm Creek and Bear Creek Lakes produced substantially higher chlorophyll-a values than other lakes of this type. This also resulted in very high daytime surface pH values from photosynthetic activity. Hypolimnetic NH_3-N, total phosphorus and orthophosphorus were also noticably high in these lakes. However, epilimnetic values of these parameters were not atypically high as they were probably being utilized in plankton production, and mixing from the deeper waters was inhibited by the strong summer stratification (Figure C-14). High turbidity values, usually from the hypoliminion, were found in the lakes associated with the highly errodable Crowley Ridge soils. These include Lakes Frierson, Poinsett, Bear Creek and Storm Creek. Although Cane Creek Lake drains a sandy-loam type escarpment, the high hypolimnetic turbidity values from this lake may have been associated with organic decomposition activities in this relatively new lake which has an abundance of standing timber. The high total phosphorus and orthophosphate values from the hypoliminion and epiliminion of Lake June was probably not from natural sources.

Fecal coliform values in these lakes, although higher than in other types are substantially below levels of concern. At the left shore station of the transect on Harris Brake Lake, the coliform colonies were too numerous to count for the size sample filtered. Several cottages and a commercial boat dock are located near that shoreline of the lake.

Type D - These are small impoundments of the Delta area of the state, but include two similar type lakes from the large river alluvium of the Gulf Coastal Ecoregion. These type lakes are generally 200 to 500 acres in size with average depths of around five feet. This group includes several natural, oxbow-cutoff lakes which have been modified by a water control structure to increase their isolation from the parent stream and maintain higher dry-season water levels. These lakes are only occasionally flooded by the parent stream and generally have very small direct runoff watersheds. The other lakes of this type are man-made, but they are almost totally isolated from their watershed by levees. Water levels are maintained through occasional pumping from adjacent waterways. Where watersheds exist that discharge directly to the oxbow lakes in this group, the runoff is primarily from row crop agriculture.

Virtually all of these lakes were constructed or modified for the purpose of providing public fishing in an area where much of the natural waters had been adversely impacted by agriculture runoff. The watershed to lake-area ratio for many lakes in this type is near 1; the median value is 3.8 with an average of 4.4. One of these lakes has a ratio of 16.4 as a result of several agriculture drainage channels being cut into the lake. As a result of the very low water exchange rate and the fertile soils on which these lakes are located and receive drainage, the chlorophyll-a values average the highest of all other lake types. Additionally, several of these lakes have or are presently being fertilized annually with commercial fertilizer for fisheries management purposes. The water quality data collected is shown in Appendix Table A-4. Chlorophyll-a values in three of these lakes exceed 100 ug/l; one lake was over 174 ug/l and one additional lake had a value of 98 ug/l. The median chlorophyll-a value for all lakes of this type was 52.8 ug/l with an average of 65 ug/l. As a result of the dense algae blooms, the secchi visibilities ranged from 12 to 41 inches with an average of 27 inches. On several of the lakes the daytime pH values exceed 9.0 SU. Total phosphorus values in this type lake also average the highest of all other lake types, but values are not greatly dissimilar in the epiliminion and hypoliminion. The dissolved oxygen stratifies rather sharply in most of these lakes although the water temperature is only mildly stratified. This is probably a result of occasional mixing of the waters by heavy rain or wind and aided by the shallow average depth.

Type E - These are the large lowland lakes of the Delta, Gulf Coastal and the large alluvial areas of the Arkansas River Valley Ecoregion. They range from several thousand to over 30,000 acres in size, but average depth is usually less than 10 feet. This group also includes four large, oxbow-cutoff lakes which have been substantially modified by construction of drainage ditches, levees and other water control structures. Watershed types include mixtures of intensive row crop agriculture, small farms and pastures (with increasing amounts of confined animal production) and timberlands. The primary purposes for which these lakes were constructed include three main stream reservoirs for flood control and three for navigation, one of which has considerable recreation and fish and wildlife enhancement features. Several were constructed for water supply, two for industrial, and one for municipal uses. The modified natural, oxbow lakes are used primarily for recreation. One lake of this type was built primarily for public fishing.

The range of watershed to lake area ratios within this type of lake is extremely large. The navigation impoundments on the main stream of the large rivers have W/A ratios of 500 to several thousand and are therefore somewhat meaningless in comparison to the other lakes. The flood control reservoirs, as might be expected, also have relatively large W/A ratios. In contrast the oxbow lakes have W/A ratios of usually less than 10, except for Lower Lake Chicot where thousands of acres of agriculture drainage was diverted into the lake in the past. Currently, much of this drainage is being captured and pumped into the Mississippi River.

Water quality data from these lakes can be found in Appendix Table A-5. Secchi values for most of these lakes are about three feet or less. This is influenced in a few of these lakes by soil particle turbidity, some of which is in the colloidal form. The oxbow lakes have high plankton production which controls secchi visibility, and other lakes have brown, lignin-stained waters. chlorophyll-a values are lower in these lakes than in the other lowland types, perhaps due to the higher flushing rates. The exceptions are the large oxbow lakes in this group which have very high chlorophyll-a levels but have very low flushing rates. Phosphorus values are moderately high but lower than in most Type D lakes. These values can probably be correlated to soil particle inwash since orthophosphate values were generally below detectable levels. However, two of the large oxbow lakes (Upper Chicot and Grand) which receive intensive agriculture runoff from adjacent crop lands have noticably higher total phosphorus and orthophosphate values. Waters of this type lake are "soft" to "moderately soft" with limited buffering capacity. Values for pH are normally very slightly acidic, but moderate to large plankton populations sharply increase the pH values during daylight hours.

Water Quality Standards

As a result of the high variability of the water quality within lakes, the development of water quality standards for lakes has been primarily by default or "spill-over" from the stream standards. Although the designated beneficial uses for all waterbodies may be appropriate for lakes, the protective criteria may require added dimensions. Considerations should be given to lake water quality variability resulting from location. On a national scale, latitudinal and elevation differences of lakes significantly influence stratification patterns and annual yield or production values. Other factors affecting lake variability include morphometric features such as size, average depth, size of watershed, shape of basin, etc. Operational and management activities such as water level manipulation and discharge levels, magnitudes, and frequencies also can be influencing factors. Of significant importance is the natural, inherent variability within lakes resulting in spacial differences, both horizontally and vertically, seasonal variations and climatological influences such as wind and rainfall storm events.

Generalized and even regional lake standards may present problems, particularly when a specific criteria results in a positive effect on one lake use and a negative effect on another use. For example, chlorophyll-a, phosphorus or water clarity criteria may be designed to enhance the drinking water or certain recreational uses of a lake, but may limit the recreational fishing potential of the lake. Such criteria would be acceptable for lakes used primarily for public water supply, but would be counterproductive for lakes created for the primary purpose of public fishing.

With the above discussions considered, Arkansas' water quality criteria for lakes is limited in parameters, designed with great flexibility and, in some cases, somewhat ambiguous. The surface water quality standards for lakes contain the following specific criteria:

Temperature	Maximum allowable from man-induced causes is 32°C (89.6°F), measured at mid-depth or three feet, whichever is less.
Turbidity	Any waste discharge or instream activity shall not cause turbidity values to exceed 25 NTU.
pH	As a result of waste discharge, pH values shall not be below 6.0 or above 9.0 standard units.
Dissolved Oxygen	5 mg/l
Fecal Coliform	Between April 1 and September 30 values shall not exceed the geometric mean of 200 colonies per 100 ml nor shall 10% of the samples exceed 400 colonies per ml.
Minerals	(Guidelines only) - An increase of one-third over naturally occurring levels or 15 mg/l, whichever is higher may be permitted for Cl and SO_4. Naturally occurring background levels from least-disturbed ecoregion reference streams plus one-third of that value for chlorides and sulfates or 15 mg/l, whichever is highest, provides the following guidelines:

Region	Cl	SO4	TDS
Ozark Highlands	17	23	240
Boston Mountains	17	15	85
Ark River Valley	15	17	103
Ouachita Mts.	15	20	128
Gulf Coastal	19	41	123
Delta	48	37	390

Appendix B compares the lake water quality criteria and guidelines in our existing standards to the recent data collected for the significant publicly-owned lakes. Figure B-1 is a plot of the temperature data relative to the maximum temperature criteria. The data is from the one meter depth (approximately 3 feet) and is grouped into Type A and B lakes and Type C, D, and E lakes. Only one lake exceeded the 32^{o}C maximum limit. This was SWEPCO Lake which is used as a cooling lake for a fossil fuel power generation facility.

Turbidity data is plotted in Figure B-2. Both epiliminion and hypoliminion values are shown. For lakes with multiple stations, the maximum values from all stations for the epiliminion and hypoliminion were used. Epiliminion values for Types A and B lakes were normally below 5 NTU; however, the upper station of several of these lakes had noticably higher values. The upper station of Beaver Lake and the single station on SWEPCO Lake had hypolimnetic values above the 25 NTU maximum criteria. Additionally, the surface sample taken from Lake Sequoyah, which had been drastically dewatered at the time of sampling was over 35 NTU and is not shown on Figure B-2. Types C, D, and E lakes had slightly higher turbidity values in both the epiliminion and hypoliminion; however, only two lakes (Frierson and Nimrod) had hypolimnetic values above the 25 NTU limit.

Both epiliminion and hypoliminion pH data are plotted in Figure B-3. The extreme pH values were used for lakes with multiple stations. Eight of the Type A lakes had hypolimnetic pH values at or below the 6 SU minimum criteria. All of these lakes are located in the Ouachita Mountains which typically produce low pH waters and have very limited buffering capacity against pH changes. Although the Types A and B include lakes from the Ozark Highlands region, which has fairly well buffered waters, the distribution of pH values seems to be wider within this group than in the Types C, D, and E. Eight lakes from the Types C, D, and E groups had epilimnetic pH values at or above the 9 SU maximum criteria. Three of these lakes also had hypolimnetic pH values in this range. These very high pH values identify lakes with dense phytoplankton populations and high chlorophyll-a values. The lakes which also had high hypolimnetic pH values were not stratified.

The state's water quality standards list the minimum dissolved oxygen criteria as 5 mg/l, but without explanation as to depth for determination, seasonal variability or diurnal fluctuations. Such criteria was listed primarily at the insistence of the Environmental Protection Agency. Figure B-4 is a plot of the D.O.

data at the lower station of each lake at the one meter depth. Nine lakes from the Types C, D, and E group had D.O. values below the 5 mg/l criteria. For these nine lakes the surface D.O. value was plotted in Figure B-4. Due to a very shallow stratification, the surface D.O. value of three of these lakes (June, Calion and Hogue) was above the 5 mg/l limit. However, the surface values for Lakes Atkins, Overcup, Wallace, Ashbaugh, Upper Chicot, and Felsenthal remained below the 5 mg/l level as shown in the figure. Generally, the one meter depth D.O. values averaged higher in the Types A and B lakes than in the Types C, D, and E group. In contrast, the surface D.O. values in several of the plankton rich lakes of the latter group reached highly supersaturated values.

The fecal coliform values for all lakes was substantially below the criteria established for swimmable waters. For the lakes where five samples were taken along a shore-to-shore transect, the values shown in the Appendix A tables are the average of the five values since zero values were common at one or more points of the transects. Typically, the highest values were found near the shore, usually near a dwelling. Contrary to the typical data, Lakes Hinkle and Wilhelmena had fecal coliform colonies too numerous to count for the dilutions used at all five points of the transect. Both of these lakes have intensive culture, caged fish production facilities near the sample site. Although, the fecal coliform test should not give a positive test to poikilotherm contamination, the results indicate some type of anomalous condition. A follow-up bacteria sampling was done later in the year on these lakes. The results indicate that the organism giving the positive results is a bacteria from the genus Klebsiella. Since this is a naturally occurring bacteria of several sources, including most soils, the state's water quality standards exclude this genus from the fecal coliform definition.

The state's water quality standards provide only guidelines for limiting contamination by chlorides, sulfates, and total dissolved solids. These guidelines were established from naturally occurring background levels from each of the ecoregions within the state. Some flexibility is allowed by allowing discharges to increase the levels of chlorides and sulfates up to one-third above naturally occurring values or to 15 mg/l, whichever is higher. Figures B-5 through B-10 compare the mineral levels found in this study to the guideline values for waters of each ecoregion. In these figures the lakes were grouped into the ecoregion which dominates their watershed. Mineral data plotted in these figures is the average of the hypoliminion and epiliminion values from the lower station on each lake. The mineral values for all lakes, except one, are substantially below the guideline values. Sulfate guideline for Ozark Highland waters is greatly exceeded in SWEPCO Lake.

Trophic Status

A ranking of all lakes sampled relative to their trophic status was done with a simple relationship of the three principal parameters normally considered in trophic state determination. Total phosphorus values converted to ug/l plus chlorophyll-a values in ug/l was divided by secchi depth values in inches to provide a relative ranking index for all lakes. Table 2 lists the lakes sampled including all stations for lakes with multiple stations. They are ranked in descending order according to the ranking index. Highest index values indicate the richest trophic status. The ranking index for Old Town Lake is more than 1.5 times the second highest value. Grand and Mallard Lakes have similar values and make up the second highest group. Lakes Greenlee, Horseshoe, Upper Chicot and June group third highest and are followed by Lake Wallace, Bear Creek and Bois D'Arc. Further grouping becomes difficult beyond this level although the lakes that follow include Conway, Storm Creek, Erling, First Old River, and Tri-County. Below these 15 lakes the ranking index changes gradually to the lowest value. The lower one-third of the ranked list is made up of Types A and B lakes only and 70 percent of the Type A lake stations are in the lower one-third. Eighty-five percent of the Type D lakes are in the upper one-third of the list which also includes 63 percent of the Type C and 50 percent of the Type E lakes. This demonstrates the richer trophic status of Types C, D, and E lakes over Types A and B lakes. Several of the upper lake stations of Type A were above the lower one-third of the ranking, but none of the lower lake stations of Type A except for Lakes Hamilton and Catherine, were above that level. Both the upper and lower stations of Lakes Hamilton and Catherine were above the lowest one-third of the ranked list. The upper station of Beaver Lake had the highest index value of all Type A lakes except Lake Catherine; however, the lower station on Beaver Lake had the next to lowest value of all lakes sampled. The upper station on Dierks Lake had a similar value to upper Beaver Lake. The trophic ranking index for Lake Catherine was almost twice as high as the index for any other Type A lake.

Of the ten lakes with the highest values for the ranking index, five are oxbow lakes which are, for the most part, separated from the parent stream. Three other lakes of this group have been or are presently fertilized with commercial fertilizer for fisheries management purposes. The very high trophic status of Old Town Lake is most likely a result of cultural eutrophication resulting from drainage of agriculture runoff into the lake. The same is probably the case in Grand Lake. It should be anticipated that this will also be the future direction for Horseshoe Lake and Upper Lake Chicot.

TABLE 2. Trophic Ranking of Arkansas' Significant Publicly-Owned Lakes

LAKES	STN	TL-P	CHLOR a	SECCHI	INDEX	TYPE
OLD TOWN	L	0.32	174.3	12	41.19	D
GRAND	L	0.30	147.5	17	26.32	E
MALLARD	L	0.20	115.8	14	22.56	D
GREENLEE	L	0.29	22.7	20	15.64	D
HORSESHOE	L	0.10	87.7	13	14.44	E
UPPER CHICOT	L	0.25	36.1	20	14.31	E
JUNE	L	0.25	31.8	22	12.81	C
WALLACE	L	0.19	98.0	26	11.08	D
BEAR CREEK	L	0.09	72.2	15	10.81	C
BOIS D'ARC	L	0.11	110.8	21	10.51	D
CONWAY	L	0.14	20.1	18	8.89	E
CONWAY	U	0.17	34.4	26	7.86	E
STORM CREEK	L	0.09	74.6	21	7.84	C
ERLING	U	0.14	16.5	21	7.45	E
1ST OLD RIVER	L	0.10	52.1	21	7.24	D
TRICOUNTY	L	0.11	30.5	22	6.39	C
BAILEY	L	0.14	11.9	31	4.90	C
ERLING	L	0.12	19.2	30	4.64	E
OVERCUP	L	0.11	19.6	28	4.63	C
LOWER CHICOT	L	0.06	45.1	24	4.38	E
FRIERSON	L	0.06	30.0	22	4.09	C
CANE CREEK	L	0.07	32.6	28	3.66	C
GRAMPUS	L	0.07	53.5	35	3.53	D
ASHBAUGH	L	0.06	28.2	28	3.15	D
WILSON	L	0.08	39.5	38	3.14	D
ENTERPRISE	L	0.07	55.4	41	3.06	D
UP WHITE OAK	L	0.09	21.0	37	3.00	C
DESARC	L	0.08	8.1	30	2.94	D
CHARLES	L	0.06	18.3	27	2.90	B
HARRIS BRAKE	L	0.10	21.4	42	2.89	C
COLUMBIA	U	0.08	14.4	36	2.62	E
COLUMBIA	L	0.08	20.9	39	2.59	E
CALION	L	0.06	9.4	27	2.57	C
FELSENTHAL	U	0.08	3.5	36	2.32	E
BARNETT	L	0.15	5.4	68	2.29	B
GA. PACIFIC	L	0.06	9.9	31	2.25	E
ELMDALE	L	0.05	11.0	30	2.03	B
HOGUE	L	0.05	22.7	36	2.02	D
FELSENTHAL	L	0.07	2.7	37	1.96	E
HURRICANE	L	0.05	20.3	38	1.85	C
ATKINS	L	0.04	13.4	30	1.78	C
MILLWOOD	L	0.04	14.0	35	1.54	E
CATHERINE	U	0.04	5.9	31	1.48	A
LO WHITE OAK	L	0.07	13.4	59	1.41	C
CATHERINE	L	0.04	21.4	46	1.33	A
WILHELMENA	L	0.05	9.7	46	1.30	B
BOBB KIDD	L	0.04	11.3	43	1.19	B

LAKES	STN	TL-P	CHLOR a	SECCHI	INDEX	TYPE
MILLWOOD	U	0.04	7.2	40	1.18	E
BLUE MT.	L	0.03	8.9	35	1.11	E
NIMROD	L	0.03	8.6	44	0.88	E
BEAVER	U	0.08	2.7	103	0.80	A
DIERKS	U	0.04	12.0	67	0.78	A
BREWER	L	0.03	8.0	50	0.76	B
FAYETTEVILLE	L	0.03	5.9	55	0.65	B
HAMILTON	U	0.03	7.5	63	0.60	A
HAMILTON	L	0.03	10.2	71	0.57	A
GREESON	U	0.03	8.1	76	0.50	A
SUGARLOAF	L	0.04	4.0	89	0.49	B
DEGRAY	U	0.03	5.6	73	0.49	A
HORSEHEAD	L	0.03	1.3	65	0.48	B
GILLHAM	U	0.02	4.1	51	0.47	A
POINSETT	L	0.03	4.0	73	0.47	C
HINKLE	L	0.03	5.4	78	0.45	B
BEAVERFORK	L	0.03	4.8	78	0.45	B
SHEPHERD SPGS.	L	0.03	2.8	74	0.44	B
DIERKS	L	0.02	9.1	67	0.43	A
SHORES	L	0.03	2.7	79	0.41	B
GILLHAM	L	0.02	4.3	59	0.41	A
DEQUEEN	U	0.02	9.4	75	0.39	A
SPRING	L	0.03	0.3	79	0.38	B
MAUMELLE	U	0.03	4.5	92	0.38	A
DEQUEEN	L	0.02	2.5	71	0.32	A
MAUMELLE	L	0.03	3.4	115	0.29	A
COVE	L	0.03	1.6	115	0.27	B
CRYSTAL	L	0.03	3.5	136	0.25	B
FT. SMITH	L	0.03	2.1	141	0.23	B
WEDDINGTON	L	0.03	0.0	137	0.22	B
SWEPCO	L	0.03	3.8	156	0.22	B
OUACHITA	U	0.03	1.9	148	0.22	A
WINONA	L	0.03	0.0	149	0.20	A
BEAVER	M	0.02	2.0	131	0.17	A
OUACHITA	M	0.03	1.1	212	0.15	A
GREESON	L	0.01	2.4	95	0.13	A
GREERS FERRY	L	0.02	0.3	158	0.13	A
NORFORK	U	0.02	1.2	186	0.11	A
DEGRAY	L	0.01	2.3	110	0.11	A
BULL SHOALS	U	0.02	0.6	186	0.11	A
GREERS FERRY	U	0.02	0.2	186	0.11	A
NORFORK	L	0.02	0.3	214	0.09	A
BEAVER	L	0.02	0.5	218	0.09	A
BULL SHOALS	M	0.02	0.6	246	0.08	A
OUACHITA	L	0.01	2.0	150	0.08	A
BULL SHOALS	L	0.02	0.3	257	0.08	A

Lakes Stratification

Arkansas lakes can generally be characterized as warm monomictic with reference to their stratification characteristics and their single overturn period. Most form a distinctive summertime stratification and have a late fall-winter-spring mixing period. However, some lakes form very weak or no summer stratification and are frequently mixed by extreme summertime meteorological conditions of wind and/or rainfall (Appendix C). An anoxic hypoliminion is also typical of most of these lakes.

A unique stratification characteristic of several of the large, deep lakes with very large storage volumes is a dissolved oxygen depression to or near anoxic conditions in the metaliminion followed by an increase in D.O. levels in the hypoliminion (Figures C-3, C-5, and C-6). Another unique D.O. stratification pattern was observed in both large and small Ozark Highland Lakes. This pattern shows slight to substantial increases in D.O. usually in the upper level of the metaliminion. This is followed by the typical D.O. sag to an anoxic hypoliminion in the smaller lakes or a D.O. sag with recovery to a secondary D.O. peak in the hypoliminion of the large, deep lakes (Figures C-5, C-7, and C-8). These initial subsurface D.O. peaks produce supersaturated values. In Lake Weddington (Figure C-8) this phenomenon occurred near five meters deep. It is most likely that these supersaturated D.O. peaks are a result of concentrations of phytoplankton at subsurface depths. It is not clear why this condition was apparent only in lakes from the Ozark Highland area.

Several of the large, relatively shallow lakes with a dominance of open, unprotected water and very limited shoreline irregularities such as bays and coves had vertically straight-line D.O. and temperature profiles. Complete mixing probably occurs continuously in these lakes (Figure C-20). Additionally, most of the small and very shallow oxbow, round or oval shaped lakes, many of which are partially wind-protected by standing timber in the lake or around the shoreline, are only very weakly stratified. This stratification is usually very near the surface (Figure C-17, C-18, and C-19). Most of these lakes have less than 5^{o}C difference in water temperature from surface to bottom indicating that mixing occurs frequently or at least late into the stratification season. Several of the more typically structured lakes, but of the shallow type with relatively small storage volumes, showed evidence of recent mixing and the beginning of restratification (Figure C-16). These lakes were among the earliest sampled which was shortly after a very atypically wet late Spring and Summer that had pushed annual rainfall totals more than 10 inches above normal. Two of the larger lakes in this group, Lakes Erling and Conway, showed a remnant of the stratification only at the lower station (Figures C-23 and C-24). Substantial surface outflow was occurring at both lakes during the sample period.

One of the more interesting D.O.-Temperature profiles observed was on Felsenthal Reservoir (Figure C-21). This is a main stream reservoir of the Ouachita River with a very large watershed. The lake is only a few years old and floods from 14,000 to 30,000 acres of bottomland hardwood timber. As a result of the above average Spring and Summer rainfall, this lake had remained several feet and several thousand acres above the normal summertime levels. During the sample period, the lake was being dewatered rapidly off the flooded timber. Dissolved oxygen-temperature profiles were taken in the main channel of the lake near the dam and near the upper end. Additionally, profiles were taken on the west side of the lake in the lower section in a flooded oxbow lake and on the east side of the lake in the old river channel which had been blocked by the dam. There was virtually no difference between surface and bottom D.O. or temperature at any of the stations. The maximum D.O. found at any station at any depth was 2.1 mg/l.

Degraded, Threatened or Impaired Lakes

This first-time, single-point-in-time data base for most of Arkansas' lakes does not allow a definitive determination of the degraded, threatened or impaired status of a lake. However, none of the statutory designated uses, i.e., public, agriculture or industrial water supply; propagation of fish and wildlife, recreational uses and navigation, have been eliminated or threatened in any of the lakes. Although, there were water quality values in some lakes which exceeded the specific criteria, most of these incidences were a result of short-term, natural occurrences, or were of a magnitude which did not threaten an existing use.

No evidence of degraded water quality in any lake from point source discharges could be identified. However, the operation of SWEPCO Lake as a cooling water source for an electric power plant and discharges from the ash or coal storage areas has substantially increased the water temperature and sulfate concentrations in the lake. These changes have shown no impairment of the lake uses.

Nonpoint source impacts are generally more subtle and require more intensive and long-term data. Additionally, water quality effects from this source are often only identifiable seasonally or may be cyclic chronologically. It is therefore, beyond the scope of this data base to make such determinations. Consequently, evaluations of nonpoint source impacts must be made relative to their impacts on existing uses.

Chlorophyll-a values which are also seasonally and spacially variable may, however, be a possible indicator of nonpoint source contributions to accelerated eutrophication. Although this parameter will not distinguish between natural and cultural eutrophication, very high values and a thorough knowledge of the magnitude of activities within the watershed of a specific lake should provide conclusive evidence about the cause of such impacts. Old Town Lake is obviously significantly impacted by enriched, agricultural runoff. Although of a lesser magnitude and perhaps not as conclusive from the existing data, Grand Lake, Horseshoe Lake and Upper Lake Chicot also suffer from similar impacts.

Summary

Seventy-seven (77) impoundments in the State were selected as Arkansas significant publicly-owned lakes and defined as an impoundment of approximately 100 acres or more which contains access designed to enhance public use in and on the waters. First time water quality data was collected from many of these lakes during the mid to late summer of 1989. Data from the same time period was available for several of the larger impoundments from the Corps of Engineers. This data was supplemented by additional stations on a few of the Corps impoundments. The data collected and analyzed included dissolved oxygen-temperature profiles, fecal coliform, chlorophyll-a, and ten other parameters including several minerals, nutrients and other basic parameters which were taken from both the epiliminion and hypoliminion of each lake.

All lakes were categorized into five basic types based primarily on their morphometric features. This classification system generally resulted in the separation of the lakes by location into upland or lowland areas. These physical characteristics apparently substantially affected many of the chemical properties of the lake since several of the chemical parameters were noticably different among the lake types. The lake's D.O.-temperature profile and trophic level were strongly correlated to lake type. However, certain mineral content and their affects on pH, alkalinity and conductivity were more related to the watershed geology of the lake.

Comparison of actual lake water quality data to the water quality standards was made with certain qualifications. This was necessary because the existing standards do not always address the inherent variability of many water quality parameters in lakes. However, almost all of the lake data analyzed fell within the acceptable specific criteria limits established by the surface water quality standards. In SWEPCO Lake the temperature and sulfate standards were exceeded. The turbidity limit was exceeded in the hypoliminion of the following lakes: SWEPCO, the upper station of Beaver, Frierson and Nimrod. The upper limit for pH was exceeded in several lakes where high phytoplankton populations existed. Also, several of the Ouachita Mountain lakes had pH values below 6.0 S.U. in the hypoliminion. This is likely a natural condition resulting from the low pH runoff from the pine forest dominated watershed and the limited buffering capacity of these waters. Because the D.O. criteria for lakes and reservoirs is somewhat ambiguous, an arbitrary comparison of D.O. values from the one meter depth or surface was made from each lake. Most of these values exceeded the 5 mg/l criteria; however, six lakes which had previously been meteorologically or mechanically mixed exhibited all D.O. values below the criteria. This was most likely a temporary condition.

A ranking of all lakes according to their trophic level (level of richness) was made using total phosphorus, chlorophyll-a and secchi visibility as influencing factors. The relative ranking index showed Old Town Lake to be substantially higher than the next group of lakes. Old Town Lake, Grand Lake, Horseshoe Lake and Upper Lake Chicot are most likely exhibiting characteristics of accelerated eutrophication from agriculture runoff.

APPENDIX A

WATER QUALITY DATA BY LAKE TYPES

The following tables list the water quality data collected during the summer of 1989. The majority of the data was collected by personnel from the Arkansas Department of Pollution Control and Ecology and analyzed in the Department's laboratory. Data from the large Corps of Engineers operated lakes which include Dierks, Gillham, DeQueen, Greeson, DeGray, Norfork, Beaver, Bull Shoals, Greers Ferry, Ouachita, Blue Mountain, Nimrod, Millwood, Upper and Lower Lake Chicot was provided by the Little Rock and Vicksburg District Corps of Engineers. Supplemental data was taken by Department personnel from Lakes Ouachita, Greeson, and DeGray to provide multiple stations on these lakes.

The unit of measure for the parameters listed are as follows: fecal coliform in number of colonies per 100 ml; chlorophyll-a in ug/l; secchi in inches; pH in standard units; turbidity in NTU; conductivity in micromhos per centimeter; alkalinity, chlorides, sulfates, ammonia-nitrogen, nitrite plus nitrate-nitrogen, total phosphorus, orthophosphate phosphorus, and total organic carbon in mg/l. Parameters listed in the tables in lower case and in parenthses are from the deep levels or hypoliminion; those in upper case are from the epiliminion. Nutrient data analyzed by ADPC&E lab has the following limits of detection: NO_2+NO_3-N= 0.02 mg/l; NH_3-N=0.05 mg/l; total phosphorus and orthophosphate phosphorus=0.03 mg/l. Detection limits of data provided by the Corps of Engineers is the same for NO_2+NO_3-N but 0.01 mg/l for total phosphorus and orthophosphate phosphorus. Therefore all values for these parameters which are the same as the detection limit are at the value given or below. The station designations are "L" for the station in the lower part of the lake normally very near the dam; "M" is a mid lake station and "U" is a station near the upper end of the lake.

Fecal coliform values designated as "TN-1" indicate that the sample taken at one point on the five-sample transect exceeded the desirable number of colonies for an accurate count at the dilution level used. Similarly, a value of "TN-5" indicates this condition existed at all five points on the transect.

In several of the Corps lakes, analysis of chlorides and sulfates had been discontinued within the last several years. The data used was the mean value of the period of record for the lake.

TABLE A-1. Water Quality Data from Type A Lakes

NO.	LAKES	STN	F.COLI	CHLOR a	SECCHI	PH	(ph)	TURB	(turb)	TDS	(tds)	COND	(cond)	ALK	(alk)	CL	(cl)	SO4	(so4)	NH3-N	(nh3-n)	NO2-NO3	(no2-no3)	TL-P	(tl-p)	O-PO4	(o-po4)	TOC	(toc)
1	WINONA	L	1	0.0	149	7.1	5.9	1.5	3.0	23	27	22.1	22.4	7.2	6.8	2.5	2.2	3.0	3.0	0.05	0.05	0.02	0.13	0.03	0.03	0.03	0.03		
2	DIERKS	U	0	12.0	67	6.1	6.0	1.4	7.2			39.0	78.0	12.0	22.0							0.02	0.02	0.04	0.20	0.01	0.17		
2	DIERKS	L	0	9.1	67	8.0	5.9	1.2	9.8			37.0	54.0	11.0	17.0	2.9		5.0				0.02	0.02	0.02	0.11	0.01	0.09		
3	GILLHAM	U	2	4.1	51	6.1	5.9	1.4	8.4			37.0	60.0	10.0	16.0							0.02	0.02	0.02	0.08	0.01	0.05		
3	GILLHAM	L	2	4.3	59	6.8	5.9	1.2	9.0			35.0	[illegible]	11.0	14.0	2.6		4.4				0.02	0.02	0.02	0.08	0.01	0.05		
4	DEQUEEN	U	4	9.4	75	7.9	6.1	2.0	4.3			37.0	48.0	10.0	13.0							0.02	0.02	0.02	0.05	0.01	0.03		
4	DEQUEEN	L	5	2.5	71	7.9	5.8	1.2	5.4			37.0	46.0	11.0	13.0	3.1		4.8				0.02	0.02	0.02	0.05	0.01	0.04		
5	CATHERINE	U	TN-1	5.9	31	6.5	6.0	7.0	4.0	42	37	59.9	54.9	18.1	20.5	3.6	2.9	4.0	2.0	0.06	0.10	0.02	0.05	0.04	0.03	0.03	0.03		
5	CATHERINE	L	12	21.4	46	7.0	6.5	3.5	4.0	42	53	63.8	87.5	17.6	20.5	5.1	7.0	3.0	7.0	0.05	0.55	0.02	0.09	0.04	0.04	0.03	0.03		
6	GREESON	U	11	8.1	76	7.3	6.5	2.0	7.0	32	52	29.0	46.5	10.8	22.1	1.7	1.8	2.0	7.0	0.05	0.23	0.03	0.02	0.03	0.06	0.03	0.03	3.7	5.7
6	GREESON	L		2.4	95	6.2	6.0	1.6	3.2			32.0	35.0					3.0	3.0	0.01	0.01	0.02	0.27	0.01	0.01	0.01	0.01	2.9	3.0
7	HAMILTON	U	4	7.5	63	7.5	6.4	2.5	6.5	29	34	46.7	49.5	17.1	18.6	2.6	2.5	1.0	1.0	0.05	0.05	0.02	0.04	0.03	0.03	0.03	0.03		
7	HAMILTON	L	1	10.2	71	8.2	5.9	2.0	6.0	30	32	46.5	54.2	17.1	20.0	2.8	2.6	1.0	1.0	0.06	0.08	0.02	0.06	0.03	0.03	0.03	0.03		
8	MAUMELLE	U	0	4.5	92	7.6	6.9	2.0	7.0	23	51	25.7	51.8	7.8	25.5	1.9	2.2	4.0	11.0	0.13	0.63	0.02	0.02	0.03	0.03	0.03	0.03	3.3	6.1
8	MAUMELLE	L	1	3.4	115	7.9	6.8	1.5	5.5	24	47	25.5	54.9	15.2	25.9	2.0	3.0	4.0	9.0	0.15	0.59	0.02	0.02	0.03	0.06	0.03	0.06	3.7	5.0
9	DEGRAY	U	0	5.6	73	7.1	6.5	2.0	12.0	40	65	50.6	71.7	19.6	33.3	1.6	1.7	3.0	8.0	0.05	0.49	0.02	0.02	0.03	0.20	0.03	0.15	4.0	5.6
9	DEGRAY	L		2.3	110	6.2	6.6	1.0	1.8			51.0	50.0					4.0	4.0	0.01	0.04	0.01	0.21	0.01	0.01	0.01	0.01	4.3	4.7
10	NORFORK	U	0	1.2	186	8.2	7.5	0.5	3.7			315.0	318.0	48.0	166.0							0.03	0.21	0.02	0.02	0.01	0.01		
10	NORFORK	L	0	0.3	214	8.6	7.7	0.4	0.3			272.0	288.0	144.0	144.0	2.8		5.1				0.03	0.36	0.02	0.02	0.01	0.01		
11	BEAVER	U	1	2.7	103	8.0	7.2	1.2	30.0			134.0	147.[illegible]	46.0	54.0							0.02	0.28	0.08	0.07	0.01	0.03		
11	BEAVER	M	0	2.0	131	8.5	7.3	0.9	14.0			131.0	123.0	50.0	40.0							0.02	0.68	0.02	0.03	0.01	0.01		
11	BEAVER	L	0	0.5	218	8.6	7.4	0.3	1.1			141.0	141.0	56.0	52.0	3.3		6.9				0.02	0.45	0.02	0.02	0.01	0.01		
12	GREERS FERRY	U	0	0.2	186	7.0	6.5	0.3	5.5			43.0	37.0	13.0	11.0							0.02	0.18	0.02	0.02	0.01	0.01		
12	GREERS FERRY	L		0.3	158	6.6	6.9	0.3	3.0			38.0	41.0	11.0	11.0	1.7		4.0				0.02	0.17	0.02	0.04	0.01	0.01		
13	OUACHITA	U	0	1.9	148	7.6	5.4	1.0	5.5	32	36	50.4	47.3	19.5	16.1	2.2	2.3	1.0	2.0	0.05	0.05	0.02	0.27	0.03	0.03	0.03	0.03		
13	OUACHITA	M	0	1.1	212	7.8	5.2	1.0	2.0	32	37	50.1	50.6	19.5	18.1	2.3	2.5	1.0	2.0	0.05	0.05	0.02	0.19	0.03	0.03	0.03	0.03		
13	OUACHITA	L		2.0	150	6.6	6.8	1.2	0.6			55.0	56.0					4.0	4.0	0.01	0.01	0.01	0.18	0.01	0.01	0.01	0.01	5.6	4.7
14	BULL SHOALS	U	0	0.6	186	8.0	7.4	0.5	22.0			263.0	263.0	126.0	116.0							0.02	0.37	0.02	0.06	0.01	0.02		
14	BULL SHOALS	M	0	0.6	246	8.0	7.5	0.4	1.8			277.0	295.0	134.0	136.0							0.02	0.32	0.02	0.02	0.01	0.01		
14	BULL SHOALS	L	0	0.3	257	8.4	7.7	0.8	0.2			245.0	259.0	110.0	122.0	4.4		7.1				0.02	0.32	0.02	0.02	0.01	0.01		

TABLE A-2. Water Quality Data from Type B Lakes

NO.	LAKES	STN	F.COLI	CHLOR a	SECCHI	PH	(ph)	TURB	(turb)	TDS	(tds)	COND	(cond)	ALK	(alk)	CL	(cl)	SO4	(so4)	NH3-N	(nh3-n)	NO2-NO3	(no2-no3)	TL-P	(tl-p)	O-PO4	(o-po4)	TOC	(toc)
15	CRYSTAL	L	1	3.5	136	8.4	6.8	1.0	12.0	117	144	194.0	237.0	91.0	114.0	3.4	3.3	2.0	2.0	0.05	0.05	0.02	0.02	0.03	0.18	0.03	0.03	5.6	9.8
16	SHORES	L	0	2.7	79	6.7	6.6	2.0	17.0	31	38	44.8	59.6	19.1	27.4	1.5	1.5	1.0	1.0	0.05	0.18	0.02	0.02	0.03	0.03	0.03	0.03	1.5	2.4
17	SPRING	L	52	0.3	79	6.6	6.5	2.6	5.4	33	54	29.6	38.5	9.8	27.9	2.3	2.0	4.0	10.0	0.11	0.28	0.02	0.06	0.03	0.03	0.03	0.03	1.3	2.4
18	HORSEHEAD	L	4	1.3	65	7.1	6.4	2.5	14.0	24	29	29.1	39.4	10.8	15.2	1.5	1.5	2.0	2.0	0.05	0.19	0.02	0.02	0.03	0.03	0.03	0.03	1.5	1.3
19	WEDDINGTON	L	1	0.0	137	8.3	7.0	1.0	10.0	77	97	129.0	156.0	57.8	74.4	2.3	2.7	2.0	2.0	0.06	0.16	0.02	0.02	0.03	0.06	0.03	0.03	3.8	5.3
20	COVE	L	0	1.6	115	6.7	6.3	1.6	17.0	26	51	27.0	39.2	9.8	25.0	1.5	1.7	3.0	9.0	0.05	0.38	0.02	0.02	0.03	0.03	0.03	0.03	1.0	3.3
21	ELMDALE	L	2	11.0	30	9.2	7.2	5.5	8.5	73	100	125.0	182.0	52.9	82.2	6.1	5.8	2.0	1.0	0.08	0.48	0.02	0.02	0.05	0.09	0.03	0.03	7.5	5.5
22	FAYETTEVILLE	L	2	5.9	55	8.6	7.0	3.9	15.0	105	158	172.0	281.0	73.4	132.0	4.8	5.4	4.0	4.0	0.05	3.16	0.02	0.02	0.03	0.65	0.03	0.05	7.3	8.3
23	BOBB KIDD	L	8	11.3	43	8.9	7.2	3.0	9.0	86	107	150.0	197.0	53.8	92.0	5.3	5.5	8.0	4.0	0.10	1.40	0.02	0.02	0.04	0.55	0.03	0.14	7.0	8.4
24	WILHELMENA	L	TN-5	9.7	46	6.8	6.3	3.6	8.6	27	49	26.1	46.8	9.3	30.3	2.4	2.7	4.0	13.0	0.05	2.17	0.02	0.02	0.05	0.55	0.03	0.46	4.7	7.3
25	BARNETT	L	3	5.4	68	7.7	6.8			27	73	36.5	97.1	11.7	49.8	3.2	3.4	3.0	13.0	0.14	1.68	0.02	0.02	0.15	0.45	0.03	0.33		
26	SUGARLOAF	L	2	4.0	89	7.1	6.7	2.9	3.6	41	56	55.7	78.8	14.7	24.5	2.7	3.0	9.0	9.0	0.05	0.58	0.02	0.02	0.04	0.12	0.03	0.11	3.3	3.4
27	FT. SMITH	L	0	2.1	141	7.7	6.5	1.5	5.4	26	34	39.1	47.2	14.2	17.6	1.5	1.5	2.0	3.0	0.05	0.05	0.02	0.19	0.03	0.03	0.03	0.03	1.0	1.1
28	SEQUOYAH	L		39.2				36.0		85		154.0		63.6		1.6		5.0		0.28		0.02		0.11		0.03		3.4	
29	SWEPCO	L	2	3.8	156	8.3	7.4	1.0	32.0	180	211	317.0	386.0	85.2	129.0	10.2	11.3	58.0	48.0	0.09	0.68	0.02	0.02	0.03	0.04	0.03	0.03	2.7	4.6
30	SHEPHERD SPG	L	6	2.8	74	7.3	6.2	2.5	4.6	31	34	45.7	42.6	18.1	14.2	1.5	1.5	2.0	4.0	0.05	0.05	0.02	0.28	0.03	0.03	0.03	0.03	1.8	0.5
31	CHARLES	L	0	18.3	27	8.9	8.4	5.0	5.5	150	143	244.0	252.0	126.0	126.0	3.4	3.2	4.0	2.0	0.11	0.05	0.02	0.02	0.06	0.04	0.03	0.03	9.9	7.8
32	BEAVERFORK	L	3	4.8	78	7.1	6.4	2.5	6.0	35	46	46.9	69.6	10.3	23.0	5.0	5.0	5.0	5.0	0.05	0.12	0.02	0.02	0.03	0.03	0.03	0.03	4.1	4.4
33	HINKLE	L	TN-5	5.4	78	6.3	6.4	2.2	3.0	33	43	36.7	53.1	11.3	23.5	2.1	2.2	4.0	5.0	0.08	0.58	0.02	0.02	0.03	0.05	0.03	0.03	3.7	4.1
34	BREWER	L	2	8.0	50	8.3	6.9	3.0	8.5	28	56	36.1	72.7	11.3	33.3	2.3	2.6	3.0	11.0	0.05	0.82	0.02	0.02	0.03	0.04	0.03	0.07	3.1	4.7

TABLE A-3. Water Quality Data from Type C Lakes

NO.	LAKES	STN	F.COLI	CHLOR a	SECCHI	PH	(ph)	TURB	(turb)	TDS	(tds)	COND	(cond)	ALK	(alk)	CL	(cl)	SO4	(so4)	NH3-N	(nh3-n)	NO2-NO3	(no2-no3)	TL-P	(tl-p)	O-PO4	(o-po4)	TOC	(toc)
35	JUNE	L	19	31.8	22	6.3	5.8	7.5	8.5	80	72	66.2	54.3	9.3	7.8	11.6	8.9	7.0	7.0	0.05	0.05	0.02	0.02	0.25	0.25	0.08	0.08		
36	BAILEY	L	24	11.9	31	6.5	6.2	8.0	12.0	32	38	31.2	32.9	17.6	11.2	3.3	3.6	5.0	5.0	0.15	0.21	0.02	0.02	0.14	0.13	0.05	0.05		
37	TRICOUNTY	L	4	30.5	22	6.8	6.5	8.4	9.4			42.1	48.8	13.7	17.6	3.3	3.1	6.0	6.0	0.05	0.08	0.02	0.02	0.11	0.15	0.03	0.03	13.4	14.0
38	COX CREEK	L																											
39	HURRICANE	L	29	20.3	38	7.6	6.9	4.0	5.5	64	95	86.3	108.0	37.9	51.8	3.4	3.5	4.0	13.0	0.05	0.77	0.02	0.02	0.05	0.21	0.03	0.19		
40	FRIERSON	L	2	30.0	22	6.9	6.3	16.0	26.0	47	53	42.8	44.1	14.2	15.2	2.0	2.1	4.0	5.0	0.05	0.16	0.02	0.02	0.06	0.06	0.03	0.03	5.9	5.5
41	STORM CREEK	L	1	74.6	21	9.1	7.1	8.8	16.0	91	110	140.0	174.0	69.1	86.2	1.4	1.6	7.0	14.0	0.05	1.55	0.02	0.02	0.09	0.40	0.03	0.29	8.5	8.4
42	CALION	L	3	9.4	27	6.6	6.3	7.0	15.0			60.0	61.4	8.8	9.8	9.4	9.0	6.0	7.0	0.05	0.05	0.02	0.02	0.06	0.06	0.03	0.03	12.0	12.4
43	POINSETT	L	1	4.0	73	7.1	6.7	2.5	25.0	48	77	62.1	90.5	8.8	29.4	3.2	3.2	15.0	13.0	0.11	0.78	0.02	0.02	0.03	0.29	0.03	0.15	4.1	5.3
44	BEAR CREEK	L	1	72.2	15	9.0	7.1	15.0	5.4	80	104	116.0	162.0	55.9	79.4	1.7	1.9	6.0	17.0	0.05	1.73	0.02	0.02	0.09	0.51	0.03	0.44	8.6	8.5
45	UP WHITE OAK	L	12	21.0	37	7.1	6.5	3.0	7.0	44	75	23.5	45.9	7.8	21.5	3.0	3.3	3.0	14.0	0.06	0.05	0.02	0.02	0.09	0.08	0.05	0.03		
46	ATKINS	L	20	13.4	30	6.6	6.5	4.5	4.5	47	50	61.5	61.1	20.5	20.5	3.6	3.4	3.0	4.0	0.20	0.19	0.02	0.02	0.04	0.05	0.03	0.03		
47	OVERCUP	L	6	19.6	28	6.8	7.0	4.5	5.5	42	62	67.0	99.7	23.4	42.0	4.6	4.5	3.0	4.0	0.26	1.13	0.02	0.02	0.11	0.13	0.03	0.03		
48	LO WHITE OAK	L	1	13.4	59	7.7		2.5	3.0	33	42	22.8	33.3	6.8	13.7	2.4	2.3	2.0	3.0	0.05	0.19	0.02	0.02	0.07	0.07	0.03	0.03		
49	HARRIS BRAKE	L	TN-1	21.4	42	6.8	6.8	4.0	3.0	27	29	37.1	38.8	12.7	13.7	3.2	3.2	2.0	3.0	0.17	0.18	0.02	0.02	0.10	0.10	0.03	0.03		
50	CANE CREEK	L	2	32.6	28	6.6	6.7	5.5	22.0	45	100	55.2	136.0	16.7	69.6	2.6	4.0	7.0	28.0	0.05	1.68	0.02	0.02	0.07	0.60	0.03	0.30		

TABLE A-4. Water Quality Data from Type D Lakes

NO.	LAKES	STN	F.COLI	CHLOR a	SECCHI	PH	(ph)	TURB	(turb)	TDS	(tds)	COND	(cond)	ALK	(alk)	CL	(cl)	SO4	(so4)	NH3-N	(nh3-n)	NO2-NO3	(no2-no3)	TL-P	(tl-p)	O-PO4	(o-po4)	TOC	(toc)
51	WILSON	L	7	39.5	38	6.8	6.6	4.5	4.5		20	42.5	44.2	16.7	17.6	3.5	3.5	1.0	1.0	0.05	0.11	0.02	0.02	0.08	0.09	0.03	0.03		
52	ENTERPRISE	L	18	55.4	41	6.5	6.2	3.5	12.0	29	35	36.6	48.4	11.8	17.6	3.5	3.2	2.0	3.0	0.05	0.05	0.02	0.02	0.07	0.19	0.03	0.08		
53	1ST OLD RIVE	L	1	52.1	21	9.5	7.0	9.0	16.0	108	114	147.0	181.9	73.5	86.2	3.0	3.0	1.0	4.0	0.05	2.22	0.02	0.02	0.10	0.07	0.03	0.24	10.9	10.4
54	HOGUE	L	0	22.7	36	8.3	6.7	6.0	40.0	61	84	87.1	139.0	43.1	66.6	2.7	3.6	1.0	1.0	0.07	1.06	0.02	0.02	0.05	0.33	0.03	0.03	11.4	11.4
55	GREENLEE	L	2	22.7	20	8.3	7.5	9.0	9.7	64	60	68.3	67.3	23.0	23.0	4.9	4.7	9.0	7.0	0.05	0.05	0.02	0.02	0.29	0.28	0.17	0.16		
56	MALLARD	L	0	115.8	14	9.2	8.2	16.0	18.0	134	135	171.0	177.0	78.3	77.3	6.6	6.5	1.0	2.0	0.07	0.16	0.02	0.02	0.20	0.20	0.03	0.03	16.6	17.2
57	GRAMPUS	L	7	53.5	35	6.5	6.1	4.0	48.0	14	42	25.6	66.9	10.8	30.4	2.2	2.4	2.0	3.0	0.05	0.05	0.02	0.02	0.07	0.37	0.03	0.09		
58	DESARC	L	0	8.1	30	6.8	7.1	5.5	7.3	48	82	64.5	136.0	26.0	64.7	3.0	2.8	6.0	6.0	0.05	1.84	0.02	0.02	0.08	0.24	0.03	0.10		
59	WALLACE	L	11	98.0	26	6.5	6.3	7.0	20.0	20	37	43.7	61.6	19.6	29.4	2.0	2.0	1.0	4.0	0.05	0.23	0.02	0.02	0.19	0.56	0.03	0.16		
60	PINE BLUFF	L																											
61	ASHBAUGH	L	6	28.2	28	7.2	7.1	5.5	5.5	94	92	147.0	147.0	66.6	65.6	2.6	2.6	3.0	4.0	0.05	0.05	0.02	0.02	0.06	0.06	0.03	0.03	9.9	7.7
62	BOIS D'ARC	L	0	110.8	21	9.6	7.1	16.0	7.5	77	78	88.3	82.9	30.4	33.3	4.9	4.8	3.0	3.0	0.05	0.21	0.02	0.02	0.11	0.16	0.03	0.03	11.1	9.3
63	OLD TOWN	L	0	174.3	12	9.4	9.3	24.0	24.0	72	69	99.1	93.3	44.1	44.1	2.0	1.9	5.0	6.0	0.05	0.05	0.02	0.02	0.32	0.32	0.07	0.06		

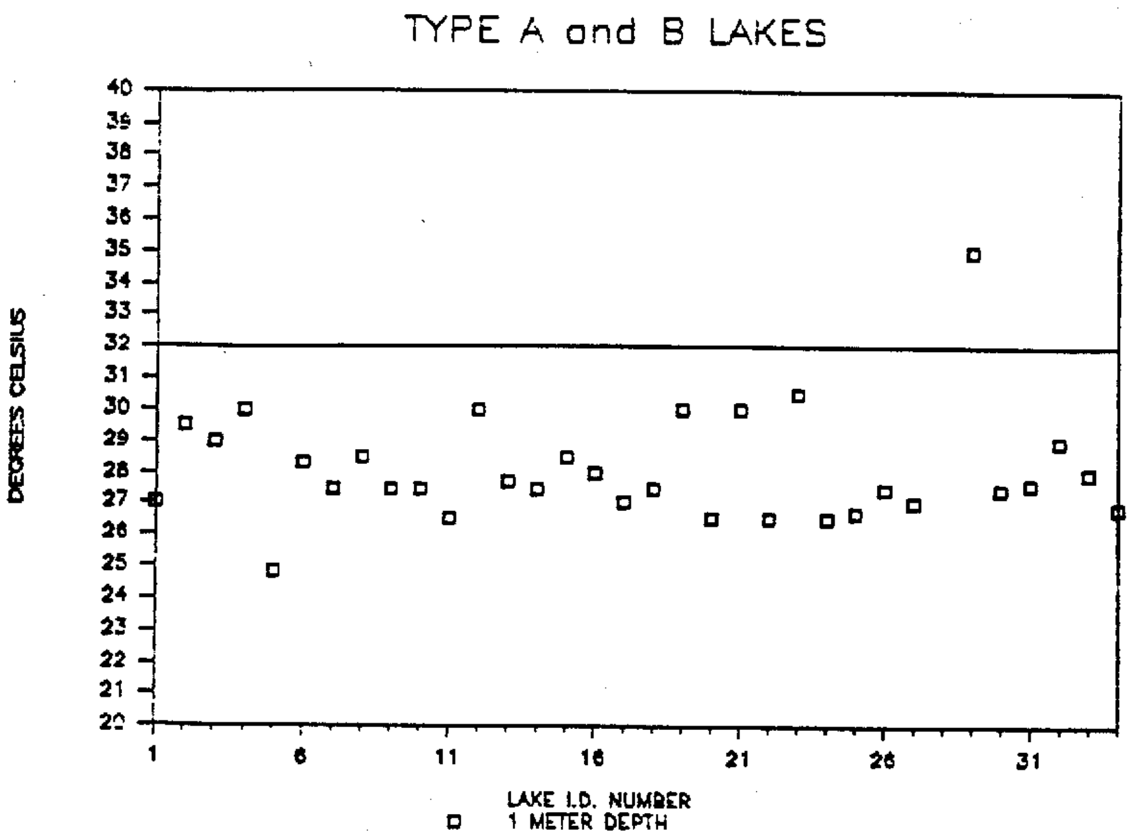
TABLE A-5. Water Quality Data from Type E Lakes

NO.	LAKES	STN	F.COLI	CHLOR a	SECCHI	PH	(ph)	TURB	(turb)	TDS	(tds)	COND	(cond)	ALK	(alk)	CL	(cl)	SO4	(so4)	NH3-N	(nh3-n)	NO2-NO3	(no2-no3)	TL-P	(tl-p)	O-PO4	(o-po4)	TOC	(toc)
64	HORSESHOE	L	0	87.7	13	9.4	9.2	17.0	16.0	100	82	131.0	131.0	61.3	61.3	1.3	1.3	8.0	9.0	0.05	0.05	0.02	0.02	0.10	0.10	0.03	0.03	6.7	7.1
65	UPPER CHICOT	L		36.1	20	7.6		11.0				221.0		110.0				1.0		0.01		0.18		0.25		0.15		14.0	
66	GRAND	L	10	147.5	17	9.0	9.0	15.0	15.0	74	97	15.5	15.6	75.5	75.5	2.9	2.8	1.0	1.0	0.05	0.05	0.02	0.02	0.30	0.28	0.10	0.09		
67	GA. PACIFIC	L	0	9.9	31	7.1	6.6	6.8	8.2			56.8	63.3	11.8	13.7	2.9	2.7	8.0	8.0	0.05	0.05	0.02	0.02	0.06	0.06	0.03	0.03	8.5	9.7
68	BLUE MT.	L	4	8.9	35	6.6	6.1	6.0	20.0			60.0	75.0	17.0	17.0	4.0		8.6				0.02	0.04	0.03	0.04	0.01	0.03		
69	COLUMBIA	U	0	14.4	36	6.1	5.9	2.0	5.5	68	76	56.2	56.7	7.8	10.7	8.2	7.5	6.0	8.0	0.05	0.05	0.02	0.02	0.08	0.09	0.03	0.03		
69	COLUMBIA	L	0	20.9	39	7.0	6.7	4.0	7.5	72	117	72.0	105.0	10.7	32.7	11.0	11.7	4.0	20.0	0.05	1.08	0.02	0.02	0.08	0.15	0.03	0.08		
70	NIMROD	L	0	8.6	44	6.4	5.9	6.1	32.0			35.0	48.0	10.0		2.7		4.0				0.02	0.02	0.03	0.07	0.01	0.04		
71	LOWER CHICOT	L		45.1	24	8.5		11.0				234.0		93.0				7.0		0.01		0.01		0.06		0.03		11.5	
72	CONWAY	U	15	34.4	26	6.8	6.6			47	48	66.2	64.0	22.5	22.0	4.3	4.0	4.0	4.0	0.17	0.16	0.02	0.02	0.17	0.16	0.03	0.03		
72	CONWAY	L	13	20.1	18	7.2	7.1			52	58	73.0	90.1	26.4	33.2	4.8	4.7	5.0	4.0	0.17	0.53	0.02	0.02	0.14	0.16	0.03	0.03		
73	ERLING	U	1	16.5	21	6.3	5.9	7.5	13.0	71	74	46.9	49.5	8.8	9.8	6.3	6.3	6.0	7.0	0.05	0.08	0.02	0.03	0.14	0.17	0.03	0.05		
73	ERLING	L	5	19.2	30	6.4	6.4	5.0	11.0	70	108	51.4	97.6	9.8	33.2	7.2	8.1	5.0	13.0	0.05	1.13	0.02	0.02	0.12	0.26	0.03	0.14		
74	OZARK	L																											
75	FELSENTHAL	U	5	3.5	36	6.5	6.4	5.3	4.9			73.9	71.8	18.1	17.6	4.4	3.9	14.0	13.0	0.05	0.05	0.06	0.06	0.08	0.09	0.03	0.03	13.3	13.4
75	FELSENTHAL	L	6	2.7	37	6.5	6.3	6.2	6.2			88.7	82.9	16.7	17.2	10.3	8.0	7.0	8.0	0.05	0.05	0.10	0.08	0.07	0.09	0.03	0.03	9.9	11.2
76	MILLWOOD	U	4	7.2	40	7.6	6.5	2.3	5.6			69.0	61.0	24.0	19.0	2.6	3.8	3.8	3.3			0.02	0.02	0.04	0.05	0.02	0.02		
76	MILLWOOD	L	3	14.0	35	7.0	6.2	4.4	5.9			63.0	60.0	20.0	19.0	6.0		5.9				0.02	0.02	0.04	0.05	0.02	0.02		

APPENDIX B

LAKES DATA COMPARED TO WATER QUALITY CRITERIA AND GUIDELINES

FIGURE B-1. Temperature Data



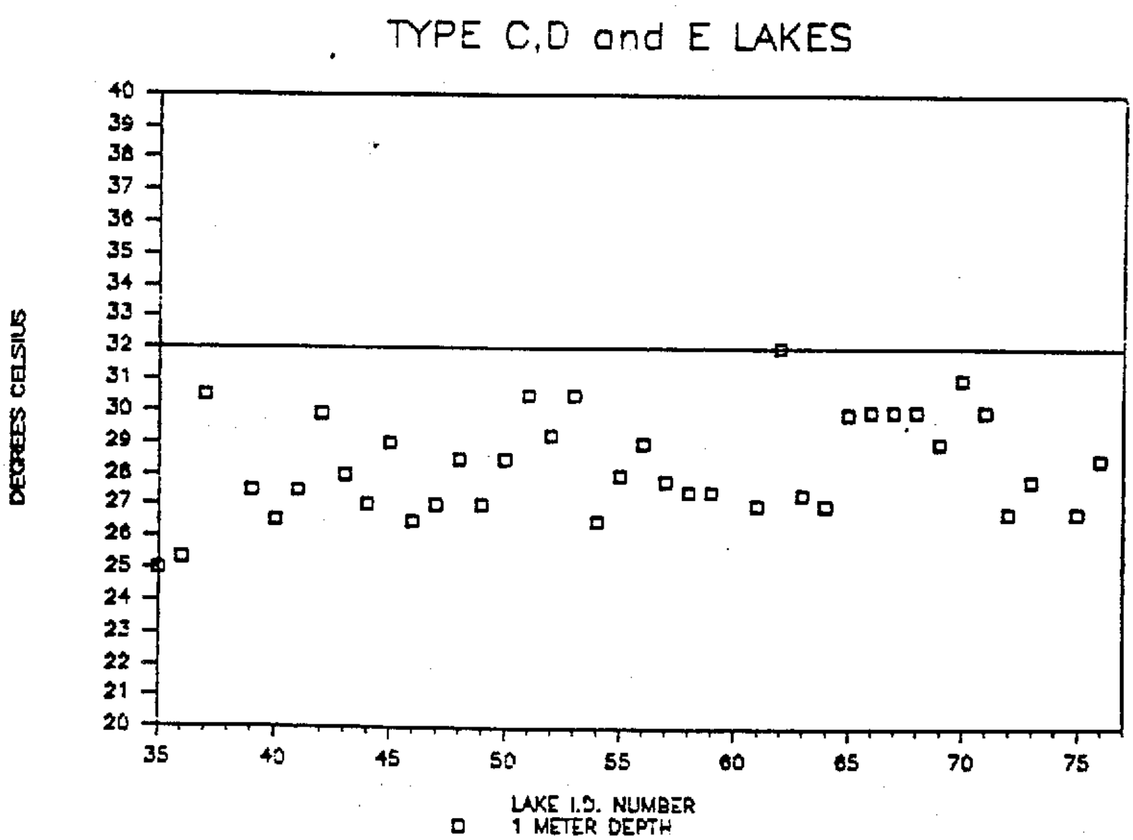
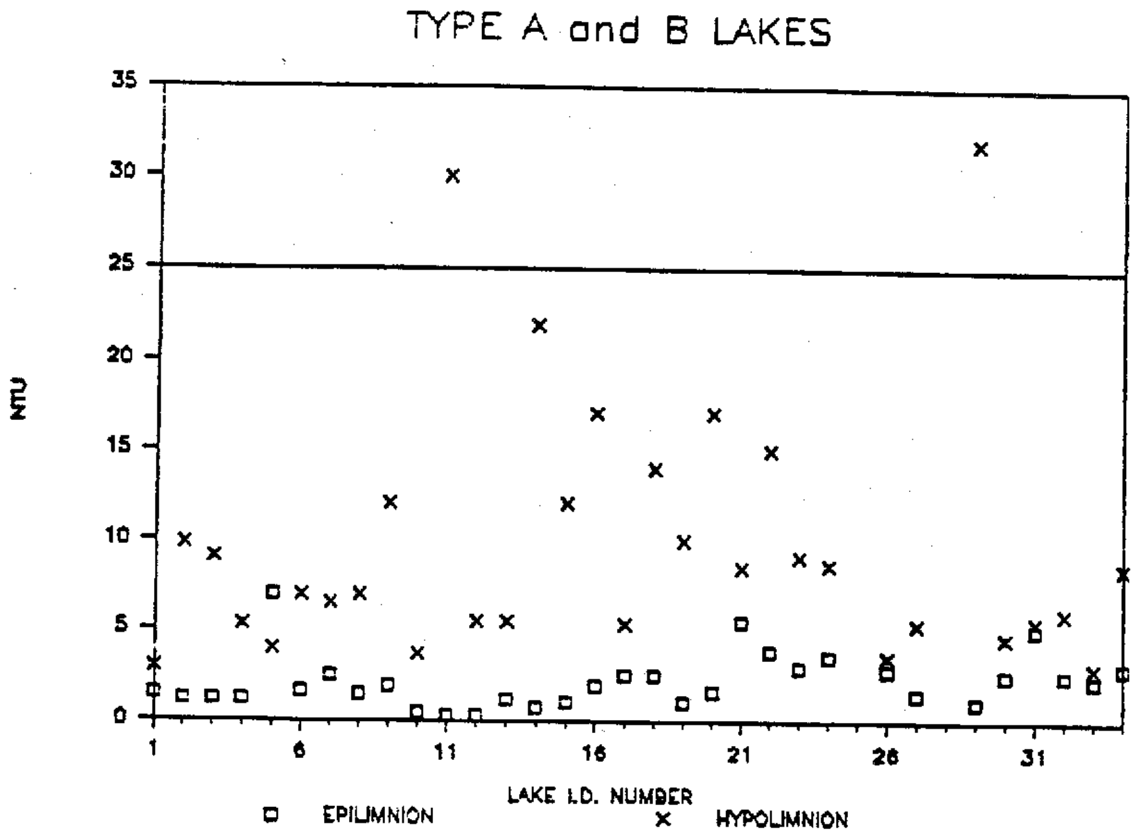


FIGURE B-2. Turbidity Data



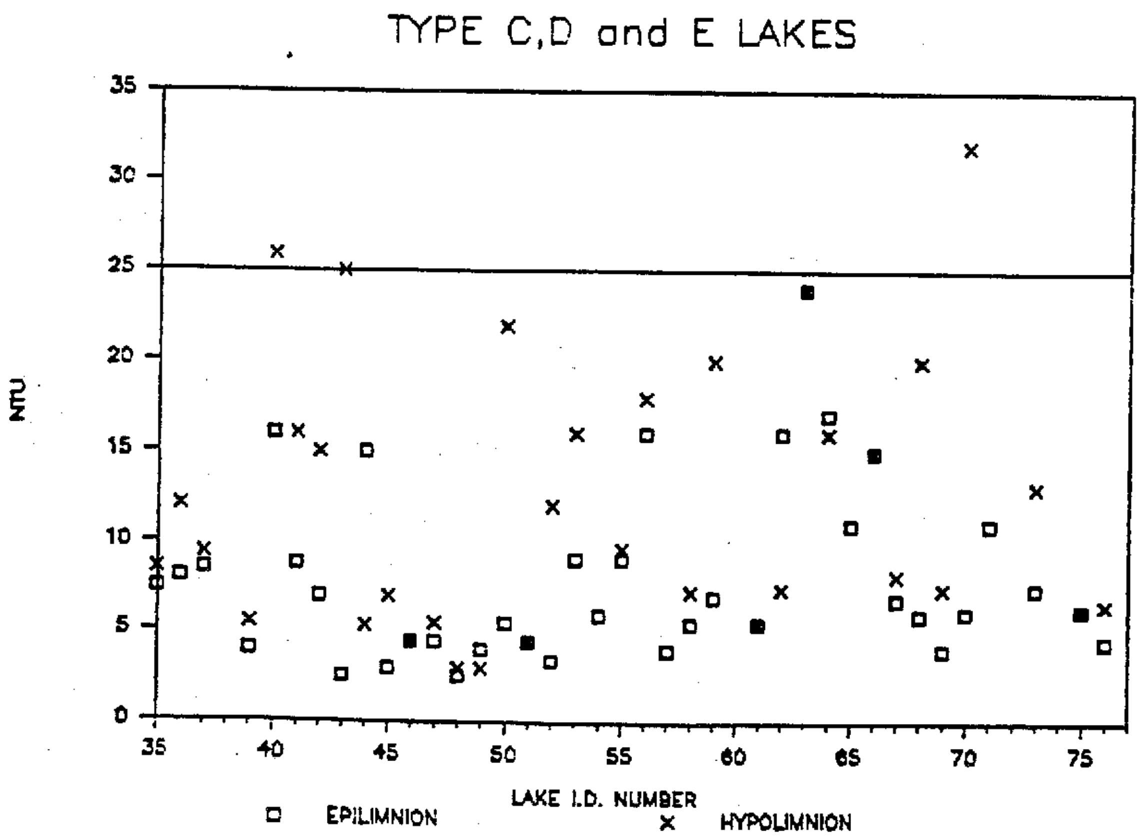
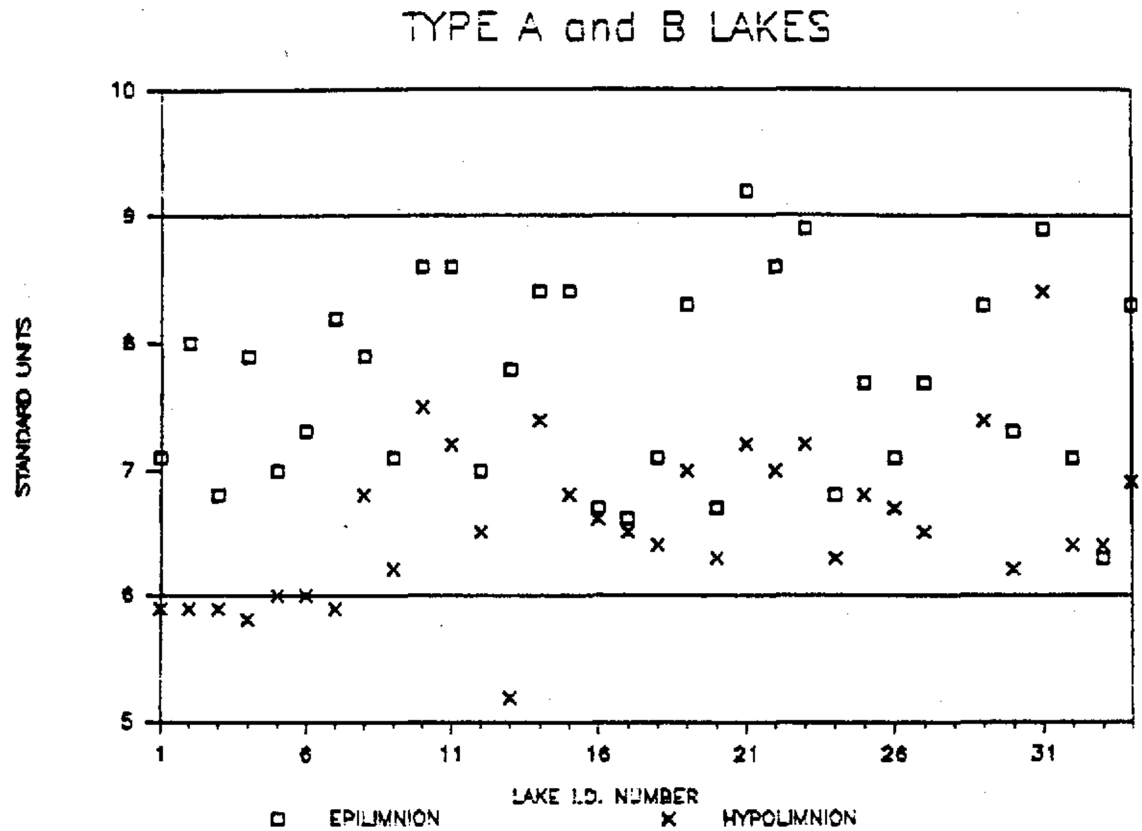


FIGURE B-3. pH Data



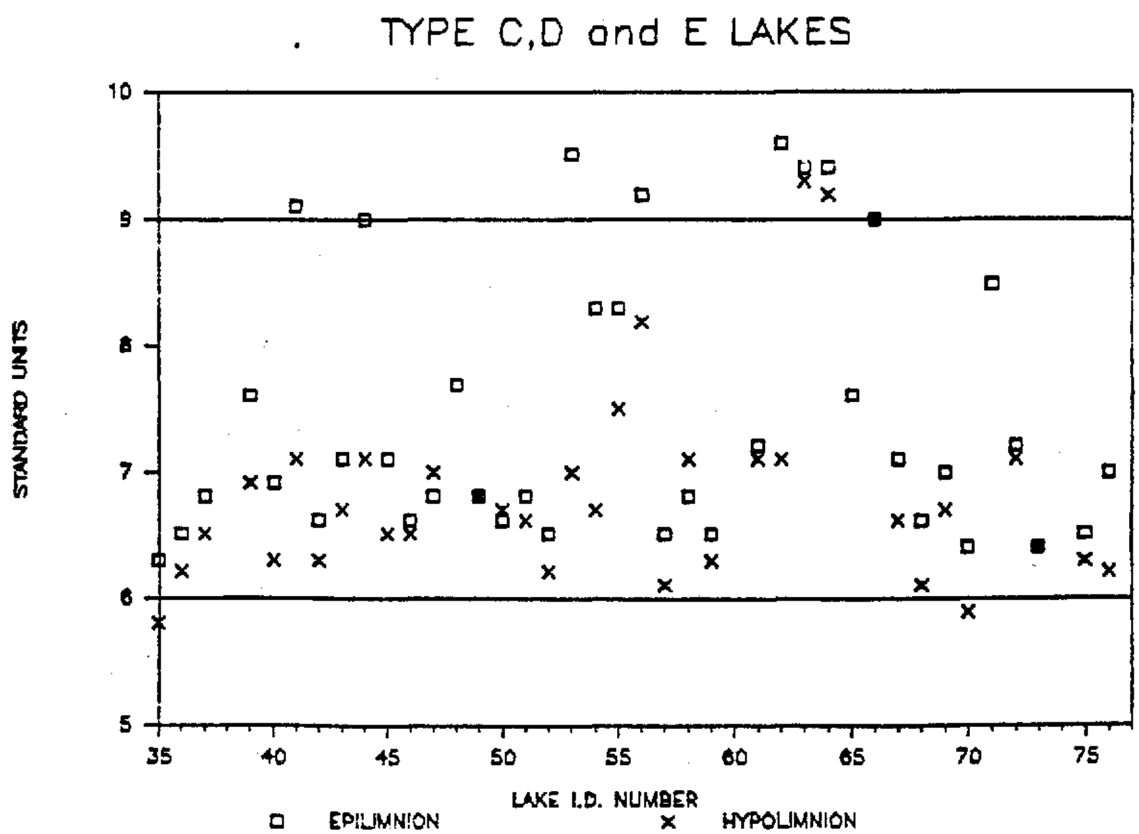
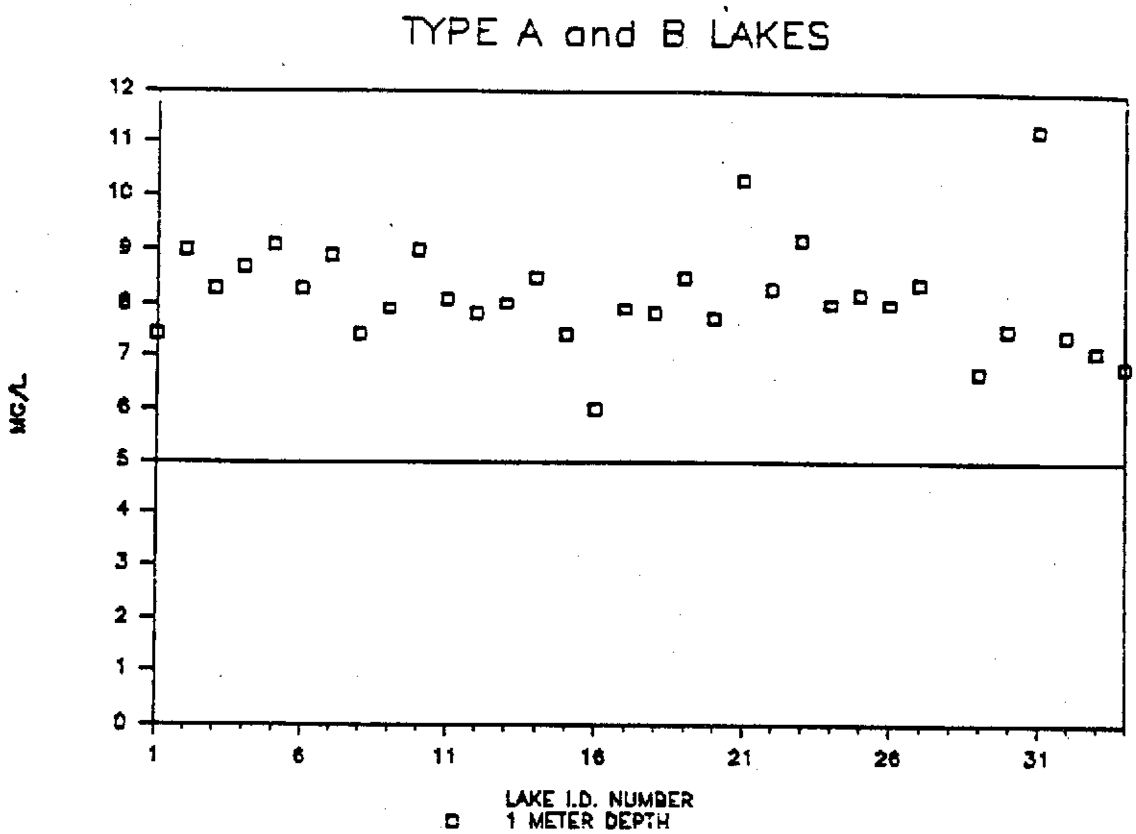


FIGURE B-4. Dissolved Oxygen Data



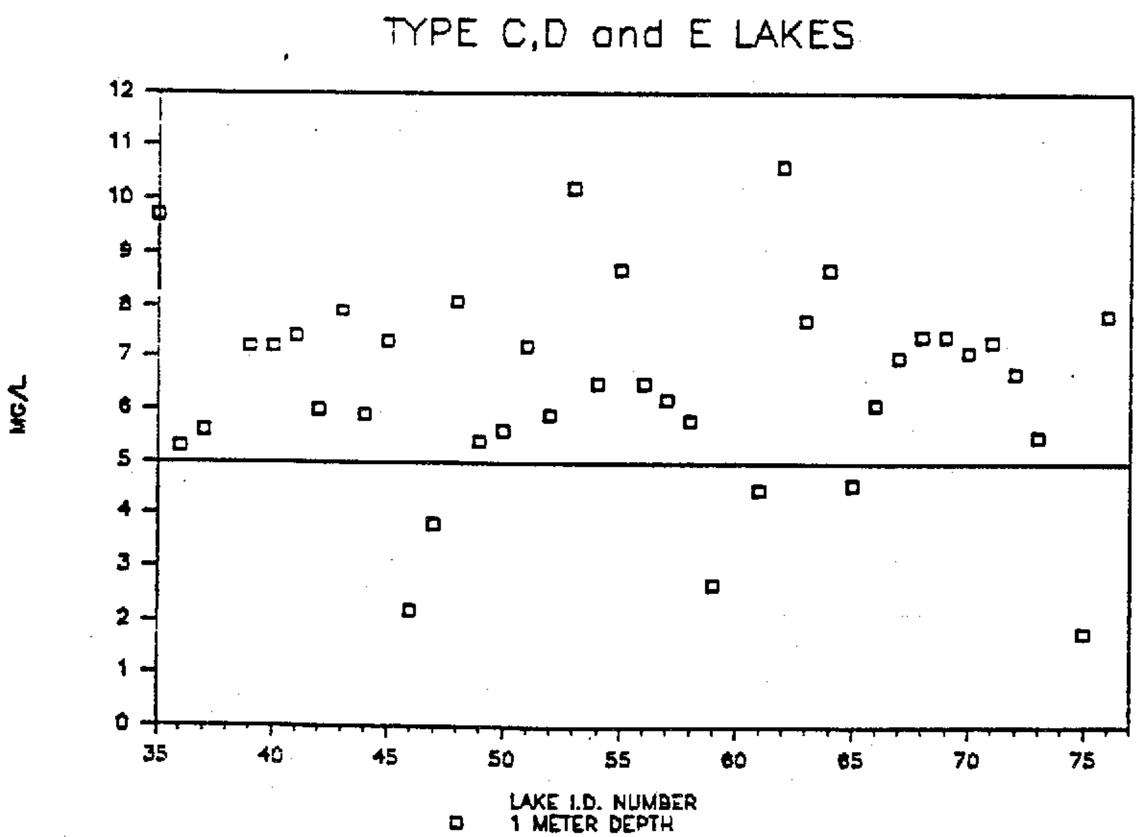
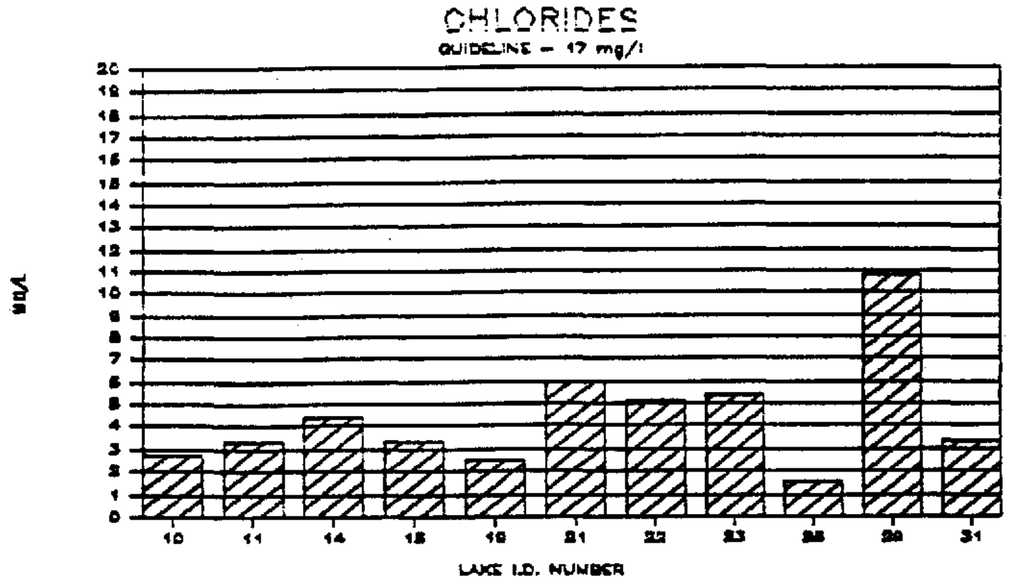
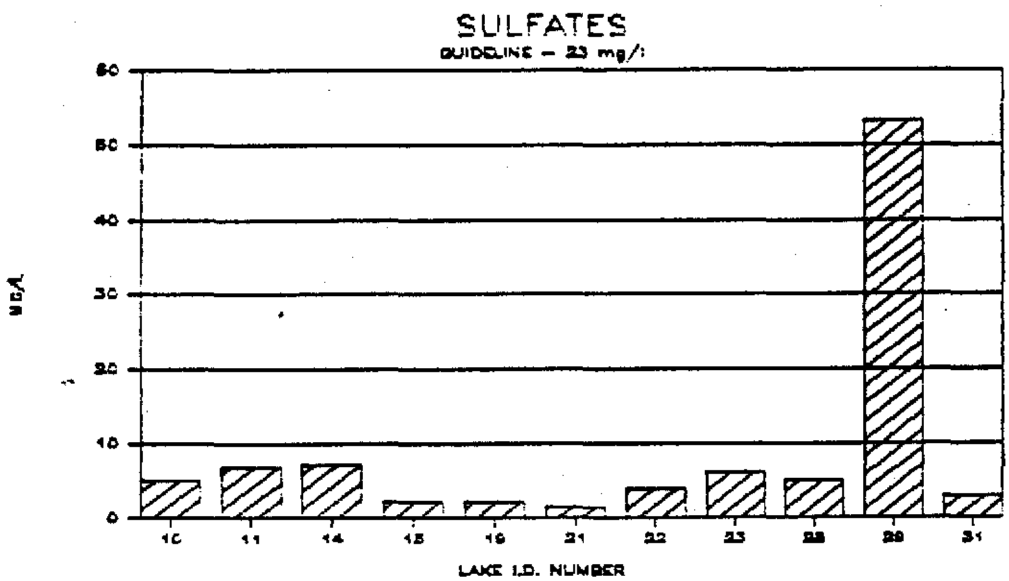


FIGURE B-5. Ozark Highlands Lakes - Minerals





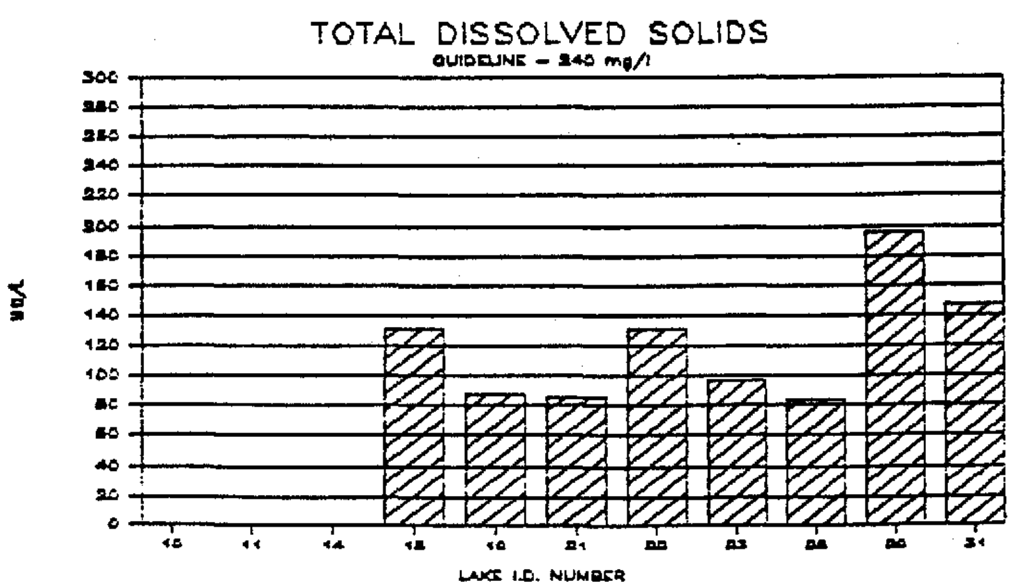
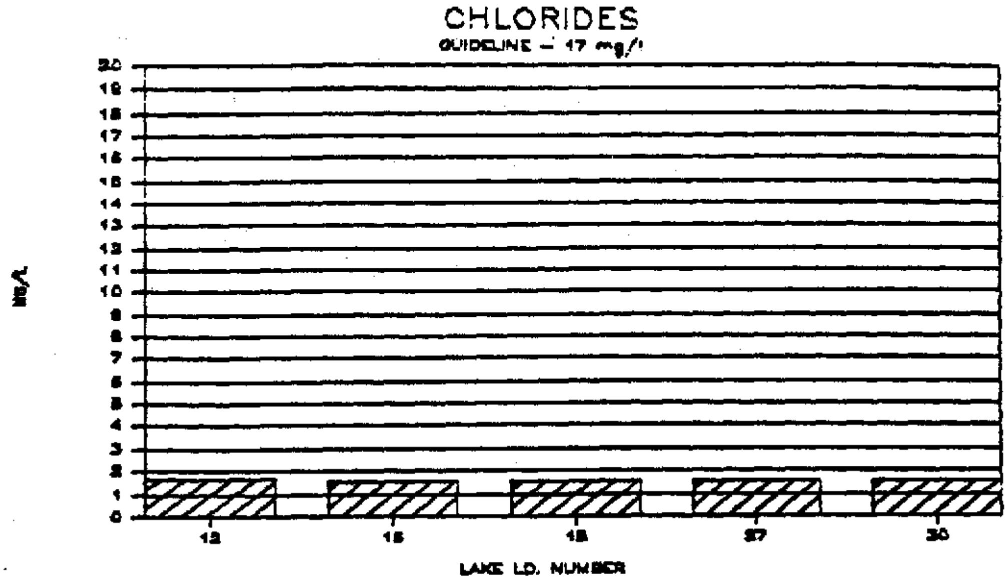
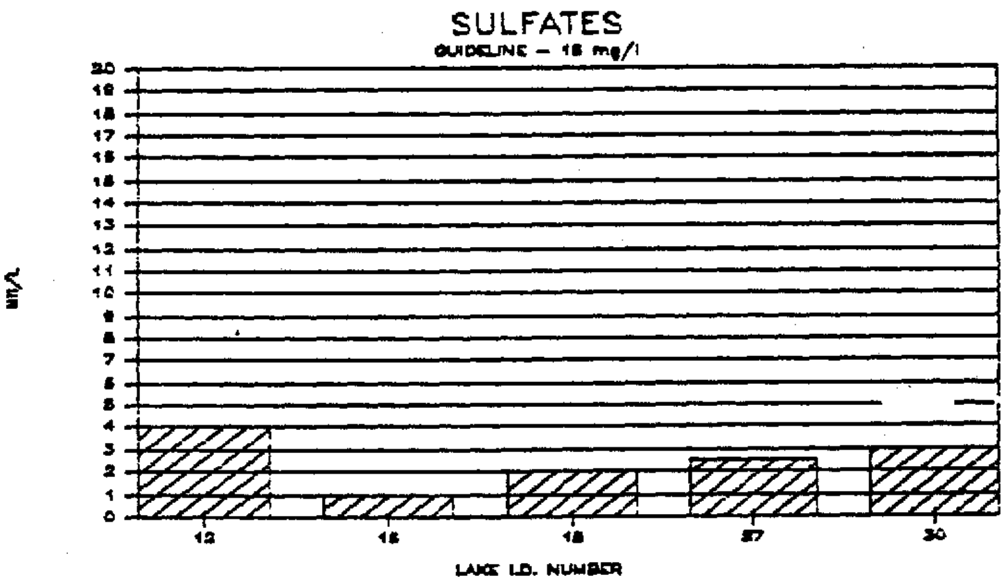


FIGURE B-6. Boston Mountains Lakes - Minerals





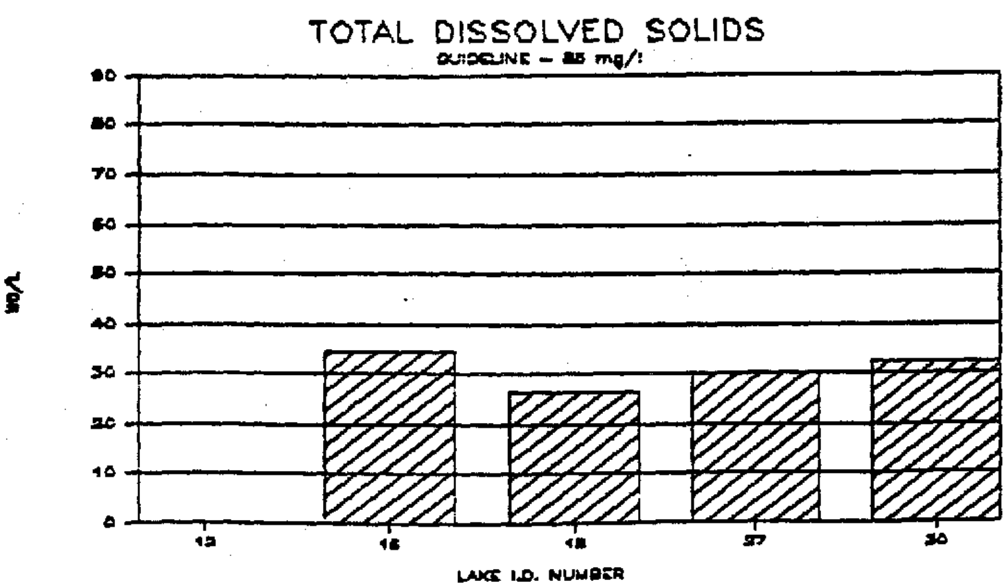
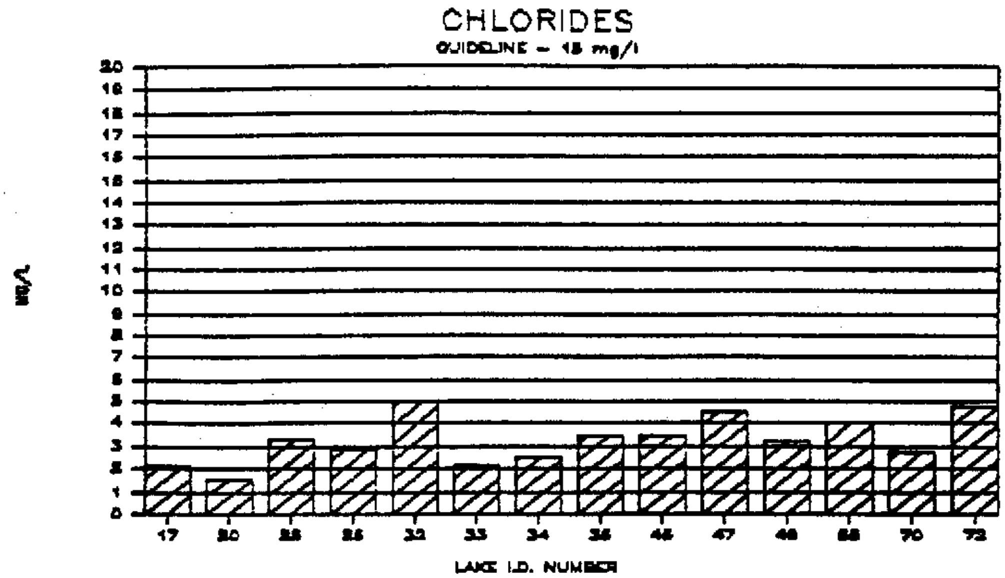
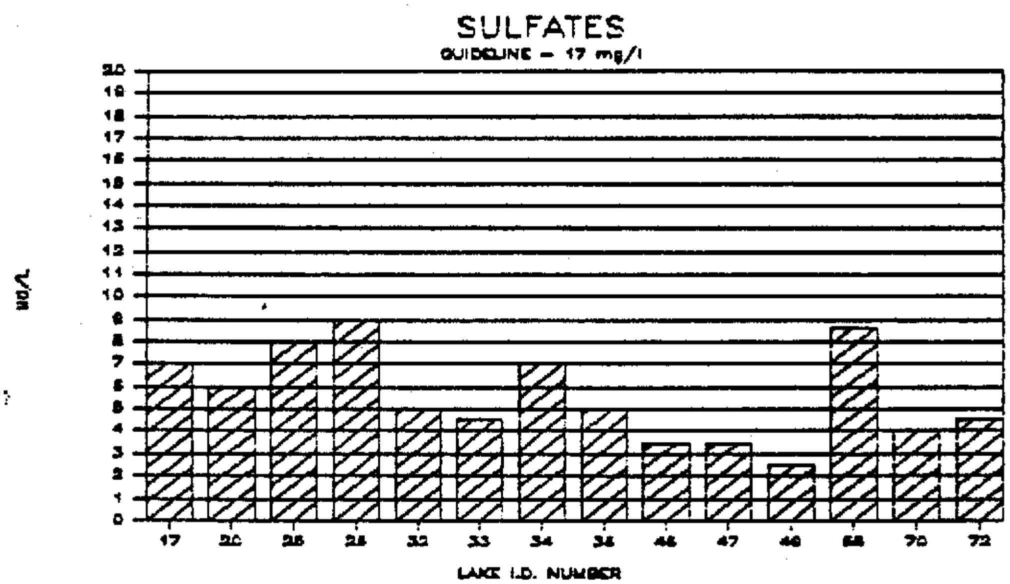


FIGURE B-7. Arkansas River Valley Lakes - Minerals





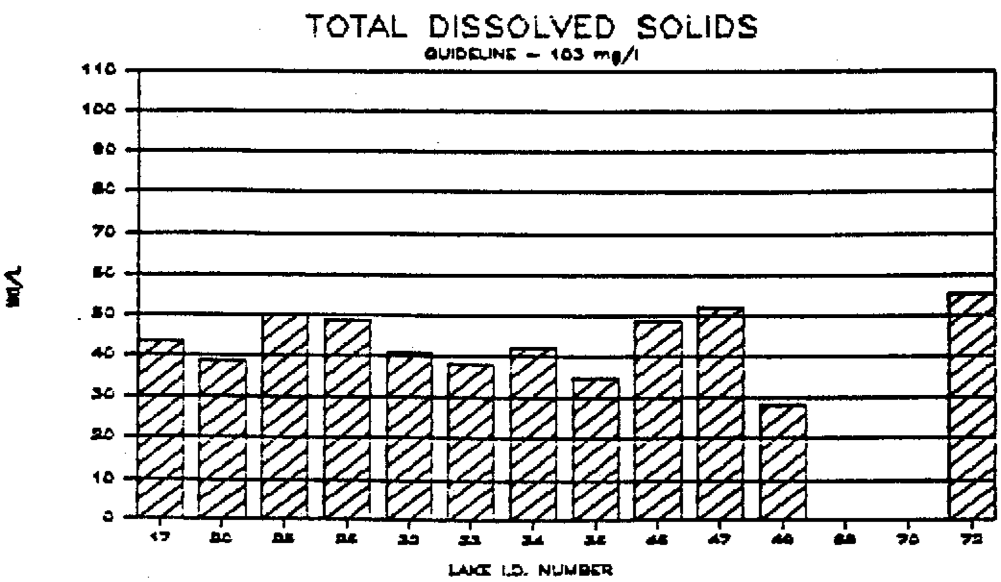
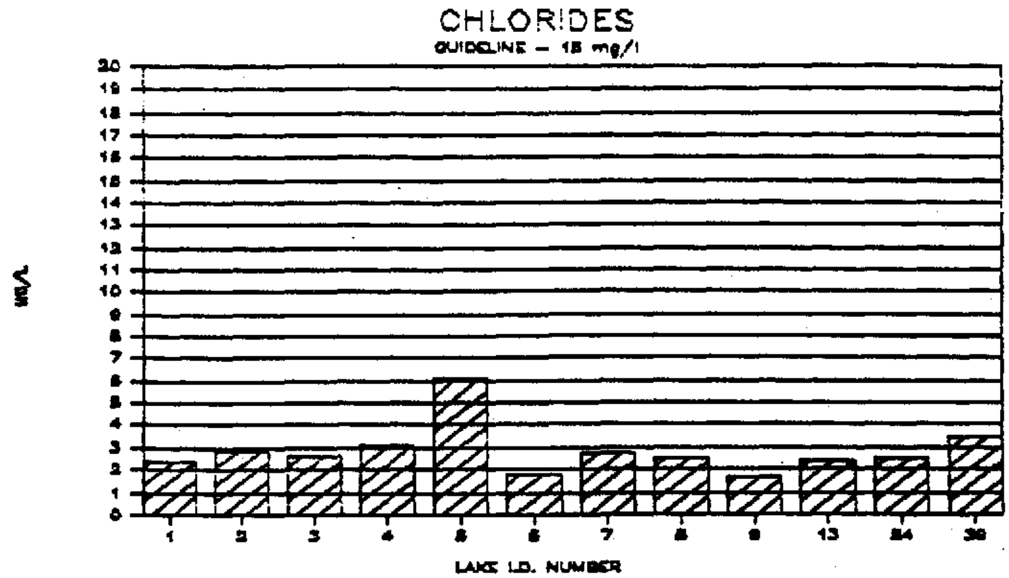
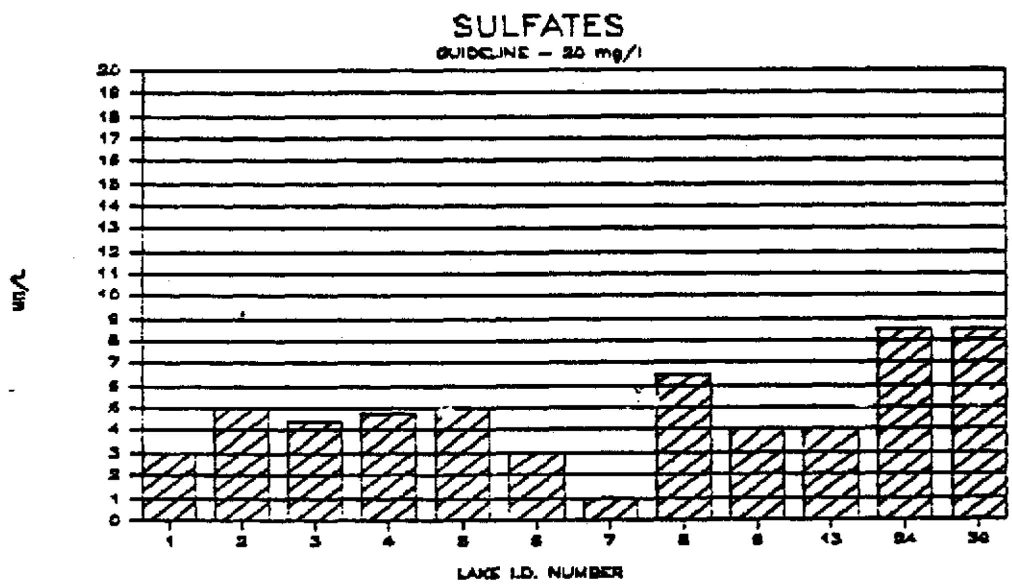


FIGURE B-8. Ouachita Mountains Lakes - Minerals





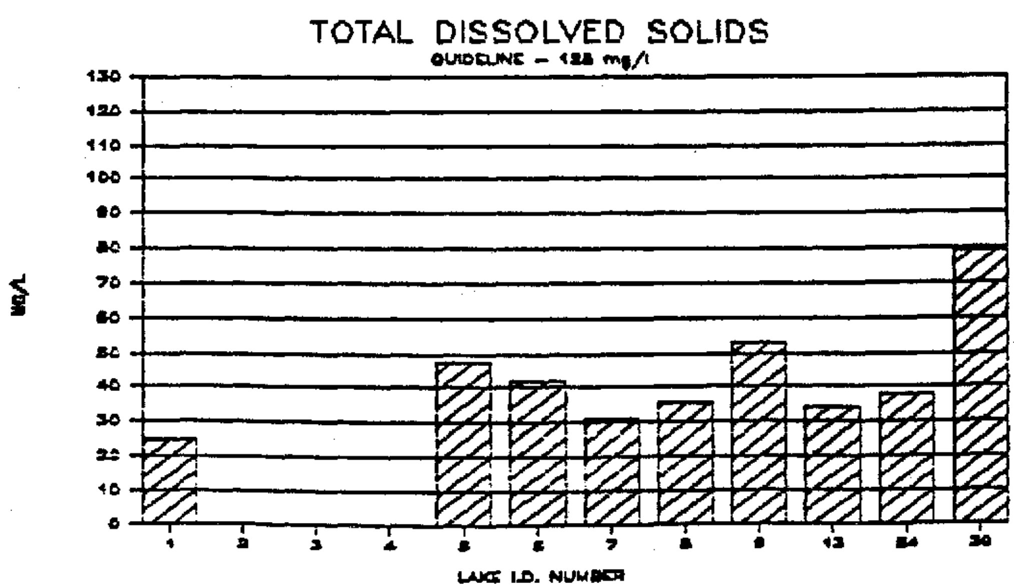
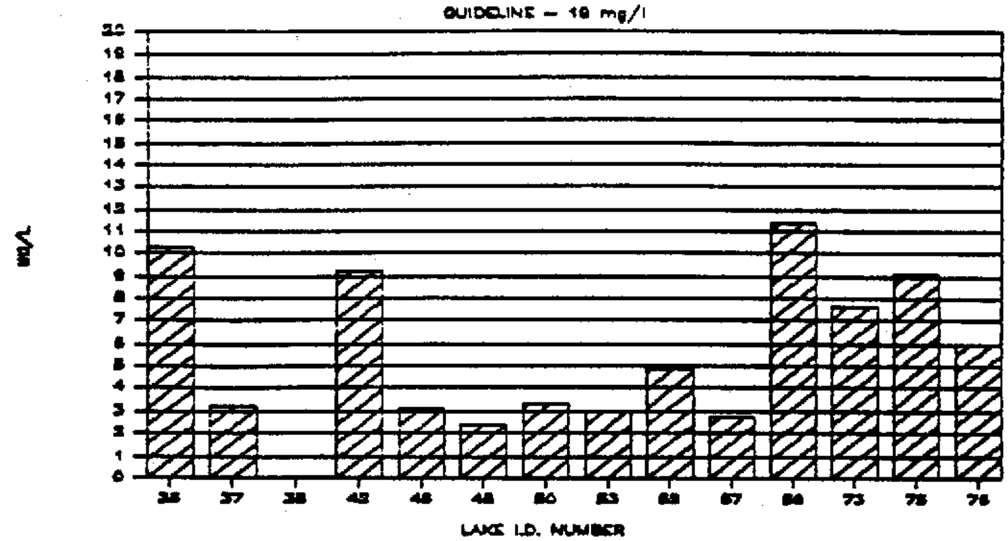


FIGURE B-9. Gulf Coastal Lakes - Minerals

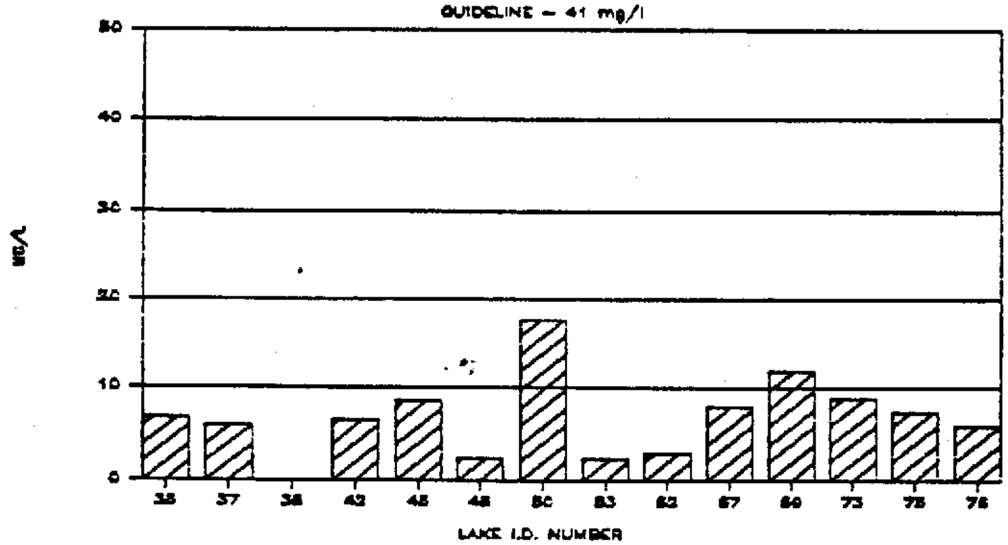
CHLORIDES

GUIDELINE — 19 mg/l



SULFATES

GUIDELINE — 41 mg/l



TOTAL DISSOLVED SOLIDS

GUIDELINE — 123 mg/l

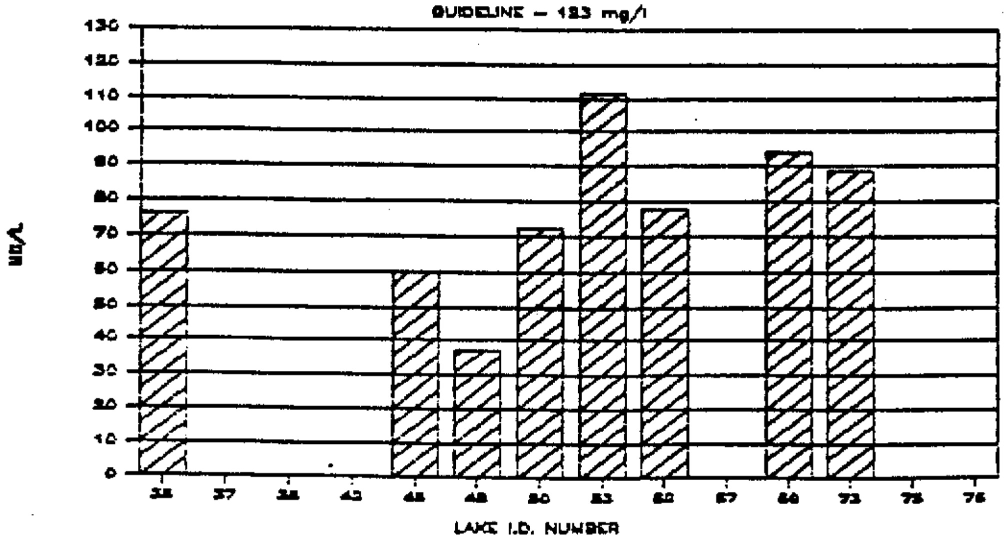
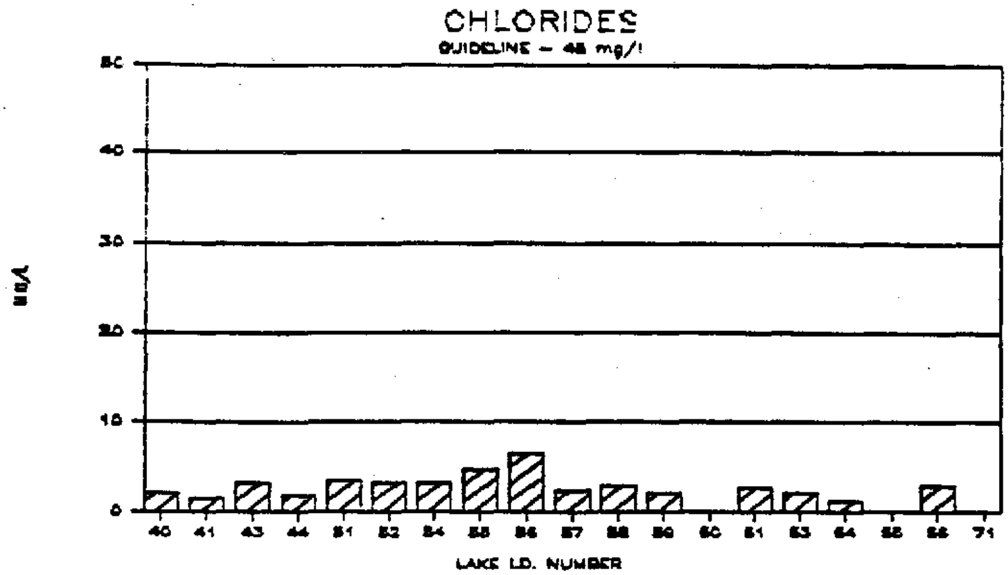
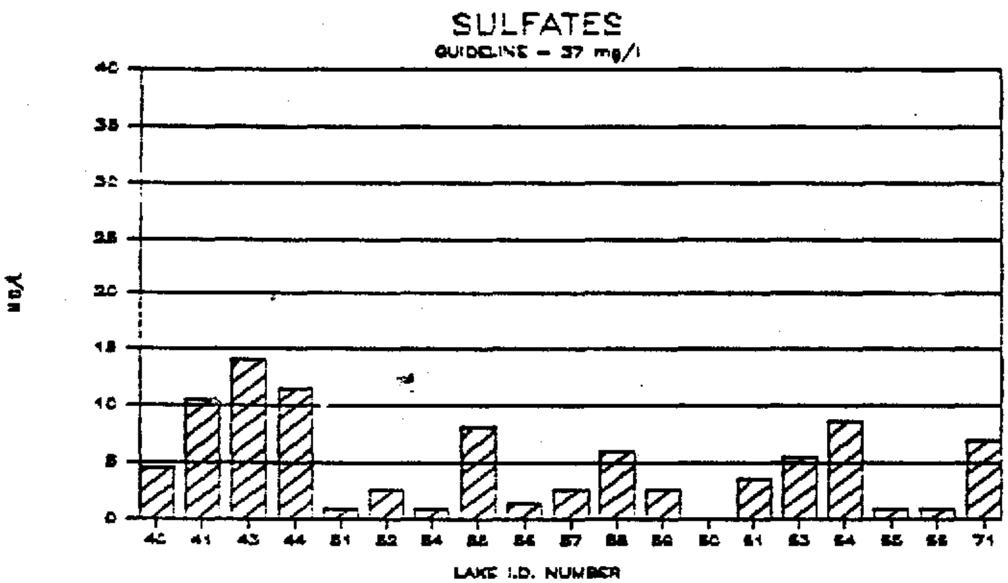
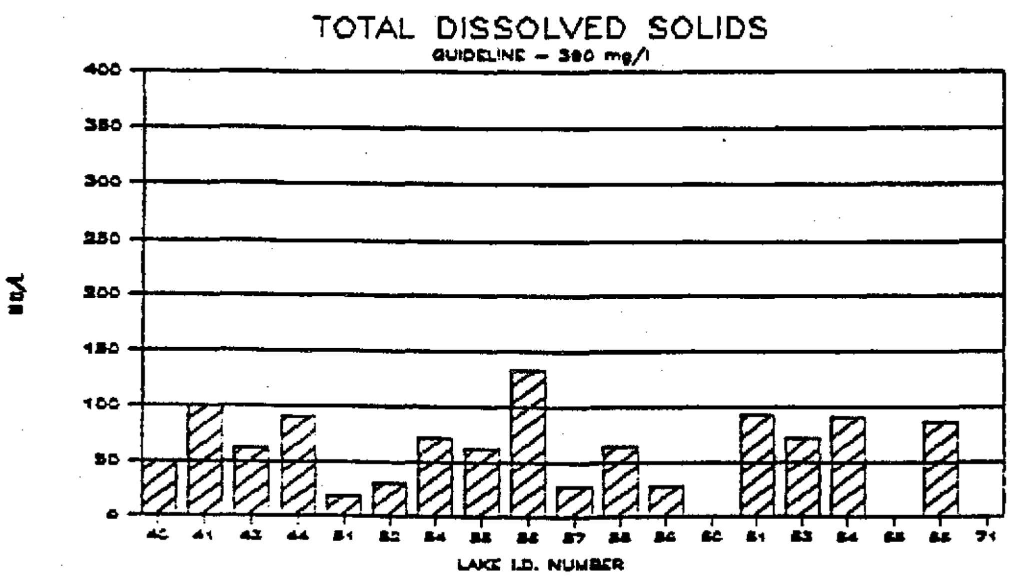


FIGURE B-10. Delta Lakes - Minerals







APPENDIX C

LAKES DISSOLVED OXYGEN AND TEMPERATURE PROFILES

This appendix contains a graphic representation of the dissolved oxygen and temperature data collected for all lakes sampled during the survey period. The squares represent data points for D.O. values and the x's are temperature data. Both are plotted on the same scale which is consistent in all figures. Depths are designated in meters. The depth scale will vary among the figures although the lakes are grouped so that the depth scale is consistent among several consecutive figures. On all but one figure, the depth scales are the same on a page. Figures are printed, generally, in numerical order by lake identification number.

FIGURE C-1

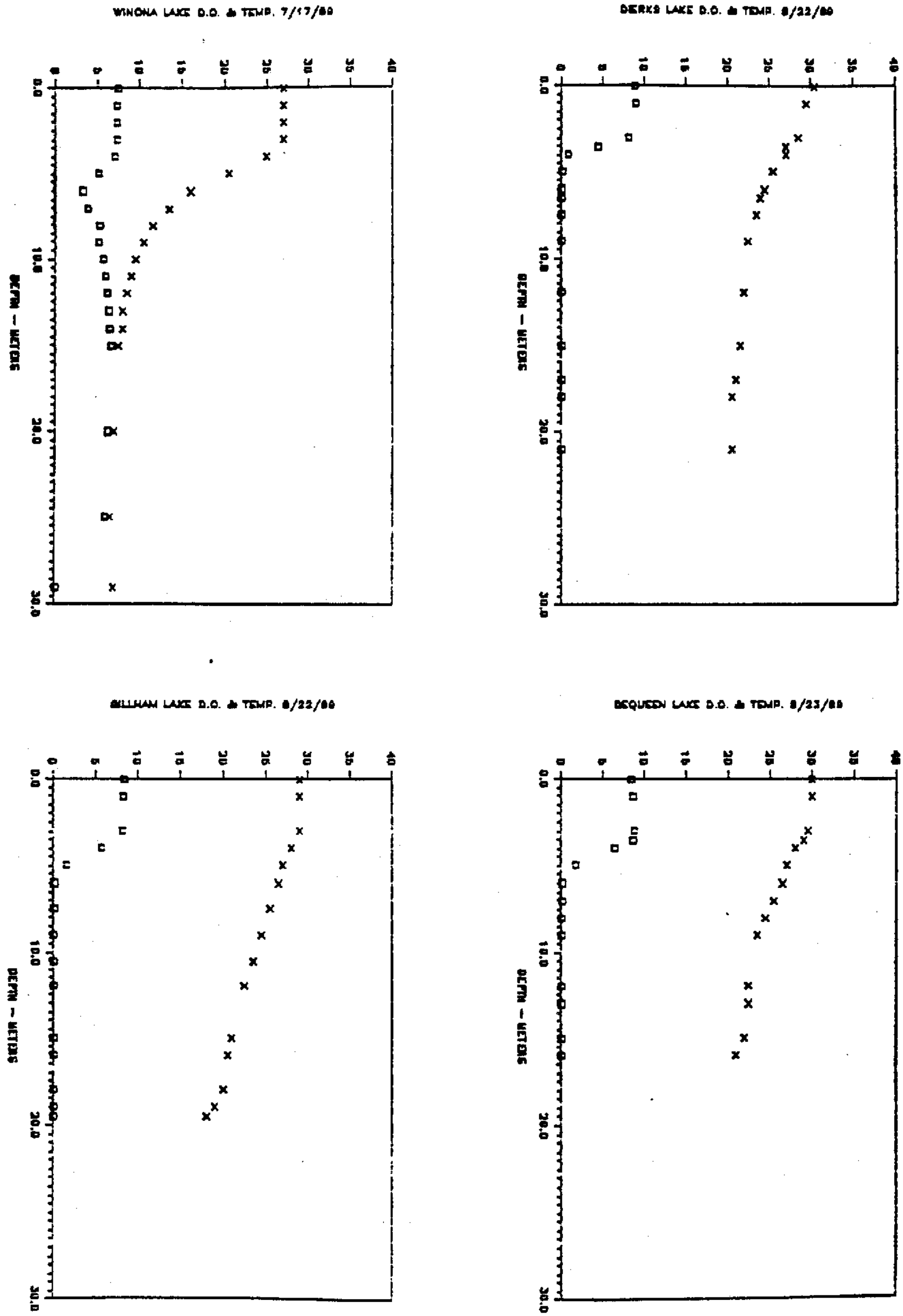

WINONA LAKE D.O. & TEMP. 7/17/89
DIERKS LAKE D.O. & TEMP. 8/22/89
GILLHAM LAKE D.O. & TEMP. 8/22/89
DEQUEEN LAKE D.O. & TEMP. 8/23/89
DEPTH — METERS

FIGURE C-2

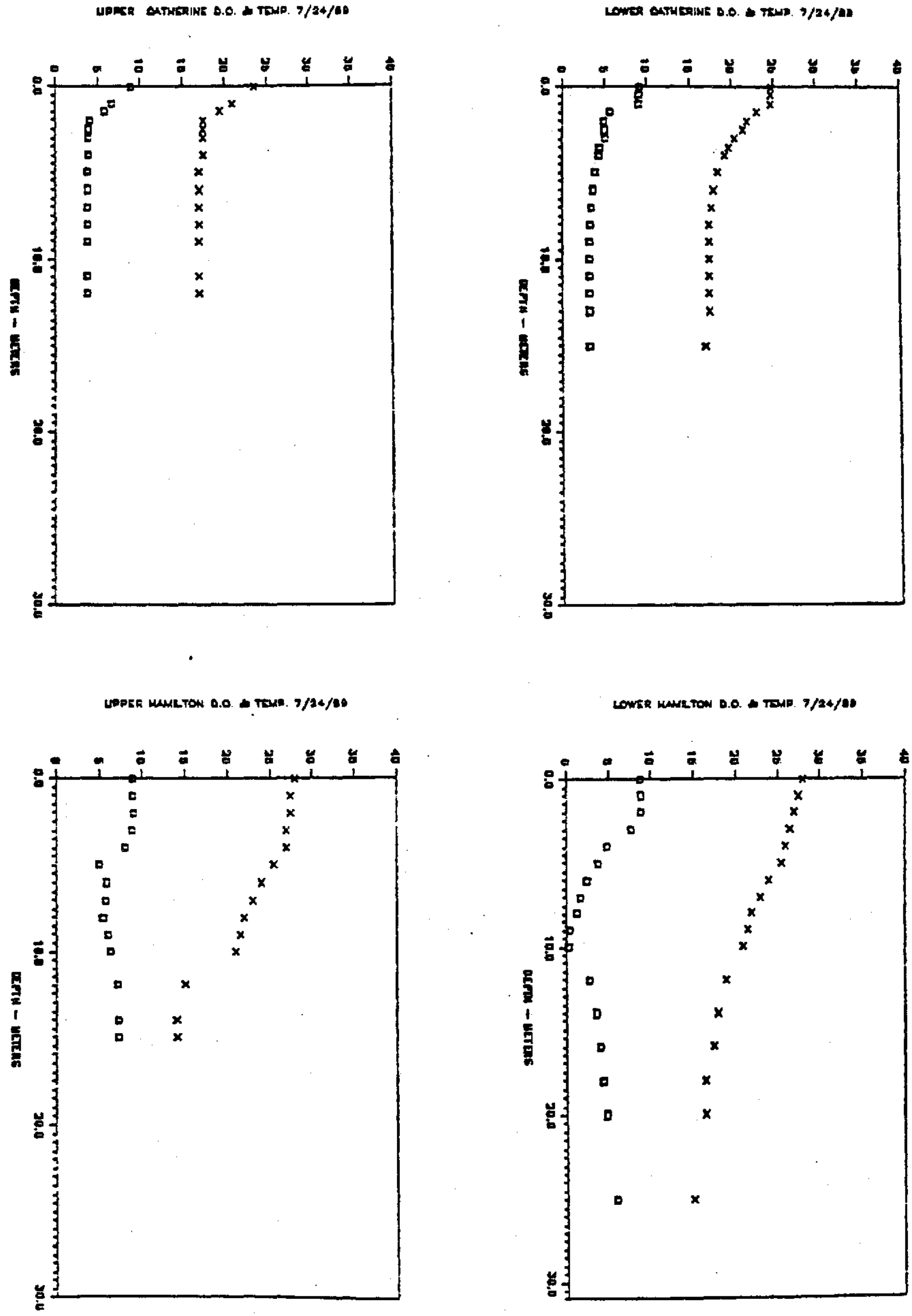
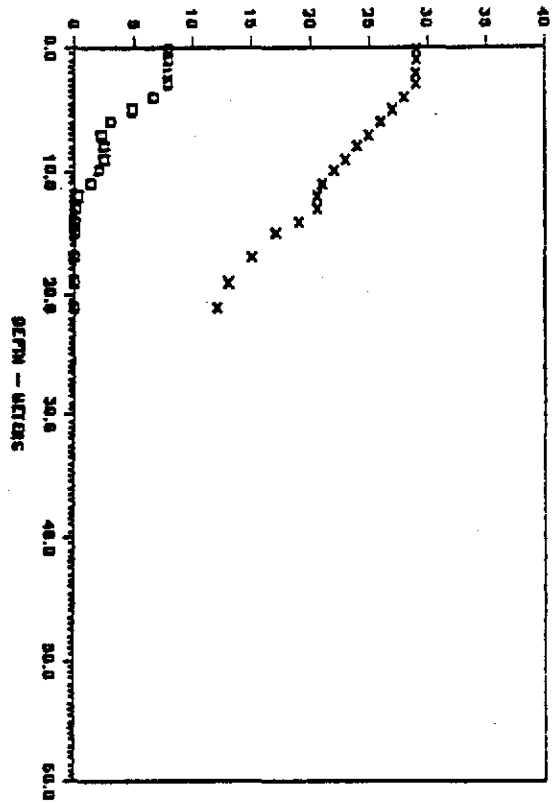
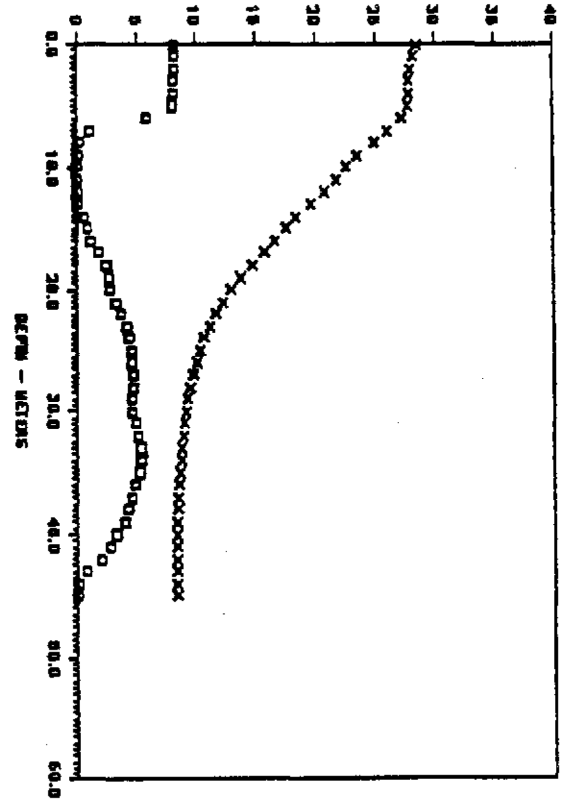

UPPER CATHERINE D.O. & TEMP. 7/24/89
LOWER CATHERINE D.O. & TEMP. 7/24/89
UPPER HAMILTON D.O. & TEMP. 7/24/89
LOWER HAMILTON D.O. & TEMP. 7/24/89
DEPTH - METERS
0 5 10 15 20 25 30 35 40
0.0 10.0 20.0 30.0

FIGURE C-3

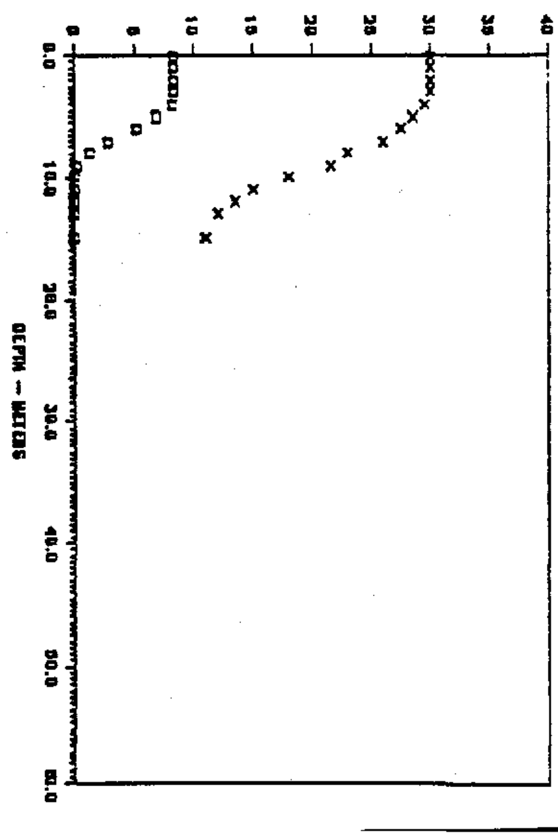
UPPER GREESON D.O. & TEMP. 8/1/89



LOWER GREESON LAKE D.O. & TEMP. 8/14/89



UPPER DEGRAY D.O. & TEMP. 8/1/89



LOWER DEGRAY LAKE D.O. & TEMP. 8/14/89

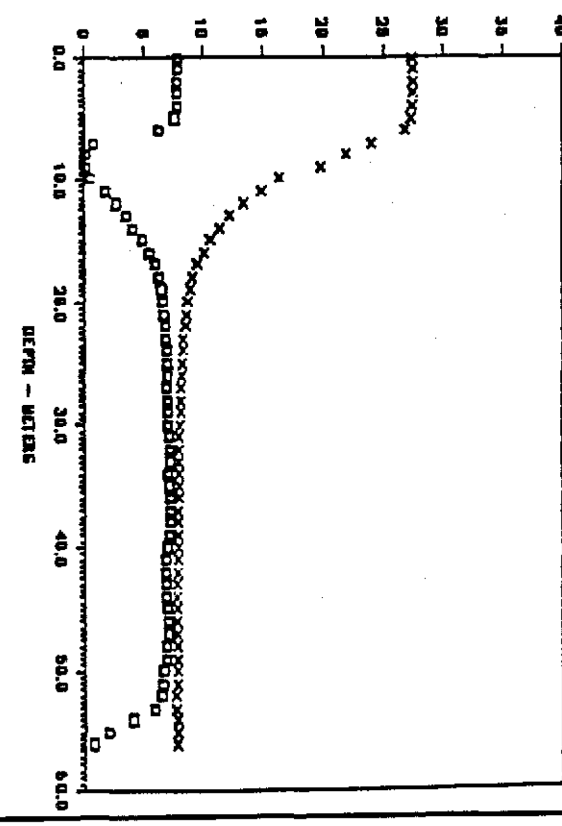
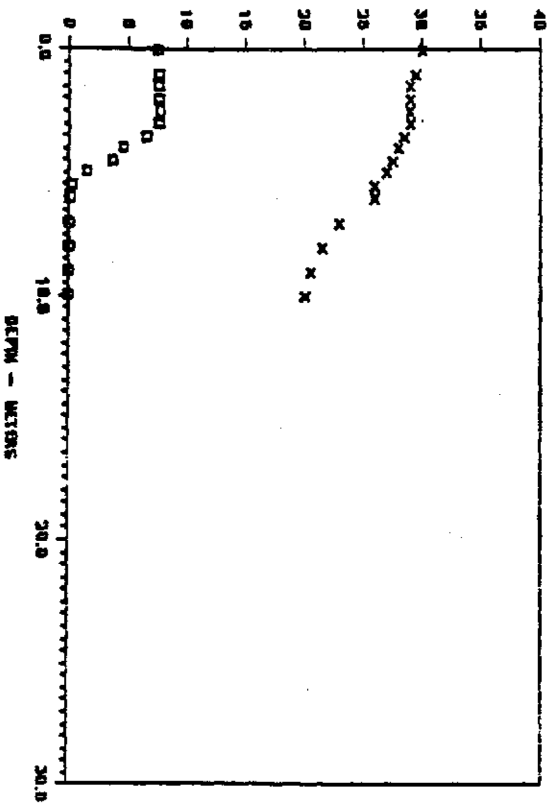
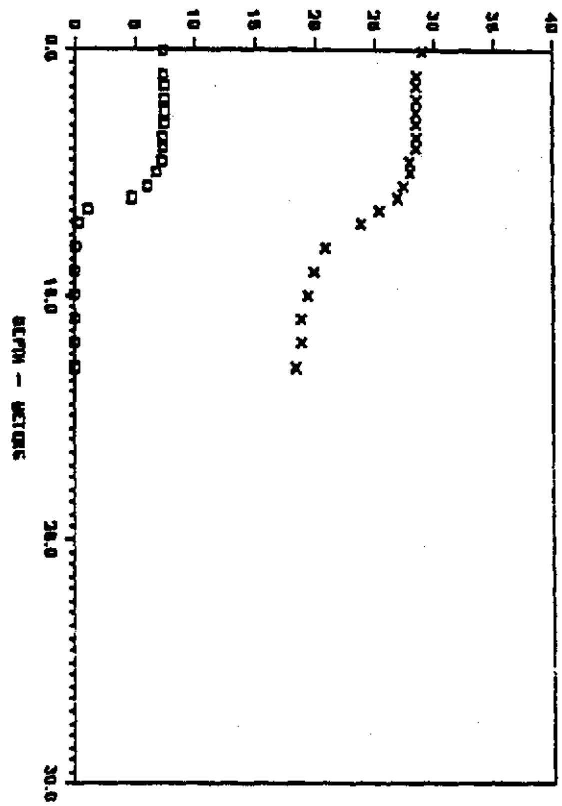


FIGURE C-4

UPPER MAUMELLE D.O. & TEMP. 8/24/89



LOWER MAUMELLE D.O. & TEMP. 8/24/89



GREERS FERRY LAKE D.O. & TEMP. 8/24/89

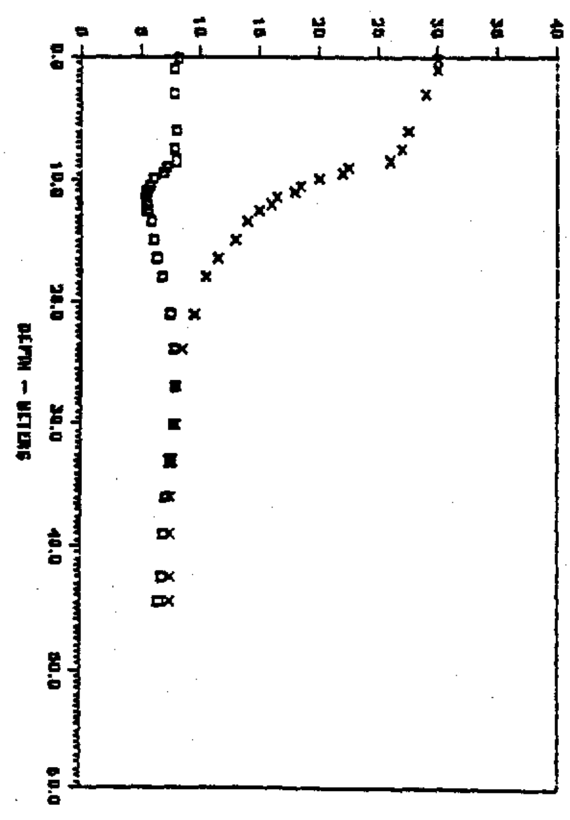
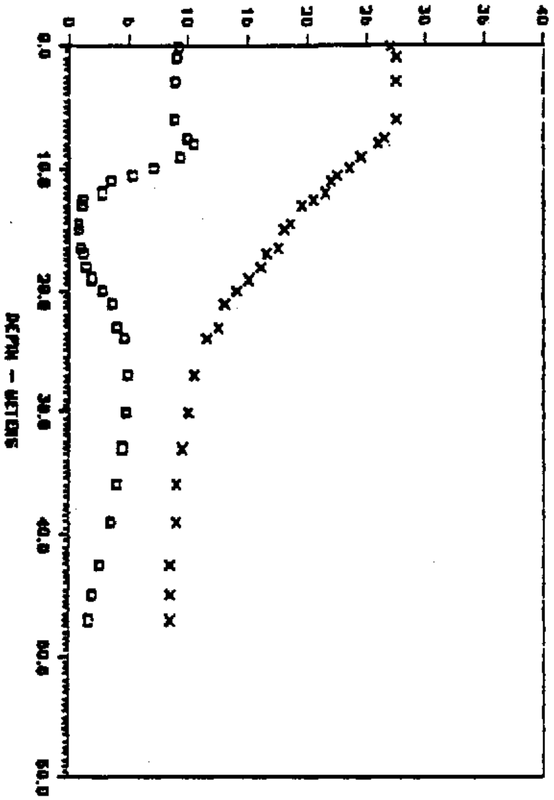
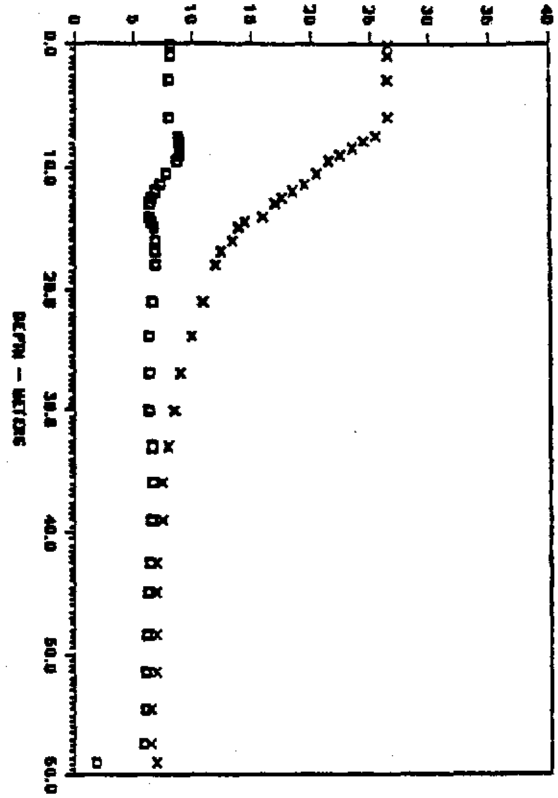


FIGURE C-5

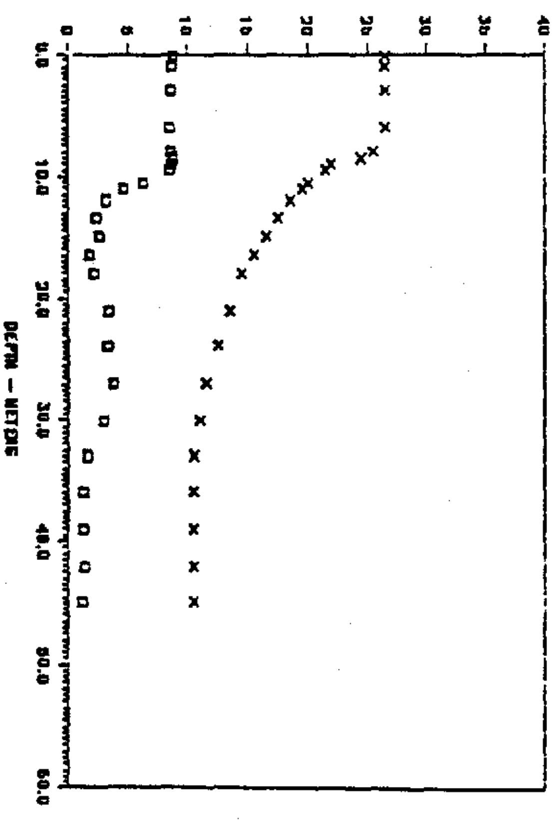
NORFORK LAKE D.O. & TEMP. 8/15/89



BEAVER LAKE D.O. & TEMP. 8/8/89



MID BULL SHOALS D.O. & TEMP. 8/16/89



LOWER BULL SHOALS D.O. & TEMP. 8/16/89

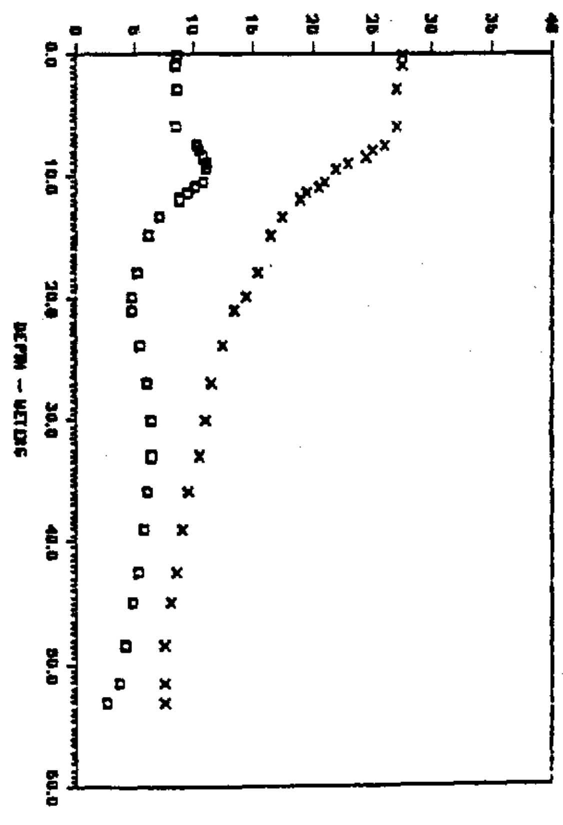
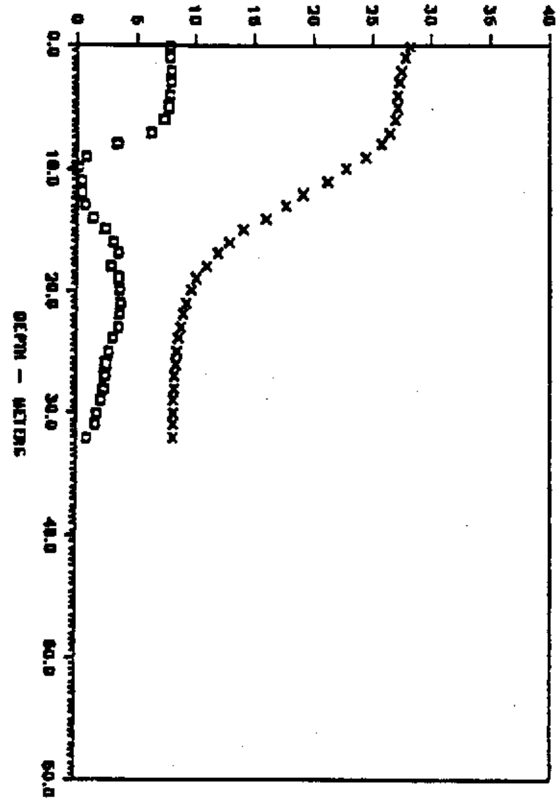
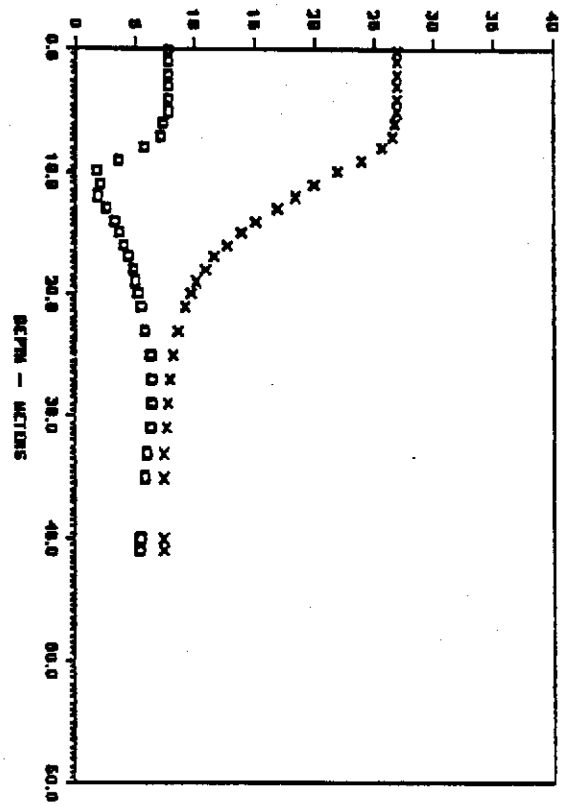


FIGURE C-6

UPPER OUACHITA D.O. & TEMP. 7/25/89



MIDDLE OUACHITA D.O. & TEMP. 7/25/89



LOWER OUACHITA D.O. & TEMP. 8/14/89

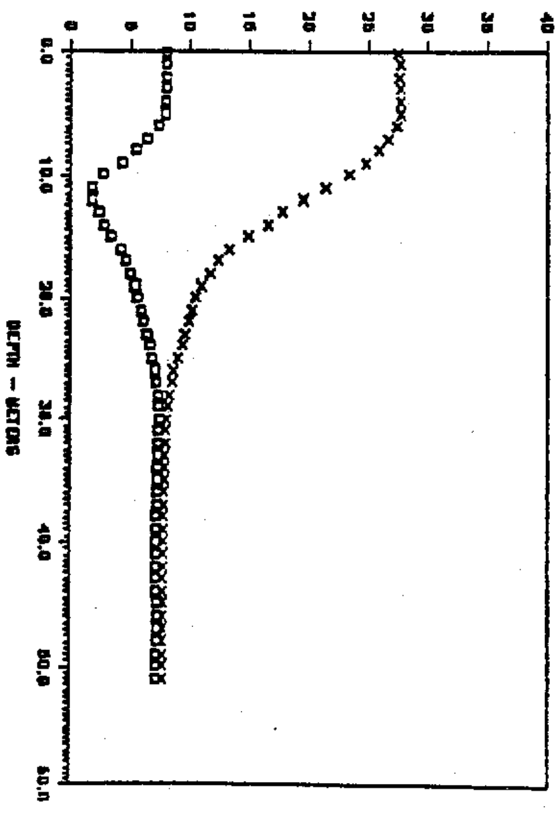
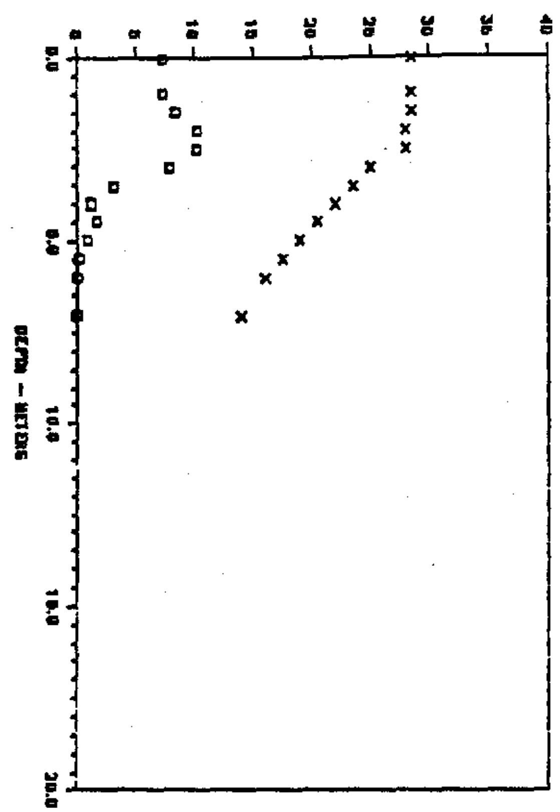
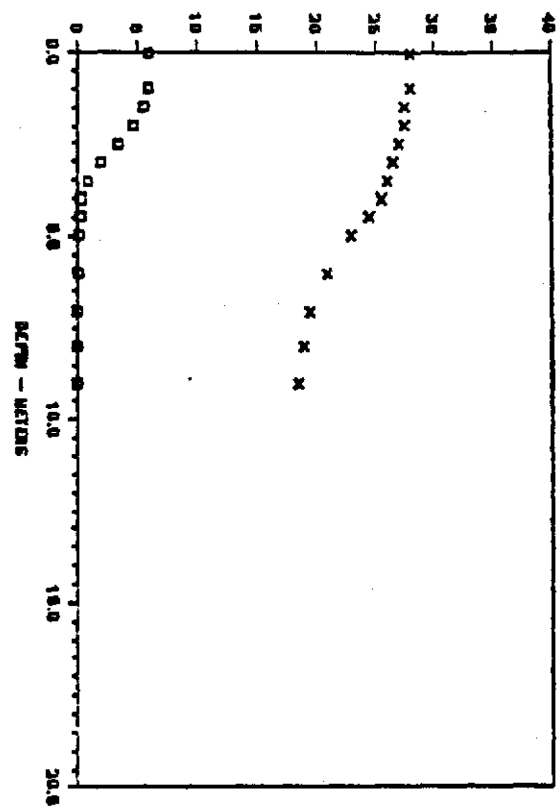


FIGURE C-7

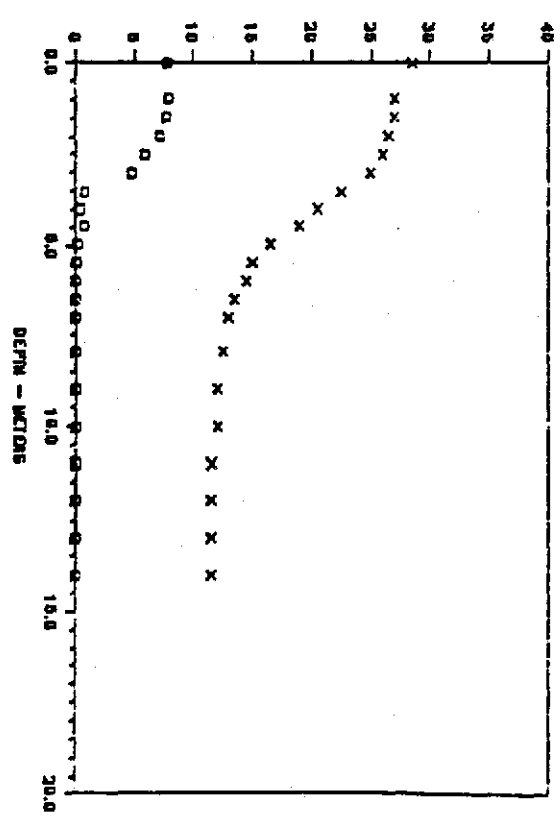
CRYSTAL LAKE D.O. & TEMP. 8/29/89



SHORES LAKE D.O. & TEMP. 8/21/89



SPRING LAKE D.O. & TEMP. 8/17/89



HORSEHEAD LAKE D.O. & TEMP. 8/21/89

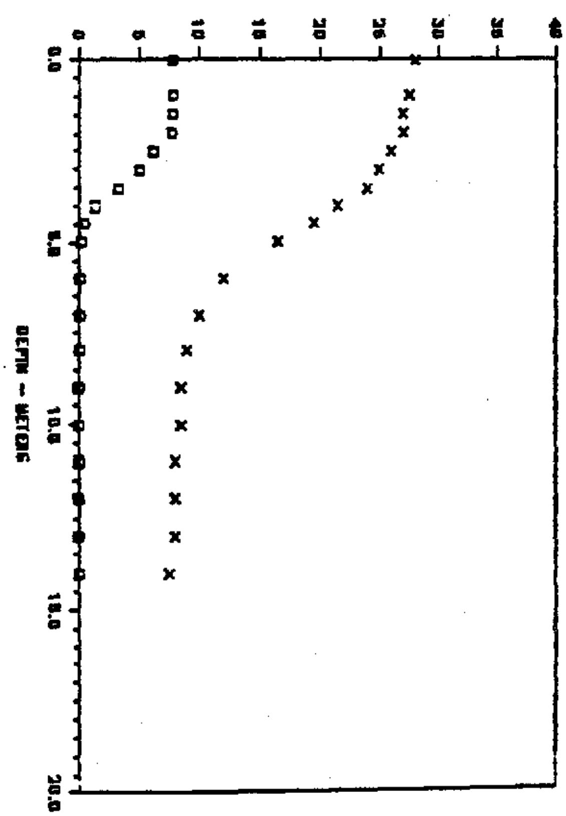
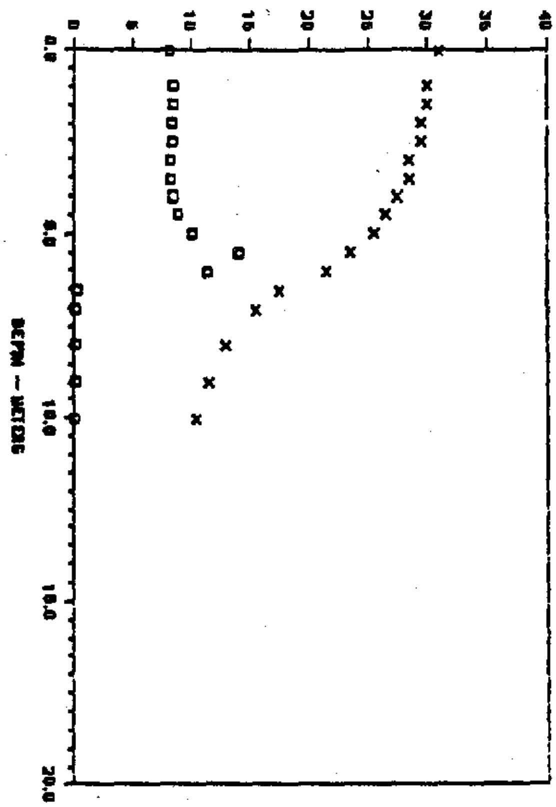
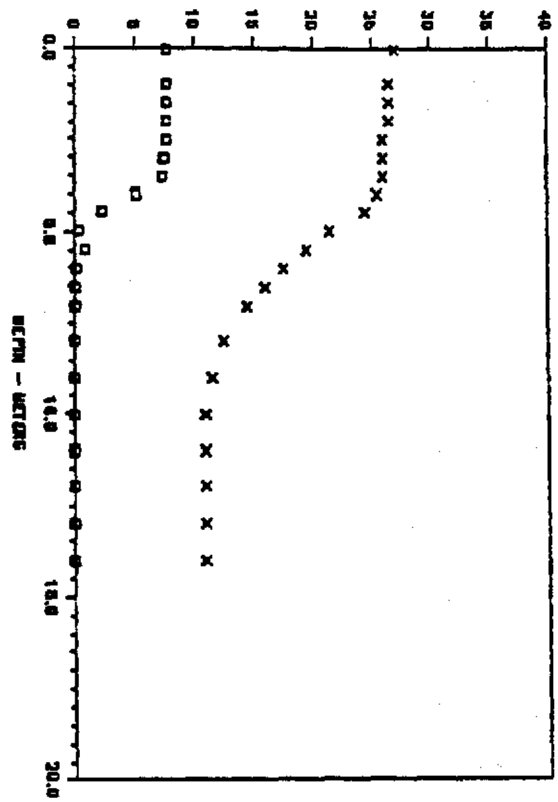


FIGURE C-8

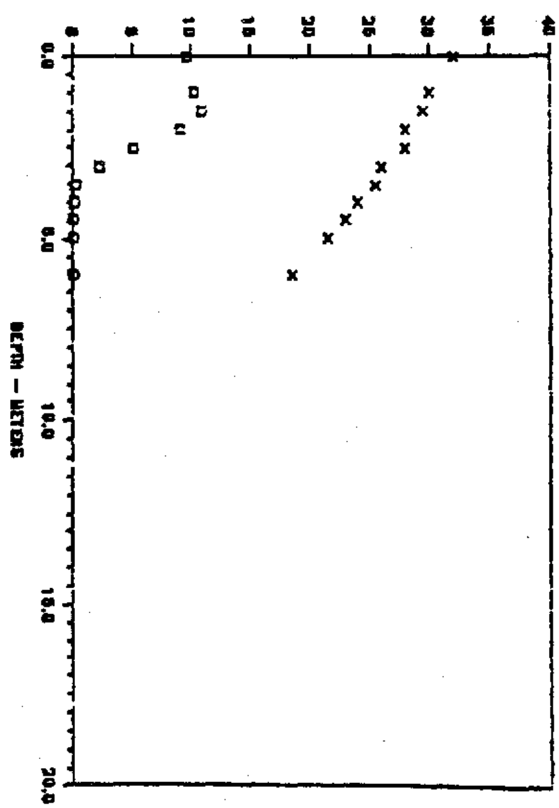
WEDDINGTON LAKE D.O. & TEMP. 8/28/89



COVE LAKE D.O. & TEMP. 8/28/89



ELMDALE LAKE D.O. & TEMP. 8/28/89



FAYETTEVILLE LAKE D.O. & TEMP. 8/22/89

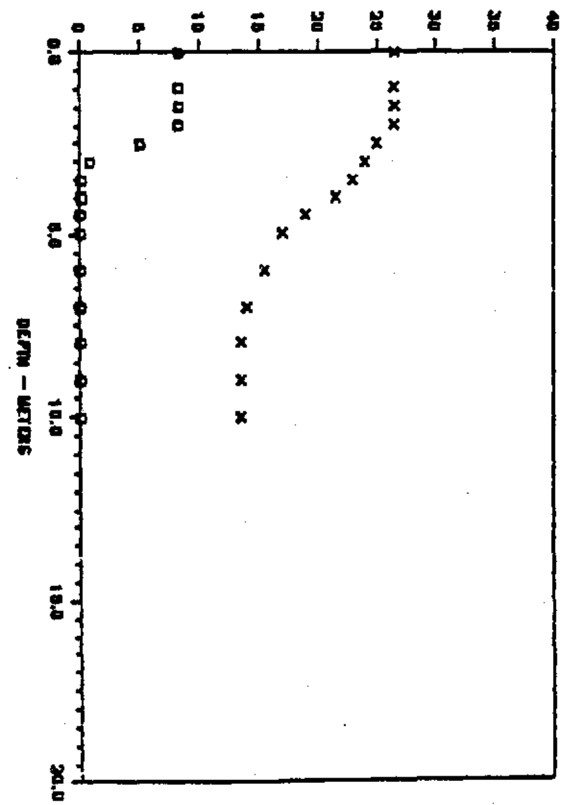


FIGURE C-9

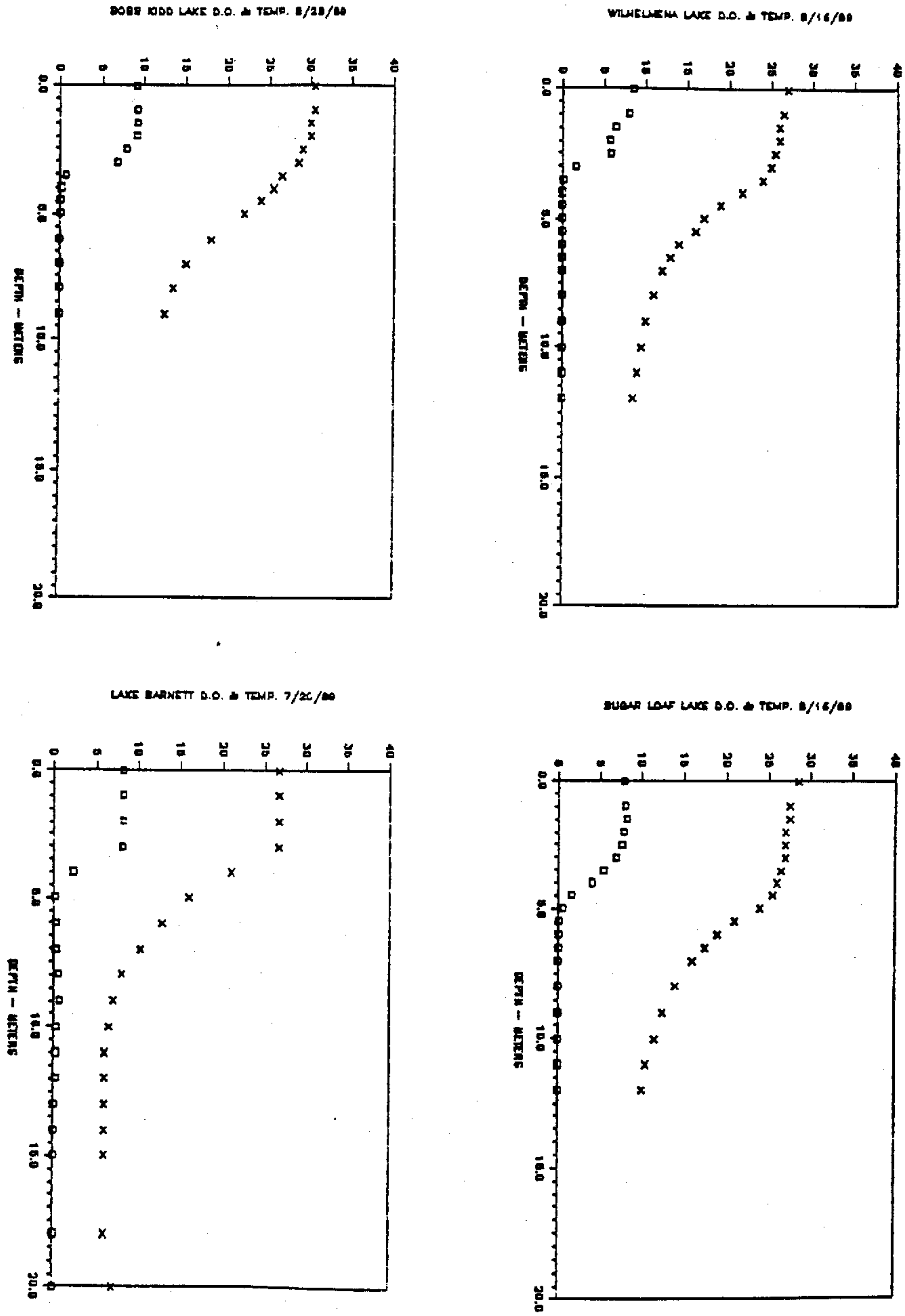
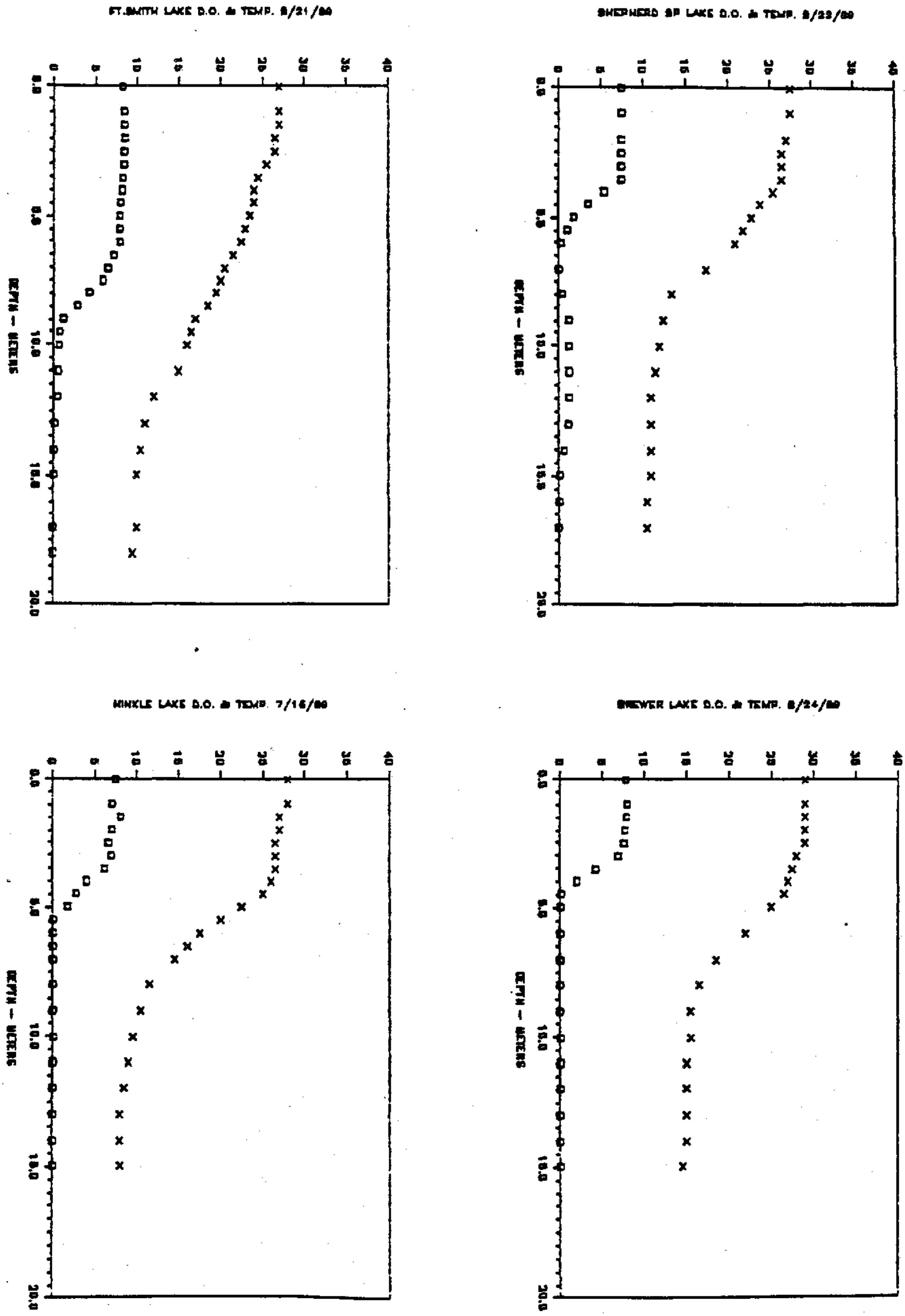

BOSS KIDD LAKE D.O. & TEMP. 8/28/89
WILHELMENA LAKE D.O. & TEMP. 8/16/89
LAKE BARNETT D.O. & TEMP. 7/20/89
SUGAR LOAF LAKE D.O. & TEMP. 8/16/89
DEPTH — METERS
0.0
5.0
10.0
15.0
20.0
0
5
10
15
20
25
30
35
40

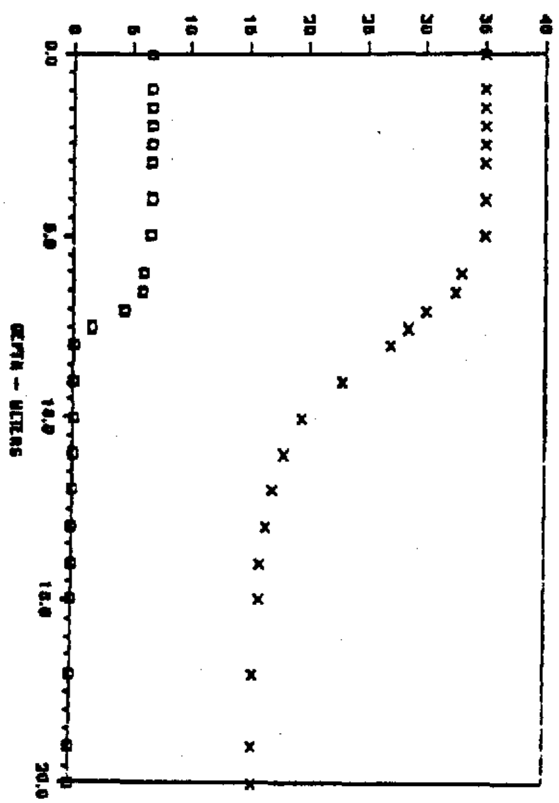
FIGURE C-10



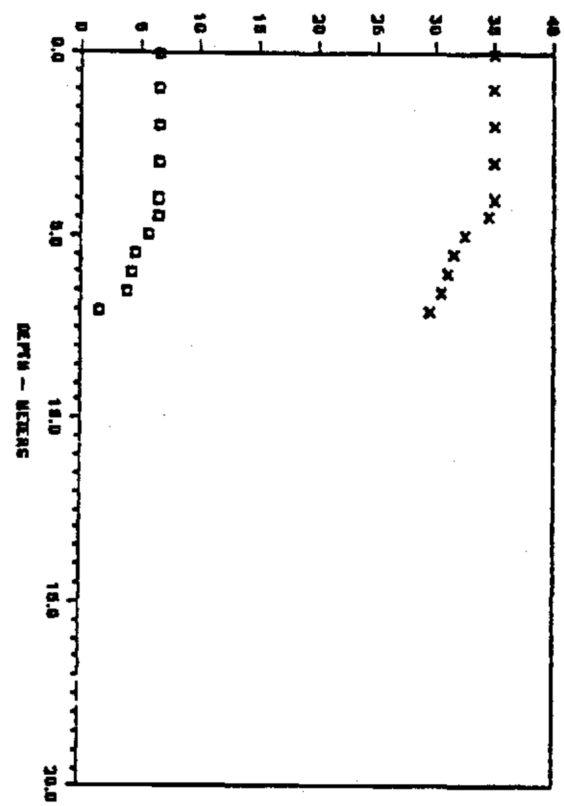
FT.SMITH LAKE D.O. & TEMP. 8/21/89
SHEPHERD SP LAKE D.O. & TEMP. 8/23/89
HINKLE LAKE D.O. & TEMP. 7/16/89
BREWER LAKE D.O. & TEMP. 8/24/89
DEPTH — METERS

FIGURE C-11

SWEPCO LAKE D.O. & TEMP. 8/29/89



SWEPCO INTAKE D.O. & TEMP. 8/29/89



SWEPCO OUTFALL D.O. & TEMP. [illegible]/89

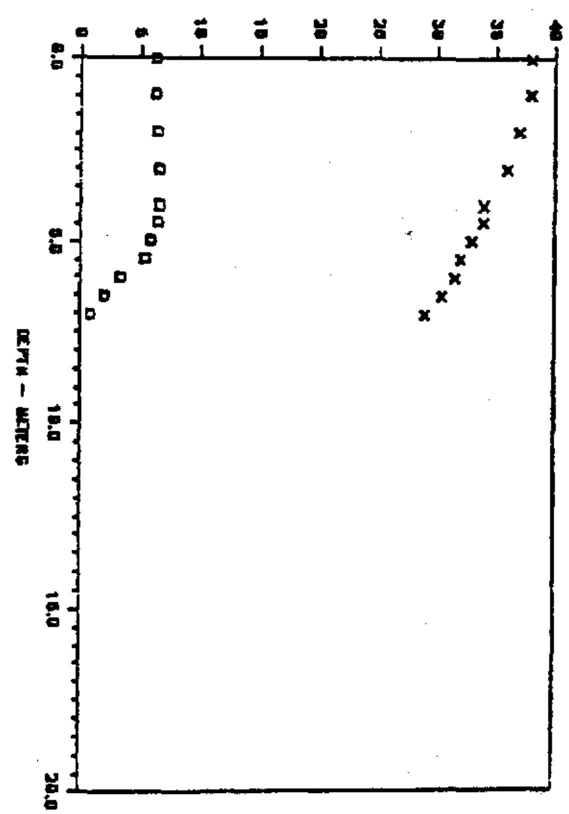
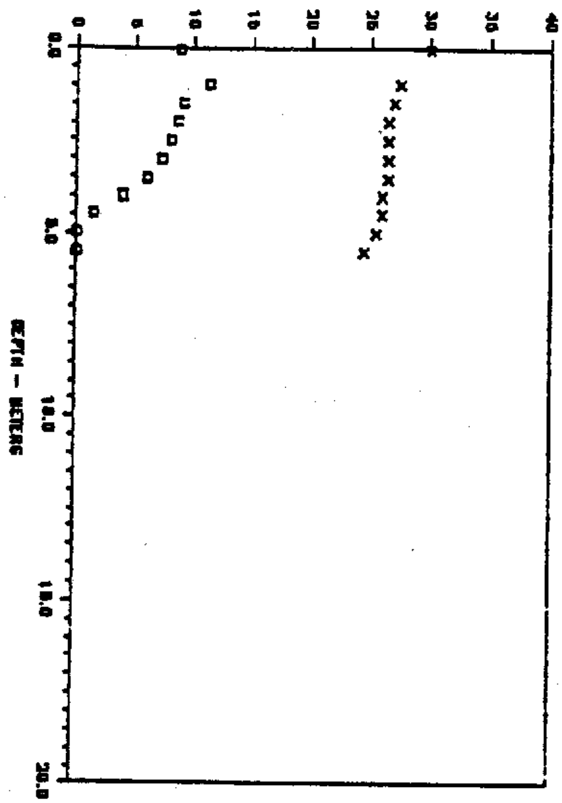


FIGURE C-12

CHARLES LAKE D.O. & TEMP. 7/16/88



BEAVERFORK LAKE D.O. & TEMP. 7/24/88

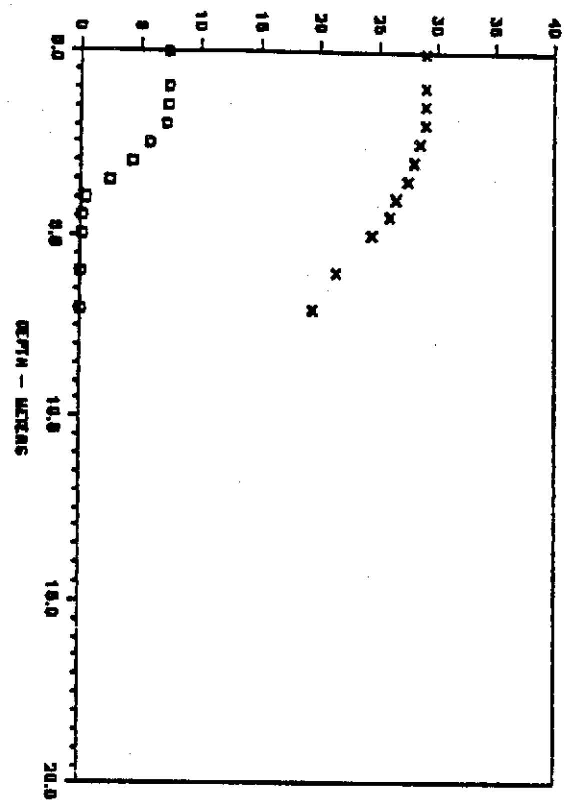


FIGURE C-13

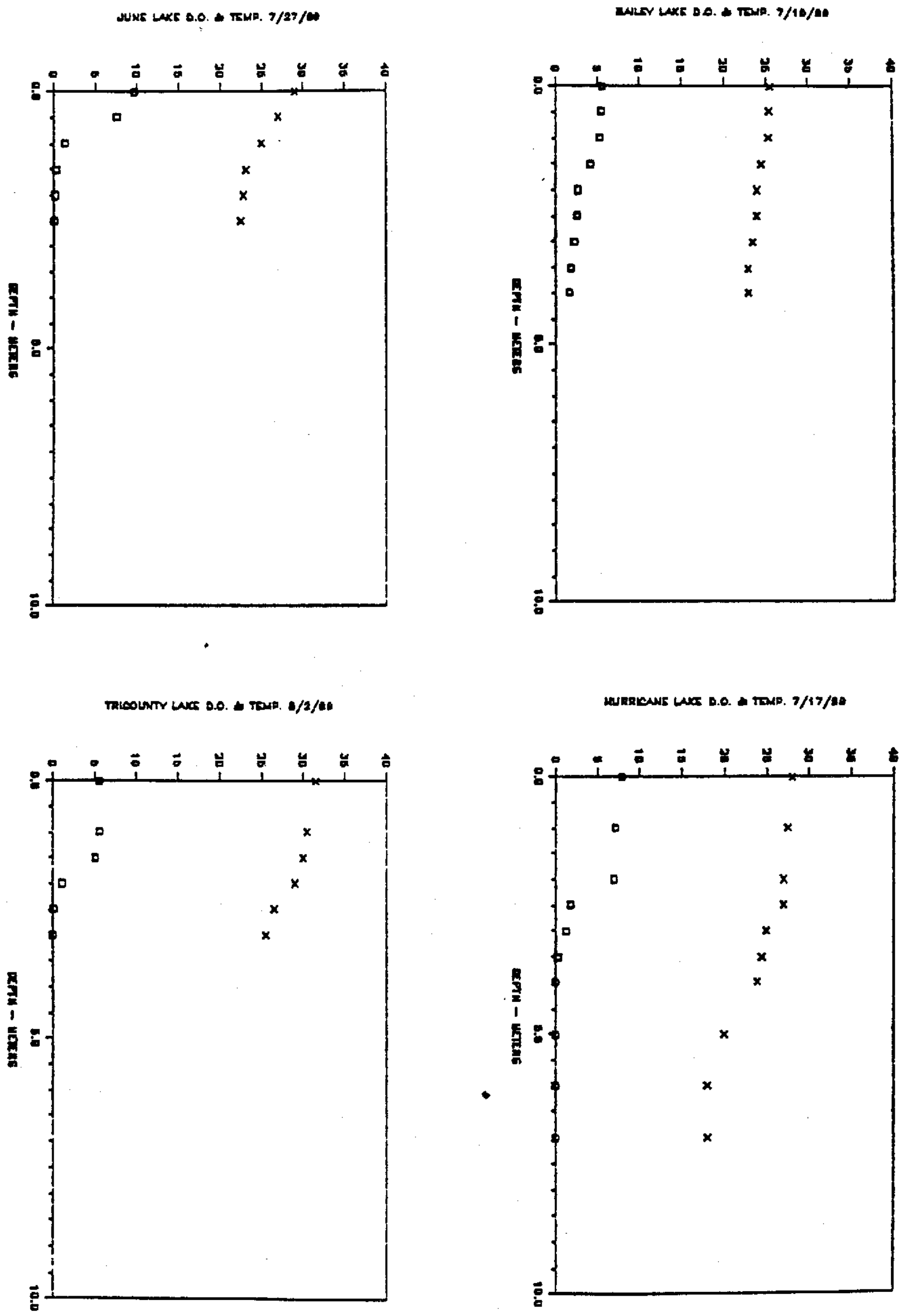
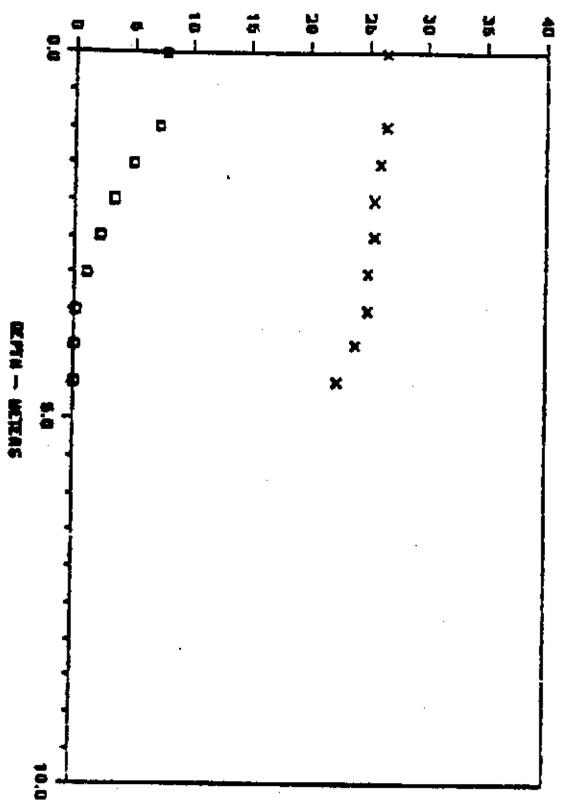
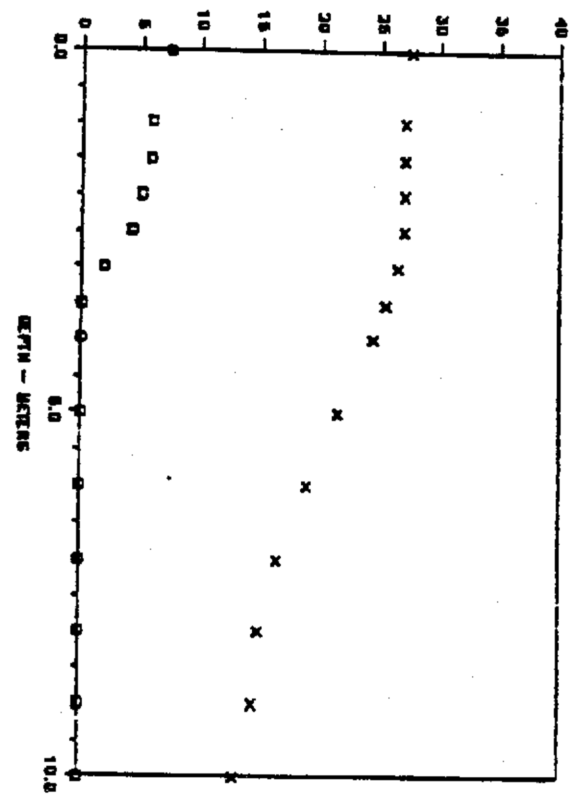

JUNE LAKE D.O. & TEMP. 7/27/88
BAILEY LAKE D.O. & TEMP. 7/18/88
TRICOUNTY LAKE D.O. & TEMP. 8/2/88
HURRICANE LAKE D.O. & TEMP. 7/17/88

FIGURE C-14

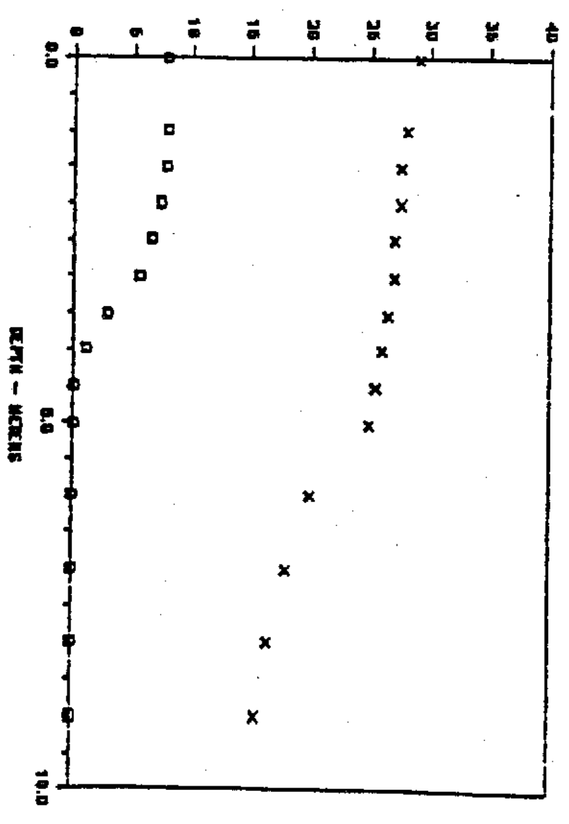
FRIERSON LAKE D.O. & TEMP. 8/16/89



BEAR CREEK LAKE D.O. & TEMP. 8/10/89



POINSETT LAKE D.O. & TEMP. 8/14/89



STORM CREEK LAKE D.O. & TEMP. 8/10/89

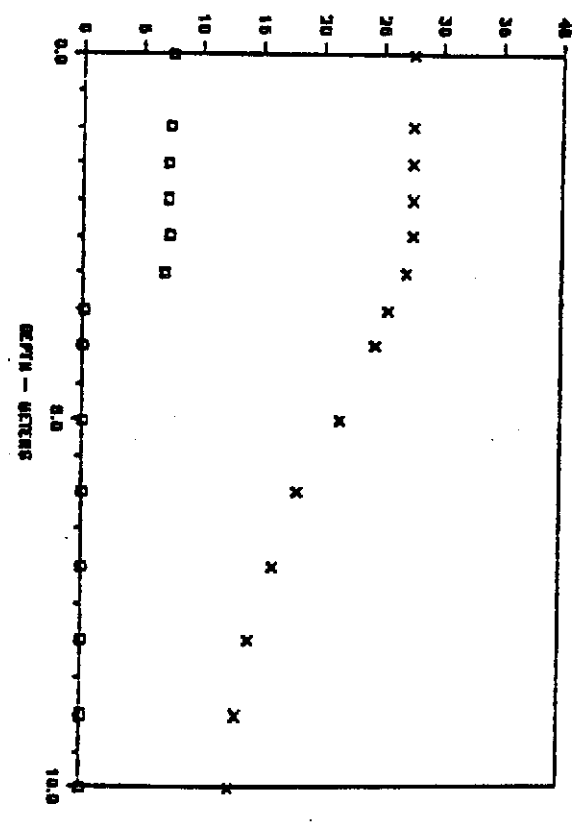
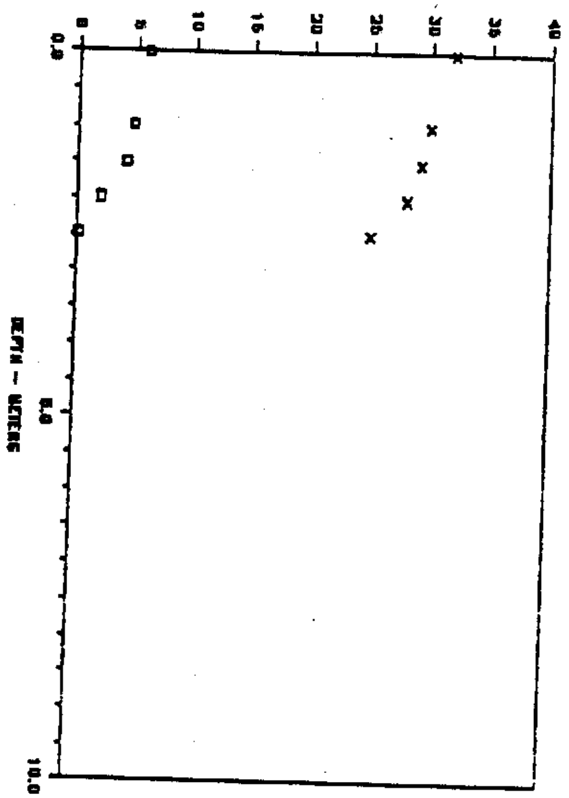
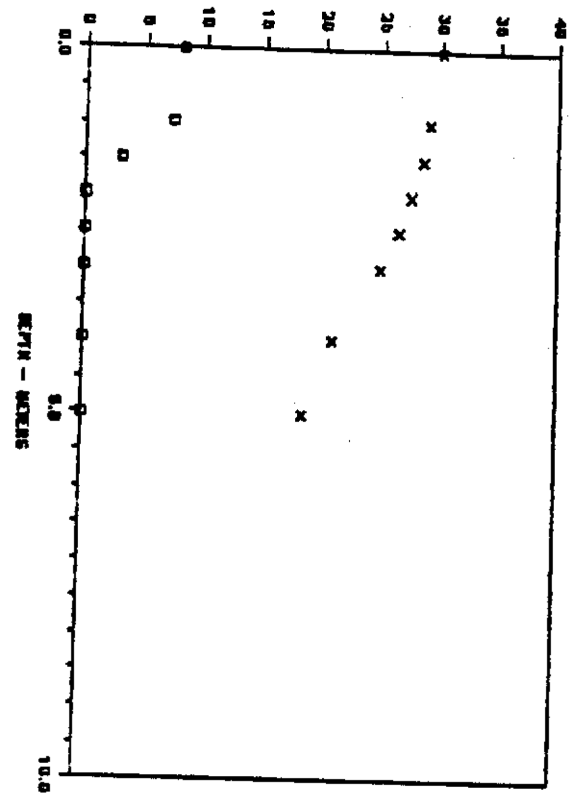


FIGURE C-15

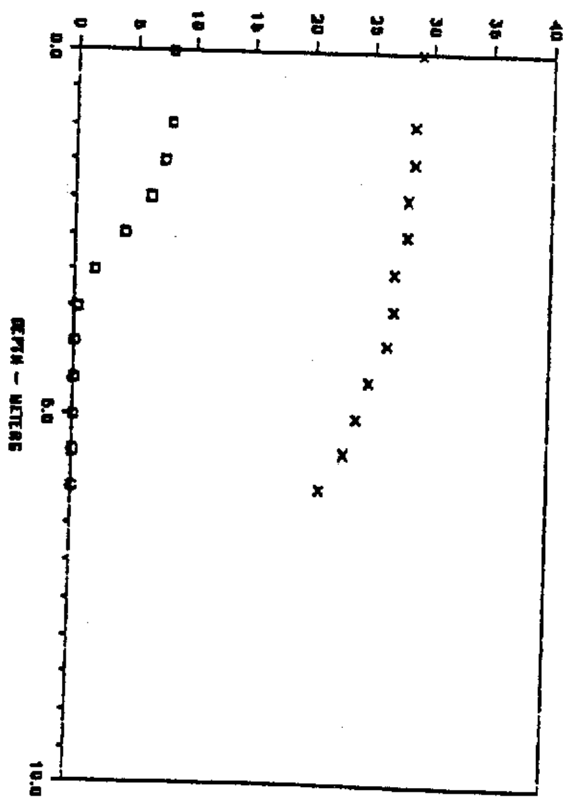
DALTON LAKE D.O. & TEMP. 8/2/89



UPPER WHITE OAK D.O. & TEMP. 7/26/89



LOWER WHITE OAK D.O. & TEMP. 7/26/89



DANE CREEK LAKE D.O. & TEMP. 8/8/89

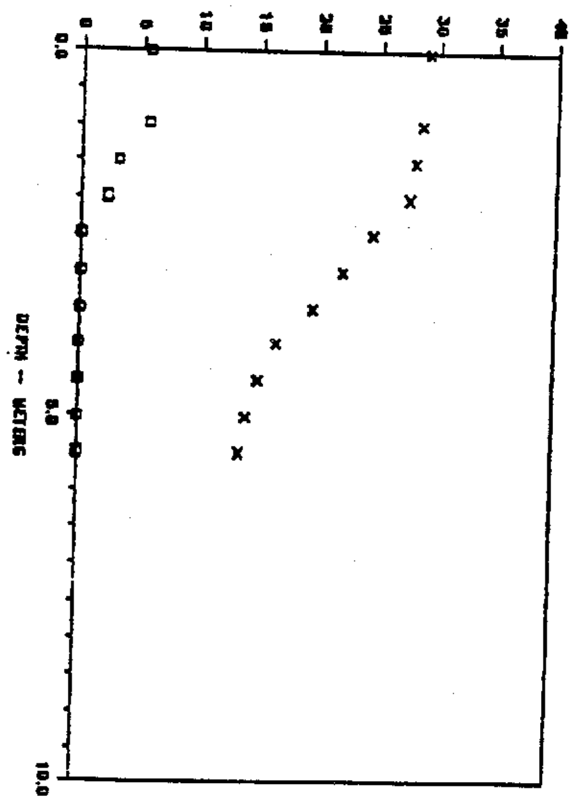
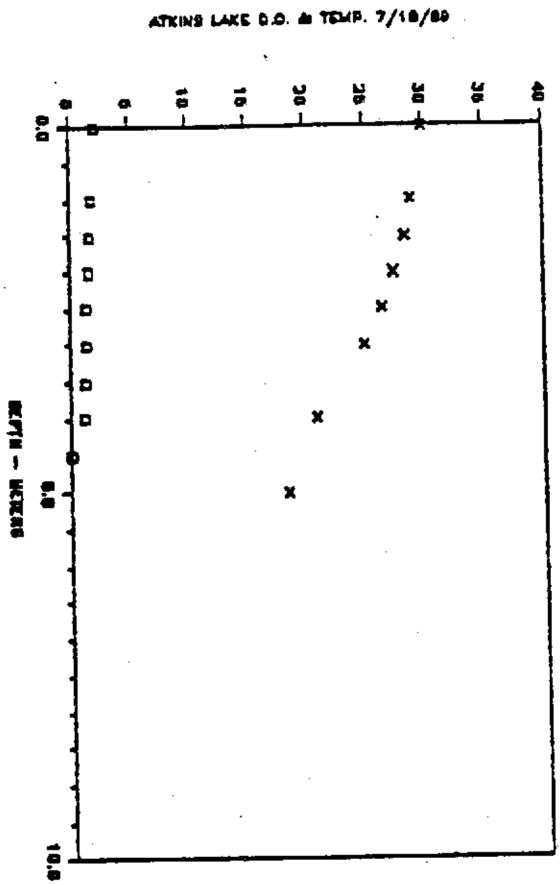
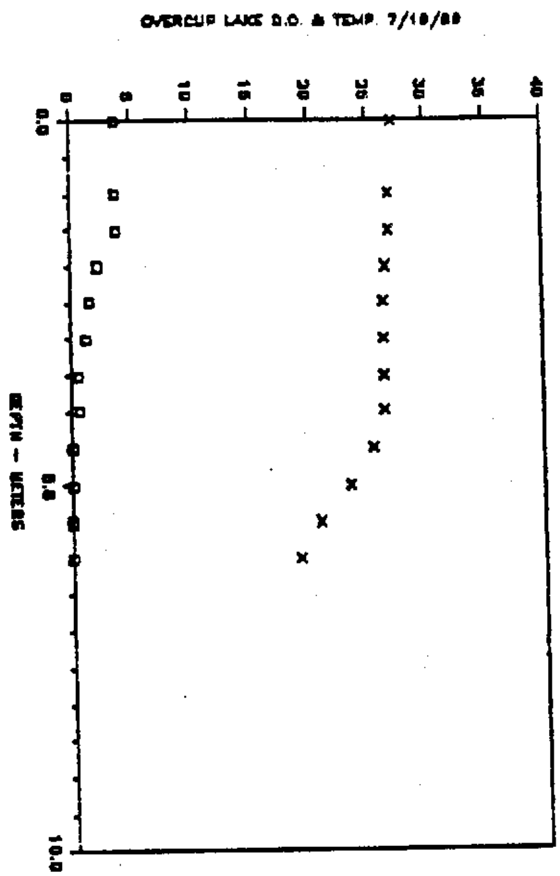


FIGURE C-16


ATKINS LAKE D.O. & TEMP. 7/19/89
DEPTH — METERS


OVERCUP LAKE D.O. & TEMP. 7/19/89
DEPTH — METERS

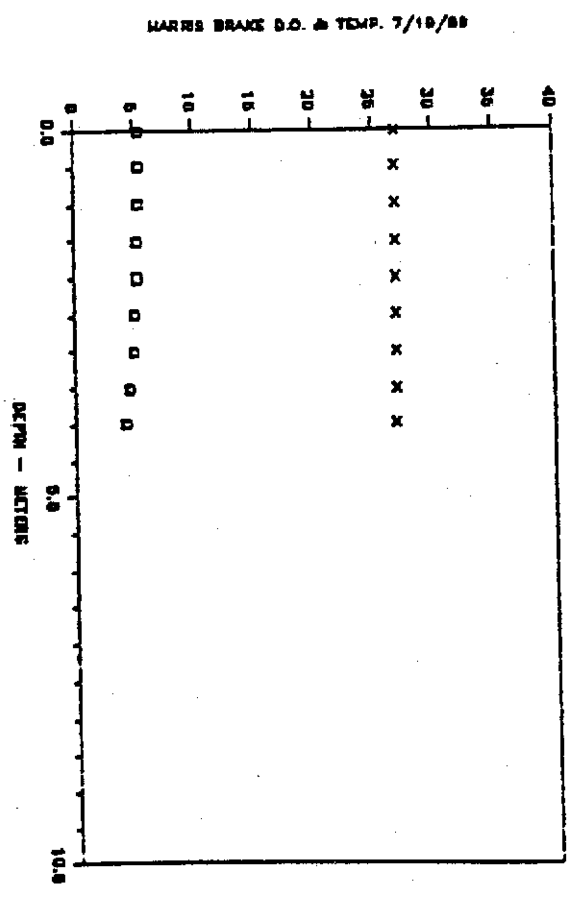
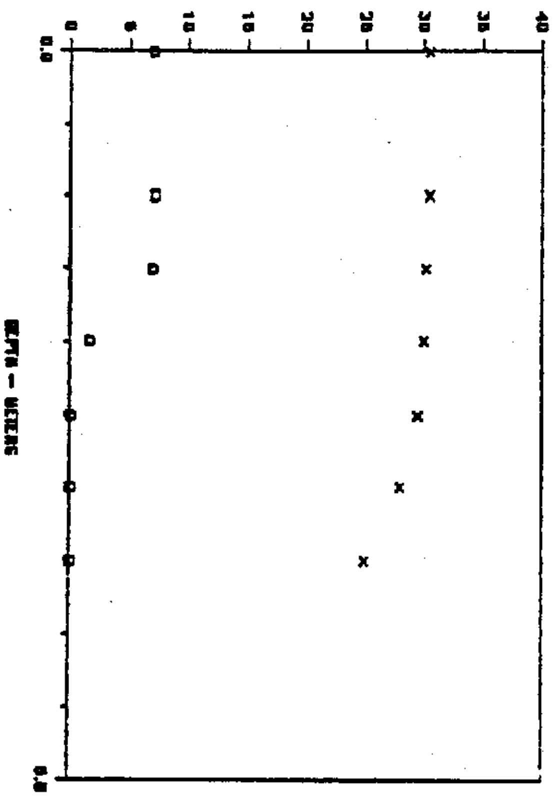
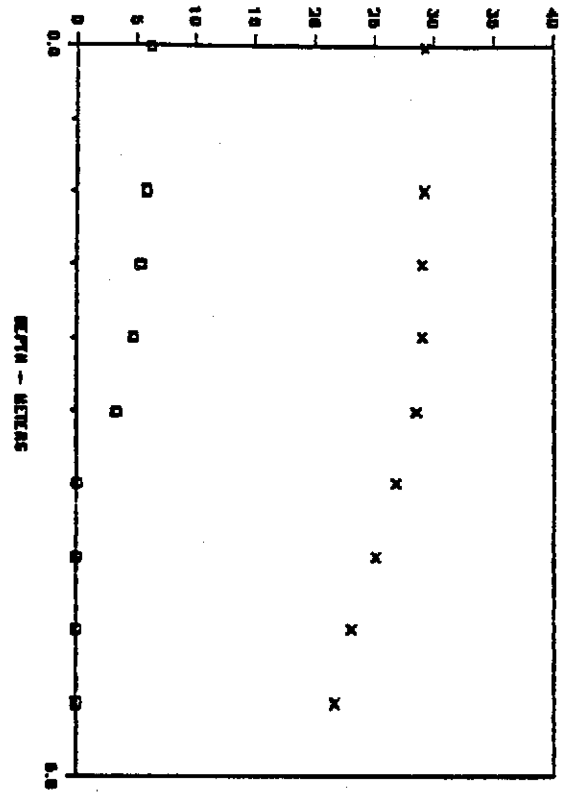

HARRIS BRAKE D.O. & TEMP. 7/19/89
DEPTH — METERS

FIGURE C-17

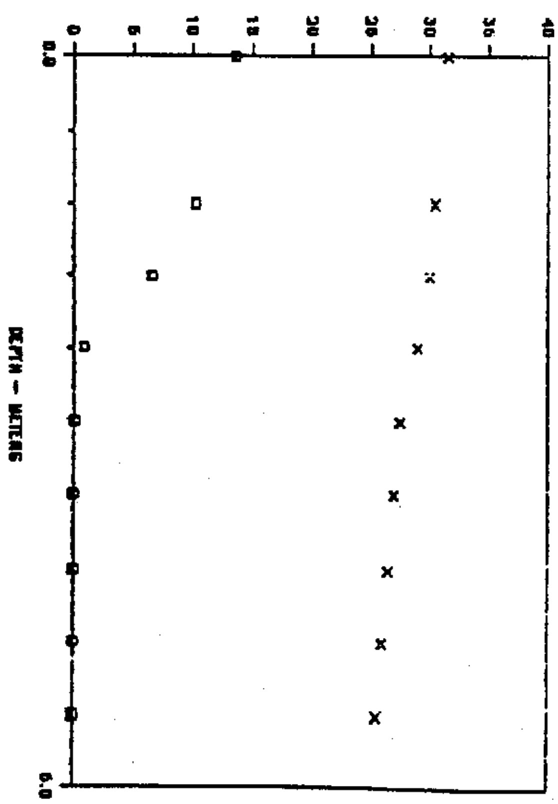
WILSON LAKE D.O. & TEMP. 8/7/89



ENTERPRISE LAKE D.O. & TEMP. 8/7/89



FRST OLD RIVER LAKE D.O. & TEMP.7/31/89



HOGUE LAKE D.O. & TEMP. 8/14/89

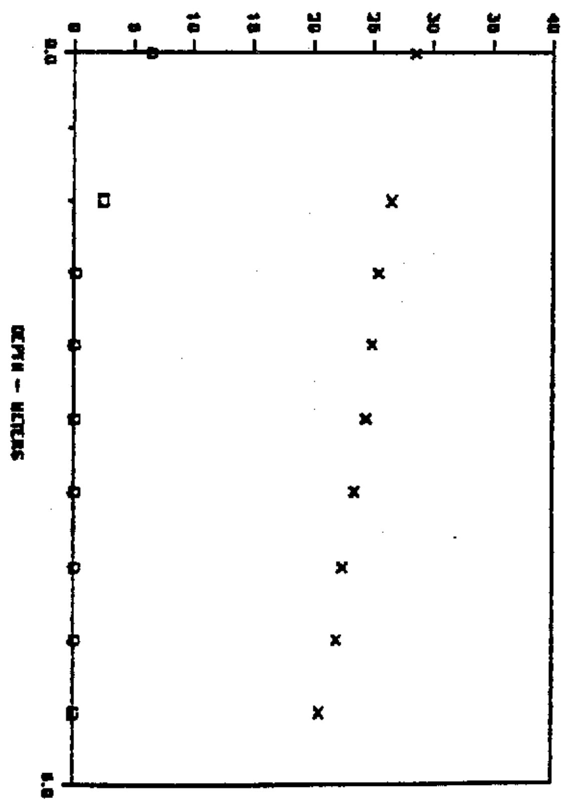
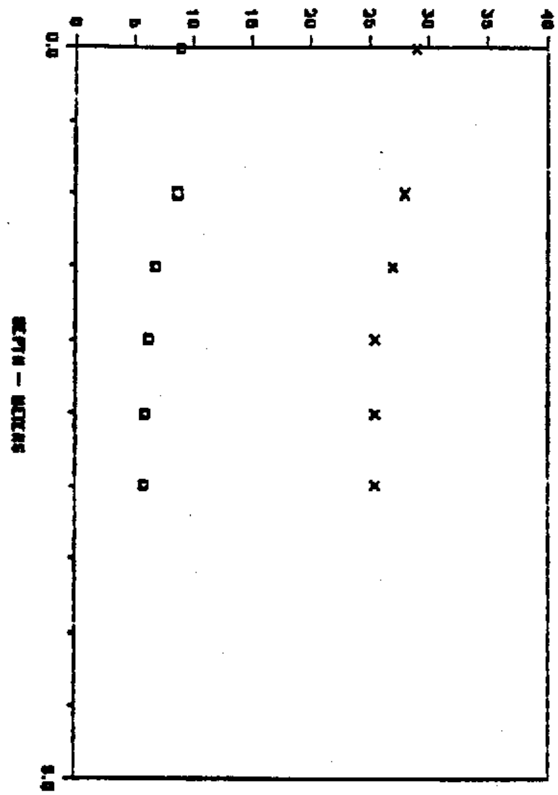
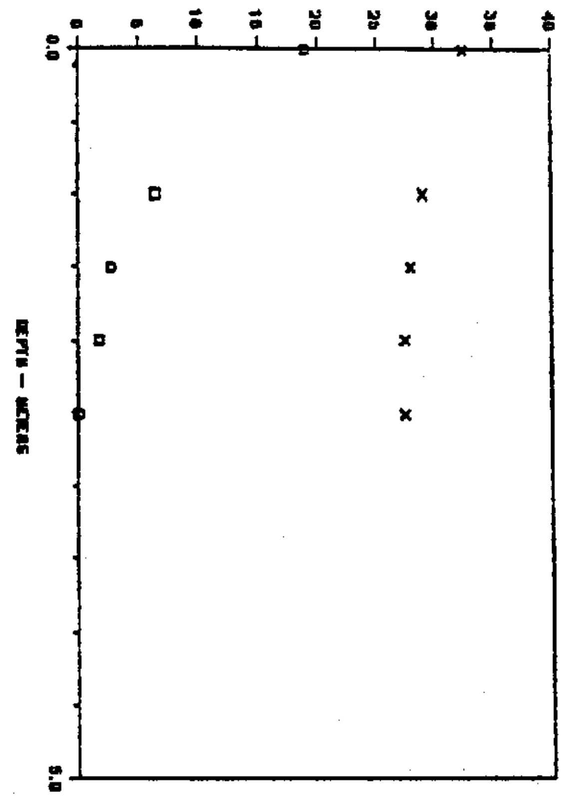


FIGURE C-18

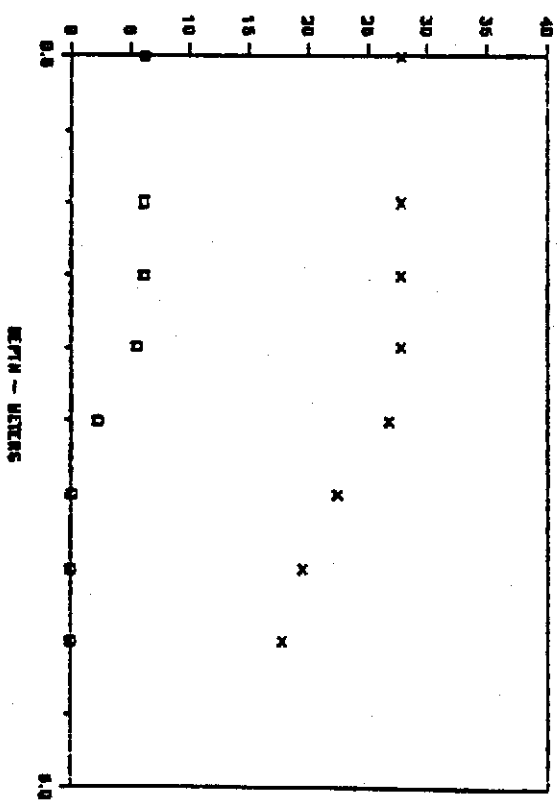
GREENLEE LAKE D.O. & TEMP. 8/9/89



MALLARD LAKE D.O. & TEMP. 8/14/89



GRAMPUS LAKE D.O. & TEMP. 8/8/89



DEBARC LAKE D.O. & TEMP. 8/9/89

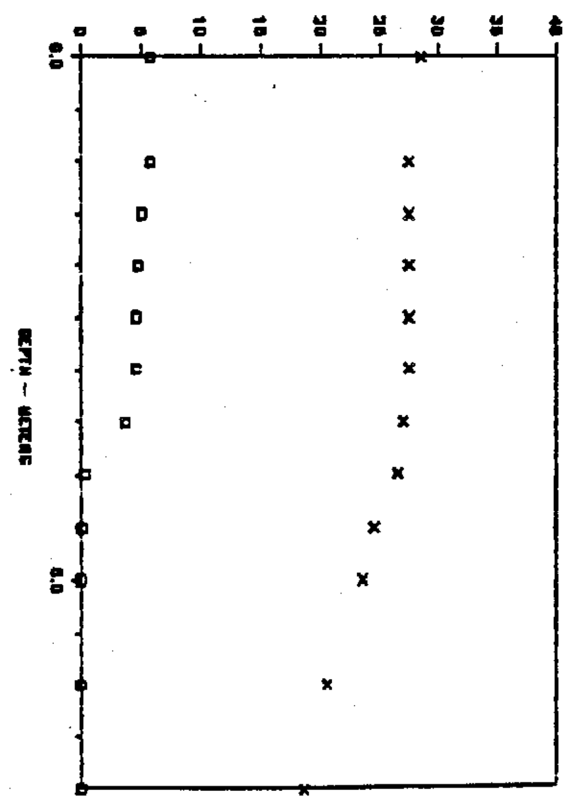


FIGURE C-19

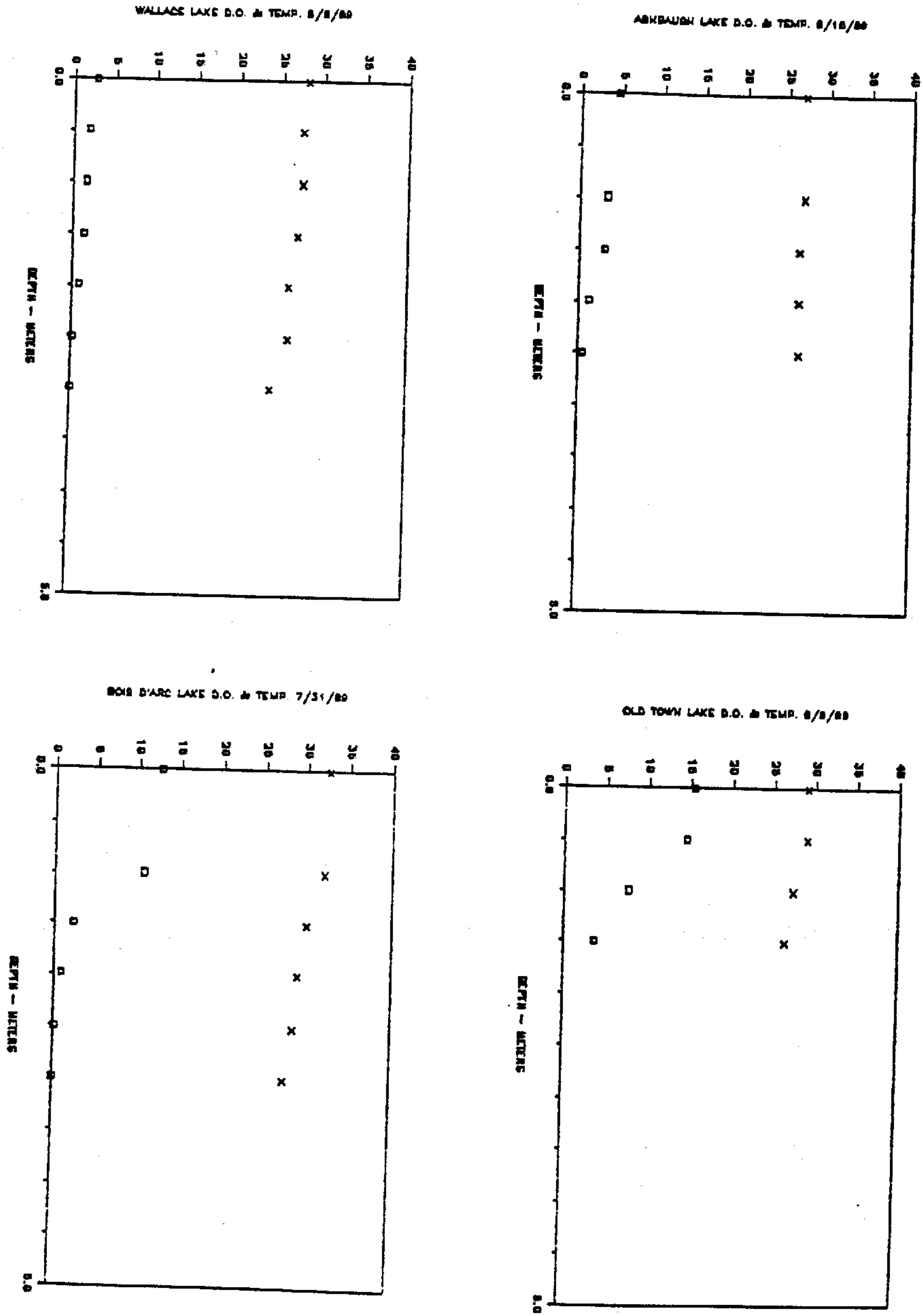
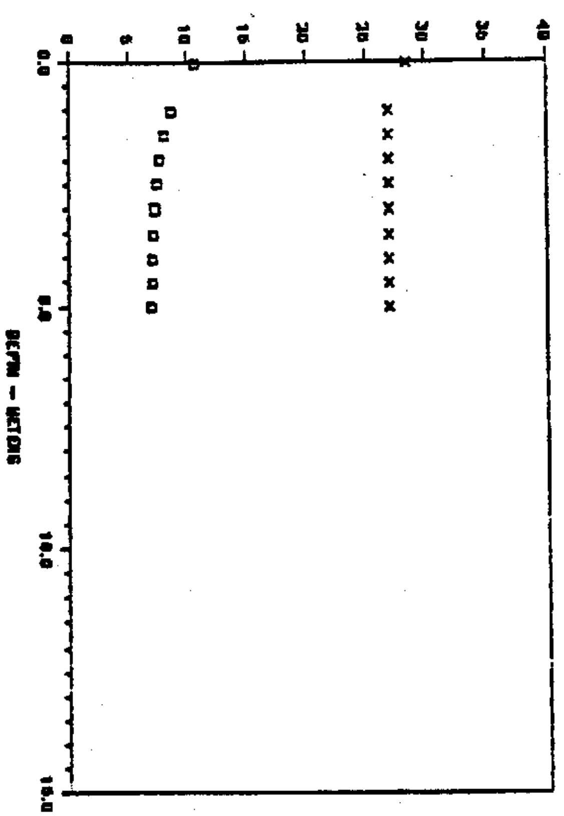
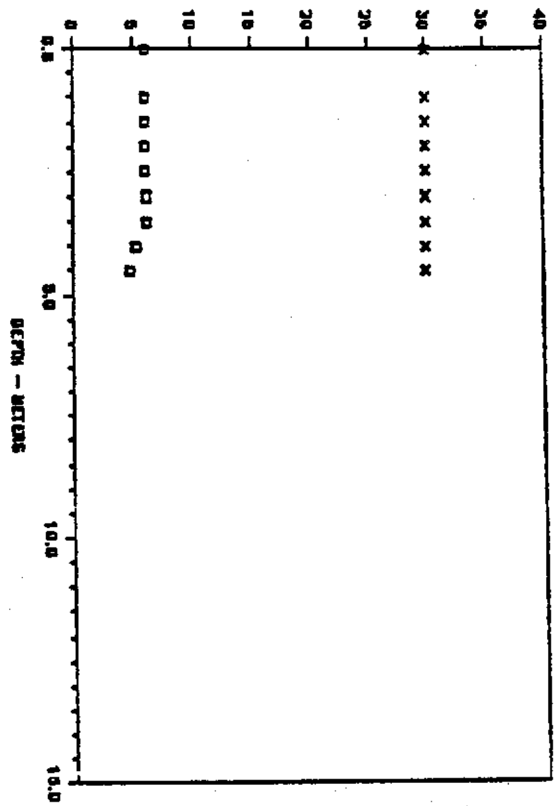

WALLACE LAKE D.O. & TEMP. 8/8/89
ASHBAUGH LAKE D.O. & TEMP. 8/16/89
BOIS D'ARC LAKE D.O. & TEMP. 7/31/89
OLD TOWN LAKE D.O. & TEMP. 8/8/89
DEPTH — METERS

FIGURE C-20

HORSESHOE LAKE D.O. & TEMP. 8/10/80



GRAND LAKE D.O. & TEMP. 8/7/80



GA. PACIFIC LAKE D.O. & TEMP. 8/3/80

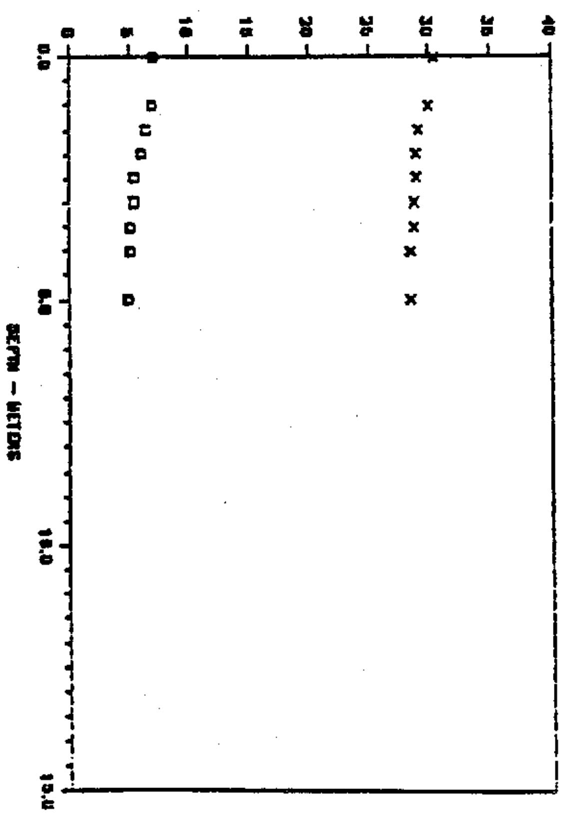


FIGURE C-21

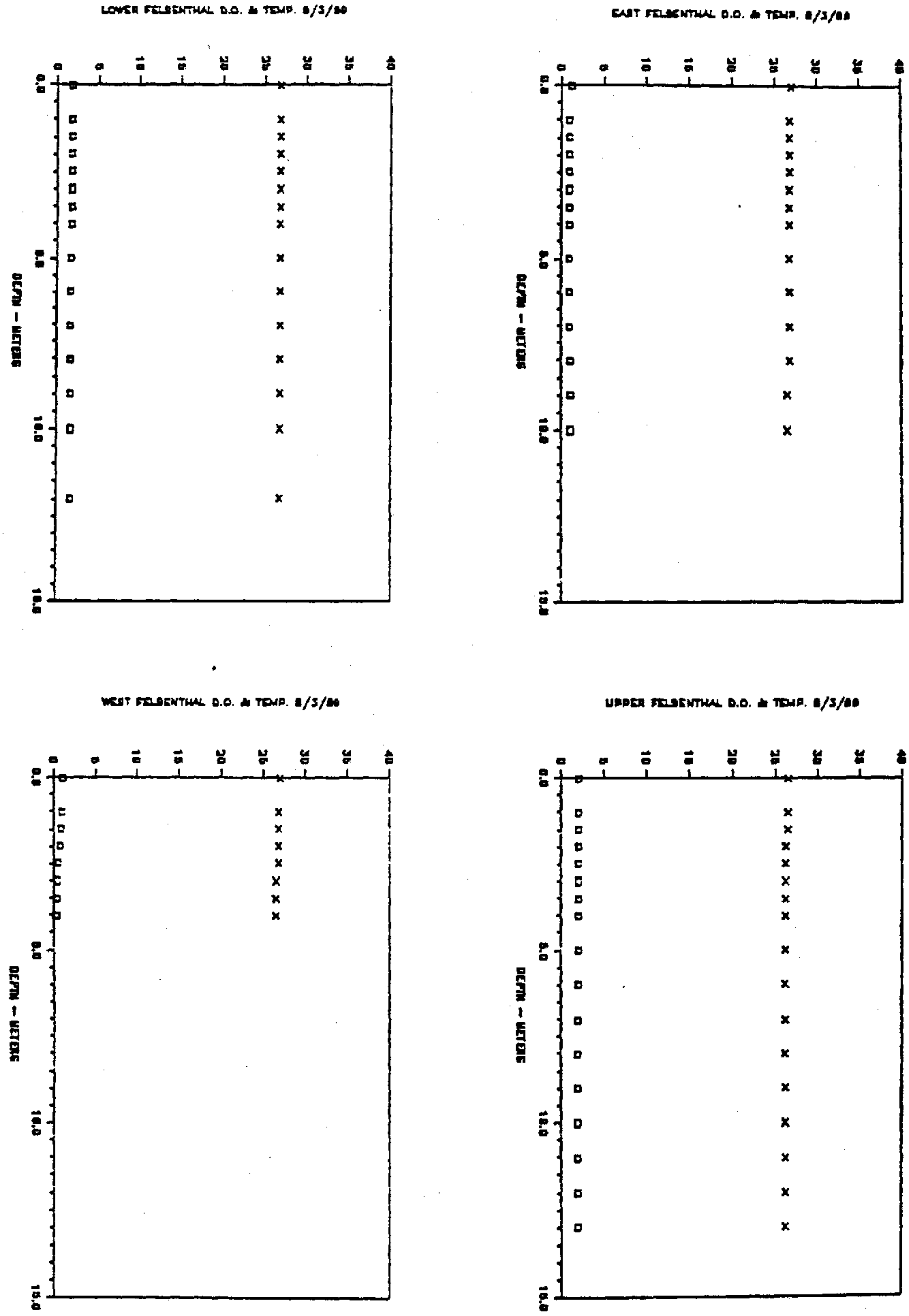
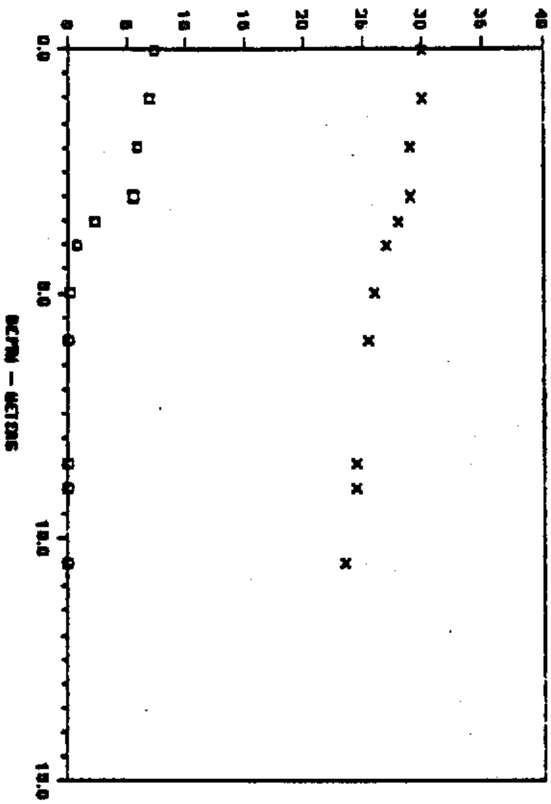
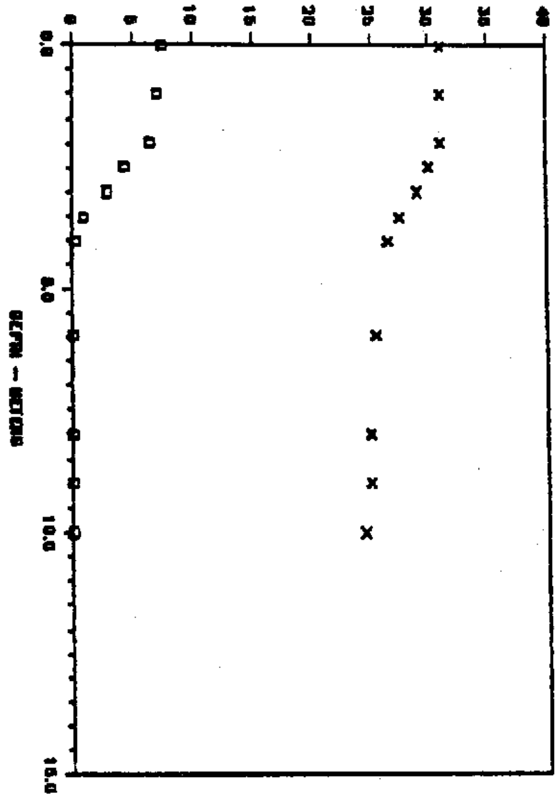

LOWER FELSENTHAL D.O. & TEMP. 8/3/88
EAST FELSENTHAL D.O. & TEMP. 8/3/88
WEST FELSENTHAL D.O. & TEMP. 8/3/88
UPPER FELSENTHAL D.O. & TEMP. 8/3/88
DEPTH - METERS

FIGURE C-22

BLUE MT. LAKE D.O. & TEMP. 8/7/89



NIMROD LAKE D.O. & TEMP. 8/7/89



MILLWOOD LAKE D.O.& TEMP. 8/21/89

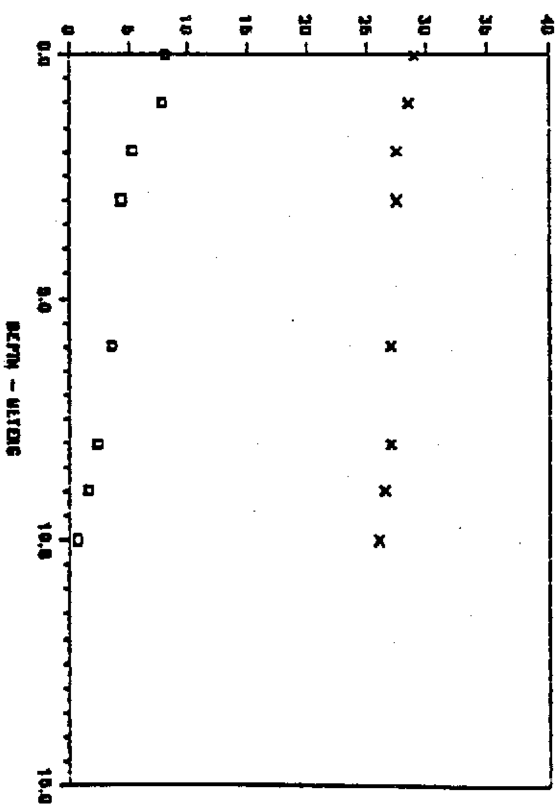


FIGURE C-23

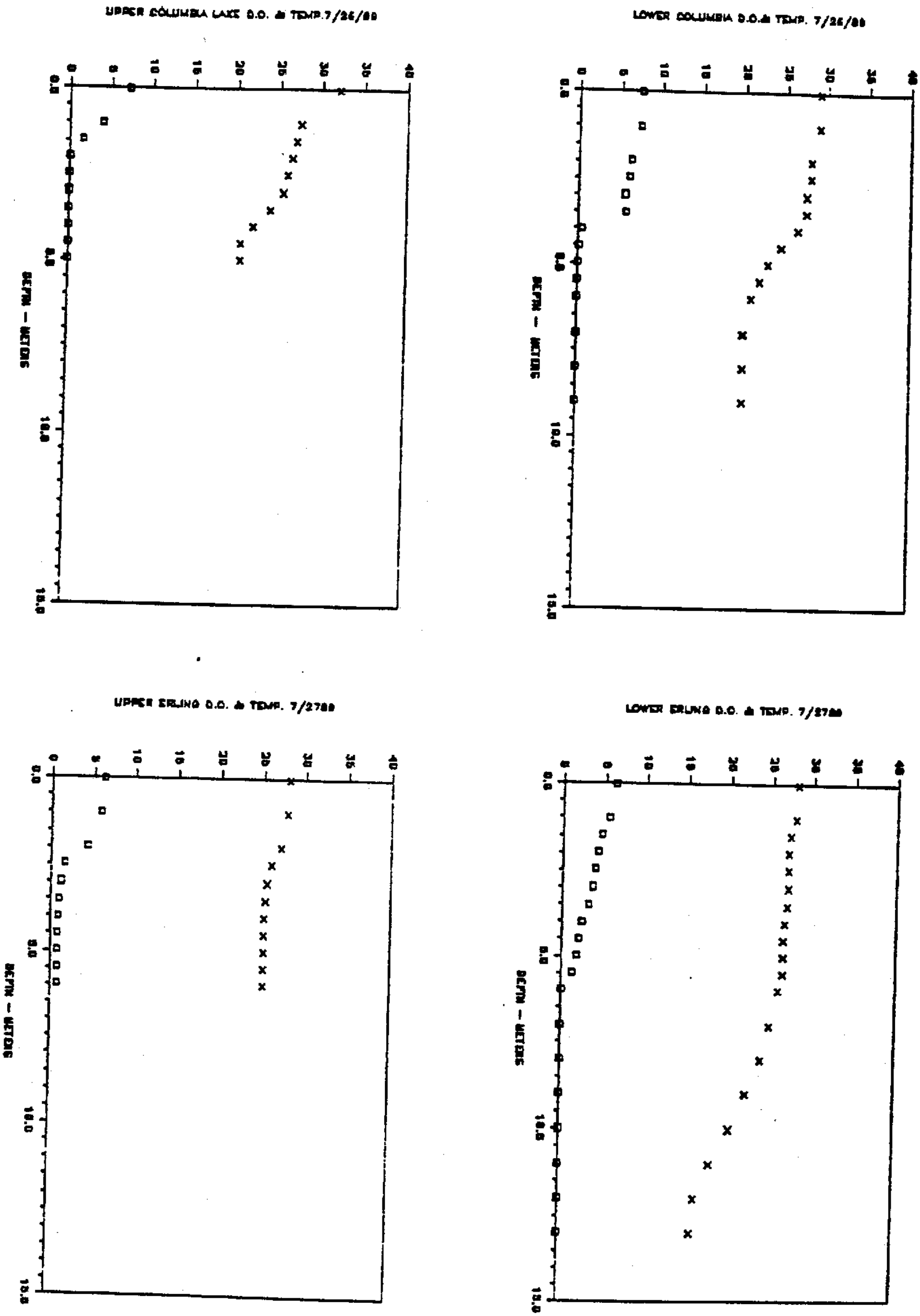
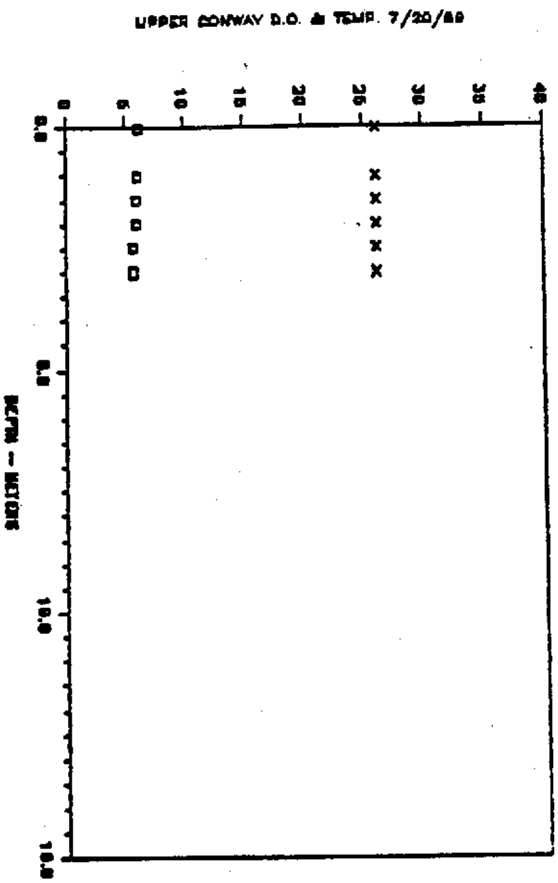
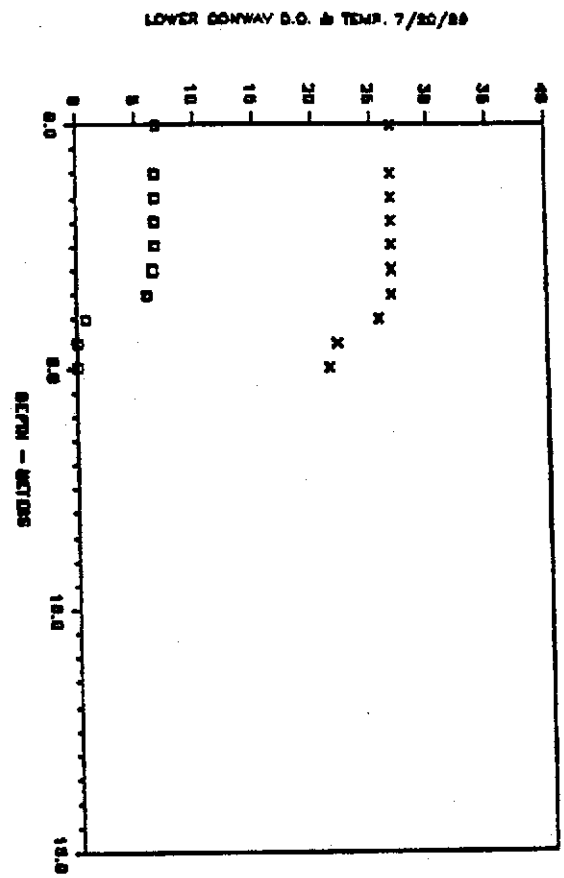

UPPER COLUMBIA LAKE D.O. & TEMP.7/26/89
LOWER COLUMBIA D.O.& TEMP. 7/26/89
UPPER ERLING D.O. & TEMP. 7/2789
LOWER ERLING D.O. & TEMP. 7/2789
DEPTH — METERS

FIGURE C-24


UPPER CONWAY D.O. & TEMP. 7/20/89
DEPTH - METERS


LOWER CONWAY D.O. & TEMP. 7/20/89
DEPTH - METERS