FINAL REPORT FOR
BEAVER LAKE - PHASE I
DIAGNOSTIC/FEASIBILITY STUDY

Prepared for
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Summary and Conclusions:

Beaver Lake Clean Lake Study

Findings of the Beaver Lake Clean Lake Study include:

1) Based on nutrient loads, the trophic status of Beaver Lake in 1991 is similar to the trophic status of the lake during the 1974 NES defined survey (i.e., mesotrophic).

2) Although the trophic status of Beaver Lake based on loads was similar between the two studies, the Lake had slightly lower total phosphorus and chlorophyll a concentrations and higher Secchi transparencies in 1991 compared to 1974.

3) Based on comparisons of nutrient data between 1991 and 1974 there are no indications that Beaver Lake is more eutrophic in 1991.

4) Since the new City of Fayetteville's waste water treatment plant went on-line in 1988, phosphorus and nitrogen point source loads have decreased and DO concentrations have increased significantly in the White River.

5) Nonpoint source pollution contributions of phosphorus and nitrogen in the White River were greater in 1991 than in 1974 indicating an increase in nonpoint source load.

6) Of the major tributaries monitored, the White River and War Eagle Creek contribute 60% of the phosphorus and nitrogen loads to Beaver Lake; Although War Eagle Creek contributes 20% and 30% of the phosphorus and nitrogen loads to Beaver lake, respectively, it is considered a least-distributed stream in the ecoregion (ADPCE 1987).

7) Urban runoff appears to be affecting the water quality of Town Branch which in turn affects the water quality of the West Fork of the White River.

8) The intensive surveys indicated nutrient concentration decreased down the reservoir. Mesotrophic conditions existed from the headwater tributaries of the White River and War Eagle Creek, downstream to the BWD intake structure; oligotrophic conditions existed in the lower portions of the reservoir.

9) Fecal coliform bacteria occasionally exceeded body contact criteria in the vicinity of Town Branch, the White River upstream and downstream of the Fayetteville wastewater treatment plant in the White River, and in War Eagle Creek.

10) Groups of restoration alternative considered included:

- Watershed management techniques,
- In-lake restoration techniques,
- Regulatory considerations, and
- Lake association

The alternatives considered to be most viable included watershed management techniques and a lake association. Watershed management techniques are already being implemented in the watershed.

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a.1.0 LAKE IDENTIFICATION AND LOCATION

a.1.1 Background

Beaver Lake is located in Washington, Benton and Carroll counties in northwest Arkansas, approximately 6.4 km east of Rogers. The Lake is a Corps of Engineers impoundment created by damming the White River at river kilometer 980. Construction of the dam was completed in 1964, and the Lake reached conservation-water supply pool level (341 m NGVD) in 1968. At this level, the Lake covers 11,421 ha. At flood control pool level (344 m NGVD) Beaver Lake has a surface are of 12,829 ha.

Beaver Lake drains an area approximately 307,174 ha in size. The White River, War Eagle Creek and Richland Creek are the three primary tributaries to Beaver Lake with additional inflow from smaller creeks and unnamed tributaries. Figure a.1.1 shows the location of Beaver Lake.

a.1.2 Location

Location information for Beaver Lake is presented below:

- Lake Name: Beaver
- State: Arkansas
- Counties: Washington, Benton and Carroll
- Nearest Municipality: Rogers
- Latitude/Longitude: 36° 21' 24"/94° 55'00"
- EPA Region: VI
- EPA Major Basin Name: Mississippi River
- EPA Minor Basin Name: Upper White and Kings River code: 4K
- Major Tributaries: White River, War Eagle Creek, Richland Creek
- Receiving Water Body: White River

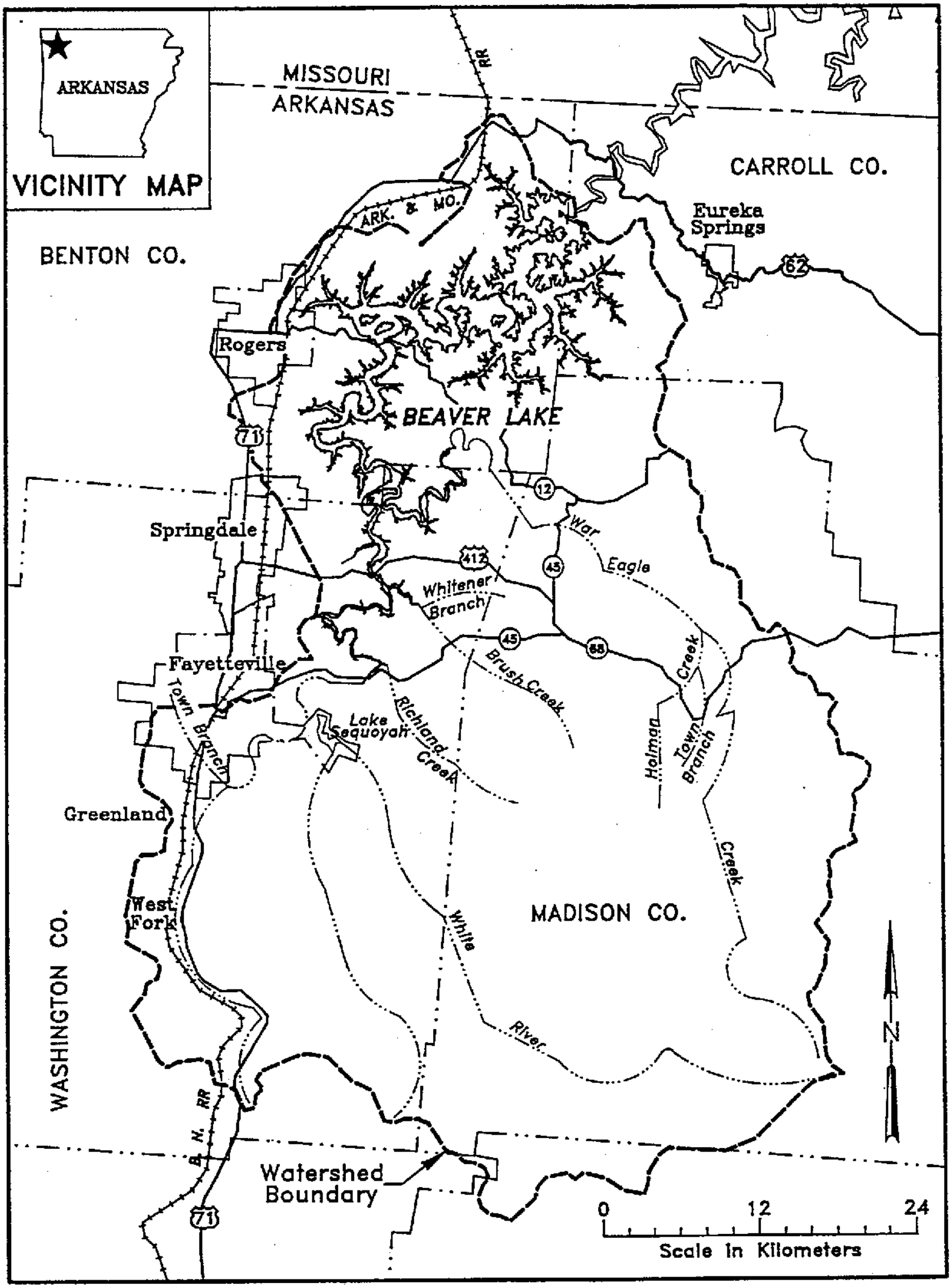

Figure a.1.1. Vicinity map of Beaver Lake.

a.1.3 Water Quality Standards

Beaver Lake was constructed for the purposes of flood control, hydropower generation, and water supply. Under the authority of amendments to the Flood Control Act of 1944, recreation and fish and wildlife opportunities are also provided. Under the State of Arkansas regulations, the designated beneficial uses (ADPCE 1991) for Beaver Lake are:

- Domestic, industrial, and agricultural water supply;
- Primary and secondary contact recreation; and
- Fishery.

The designated uses of War Eagle and Richland Creeks, and the Main, Middle, and West forks of the White River include:

- Domestic, industrial and agricultural water supply;
- Primary and secondary contact recreation; and
- Perennial Ozark Highlands fishery.

Specific water quality standards of concern in Beaver Lake are as follows:

1) Temperature - The maximum temperature rise above natural temperatures outside the mixing zone shall not exceed 2.8°C nor shall the maximum water temperature exceed 32°C.
2) Turbidity - Waste discharges from municipal, industrial, agricultural, or other sources, shall not result in turbidity values exceeding 25 NTU.
3) pH - As a result of waste discharges, pH must not fluctuate in excess of 1.0 unit over a 24 hour period, and pH values shall not be below 6.0 or above 9.0 su.
4) Bacteria in Primary Contact Waters - Between 1 April and 30 September, fecal coliforms shall not exceed a geometric mean of 200 cols/100 mL,

nor exceed 400 cols/100 mL in more than 10 percent of the samples during any 30 day period. Between 1 October and 30 March, the geometric mean shall not exceed 1000 cols/100 mL, and in any 30 day period, no more than 10 percent of the samples may equal or exceed 2000 cols/100 mL.

5) Bacteria in Secondary Contact Waters - The fecal coliform content shall not exceed a geometric mean of 1000 cols/100 mL, nor equal or exceed 2,000 cols/100 mL in more than 10 percent of the samples taken in any 30-day period.

6) Nutrients - materials stimulating algal growth shall not be present in concentrations sufficient to cause objectionable densities of algae or other nuisance aquatic vegetation. For total phosphorus, that guideline concentration is less than 50 μg/L.

7) Toxic Substances - Discharges shall not be allowed which will cause toxicity to human, animal, plant or aquatic life or interfere with normal propagation, growth and survival of aquatic biota outside the mixing zone.

Specific water quality standards of concern in War Eagle and Richland Creeks and in the West Fork of the White River and in the White River (from the Missouri line to its headwaters) are as follows:

- Temperature - The maximum temperature rise above natural temperatures outside the mixing zone shall not exceed 2.8°C nor shall the maximum water temperature exceed 29°C.
- Turbidity - Waste discharges from municipal, industrial, agricultural, or other sources, shall not result in turbidity values exceeding 10 NTU.
- pH - As a result of waste discharges, pH must not fluctuate in excess of 1.0 unit over a 24 hour period, and pH values shall not be below 6.0 or above 9.0 su.

- Dissolved Oxygen - The minimum dissolved oxygen limit for streams with watersheds over 100 mi^2 is 6 mg/L.
- Bacteria - same as listed above
- Nutrients - same as listed above
- Toxic Substances - same as listed above
- Mineral Quality - The following limits for chloride, sulfate, and TDS apply:

White River (Missouri Line to headwaters)

Chlorides	20 mg/L
Sulfates	20 mg/L
Total Dissolved Solids	160 mg/L

West Fork, White River

Chlorides	20 mg/L
Sulfates	20 mg/L
Total Dissolved Solids	150 mg/L

War Eagle and Richland Creeks

Chlorides	13 mg/L
Sulfates	17 mg/L
Total Dissolved Solids	240 mg/L

a.2.0 DESCRIPTION OF GEOLOGY, HYDROLOGY, AND SOILS IN DRAINAGE BASIN

a.2.1 Watershed Geology

The surface formations of the Beaver Lake Watershed consist of limestone, dolomite, sandstone, shale and chert. A geologic map of the watershed is presented in Figure a.2.1. The older formations crop out along the lower elevation of the White River valley in the Salem Plateau. These formations include, in ascending order, the Cotter Powell Dolomites, Everton Formation, St. Peter Sandstone, Chert Limestone, and the Chattanooga Shale. Most of these formations occur below the top of the conservation water supply pool of Beaver Lake (EL 341 m NGVD). The higher elevations of the Salem Plateau and most of the Springfield Plateau is covered by the Mississippian Boone Formation. The younger formations are present in the Boston Mountain region and include the Mississippian Bartesville Sandstone, Fayetteville Shale, Pitkin Limestone, and the Pennsylvanian Hale, Bloyd and Atoka Formations.

Rock strata in the watershed are nearly flat lying, dipping gently toward the south-southwest and are a part of the dome formed by the uplift of the St. Francis Mountains in southeast Missouri. Minor folds and normal faults are common in the area.

The general quality of natural waters flowing through the watershed is related to the geologic province represented within the watershed. The White River headwaters are in the Boston Mountains which is underlain largely by interbedded sandstone and shale. The Boston Mountains represent a deeply dissected plateau composed mainly of interbedded sandstone and shale formations. Included in this group are the Mississippian Batesville Sandstone and Fayetteville Shale and the Pennsylvanian Hale, Bloyd and Atoka Formations. The sandstones are composed mostly of quartz grains cemented by iron oxides, secondary quartz, and clay minerals. The shales are illitic, carboniferous aluminosilicates. Although silicon and aluminum are major constituents of these rocks, they are not commonly found in surface waters because of their relatively low solubilities. Natural surface waters in this area are a calcium bicarbonate type water with a dissolved solids range of 25-125 mg/L. Water is soft to moderately hard with a

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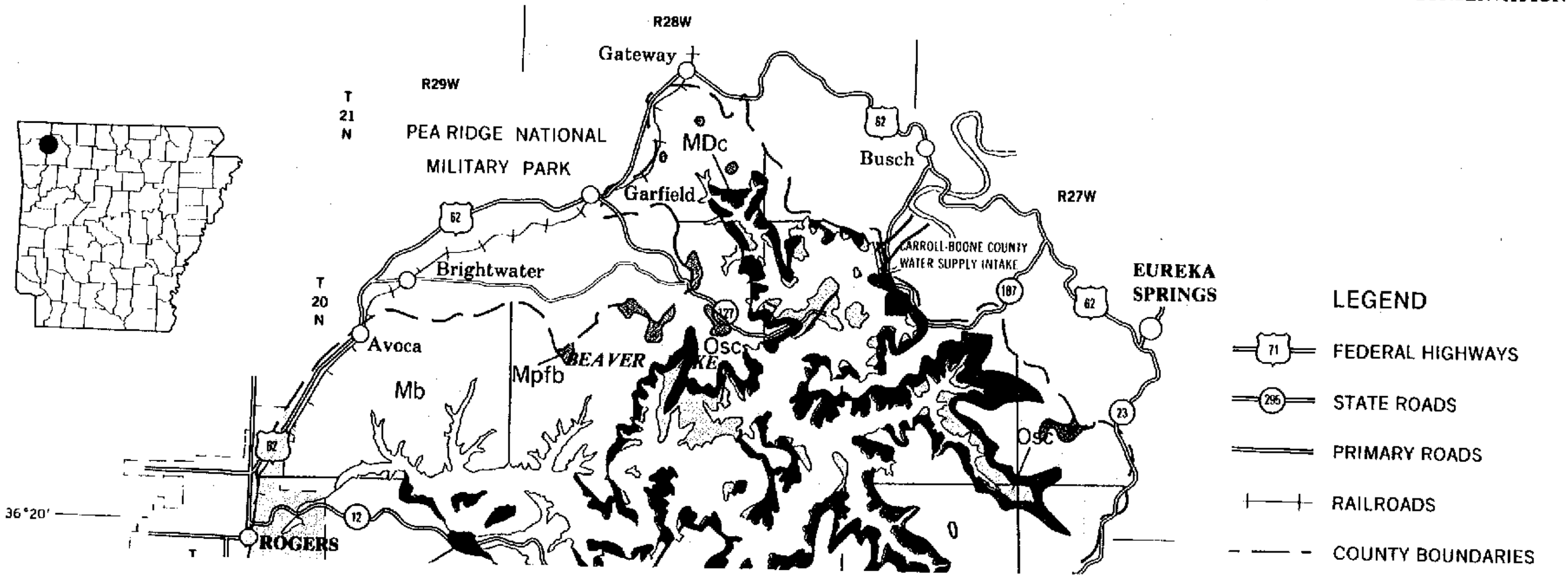

hardness range of 0 to 80 mg/L (Lamonds 1972). As surface waters flow north through the Springfield Plateau, they become harder and more alkaline.

The area surrounding Beaver Lake in the higher elevation of the Salem Plateau south to the Boston Mountains is covered by the Mississippian Boone Formation. The Boone Formation consists of limestone, interbedded limestone and chert, and chert. The formation is approximately 300 feet thick in the area and is underlain by the St. Joe Formation, which is a non-cherty, crystalline, fossilliferous limestone.

a.2.2 Watershed Hydrology

Three major normal faults with several minor faults are present in the area. Less important structurally, but very important hydrologically, are the numerous joints and fractures that occur in these limestones and cherts. The Boone Formation together with the St. Joe Formation forms the major important shallow aquifer for this region. Areas underlain by the Boone-St. Joe aquifer are susceptible to groundwater contamination by nonpoint sources such as septic tanks, chicken houses, the spreading of fertilizer, and landfills. The Boone-St. Joe aquifer is most susceptible to contamination in areas where:

- overlying soils are thin or drain rapidly, and
- joints and fractures are present.

The joints and fractures present in the Boone-St. Joe aquifer are zones of recharge to the aquifer and usually contain groundwater that moves rapidly through these channels without much natural filtering. The capacity of the aquifer to transmit groundwater to wells and springs depends largely on the size and number of interconnected joints, fractures and other openings. Springs are numerous in the area and have been found to lie on or be within a short distance of fracture zones (Steele and Adamski 1987).

Five percent of the Batesville, Hale and Athen Formations will generally yield small quantities of relatively good water to wells for domestic use. Shales in the area tend to yield hard water that is high in iron and sulfate.

The Boone-St. Joe aquifer is very soluble; hence, it is characterized by the development of sinkholes, caves, disappearing streams, and solution channels. Due to this karstic geology in the Beaver Lake watershed, it is not possible to accurately assess the extent of groundwater recharge to the Lake. The main soluble constituents contributed by the cherty limestone of the Boone Formation are larger quantities of calcium. The dolomites of the Salem Plateau are an important source of magnesium as well as calcium to waters of Beaver Lake. Horn and Garner (1965) found magnesium concentrations (2-6 ppm) in the White River portion of the Salem Plateau to increase 2 to 3 times over concentrations (10-15 ppm) found in other areas of the watershed. Wells and springs that were sampled during groundwater studies of the Boone-St. Joe aquifer in populated areas or areas with significant agricultural land use generally contained levels of nitrate, chloride, phosphate and sulfate above background levels, but these levels rarely exceeded public health standards (Ogden 1980, Steele and Adamski 1987, MacDonald et al. 1975). These studies did, however, indicate that bacterial contamination of groundwater in the Boone-St. Joe aquifer could be a problem.

For a period of record dating from 6/70 to 12/91, the average annual inflow to Beaver Lake was 1,239,400,000 m^3, and the Beaver Lake watershed received an annual average percipitation of 112.9 cm. Beaver Lake received an average annual inflow of 1,239,400,000 m^3 from surface runoff during this period. In 1991, 138.5 cm of precipitation was recorded at Beaver Dam, and the total yearly inflow to the Lake was estimated to be 1,386,100,000 m^3. The White River contributed 437,340,000 m^3 of runoff to the Lake in 1991. During this same year, Beaver Lake received an estimated flow of 1,435,000 m^3 and 3,653,000 m^3 from Richland and War Eagle Creeks, respectively (data obtained from Reservoir Control Section, Little Rock District Corps of Engineers).

a.2.3 Watershed Topography

Beaver Lake Watershed is located within portions of three physiographic subdivisions of the Ozark Highlands physiographic province (Figure a.2.2). The three

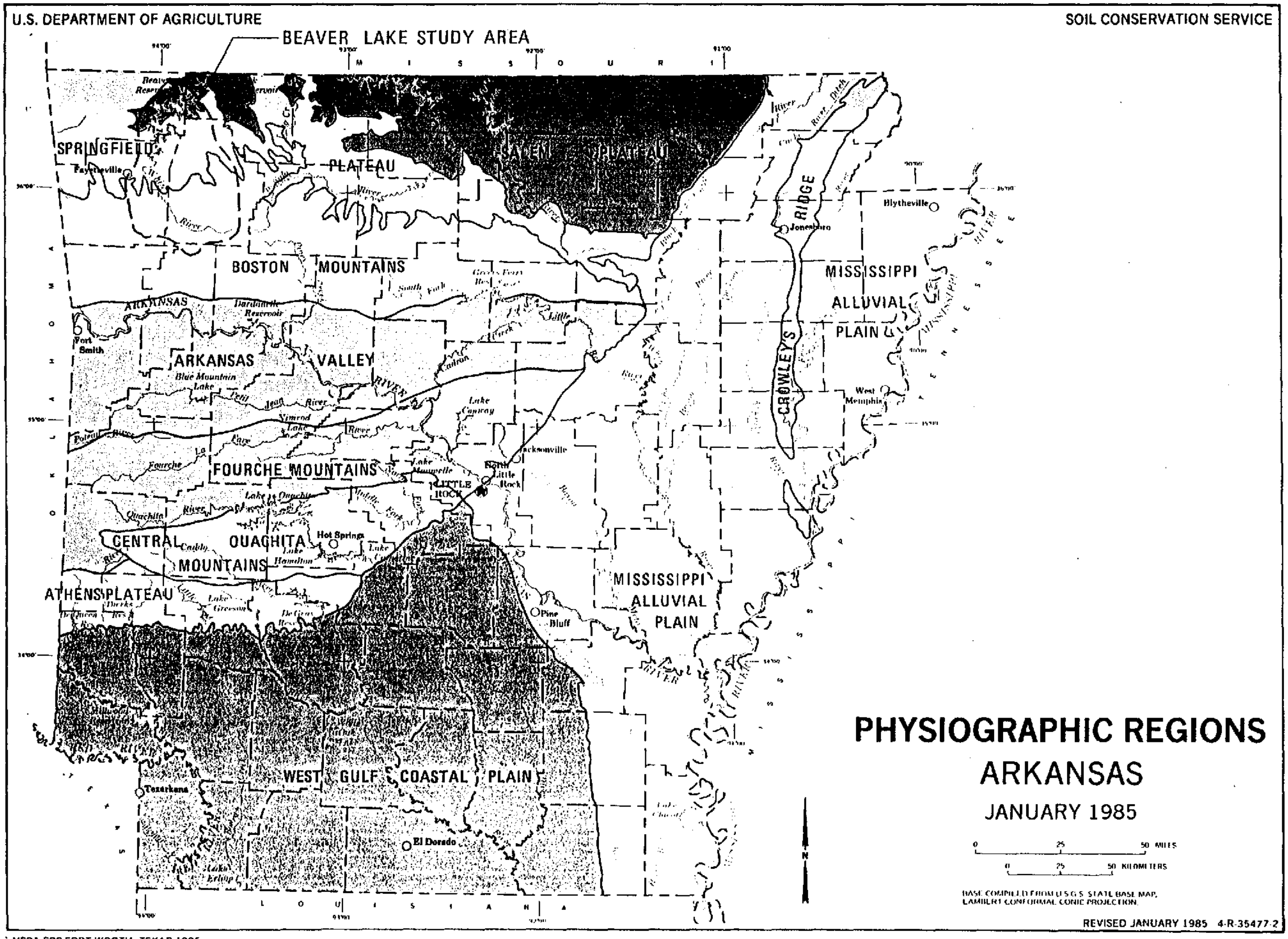

Figure a.2.2. Physiographic regions of Arkansas.

subdivisions represent well-defined erosional surfaces or plateaus and include the Salem Plateau, the Springfield Plateau, and the Boston Mountains.

All of Beaver Lake north of Monte Ne is located on the Salem Plateau, a roughly dissected area with as much as 152 m (500 ft) of relief. The middle section of the watershed is within the Springfield Plateau which has elevations ranging from 384 to 457 m (1,260 to 1,500 ft NGVD) within the watershed. Rising 152 m (500 ft) above the Springfield Plateau in the southern portion of the watershed are the Boston Mountains, in which are the headwaters of the White River. Elevations of this plateau are from 366 m (1,200 ft NGVD) along the White River Valley to 753 m (2,472 ft NGVD) in the mountains near the watershed divide.

As shown on Figure a.2.3, the watershed can be divided into seven major drainage basins. The Beaver Lake drainage basin and the northern portion of the War Eagle basin are located on the Salem and Springfield plateaus. The remaining drainage basins are within the Boston Mountain area.

The percentage of area corresponding to gentle ($\leq$10%), moderate (11-20%) and steep slopes (>20%) in each subbasin of the Lake's drainage area is described below (SCS 1969, 1977, 1984, 1986):

Beaver Lake

- 3% gently sloping stream terraces and floodplains
- 7% gently sloping uplands
- 90% moderately sloping narrow ridges and steep side slopes of mountains

War Eagle Creek

- 12% gently sloping stream terraces and floodplains
- 4% gently sloping uplands
- 30% moderately sloping narrow ridges to steep mountain side slopes (northern portion)

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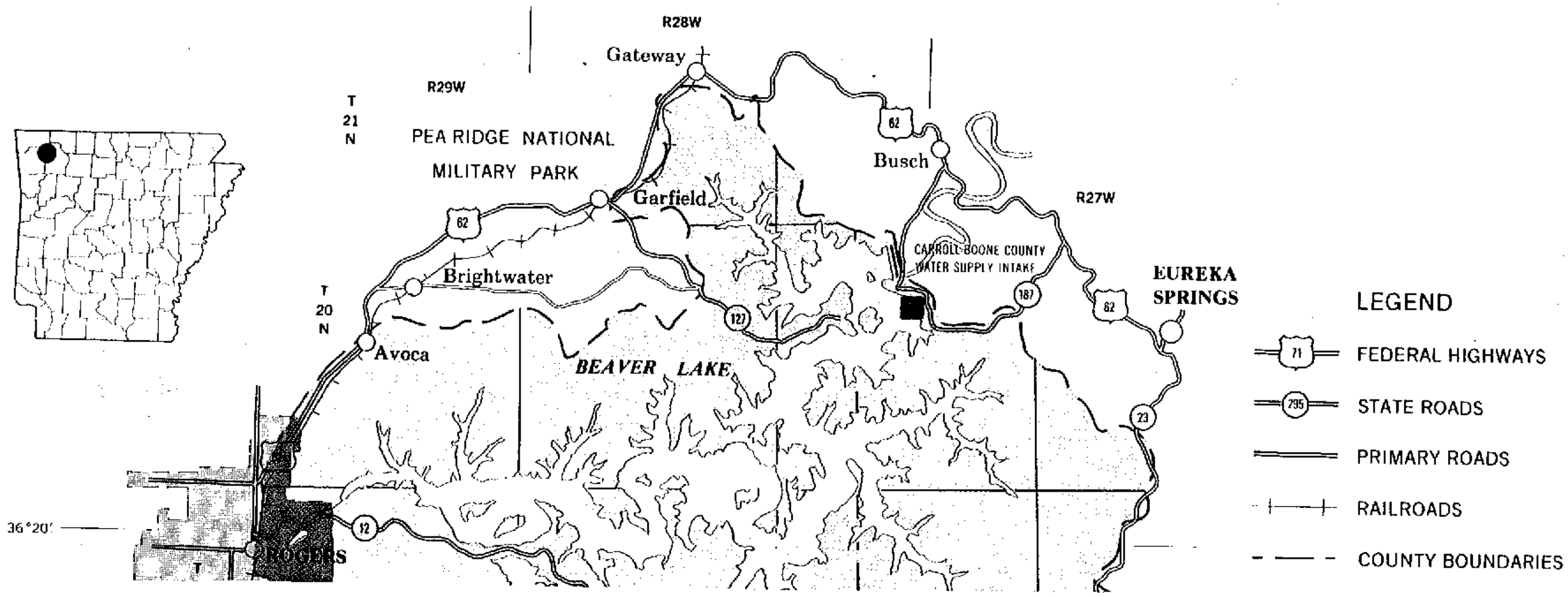

- 11% gently to moderately sloping mountaintops and benches (southern portion)
- 43% steep side slopes of mountains (southern portion)

Richland Creek

- 17% gently sloping stream terraces and flood plains
- 21% gently to moderately sloping mountaintops and benches
- 62% steep side slopes of mountains

White River

- 15% gently sloping stream terraces and flood plains
- 39% moderately to steep sloping benches, mountaintops and side slopes
- 46% steep side slopes of mountains

Middle Fork of White River

- 12% gently sloping stream terraces and flood plains
- 34% moderately to steeply sloping benches, mountaintops and side slopes
- 54% steep side slopes of mountains

West Fork of White River

- 14% gently sloping stream terraces and flood plains
- 3% gently sloping uplands
- 13% moderately to steeply sloping benches, mountaintops and side slopes
- 70% steep slopes of mountains

a.2.4 Watershed Soils

Omernik (1986) classifies the soils of the Beaver Lake watershed as ultisols. Ultisols are commonly red or yellow in color and are moist, highly weathered and acidic soils containing clay horizons with low base saturations and oxides of iron and aluminum. Ultisol soils are formed on old land surfaces, normally under forest vegetation, and they are not naturally fertile, but they respond well to fertilization and good management (Brady 1984).

The Soil Conservation Service (SCS 1986) has identified six soil associations in the Beaver Lake Watershed. Most soils in the Beaver Lake area are low in natural fertility. These general associations and their areal distributions are shown on Figure a.2.4. Table a.2.1 provides a description of these soil associations and their areal extent, erodability, land use, and erosion hazard. Where these soils are shallow, they may be poorly suited for the management of animal waste and other nonpoint sources of contamination. Most of these soils were developed in upland areas on residuum or alluvial material. In the northern, Salem-Springfield Plateau portion of the watershed, approximately 30% of the soils (Clarksville-Nixa-Noark and Captina-Tonti-Peridge) formed from residuum of cherty limestone. These soils, in general, contain abundant chert fragments ranging from sand size to small boulders, and they vary in thickness from 0.6 to 12.2 m, with an average of 3.0 m (COE 1989).

The soils found in the higher elevation of the Salem Plateau south to the Boston Mountains consist of a red regolith containing abundant chert that is produced by weathering of the Boone Limestone. These soils are primarily of the Clarkesville-Nixon-Noark association and are described by the SCS (1986) as excessively to moderately well drained, gently sloping to steep, deep to moderately shallow, cherty soils on hills and ridges. This mantle of cherty and often thin soil does not provide satisfactory biodegradation and allows rapid movement of pathogenic bacteria through the soil and percolation of surface contaminants to groundwater.

Soils in the southern, Boston Mountain portion of the watershed developed from residue and colluvium of interbedded sandstones and shales. Approximately 50% of the soils belong to the Enders-Leesberg association which the SCS (1986) describes as deep, well drained, moderately permeable to very slowly permeable soils formed on gravelly sideslopes. The Leadvale-Cleora-Razort soil units cover approximately 8% of the watershed and are formed on deep terrace and flood plain deposits. The remaining areas are covered by the Nell-Steprock-Mountainburg soil units.

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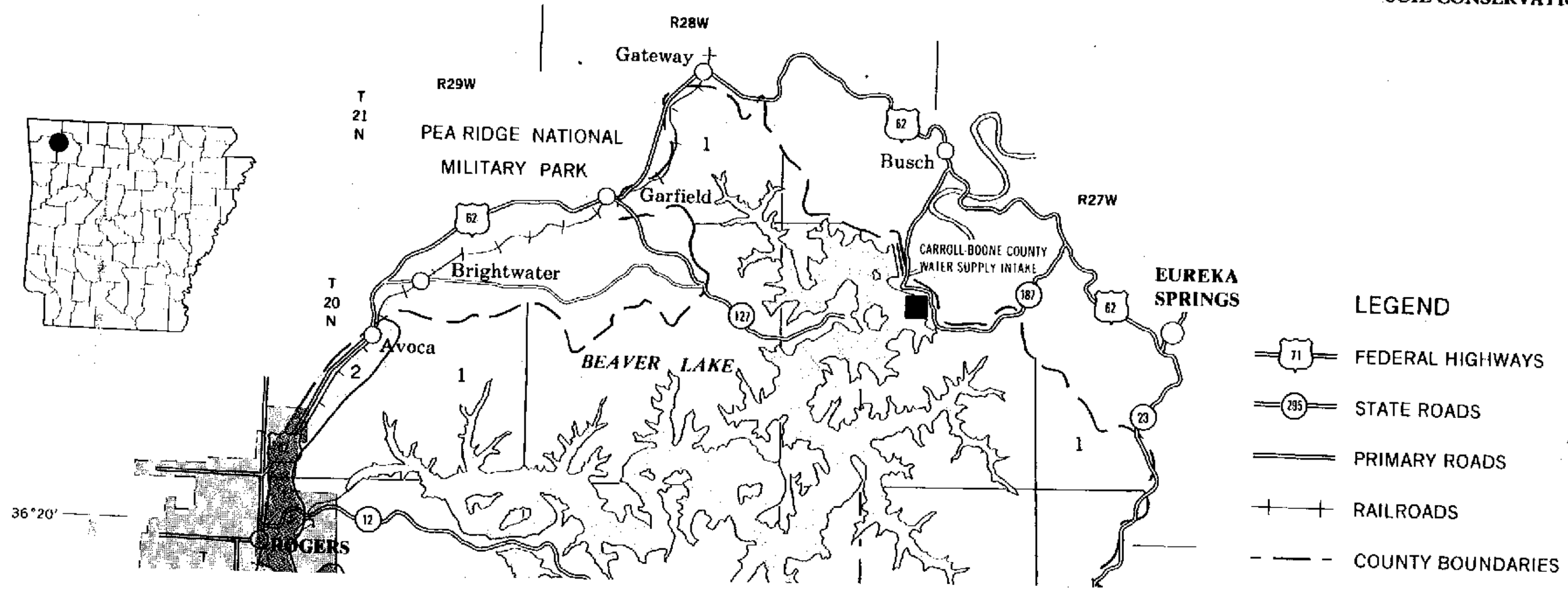

Table a.2.1. Soil Association with Respect to Erosion Hazard, Beaver Lake Watershed.

Unit No.	% of Area	Major Soils Unit	% of Unit	Erodability K	Primary Land Use	Erosion Hazard
1.	26	CLARKSVILLE: 12-50% slopes. Very cherty silt loam surface layers. Very cherty silt loam subsoil	38	.28	Mostly wooded or Non-form	Moderate-Severe
		NIXA: 3-15% slopes. Very cherty silt loam surface layers and upper subsoil over firm, brittle, very cherty fragipan; with very cherty clay lower subsoil.	35	.32 - .37	Mostly wooded or Non-form	Slight-Moderate
		NOARK: 3-50% slopes. Very cherty silt loam surface layers. Very cherty red clay subsoil.	15	.24 - .28	Mostly wooded or Non-form	Slight-Severe
		OTHER SOILS: Elsah, Tonti, Britwater.	12			
2.	3	CAPTINA: 1-8% slopes. Silt loam surface layers over loamy upper subsoils. Firm brittle fragipan lower subsoil.	35	.32 - .43	Pasture or Hayland	Slight-Moderate
		TONTI: 3-8% slopes. Cherty silt loam surface layers. Cherty silt loam upper subsoil over very cherty firm fragipan over very cherty clay.	30	.28 - .37	Pasture or Hayland	Slight-Moderate
		PERIDGE: 1-8% slopes. Silt loam surface layers over silty clay loam subsoil.	20	.24 - .37	Pasture or Hayland	Slight-Moderate
		OTHER SOILS: Nixa, Tolaka, Johnsburg, Noark	15			
3.	50	ENDERS: 3-40% slopes. Stony or gravelly loam surface layers, acid, very slowly permeable, clay subsoils over soft shale bedrock.	45	.32 - .43	Mostly wooded. Less sloping areas cleared for pasture	Moderate-Very Severe
		LEESBURG: 3-40% slopes. Stony or gravelly loam surface layers; loamy upper subsoil and loamy or clayey lower subsoil.	30	.17 - .24	Mostly wooded. Less sloping areas cleared for pasture	Moderate-Severe
		OTHER SOILS: Mountainburg, Linker, Ceda.	25			

Table a.2.1. Continued.

Unit No.	% of Area	Major Soils Unit	% of Unit	Erodability K	Primary Land Use	Erosion Hazard
4.	9	<u>NELLA:</u> 8-60% slopes. Stony or gravelly loam surface layers over gravelly loam or clay loam subsoils.	35	.15 - .20	Mostly wooded. Less sloping areas cleared for pasture	Moderate-Severe
		<u>STEPROCK:</u> 3-60% slopes. Stony or gravelly loam surface layers. Very gravelly loam subsoils over soft sandstone bedrock.	30	.17 - .20	Mostly wooded. Less sloping areas cleared for pasture	Moderate-Severe
		<u>MOUNTAINBURG:</u> 3-60% slopes. Stony or gravelly loam surface layers. Very gravelly loam subsoil; shallow to hard sandstone bedrock.	15	.15 - .24	Mostly wooded. Less sloping areas cleared for pasture	Moderate-Severe
		<u>OTHER SOILS:</u> Linker, Ceda, Enders	20			
5.	4	<u>LINKER:</u> 1-12% slopes. Loam or gravelly loam surface layers. Loam or clay loam subsoil over hard sandstone bedrock.	35	.28 - .32	Cleared and used for pasture and hayland	Slight-Moderate
		<u>STEPROCK:</u> 3-12% slopes. Gravelly or stony loam surface layers; very gravelly loam subsoil over soft sandstone bedrock.	35	.17 - .20	Cleared and used for pasture and hayland	Moderate
		<u>MOUNTAINBURG:</u> 3-20% slopes. Stony or gravelly loam surface layers; very gravelly loam subsoil; shallow to hard sandstone bedrock.	15	.15 - .24	Cleared and used for pasture and hayland	Moderate-Severe
		<u>OTHER SOILS:</u> Enders, Cane, Nella	15			
6.	8	<u>LEADVALE:</u> 1-12% slopes. Loam surface layers over loamy subsoil. Lower subsoil is a firm brittle fragipan.	35	.43	Cleared and used for pasture and hayland	Slight-Moderate
		<u>CLEORA:</u> 0-3% slopes. Stratified sandy loams. Moderately rapidly permeable. Occasionally flooded.	20	.32	Cleared and used for pasture and hayland	Slight
		<u>RAZORT:</u> 0-3% slopes. Loam surface layers; loamy, moderately permeable subsoil; rarely flooded.	15	.32 - .37	Cleared and used for pasture and hayland	Slight
		<u>OTHER SOILS:</u> Ceda, Samba, Peridge				

Source: Modified from SCS 1986a, 1986b, 1984.

a.3.0 PUBLIC ACCESS

a.3.1 Location of Access Points

The Corps of Engineers has 9 developed and 3 undeveloped recreational areas around the Lake. Seven of these have commercial boat docks (Figure a.3.1). Most of these areas have picnic and swimming areas, toilets, camping areas with electricity and water, snackbars, and playgrounds. Three other sites, Big Clifty, Blue Springs, and Ventris Vree (Ventris) have boat ramps as the only facility (Figure a.3.1) while Ventris is designated as a primitive camping area. The Big Clifty facility is currently being leased to Carroll County, and the county is responsible for its operation and maintenance. The Lost Bridge Campground has been closed for renovation, and it will re-opened in the spring of 1992.

Table a.3.1 Summarizes public access to Beaver Lake.

a.3.2 Regional Transportation to Beaver Lake

Beaver Lake is located near U.S. highways 62, 71, and 412 and state highways 12, 23, 45, 47, 72, and 94. Figure a.3.2 highlights the major highway accesses to Beaver Lake. Table a.3.2 summarizes driving routes and distances to the lake from major population centers near the Lake.

The Fayetteville Municipal Airport is the closest airport to Beaver Lake offering direct commuter service to the Northwest Arkansas area. U.S. Air, American Airlines, and Delta Airlines provide service to the Beaver Lake area from major urban centers in the region. Table a.3.3 provides schedules and fares of airlines serving the Beaver Lake area. Private planes land at the smaller airstrips at Rogers and Springdale as well as at Fayetteville Municipal Airport.

Jefferson Bus Lines provides service from Rogers, Springdale, and Fayetteville to larger population centers in the region. The Jefferson Bus Lines schedule and fares are summarized in Table a.3.4.

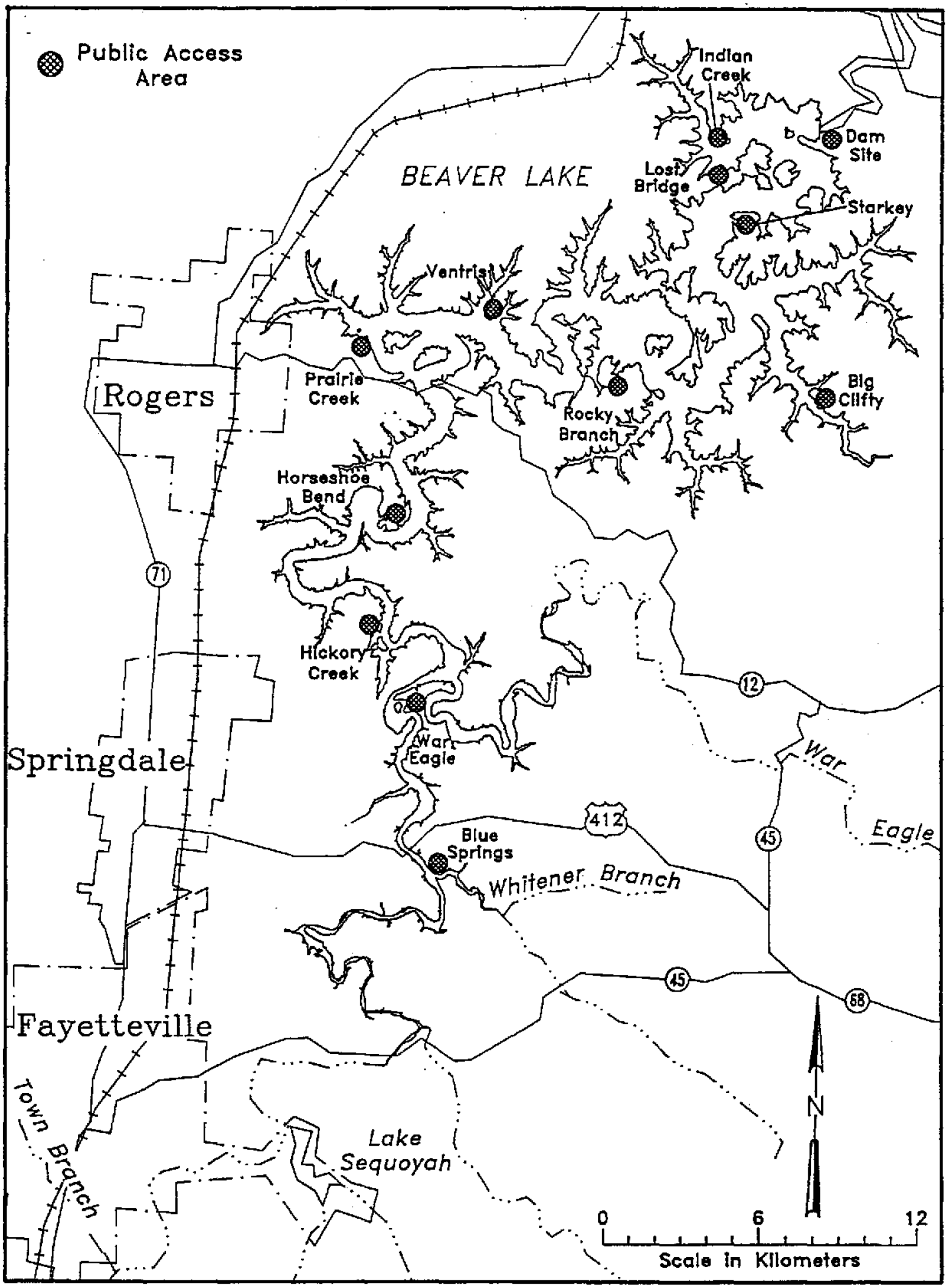

Figure a.3.1. Public access to Beaver Reservoir.

Table a.3.1. Public Access Points.

Name	Resp Agency	Type	Land Area (ha) Dev+	Total	Facilities	Fee*
Beaver Overlook	USCOE, LR Dist	Corps Park	1	12	Overlook	
Big Clifty	Carroll City	Boat Launch	0	40	Boat Ramp	No
Blue Spring	USCOE, LR Dist	Corps Park	13	27	Boat Ramp	No
Dam Site	USCOE, LR Dist	Corps Park	43	286	Boat Ramp w/electricity Camp Sites (103) Overlook Pavilion Beach Hiking Trails Showers	Y
Hickory Creek	USCOE, LR Dist	Corps Park	38	58	Campsites w/electricity (44) Boat Dock ** Boat Ramp Picnic Area Beach Playground Pavilions (2) Showers	Y

All parks are open for use year round. Quiet hour is 10:00 p.m.

* Camping Fees are $9.00 or $10.00 per night, depending on the availability of flush toilets. Camping is free at the Starkey facility. Fees are used for operation and maintenance of facilities (pers. comm Gary Whisnant COE).

** Privately operated, leased from Corps of Engineers.

+ Developed Areas

Table a.3.1. Continued.

Name	Resp Agency	Type	Land Area (ha) Dev+	Total	Facilities	Fee*
Rocky Branch	USCOE, LR Dist	Corps Park	16	64	Campsites w/electricity (50) Showers Boat Dock ** Boat Ramp Pavilion Playground	Apr-Oct
Ventris	USCOE, LR Dist	Corps Park	2	30	Boat Ramp	No
Starky	USCOE, LR Dist	Corps Park	7	43	Campsites (31) Boat Dock ** Boat Ramp Pavilion Playground	N
War Eagle	USCOE, LR Dist	Corps Park	12	19	Campsites w/electricity (26) Boat Dock ** Boat Ramp Showers Overlook Pavilion Beach	Apr-Oct

All parks are open for use year round. Quiet hour is 10:00 p.m.

* Camping Fees are $9.00 or $10.00 per night, depending on the availability of flush toilets. Camping is free at the Starkey facility. Fees are used for operation and maintenance of facilities (pers. comm Gary Whisnant COE).

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\+ Developed Areas

Table a.3.1. Continued.

Name	Resp Agency	Type	Land Area (ha) Dev+	Total	Facilities	Fee*
Lost Bridge	USCOE, LR Dist	Corps Park	12	19	Campsites w/electricity (95) Boat Dock ** Boat Ramp Showers Pavilion Youth Group Camp Area Playground Hiking Trails (3)	Y
Prairie Creek	USCOE, LR Dist	Corps Park	48	72	Campsites w/electricity (119) Boat Dock Boat Ramp Showers Pavilion Beach Picnic Area Pavilions (2) Playground Hiking Trail	Apr-Oct

All parks are open for use year round. Quiet hour is 10:00 p.m.

* Camping Fees are $9.00 or $10.00 per night, depending on the availability of flush toilets. Camping is free at the Starkey facility. Fees are used for operation and maintenance of facilities (pers. comm Gary Whisnant COE).

** Privately operated, leased from Corps of Engineers.

\+ Developed Areas

Table a.3.1. Continued.

Name	Resp Agency	Type	Land Area (ha) Dev+	Total	Facilities	Fee*
Horseshoe Bend	USCOE, LR Dist	Corps Park	45	67	Campsites w/electricity (143) Playgrounds (2) Boat Dock ** Boat Ramp Softball Field Pavilions (3) Picnic Area Beach Showers	Y
Indian Creek	USCOE, LR Dist	Corps Park	8	40	Campsites w/electricity (33) Boat Ramp Beach Picnic Area Showers	Apr-Oct

All parks are open for use year round. Quiet hour is 10:00 p.m.

* Camping Fees are $9.00 or $10.00 per night, depending on the availability of flush toilets. Camping is free at the Starkey facility. Fees are used for operation and maintenance of facilities (pers. comm Gary Whisnant COE).

** Privately operated, leased from Corps of Engineers.

\+ Developed Areas

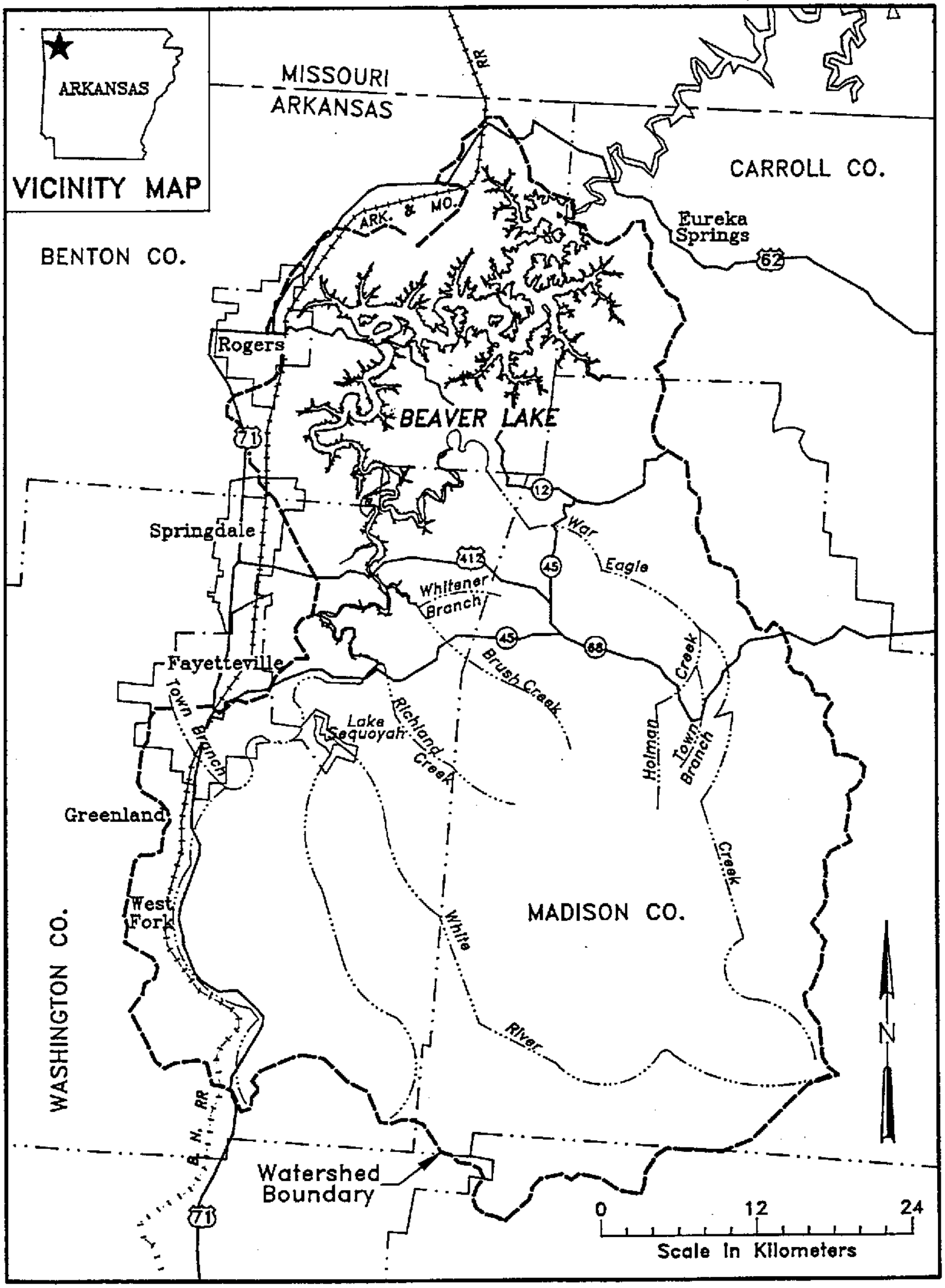

Figure a.3.2. Major highway accesses to Beaver Lake.

Table a.3.2. Road Mileages to Beaver Dam from selected cities and towns.

City or Town	Distance (km)
Dallas, TX	687
Eureka Springs, AR	19
Fayetteville, AR	77
Ft. Smith, AR	182
Harrison, AR	89
Kansas City, MO	365
Little Rock, AR	301
Memphis, TN	473
Oklahoma City, OK	443
Rogers, AR	45
St. Louis, MO	497
Shreveport, LA	568
Springdale, AR	64
Springfield, MO	161
Tulsa, OK	253

Table a.3.3. Airline schedules and fares for one way direct flights to and from Fayetteville, AR.*

Connection	Airline	Fare All Flights+	Departure	Arrival	Frequency
To Fayetteville, AR From Little Rock, AR	U.S. Air	$141.00	6:55 a.m.	7:40 a.m.	7 days/week
			10:15 a.m.	11:00 a.m.	7 days/week
			12.35 p.m.	1:20 p.m.	x 6
			2:55 p.m.	3:40 p.m.	x 6
			5:24 p.m.	6:09 p.m.	x 6
To Little Rock, AR From Fayetteville, AR	U. S. Air	$141.00	9:07 a.m.	9:55 a.m.	7 days/week
			11:40 a.m.	12:25 p.m.	x 7
			2:00 p.m.	2:45 p.m.	x 6, 7
			4:29 p.m.	5:14 p.m.	7 days/week
			6:55 p.m.	7:40 p.m.	x 6
To Fayetteville, AR From Dallas, TX	American	$159.00	6:45 a.m.	8:00 a.m.	**
			8:20 a.m.	9:35 a.m.	**
			11:20 a.m.	12:35 p.m.	**
			1:01 p.m.	2:16 p.m.	**
			2:35 p.m.	3:50 p.m.	**
			4:00 p.m.	5:15 p.m.	**
			5:20 p.m.	6:35 p.m.	**
			8:09 p.m.	9:24 p.m.	**
			9:59 p.m.	11:14 p.m.	**

* Source: Personal Communication, Poe Travel
** Tabulated for weekdays, some exceptions may apply
\+ Fares Effective February 1992
x6= Except Saturday
x7= Except Sunday

Table a.3.3. Continued.

Connection	Airline	Fare All Flights+	Departure	Arrival	Frequency
To Fayetteville, AR From Dallas, TX	Delta	$159.00	9:43 a.m. 11:45 a.m. 1:05 a.m. 3:07 a.m. 6:44 p.m. 8:40 p.m. 10:25 p.m.	10:58 a.m. 1:00 p.m. 2:20 p.m. 4:22 p.m. 7:59 p.m. 9:55 p.m. 11:40 p.m.	** ** ** ** ** ** **
To Dallas, TX From Fayetteville, AR	American	$159.00	6:00 a.m. 7:14 a.m. 8:45 a.m. 10:40 a.m. 1:35 p.m. 3:00 p.m. 4:20 p.m. 5:45 p.m. 7:25 p.m.	7:20 a.m. 8:34 a.m. 10:05 a.m. 12:00 p.m. 2:55 p.m. 4:20 p.m. 5:40 p.m. 7:05 p.m. 8:45 p.m.	** ** ** ** ** ** ** ** **

* Source: Personal Communication, Poe Travel
** Tabulated for weekdays, some exceptions may apply
\+ Fares Effective February 1992
x6= Except Saturday
x7= Except Sunday

Table a.3.3. Continued.

Connection	Airline	Fare All Flights+	Departure	Arrival	Frequency
To Dallas, TX From Fayetteville, AR	Delta	$159.00	6:15 a.m.	7:30 a.m.	**
			7:45 a.m.	9:00 a.m.	**
			11:10 a.m.	12:25 p.m.	**
			1:15 p.m.	2:30 p.m.	**
			2:50 p.m.	4:05 p.m.	**
			4:45 p.m.	6:00 p.m.	**
			8:14 p.m.	9:29 p.m.	**

* Source: Personal Communication, Poe Travel
** Tabulated for weekdays, some exceptions may apply
\+ Fares Effective February 1992
x6= Except Saturday
x7= Except Sunday

Table a.3.4. Bus schedules and fares to and from Rogers, AR.*

Connection	Carrier	Fare	Departure	Arrival	Frequency
To Rogers, Ar From Ft. Smith, AR	Jefferson Bus Lines	$16.50	3:40 a.m. 9:40 a.m. 9:50 p.m.	6:10 a.m. 12:10 p.m. 12:20 a.m.	7 days/week 7 days/week 7 days/week
To Ft. Smith, AR From Rogers, AR	Jefferson Bus Lines	$16.50	12:30 a.m. 7:00 a.m. 5:00 p.m.	3:00 a.m. 9:30 a.m. 7:30 p.m.	7 days/week 7 days/week 7 days/week
To Rogers, AR From Little Rock, AR	Jefferson Bus Lines	$42.00	7:10 a.m. 5:00 p.m. 12:35 a.m.	1:15 a.m. 11:20 p.m. 6:00 a.m.	7 days/week 7 days/week 7 days/week
To Little Rock, AR From Rogers, AR	Jefferson Bus Lines	$42.00	6:10 a.m. 12:25 a.m.	12:10 p.m. 5:55 a.m.	7 days/week 7 days/week

*Source: Personal communication, Jefferson Bus Lines

a.4.0 SIZE AND ECONOMIC STRUTURE OF POTENTIAL USER POPULATION

a.4.1 Population

Beaver Lake is located in Benton, Carroll, Madison, and Washington Counties. In 1990, the population of Benton County was approximately 97,499; the population of Carroll County was approximately 18,654; the population of Madison County was approximately 11,618; and the population of Washington County was approximately 113,409. Rogers is the nearest urban area to the Lake, and its population in 1990 was approximately 24,692 (1990 Census Computer Database). Portions of Fayetteville are located in the west fork of the White River sub-basin while portions of Springdale and Rogers are located in the lateral drainage to Beaver Lake. Table a.4.1 relates additional population characteristics of urban areas within an 80 km radius of the Lake and within adjacent counties.

a.4.2 Pertinent Economic Characteristics

The economy of the northwest Arkansas area is growing at a faster rate than the economy of the rest of the state. The total personal income of the people living in the four counties surrounding Beaver Lake grew an average of 10% in the year 1988-89, versus a 2.3% growth in personal income for the rest of the state. In recent years, the economy of the northwest Arkansas area has continued to grow steadily while economic growth in other areas of the state has slowed. Tables a.4.1 and a.4.2 provide a summary of the income levels in the counties and population centers surrounding Beaver Lake.

a.4.2.1 Major Employment Sources

The major source of white collar employment in Benton County is in the field of administration or administrative support jobs such as clerical work. Twenty-two percent of the workers in Benton County are employed in managerial or administrative positions or positions supporting administrative work. The major source of blue collar employment in Benton County is the precision production of manufactured goods (16%)

Table a.4.1. Beaver Lake potential user population socioeconomic characteristics.

	State of Arkansas	Benton County	Carroll County	Madison County	Washington County	Bentonville	Fayetteville	Harrison	Rogers	Springdale
Total population 1990*	2,350,725	97,499	18,654	11,618	113,409	11,257	42,099	9,922	24,692	29,941
male %	48%	49%	48%	49%	49%	48%	50%	45%	48%	48%
female %	52%	51%	52%	51%	51%	52%	50%	55%	52%	52%
Race: White	1,944,744	94,968	18,416	11,435	108,743	10,975	39,206	9,834	24,128	29,095
Black	373,912	124	6	3	1,676	27	1,580	0	16	33
American Indian, Esq., Aleut.	12,773	1,435	146	140	1,486	102	481	58	224	338
Asian/Pacific Islanders	12,530	455	54	13	1,043	98	657	14	191	292
Hispanic Origin	19,876	1,359	194	111	1,526	161	603	69	460	446
Households	891,179	37,555	7,550	4,392	43,372	4,266	16,894	4,189	9,705	11,432
Persons/Household	2.57	2.55	2.45	2.63	2.52	2.59	2.26	2.28	2.51	2.59
1979 Per Capita Income ($/yr)	13,887#	14,770#	13,105#	11,606#	13,775#	5,651+	6,020+	6,007+	6,378+	6,249+
1979 Median Household Income ($/yr)	12,189#	13,930#	10,898#	10,171#	12,800#	12,655+	11,455+	10,969+	14,772+	15,031+
1979 Median Family Income ($/yr)	9,453#	11,760#	10,903#	7,081#	10,439#	14,886+	16,480+	14,370+	16,950+	16,984+

* Source: 1990 Census of the Population Computer Database.
\# Source: 1991 Arkansas Statistical Abstract, Arkansas State Data Center.
\+ Source: 1980 Census of the Population.

Table a.4.2. Total personal and per capita incomes for the years 1987-89 and poverty level for the year 1980 by State and County.

Counties	Total Personal Income[1]				Per Capita Personal Income[1]				Percent of Population Below Poverty Level (1980)[2]
	Millions of Dollars			% Change	Dollars			Rank in State	
	1987	1988	1989	1988-89	1987	1988	1989	1989	
Arkansas	263	302	308	2.3	11,526	13,374	13,887	--	14.9
Benton	1,224	1,328	1,458	9.8	13,174	13,885	14,770	3	19.7
Carroll	213	221	243	9.9	11,667	12,055	13,105	15	6.9
Madison	123	125	140	11.9	10,216	10,398	11,606	37	5.5
Washington	1,314	1,412	1,546	9.5	12,064	12,761	13,775	10	32.4

[1] Source: U.S. Department of Commerce.
[2] Source: 1980 Census data provided by Arkansas Employment Security Division.

followed by machine operation, assembly, and inspection (12%) (Arkansas Employment Security Division). Table a.4.3 summarizes the major sources of employment in Benton County for the year 1980.

The major source of employment in Carroll County is the precision production of manufactured goods (18%) followed by agriculture (13%) (Arkansas Employment Security Division). Table a.4.4 summarizes the major sources of employment in Carroll County for the year 1980.

The primary source of employment for Madison County is agriculture (19%) followed by machine operation, assembly, and inspection (16%) (Arkansas Employment Security Division). Table a.4.5 summarizes the major sources of employment in Madison County for the year 1980.

The primary source of employment in Washington County is in the field of administration or jobs supporting administrative work such as clerical work (23%). Precision production of manufactured goods (13%) and specialized professions (12%) ranked second and third as the major sources of employment, respectively (Arkansas Employment Security Division). Table a.4.6 summarizes the major sources of employment in Washington County in 1980. Table a.4.7 summarizes the major employers in the four county area surrounding Beaver Lake.

a.4.2.2 Chronic Unemployment

This section summarizes unemployment in Benton, Carroll, Madison and Washington Counties (Source: Labor Market Information Section, Arkansas Employment Security Division).

- Benton County

  The 1990 unemployment rate in Benton County was 3.5%; 57.7% of the unemployed were male and 42.3% were female. Table a.4.8 summarizes unemployment in Benton County.

Table a.4.3. Major sources of employment in Benton County for the year 1980. (Source: 1980 Census data provided by the Arkansas Employment Security Division).

Occupation	Total Employed
Total, All Occupations	33,555
Executive, Administrative, and Managerial	2,845
Professional Specialty	2,387
Technicians and Related Support	637
Sales Occupations	3,003
Administrative Support, including Clerical	4,647
Service Occupations	3,893
Farming, Forestry, and Fishing	2,177
Precision Production, Craft and Repair	5,521
Machine Operators, Assemblers, Inspectors	4,085
Transportation and Material Moving	1,900
Handlers, Equip. Cleaners, Helpers, Laborers	2,460

Table a.4.4. Major sources of employment in Carroll County for the year 1980. (Source: 1980 Census data provided by the Arkansas Employment Security Division).

Occupation	Total Employed
Total, All Occupations	6,631
Executive, Administrative, and Managerial	571
Professional Specialty	464
Technicians and Related Support	108
Sales Occupations	602
Administrative Support, including Clerical	568
Service Occupations	789
Farming, Forestry, and Fishing	871
Precision Production, Craft and Repair	1,161
Machine Operators, Assemblers, Inspectors	627
Transportation and Material Moving	317
Handlers, Equip. Cleaners, Helpers, Laborers	553

Table a.4.5. Major sources of employment in Madison County for the year 1980. (Source: 1980 Census data provided by the Arkansas Employment Security Division).

Occupation	Total Employed
Total, All Occupations	4,274
Executive, Administrative, and Managerial	139
Professional Specialty	244
Technicians and Related Support	51
Sales Occupations	216
Administrative Support, including Clerical	430
Service Occupations	375
Farming, Forestry, and Fishing	822
Precision Production, Craft and Repair	656
Machine Operators, Assemblers, Inspectors	701
Transportation and Material Moving	277
Handlers, Equip. Cleaners, Helpers, Laborers	363

Table a.4.6. Major sources of employment in Washington County for the year 1980. (Source: 1980 Census data provided by the Arkansas Employment Security Division).

Occupation	Total Employed
Total, All Occupations	45,884
Executive, Administrative, and Managerial	3,758
Professional Specialty	5,687
Technicians and Related Support	1,292
Sales Occupations	4,836
Administrative Support, including Clerical	6,659
Service Occupations	5,634
Farming, Forestry, and Fishing	2,577
Precision Production, Craft and Repair	6,194
Machine Operators, Assemblers, Inspectors	3,736
Transportation and Material Moving	2,709
Handlers, Equip. Cleaners, Helpers, Laborers	2,802

Table a.4.7. Major employers of Benton, Carroll, Madison, and Washington Counties. (Source: 1991 Directory of Arkansas Manufacturers).

	Number of Employees				
Benton County	**200-299**	**300-499**	**500-999**	**1,000-2,499**	**2,500+**
Chick-N-Quick			X		
Daisy Manufacturing, Inc.			X		
Emerson Motor Company			X		
First Brands Corporation			X		
Krispy Kitchen, Division of Tysen Foods, Inc.			X		
Metal Removal Industries Tooling			X		
North Arkansas Poultry		X			
Rogers Tool Works				X	
Superior Industries International			X		
Tyson Foods, Inc.		X			
Wal-Mart*					X
Carroll County	**200-299**	**300-499**	**500-999**	**1,000-2,499**	**2,500+**
Tyson Foods, Inc.			X		
Madison County	**200-299**	**300-499**	**500-999**	**1,000-2,499**	**2,500+**
LaBarge Electronics	X				
Swift Eckrich		X			
Washington County	**200-299**	**300-499**	**500-999**	**1,000-2,499**	**2,500+**
American Air Filter	X				
Baldwin Piano & Organ Company	X				
Campbell Soup Company				X	
Cargill			X		
Clarke Industries	X				
Easco Hand Tools, Inc.			X		
George's Processing			X		
Kawneer Company, Inc.		X			
Levi Strauss & Company		X			
McClinton-Anchor Company, Inc.	X				
The Standard Register Co.		X			
Superior Industries International, Inc.		X			
Tyson Foods, Inc.					X

* Source: Bentonville Chamber of Commerce personal communication.

Table a.4.8. Unemployment in Benton County, 1990.

Benton County	Total No. in Labor Force	Employed (% of Total Labor Force)*	Unemployed (% of Total Unemployed Males or Females)*	Unemployment Rate* (%)
White Males	52,625	97.8	96.3	3.5
White Females	22,029	97.6	94.5	3.4
Black Males	11	--	--	--
Black Females	3	--	--	--
Native American Males	840	1.5	2.7	6.1
Native American Females	363	1.5	3.4	7.4
Hispanic Males	408	0.8	0.9	4.2
Hispanic Females	196	0.9	--	--

* A dash represents zero or a percent rounding to less than 0.1.

- Carroll County
  The 1990 unemployment rate in Carroll County was 6%; 57.9% of the unemployed were male and 42.1% were female. Table a.4.9 summarizes unemployment in Carroll County.

- Madison County
  The 1990 unemployment rate in Madison County was 5.9%; 41.5% of the unemployed were male and 58.5% were female. Table a.4.10 summarizes unemployment in Madison County.

- Washington County
  The 1990 unemployment rate in Washington County was 35.0%; 50.4% of the unemployed were male and 49.6% were female. Table a.4.11 summarizes unemployment in Washington County.

a.4.2.3 Housing and Urban Blight

Table a.4.12 provides a summary of the housing available in the four counties surrounding Beaver Lake.

a.4.2.4 Local Economy

According to a local real estate agent, the average price for 1/2 acre lakefront lot close to Rogers is approximately $25,000. The average price for a rural lakefront lot averages $15,000. Permanent residences comprise 90% of the homes on the lake with the remainder being vacation homes. Land not being utilized for homes is currently used for woodlands or for agriculture (Gloria Bennett, personal communication).

Beaver Lake is a favored recreation site in the area, and recreational users fish, waterski, camp, hunt, boat, trap, scuba dive, sail, birdwatch, and ride horses at the Lake.

Table a.4.9. Unemployment in Carroll County, 1990.

Carroll County	Total No. in Labor Force	Employed (% of Total Labor Force)*	Unemployed (% of Total Unemployed Males or Females)*	Unemployment Rate* (%)
White Males	10,454	99.5	97.6	5.9
White Females	4,488	99.4	97.4	5.7
Black Males	--	--	--	--
Black Females	--	--	--	--
Native American Males	30	0.2	1.3	26.7
Native American Females	5	0.1	--	--
Hispanic Males	48	0.5	--	--
Hispanic Females	14	0.3	--	--

* A dash represents zero or a percent rounding to less than 0.1.

Table a.4.10. Unemployment in Madison County, 1990.

Madison County	Total No. in Labor Force	Employed (% of Total Labor Force)*	Unemployed (% of Total Unemployed Males or Females)*	Unemployment Rate* (%)
White Males	5,229	99.3	95.5	5.7
White Females	2,153	99.2	95.6	8.1
Black Males	--	--	--	--
Black Females	--	--	--	--
Native American Males	49	0.7	4.5	28.6
Native American Females	23	0.8	4.4	34.8
Hispanic Males	--	--	--	--
Hispanic Females	--	--	--	--

* A dash represents zero or a percent rounding to less than 0.1.

Table a.4.11. Unemployment in Washington County, 1990.

Washington County	Total No. in Labor Force	Employed (% of Total Labor Force)*	Unemployed (% of Total Unemployed Males or Females)*	Unemployment Rate* (%)
White Males	62,130	96.9	93.8	3.4
White Females	26,260	97.2	95.4	4.0
Black Males	856	1.3	3.4	8.8
Black Females	334	1.2	1.9	6.3
Native American Males	675	1.0	2.7	9.0
Native American Females	216	0.7	2.7	13.9
Hispanic Males	462	0.7	0.9	4.3
Hispanic Females	208	0.8	1.1	5.8

* A dash represents zero or a percent rounding to less than 0.1.

Table a.4.12. Housing availability in major population centers within an 80 km radius of Beaver Lake (Source: 1990 Census of the Population Computer Database).

City	No. of Housing Units	No. of Households	Vacancy Rate (%)		Median Home Value ($)
			Houses	Rental Units	
Bentonville	4,482	4,266	2.1	5.8	53,900
Fayetteville	18,835	16,894	2.5	10.9	66,200
Harrison	4,189	665	2.6	11.0	48,800
Rogers	10,291	9,705	2.7	6.0	60,300
Springdale	12,008	11,432	2.0	5.2	56,700

a.5.0 SUMMARY OF HISTORICAL LAKE USES

Beaver lake is the youngest lake on the White River, and it has provided the major uses of water supply, hydroelectric power generation, recreation, and flood control since the project was completed in 1966. Table a.5.1 provides a summary of visitation to Beaver Lake for the years 1965-1990.

Beaver Lake was designed to provide up to 120 MGD for water supply. Currently, Beaver Water District and Carroll-Boone Water District withdraw water from the reservoir for water supply. The Beaver Water District intake is located at about river km 1050 (mile 656) near Lowell. The Carroll-Boone Water District intake is located about river km 994 (mile 621) near Eureka Springs. In 1990, the Madison County Rural Water Association applied to construct a water intake structure at river km 1001 (mile 625.3) near Huntsville.

Beaver Lake has two units for hydropower generation with capacities of 56,000 kw, or a total power generation capacity of 112,000 kw. The electricity generated at Beaver Lake is marketed by the Southwestern Power Administration, U.S. Department of Energy. The Southwest Power Administration has marketed over 3.5 billion kilowatt- hours (kwh) of electricity since 1965 and has averaged about 150,000,000 kwh per year for the past decade. Table a.5.2 provides a summary of power generation, and water use at Beaver Lake for the years 1965-1990.

Beaver lake has had almost 100 million recreation days of use since 1965 and has averaged about 4.75 million visitor days per year for the last decade. Recreation includes boating, water skiing, fishing, swimming, picnicking, camping, and aesthetics. Beaver Lake has a flood storage capacity of 370 x 10^6 m^3 (300,000 ac/ft). As a result of flood control operations at Beaver Lake, more than $20.9 million worth of flood damage has been prevented as of September 1988.

According to the sanitarians of the Benton, Carroll, Madison, and Washington Counties and Corps of Engineers personnel at the Office of the Resident Manager and the Public Affairs Office in Little Rock, no incidences of high concentrations of fecal coliform bacteria have occurred at the Lake, and there have been no instances of water

Table a.5.1. Beaver Lake Visitation 1965-1990.

Year	Recreation/Visitation (recreation days/yr)
1965	548,200
1966	1,536,000
1967	1,687,900
1968	1,781,800
1969	2,040,900
1970	2,088,100
1971	2,341,600
1972	2,989,000
1973	3,227,000
1974	3,478,500
1975	3,179,000
1976	3,842,400
1977	3,558,100
1978	3,623,000
1979	3,302,700
1980	4,882,600
1981	5,223,900
1982	5,369,400
1983	5,388,000
1984	3,981,000
1985	4,580,000
1986	4,345,000
1987	4,606,100
1988	5,109,700
1989	4,000,800
1990	5,452,100
1991	4,242,900

Table a.5.2. Beaver Lake usage for the years 1965-1990.

Year	Power Generation kwh/yr	Carroll-Boone Counties m^3/yr	Beaver Water District m^3/yr
1965	3,569,300*		
1966	67,532,100		
1967	28,494,600		6,373,081
1968	221,021,300		6,367,490
1969	233,246,900		
1970	138,396,700		12,314,000
1971	147,293,100		13,418,000
1972	85,382,800		
1973	305,499,600		
1974	292,778,300		
1975	225,249,300		
1976	147,943,600		
1977	24,574,400		29,015,000
1978	174,041,900		29,522,000
1979	130,400,100		30,982,000
1980	64,961,000		32,667,000
1981	69,250,400		
1982	134,268,600		
1983	185,617,100	1,532,183	31,257,000
1984	121,200,600	1,876,240	33,136,000
1985	280,594,000	1,875,426	33,300,000
1986	163,780,200	3,390,917	33,068,000
1987	164,360,500	3,415,603	34,713,000
1988	157,933,700	4,714,558	40,517,280
1989	160,455,500	4,451,629	38,184,360
1990	178,078,300**	2,124,702	18,302,000**

* May - December
** January - June

quality problems which might be injurious to human health (personal communications with Loyd Bailey, Benton County Sanitarian; Roy Hervert, Carroll County Sanitarian; Will Jeffries, Madison County Sanitarian; Rick Johnson, Washington County Sanitarian; Georgeanne Tabor, Office of the Resident Manager, Rogers; and George Losack, U.S. Army Corps of Engineers, Office of Public Affairs, Little Rock).

Beaver Lake is noted for its clear water, but the headwaters of the Lake can become turbid at times, and Beaver Water District must occasionally treat its water for turbidity. According to George Losack at the Corps' Office of Public Affairs, the Corps considers nonpoint sources of nutrients to present the greatest threat to the Lake's future water quality.

a.6.0. POPULATION SEGMENTS ADVERSELY AFFECTED BY LAKE DEGRADATION

The marina operators at Beaver Lake report that the number of fishermen, boaters, skiers, scuba divers, and tourists visiting the lake is steadily increasing each year and that their annual gross revenues continue to increase. The marina operators say that tourists are attracted to the lake specifically because Beaver Lake's clarity and overall water quality are superior to the water clarity and quality at similar lakes in Oklahoma, Kansas, and Texas (pers. comm. with marina operators). Rangers at the Office of the Resident Manager at Beaver Lake report the number of visitors at Beaver Lake to be steadily increasing each year, and no visitors have complained about poor water quality at Beaver Lake.

a.7.0 COMPARISON OF LAKE USES TO OTHER LAKES IN REGION

There are approximately 15 publicly owned lakes within an 80 km radius of Beaver Lake, including Table Rock Lake, MO, Lake Taneycomo, MO, and Bull Shoals Lake, AR, downstream on the White River. Other large lakes (>202 ha) include Lake Sequoyah, AR; Grand Lake of the Cherokees, OK and Lake Eucha, OK (Figure a.7.1).

Table a.7.1 provides a summary of access and uses available to the public at the four lakes within an 80 km radius of Beaver Lake that are comparable in size and development to Beaver Lake: Bull Shoals Lake, AR; Grand Lake of the Cherokees, OK; Lake Taneycomo, MO; and Table Rock Lake, MO.

Beaver Lake shares the same types of recreational and public uses and access facilities with these other lakes, but the Beaver Lake Watershed is less developed than the watersheds of these other lakes, and Beaver Lake has retained the aesthetic appeal of a lake in its natural setting which has not suffered the stresses caused by high numbers of visitors, commercialization, and over-development.

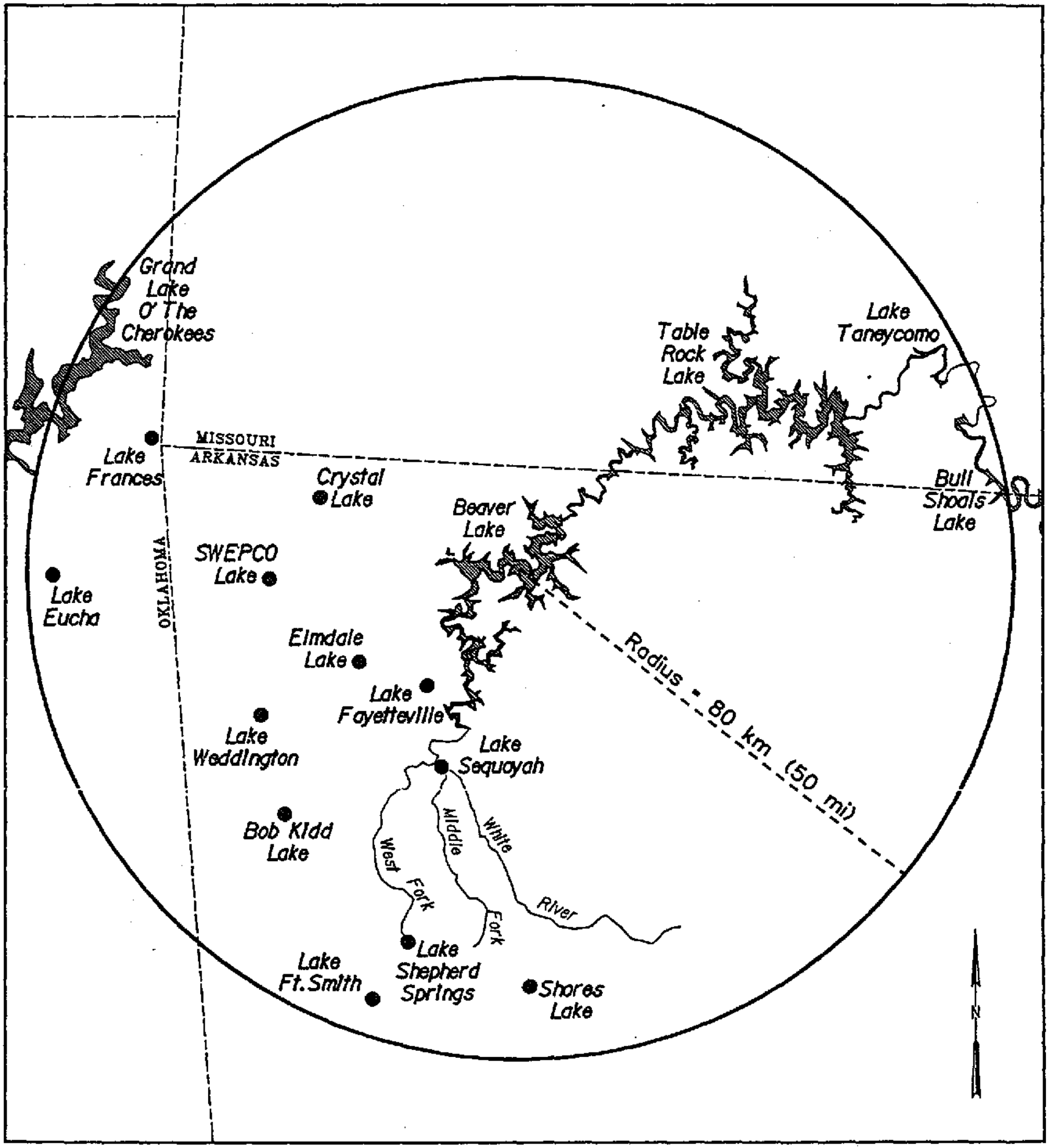

Figure a.7.1. Significant publicly owned lakes within an 80 km radius of Beaver Lake.

Table a.7.1 Significant publicly owned lakes within an 80 km radius of Beaver Lake.

Name	Recreational uses Available	Public Usage	Public Access
Bob Kidd Lake, AR	Hunting, fishing, boating, swimming	————	Concrete ramp, fishing and courtesy pier, handicap access
Bull Shoals Lake, AR	Hunting, fishing, boating, camping, swimming, scuba diving	Hydropower generation	Resorts, camping and picnic grounds, boat docks
Crystal Lake, AR	Fishing, boating, swimming	————	Concrete ramp, floating fishing pier
Elmdale Lake, AR-Currently under repair and drained			
Grand Lake of the Cherokees, OK	Hunting, fishing, boating, camping, swimming scuba diving	Hydropower generation	Resorts, camping and picnic grounds, boat docks
Lake Eucha, OK	Fishing, boating, swimming	————	N/A
Lake Fayetteville, AR	Fishing, boating	Aquatic laboratory for educational purposes	Boat ramp, commercial dock
Lake Fort Smith, AR	Fishing boating	Drinking water supply	Boat ramp, marina, State Park, swimming pool
Lake Francis, OK-drained			
Lake Sequoyah, AR	Fishing, boating	Agricultural water supply	Concrete ramp, commercial ramp
Lake Shepard Spring, AR	Fishing, boating	Drinking water supply	Boat ramp

Table a.7.1. Continued.

Name	Recreational uses Available	Public Usage	Public Access
Lake Taneycomo, MO	Hunting, fishing, boating, camping, swimming, scuba diving	Hydropower generation	Resorts, camping and picnic grounds, boat docks
Lake Wedington, AR	Hunting, fishing, boating, camping, swimming, scuba diving	————	concrete ramp, picnic grounds, swimming beach
Shores Lake, AR	Fishing, boating, camping, swimming	————	Fishing pier, boat ramp, camping, swimming
SWEPCO Lake, AR	Fishing, boating,	Cooling water source for SWEPCO power generation	Concrete ramp
Table Rock Lake, MO	Hunting, fishing, boating, camping, swimming, scuba diving	Hydropower generation	Resorts, camping and picnic grounds, boat docks

a.8.0 POINT SOURCE POLLUTION DISCHARGES

The locations of the ten point source dischargers located in the Beaver Lake Watershed are shown in Figure a.8.1. Their NPDES permit limits are listed in Table a.8.1, and their discharges are characterized in Table a.8.2.

Three of these discharges are city wastewater treatment plants discharging to tributaries of Beaver lake. There are also two industrial dischargers to the West Fork of the White River. The remainder of the dischargers are package wastewater treatment plants discharging directly into Beaver Lake.

Table a.8.3 compares nutrient loading estimates from the city wastewater treatment plants for 1975, 1979, 1980, and 1991. The 1975 loading estimates for Fayetteville are based on chemical analyses of the plant effluent. The 1975 loading estimates for West Fork and Huntsville are based on per capita loadings. (1.1 kg phosphorus/capita/yr (2.5 lb phosphorus/yr.), 3.4 kg nitrogen/capita/yr (7.5 lb nitrogen/capita/yr)). The 1979 and 1980 loading estimates are based on the 1975 data. All the 1991 loading estimates, except phosphorus at Fayetteville, were calculated using the per capital loadings and 1990 census data. The phosphorus loading from Fayetteville was estimated using concentrations and flows reported in the facility DMRs.

The effects of Fayetteville's treatment plant have been the greatest concern over the years. It is the largest of the three treatment plants and located closest to the lake. in 1988, Fayetteville put a new wastewater treatment plant on line. The new plant splits flows between the White River and a tributary to the Illinois River, and it utilizes tertiary treatment to reduce phosphorus in the effluent. The 1991 phosphorus loading from Fayetteville, is significantly less than those estimated for the previous years. As a result of splitting the flows, nitrogen loading to the White River in 1991 was approximately half of what it was in 1975 and 1979, and it is less than the loading estimated for 1980, despite the increase in population over the same period.

The increase in nutrient loadings from the West Fork and Huntsville wastewater treatment plants for 1991 compared to the previous years are the result of population

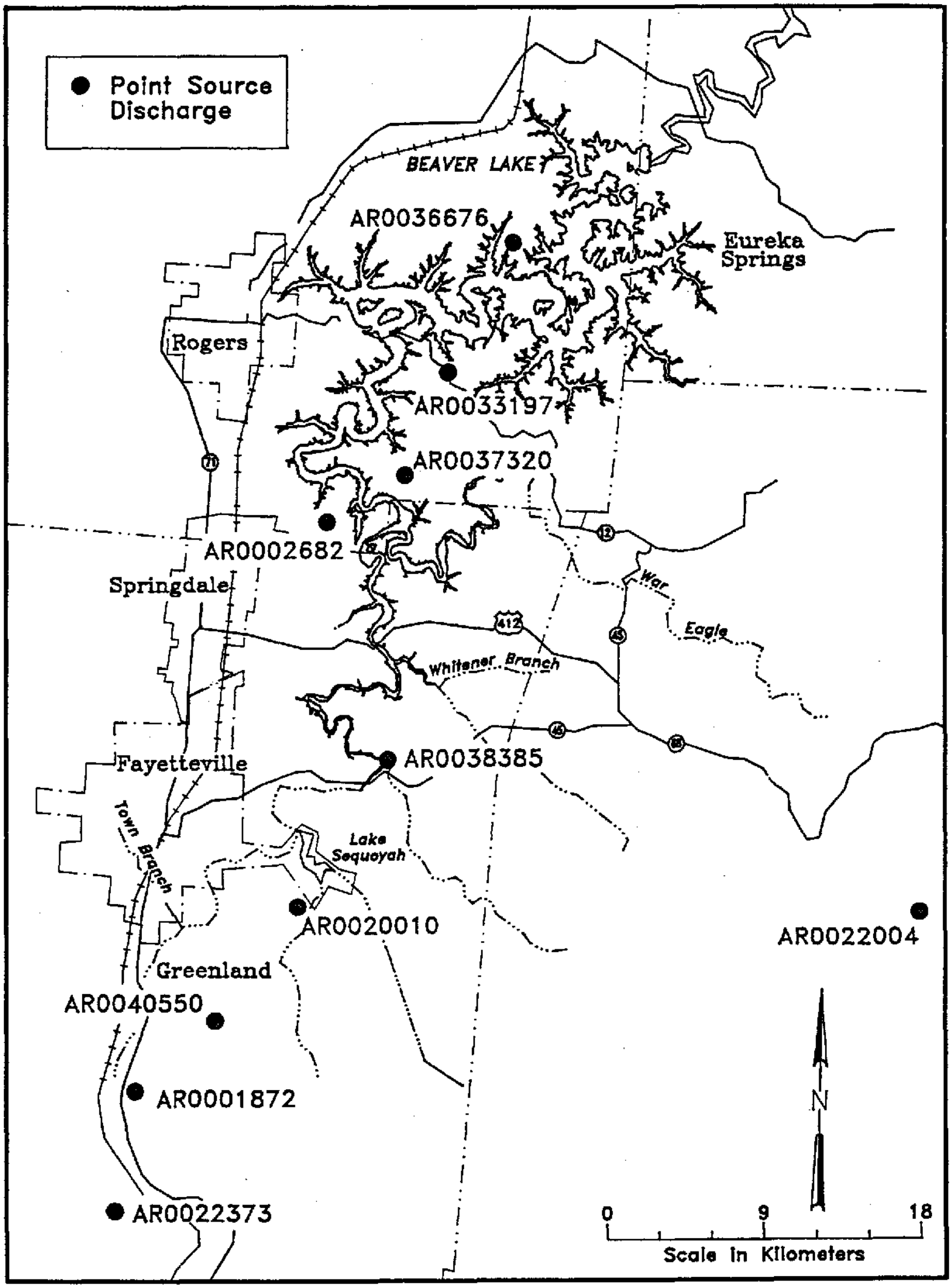

Figure a.8.1. Location of point source discharges in the Beaver Lake watershed.

Table a.8.1. NPDES permitted discharges to Beaver Lake or to tributaries of Beaver Lake.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0001872	Standard Register	Temperature COD pH TSS oil & grease Flow in conduit or through treatment plant	-- -- -- -- -- MGD Monitor Only	-- -- -- -- -- MGD Monitor Only	-- -- -- -- -- MGD Monitor Only	F° mg/L su mg/L mg/L --	-- -- 6.0 -- -- --	84.2 50.0 -- 20.0 10.0 --	95.0 75.0 9.0 30.0 15.0 --	unnamed tributary to West Fork
AR0002682	Beaver Water Works	Flow in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	Beaver Lake
AR0040550	Marshalltown Tools Inc.	Temp pH Flow, in conduit or through treatment plant	-- -- MGD Monitor Only	-- -- MGD Monitor Only	-- -- MGD Monitor Only	°F su --	-- 6.0 --	87.8 -- --	-- 9.0 --	Unnamed ditch to West Fork of the White River

Table a.8.1. Continued.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0020010	City of Fayetteville Outfall 001A	DO Dec-Mar	--	--	--	mg/L	10.0	--	--	White River
		DO Apr-Nov	--	--	--	mg/L	8.0	--	--	
		pH	--	--	--	su	6.0	--	9.0	
		TSS Dec-Mar	lb/day	776	--	mg/L	--	15.0	22.0	
			kg/day	351.9936	--					
		TSS Apr-Nov	lb/day	259	--	mg/L	--	5.0	7.0	
			kg/day	117.4824	--					
		NH_3-N Dec-Mar	lb/day	259	--	mg/L	--	5.0	7.0	
			kg/day	117.4824	--					
		NH_3-N Apr-Nov	lb/day	103	--	mg/L	--	2.0	3.0	
			kg/day	46.7208	--					
		Total P	lb/day	52	--	mg/L	--	1.0	2.0	
			kg/day	23.5872	--					
		Flow in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	
		Chlorine, total residual	--	--	--	mg/L	--	--	0.05	
		Coliform, fecal Oct-Mar	--	--	--	#/100mL	--	1000.0	2000.0	
		Coliform, fecal Apr-Sep	--	--	--	#/100mL	--	200.0	400.0	
		$CBOD_5$ Dec-Mar	lb/day	517	--	mg/L	--	10.0	15.0	
			kg/day	234.5112	--	--	--	--	--	
		$CBOD_5$ Apr-Nov	lb/day	259	--	mg/L	--	5.0	7.0	
			kg/day	117.4824	--	--	--	--	--	

Table a.8.1. Continued.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0022004	City of Huntsville	D.O Jul-Feb	--	--	--	mg/L	5.0	--	--	Town Branch of Holman Cr.
		D.O Mar-Jun	--	--	--	mg/L	6.6	--	--	
		Ph	--	--	--	su	6.0	--	9.0	
		TSS	lb/day	188	--	mg/L	--	15.0	23.0	
			kg/day	85.2768	--					
		TSS	lb/day	594	--	mg/L	--	71.0	91.0	
			kg/day	269.4384	--					
		NH_3-N Jul-Feb	lb/day	63	--	mg/L	--	5.0	8.0	
			kg/day	28.5768	--					
		NH_3-N Mar-Jun	lb/day	38	--	mg/L	--	3.0	5.0	
			kg/day	17.2368	--					
		Flow in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	
		Coliform, fecal Apr-Sep	--	--	--	#/100mL	--	200.0	400.0	
		Coliform, fecal Oct-Mar	--	--	--	#/100mL	--	1000.0	2000.0	
		BOD_5	lb/day	125	--					
			kg/day	56.7	--	mg/L	--	10.0	15.0	

Table a.8.1. Continued.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0022373	City of West Fork	D.O	--	--	--	mg/L	6.0	--	--	West Fork of White River
		BOD_5	lb/day	25.0	--	mg/L	--	30.0	45.0	
			kg/day	11.34	--					
		pH	--	--	--	su	6.0	--	9.0	
		TSS May-Oct	lb/day	12.5	--	mg/L	--	15.0	25.0	
			kg/day	5.67	--					
		TSS Nov-Apr	lb/day	25.0	--	mg/L	--	30.0	45.0	
			kg/day	11.34	--					
		NH_3-N	lb/day	4.2	--	mg/L	--	5.0	8.0	
		Flow in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	
		Coliform, fecal Apr-Sep	--	--	--	#/100mL	--	200.0	400.0	
		Coliform, fecal Oct-Mar	--	--	--	#/100mL	--	1000.0	2000.0	
		$CBOD_5$	lb/day	8.3		mg/L	--	10.0	15.0	
			kg/day	3.76488						
AR0033197	Heritage Bay Homeowner's Association	ph	--	--	--	su	6.0	--	9.0	Beaver Lake
		Flow, in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	
		BOD_5	lb/day	8.3	12.5	--	--	--	--	
			kg/day	3.76488	5.67	--	--	--	--	
		TSS	lb/day	8.3	12.5	--	--	--	--	
			kg/day	3.76488	5.67	--	--	--	--	
		Coliform, fecal	--	--	--	#/100mL	--	200.0	400.0	

Table a.8.1. Continued.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0036676	Lost Bridge S&W Imd. Dist. #1&2 Outfall 001A	Flow, in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	Beaver Lake
	Outfall 001F	NH_3-N May-Oct	lb/day	1.5	--	mg/L	--	5.0	8.0	
			kg/day	0.6804	--					
		NH_3-N Nov-Apr	lb/day	2.9	--	mg/L	--	10.0	15.0	
			kg/day	1.31544	--					
	Outfall 001Q	pH	--	--	--	su	6.0	--	9.0	
		TSS	lb/day	4.4	--	mg/L	--	15.0	23.0	
			kg/day	1.99584	--					
		Coliform, fecal Apr-Sep	--	--	--	#/100mL	--	200.0	400.0	
		Coliform, fecal Oct-Mar	--	--	--	#/100mL	--	1000.0	2000.0	
		$CBOD_5$	lb/day	2.9	--	mg/L	--	10.0	15.0	
			kg/day	1.31544	--					

Table a.8.1. Continued.

Permit Number	Facility Name	Permit Parameter	Quantity Units	Quantity Avg	Quantity Max	Concentration Units	Min	Avg	Max	Receiving Water Body
AR0037320	Centark Corp	pH	--	--	--	su	6.0	--	9.0	Beaver Lake
		TSS	lb/day	4.38	9.76	mg/L	--	15.0	30.0	
			kg/day	1.986768	4.427136					
		NH_3-N May-Oct	lb/day	1.46	2.92	mg/L	--	5.0	10.0	
			kg/day	0.662256	1.324512					
		NH_3-N Nov-Apr	lb/day	2.92	5.84	mg/L	--	10.0	20.0	
			kg/day	1.324512	2.649024					
		Flow, in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	
		Coliform, fecal Apr-Sep	--	--	--	#/100mL	--	200.0	400.0	
		Coliform, fecal Oct-Mar	--	--	--	#/100mL	--	1000.0	2000.0	
		$CBOD_5$	lb/day	2.92	5.84	mg/L	--	10.0	20.0	
			kg/day	1.324512	2.649024					
AR0038385	The Village Inc. 001A	Flow, in conduit or through treatment plant	MGD Monitor Only	MGD Monitor Only	MGD Monitor Only	--	--	--	--	Beaver Lake
	001Q	BOD_5	lb/day	0.58	--	mg/L	--	10.0	15.0	
			kg/day	0.263088	--	--	--	--		
		pH	--	--	--	su	6.0	--	9.0	
		TSS	lb/day	0.88	--	mg/L	--	--	--	
			kg/day	0.399168	1.31	--	--	15.0	25.0	
		Coliform, fecal	--	--	0.594216	#/100mL	--	200.0	400.0	

Table a.8.2. Point source discharges characteristics.

Discharge	Constituent	Units	Avg Avg Daily	Min Min Daily	Max Max Daily
Standard	Flow	MGD	.044		.1036
Register	Oil and Grease	mg/L	6.32		19.4
	COD	mg/L	48.6		218.0
	pH	su		6.0	8.11
	TSS	mg/L	10.5		50.0
	Temp	°F	72.1		84.7
Beaver Water District	Flow	MGD	.44		1.1
Fayetteville STP001A	Fecal Coliform		8		787
	Flow	MGD	5.84		22.59
	Ammonia-N	mg/L	.3		1.1
	pH	su	6.8		8.4
	Total Phos as P	mg/L	.8		1.3
	TSS	mg/L	1.7		32
Huntsville STP	Fecal Coliform		37		1350
	Flow	MGD	1.051		2.038
	Ammonia-N	mg/L	3.8		24.73
	pH	su	6.71		8.3
	TSS	mg/L	4		12
West Fork STP	Fecal Coliform		93		766
	Flow	MGD	.1047		.1435
	Ammonia-N	mg/L	3.0		5.3
	pH	su	6.9		7.39
	TSS	mg/L	6		26

Table a.8.2. Continued.

Discharge	Constituent	Units	Avg Avg Daily	Min Min Daily	Max Max Daily
Heritage Bay	Flow	MGD	.0075		.0128
	pH	su	7.2		7.3
	TSS	lb/day	.29		.54
	Fecal Coliform		14		39
Lost Bridge	Flow	MGD	.0215		.041
	Ammonia-N	mg/L	.15		.35
	Fecal colifrom		1		1
	pH	su	7.3		7.35
	TSS	mg/L	1.5		2
Centark	Fecal Coliform		3		10
	Flow	MGD	.0021		.0073
	Ammonia-N	mg/L	29.12		62.37
	pH	su	6.8		7.5
	TSS	mg/L	30		71
Village Inc.	Flow	MGD	.0025		.0115
	pH	su	7.22		7.59
	Total Phosphourus	mg/L	4.29		6.98
	Ammonia-N	mg/L	.14		.26
	Fecal coliform		1		2
	TSS	lb/day	.02		.064
		mg/L	1		1

Table a.8.3. City wastewater treatment loadings for 1975, 1979, 1980, and 1991.

Municipal WWTPs	Annual Total Phosphorus Loadings			
	EPA (1977) Avg Yr - 1975 (kg/yr)	Black & Veach (1982)		Beaver Clean Lake 1991 (kg/yr)
		Avg Yr 1979 (kg/yr)	Low Flow 1980 (kg/yr)	
Fayetteville	43,545	63,504	49,896	6,654
West Fork	920	907	907	1,822
Huntsville	1,395	1,361	1,361	1,820

Municipal WWTP's	Annual Total Nitrogen Loadings			
	EPA (1977) Avg Yr - 1975 (kg/yr)	Black & Veach (1982)		Beaver Clean Lake 1991 (kg/yr)
		Avg Yr 1979 (kg/yr)	Low Flow (kg/yr)	
Fayetteville	154,805	173,275	96,163	85,931
West Fork	2,755	1,361	1,361	5,467
Huntsville	2,225	1,361	1,361	5,460

increases. At Huntsville, the influent volume had increased beyond the design capacity of the wastewater treatment plant, so a new plant was constructed and placed on line in 1989.

a.9.0 LAND USES AND NONPOINT POLLUTANT LOADINGS

a.9.1 Land Uses

The predominant land use in the Beaver Lake watershed is forest land, which comprises about 63 percent of the basin. Table a.9.1 summarizes land use estimates by hydrologic units within the Beaver Lake watershed (SCS 1989). The forest types include oak/hickory, shortleaf pine, and cedar. Grasslands or pasture comprises about 31 percent of the basin. Pasture for cattle is the primary use of the grassland. About 4 percent of the basin is in water, either Beaver Lake (11,413 ha) or in Lake Sequoyah (202 ha). Cropland, urban and other areas occupy 0.6, 1.1 and 1.5 percent of the basin, respectively.

Agricultural practices consist of both confined and open range animal production. Confined animal production typically consists of poultry, swine and beef operations. Cattle production constitutes the predominant open range operation. Disposal of animal wastes occurs primarily through land application in the watershed.

a.9.2 Watershed Nonpoint Pollution Sources

As discussed in Section a.2.4, most soils in the Beaver lake area are low in natural fertility. As a consequence of the natural low fertility of these soils, commercial fertilizers and animal wastes are frequently land applied. Approximately 2,540 metric tons (2,800 tons) of phosphorus from these sources are available annually for land application and are applied at an average annual rate of 45 kg/ha (40 lb/ac). In unfertilized areas (e.g., wooded areas), phosphorus available to plants is less than 28 kg/ha (25 lb/ac) (Larry Ward, personal communication, 14 January 1991); however, in fescue pastures or other areas that have been fertilized over the years, phosphorus content may exceed 1,121 kg/ha (1,000 lb/ac) (Larry Ward, personal communication 14 January 1991).

Total annual erosion within the Beaver Lake watershed was estimated to be 1,305,000 metric tons (1,439,050 tons) (SCS 1986). Of this total, SCS estimated 378,000 metric tons (417,000 tons) of sediment are delivered to Beaver Lake. Factors

Table a.9.1. Land use by sub-basins of the Beaver Lake Watershed (SCS 1989).

Basin	Cropland ha	Pasture ha	Urban ha	Forest ha	Other ha	Water ha
Main Fork	1080.1 (2.1)*	8071.1 (15.8)	109.7 (0.2)	41247.9 (80.5)	426.1 (0.8)	256.2 (0.5)
Middle Fork	34.6 (0.2)	5837.1 (29.3)	1.5 (0.01)	13783.3 (69.2)	223.6 (1.1)	38.2 (0.2)
West Fork	117.1 (0.4)	10182.4 (31.5)	1790.3 (5.5)	19560.8 (60.6)	569.4 (1.8)	76.0 (0.2)
Richland Cr	189.7 (0.5)	14175.5 (40.9)	39.8 (0.1)	19699.0 (56.8)	539.1 (1.6)	55.2 (0.7)
War Eagle	526.1 (0.6)	34246.4 (39.1)	597.5 (0.7)	49673.0 (56.8)	1539.7 (1.8)	917.7 (1.0)
Beaver	687.7 (0.8)	21193.0 (26.1)	741.0 (0.9)	47600.9 (58.7)	1169.9 (1.4)	9660.3 (11.9)

* Percent of Subbasin Total

affècting soil erosion in the basin include, but are not limited to soil, erodability, slope, type of cover, and management practices. Shown on Table a.9.2 are the amounts of total erosion and sediment yields, with respect to land uses inventoried by the SCS (1986) during the Arkansas Critical Erosion Study. Also shown on this table are the primary factors related to excessive soil losses for each source. Grassland and forest land erosion account for 28 to 17 percent, respectively, of total soil loss, and 20 and 12 percent of the total sediment loss. Although 50% of the croplands are eroding at excessive rates, cropland erosion accounts for only 5% of the total soil loss. Grassland, harvested forest land, and croplands represent only 4% of the total land area in the watershed. Furthermore, erosion on road surfaces, road banks, gullies, and streambeds, which represent less than 3% of the total watershed, account for 50% of the total erosion.

Water quality problems related to erosion in the Beaver Lake watershed include:

- Increased water treatment costs due to elevated turbidity and suspended sediments, and
- Increased nutrient delivery potentially degrading water quality as a result of sediments transporting phosphorus and nitrogen.

The SCS (1986) has recommended land management practices that would reduce average annual sediment yield to Beaver Lake by 28% for approximately 17,000 ha (41,000 ac) of grasslands, 57,000 ha (14,000 ac) of cropland, and all gullies and streambeds. These recommendations emphasize the following:

- Management to maintain good ground cover on grasslands;
- Contour cropping on approximately 2,800 ha (7,000 ac) of cropland; and
- Conservation tillage on approximately 3,600 ha (9,000 ac) of cropland

Table a.9.2. Erosion with Respect to Sources Beaver Lake Watershed, Arkansas. (Source: SCS 1986)

Source of Erosion	Average Erosion Rate (Metric tons /ha/yr)	Total Erosion (Metric tons/yr)	Total Sediment Yield ((Metric tons/yr)	Primary Factors Related to Excessive Soil Losses
Grassland	3.11	369,294	77,186	Lack of desireable cover caused by poor pasture management
Forest Land	1.38	215,567	45,078	Disturbance by timber harvesting
Cropland	10.62	59,454	12,426	Lack of adequate resource management system
Farmsteads	2.89	10,947	2,268	Lack of adequate resource management system
Road Surface	--	118,119	41,359	Lack of vegetation and steep slopes
Roadbank	--	432,530	151,378	Lack of vegetation and steep slopes
Gully	--	22,621	10,158	Lack of vegetation and steep slopes
Streambank	--	76,687	38,366	Lack of vegetation and steep slopes
TOTAL ALL SOURCES		1,305,219	378,219	

a.9.3 Watershed Loadings by Land Use

Although estimates of nutrient loads by watersheds to Beaver Lake have been made (i.e., EPA 1977, Black and Veatch 1982, and Gearheart 1973), estimates of nutrient loads by land uses within watersheds have not been made. Table a.9.3 summarizes estimates of phosphorus, nitrogen and suspended solid loads to Beaver Lake by land use.

Nutrient loads for cropland, pasture, urban and forest land were estimated using export coefficients from Reckhow et. al. 1980. For other land uses, the runoff concentrations for mixed land uses from Omernick (1977) were used to estimate nutrient loads.

Export coefficients for cropland, forest and other land uses were kept the same for all the basins. Export coefficients for urban areas in the White River basin are higher than in the other basins because it was believed that urban areas in the White River Basin, namely Fayetteville, would be more developed than those in the other basins, ie. Huntsville and Prairie Creek. The loads based on land use were calibrated to the stream loads mainly by adjusting the pasture export coefficients. Pasture export coefficients for the Beaver laterals are averages of the coefficients for the other three basins.

Sediment loads based on non-urban land uses were calculated using the average erosion rates from SCS 1986. The erosion rate for farmsteads was used for other land uses. Sediment loads from urban areas were calculated using the pollutant concentration for suspended solids for commercial areas from Mills et. al. (1985). An urban areal loading was determined by multiplying this concentration by the annual rainfall. The delivery ratio for sediments to the Lake was determined by comparing the total erosion to stream sediment loads calculated from TSS concentrations and flow for the White River and Richland and War Eagle Creeks. The delivery ratio was slightly higher for the White River Basin than for Richland and War Eagle Creeks (.03 vs .02). An average delivery ratio was used for the Beaver laterals (.02).

Table a.9.3. Summary of nonpoint source loads to Beaver Lake.

Land Use	Area	% of Area	Phosphorus Load kg/yr (%)	Nitrogen Load kg/yr (%)	Suspend Solids Load kg/10^3/yr (%)
White River					
Cropland	1232	1.2	739 (3.3)	5198 (1.3)	1047 (6.6)
Pasture	24091	23.4	15658 (70.8)	228861 (57.2)	5994 (38)
Urban	1902	1.8	3803 (17.2)	15212 (3.8)	215 (1.4)
Forest	74592	72.4	1864 (8.4)	149184 (37.3)	8235 (52)
Other	1219	1,2	60 (0.3)	1481 (0.4)	282 (1.8)
War Eagle					
Cropland	526	0.6%	316 (2.6)	2220 (0.5)	335 (3.0)
Pasture	34246	39.6%	10274 (83.8)	325341 (75.6)	6390 (57.3)
Urban	598	0.7%	359 (2.9)	1793 (0.4)	51 (0.5)
Forest	49673	57.4%	1242 (10.1)	99346 (23.1)	4113 (36.9)
Other	1540	1.8%	75 (0.6)	1870 (0.4)	267 (2.4)
Richland					
Cropland	190	0.5%	114 (3.3)	801 (0.8)	181 (2.7)
Pasture	14176	40.9%	2835 (81.2)	56702 (58.1)	3968 (58.9)
Urban	40	0.1%	24 (0.7)	119 (0.1)	5 (0.1)
Forest	19699	56.9%	493 (14.1)	39398 (40.3)	2447 (36.3)
Other	539	1.6	26 (0.7)	655 (0.7)	140 (2.1)

Table a.9.3. Continued.

Land Use	Area	% of Area	Phosphorus Load kg/yr (%)	Nitrogen Load kg/yr (%)	Suspend Solids Load kg/10^3/yr (%)
Beaver Laterals					
Cropland	688	1.0	413 (3.9)	2902 (1.1)	438 (5.1)
Pasture	21193	29.7	8477 (80.1)	169544 (62.5)	3955 (46.0)
Urban	741	1.0	445 (4.2)	2223 (0.8)	63 (0.7)
Forest	47601	66.7	1190 (11.2)	95202 (35.10	3941 (45.8)
Other	1170	1.6	53 (0.5)	142' (0.5)	203 (2.4)

a.10.0 BASELINE AND CURRENT LIMNOLOGICAL DATA

a.10.1 Historic Water Quality

a.10.1.1 Historic Water Quality Sources

Routine water quality sampling in the Beaver Lake Watershed is conducted by the United States Geological Survey (USGS), under contract with the U.S. Army Corps of Engineers-Little Rock District (LRCOE); the Arkansas Department of Pollution Control and Ecology (ADPCE); and the Beaver Water District (BWD). USGS and ADPCE have been monitoring most sites since 1974. BWD has been monitoring its stations since 1979. Tables a.10.1 and a.10.2 list the stations sampled by these agencies, summarize the parameters monitored and provide the period of record for water quality monitoring. Figure a.10.1 shows the locations of these sampling stations. Special studies and theses have also provided data:

Special Studies

Beaver Lake has been the subject of numerous studies over the years. Studies were conducted before and after impoundment to document changes in the system as a result of impoundment. More recent studies have investigated specific water quality concerns and lake eutrophication. A summary of the special studies conducted on Beaver Lake is presented in Table a.10.3.

Theses

Due to its proximity to the University of Arkansas at Fayetteville, Beaver Lake also has been the subject of study in many masters and doctoral theses and dissertations. A partial list of theses and dissertations on Beaver Lake is given in Table a.10.4.

a.10.1.2 Historic Water Quality Concerns

Water quality concerns identified during various studies are summarized in Table a.10.5. Many of these concerns are based on the presence of wastewater discharged to

Table a.10.1. Summary of routine monitoring stations in the Beaver Reservoir Watershed including one station below the Beaver Reservoir Dam.

Station Description	Station Number	Responsible Agency	Period of Record	Comments
White River @ Beaver Dam, near Eureka Springs	07049691	USGS (COE)*	1967-1990	Monitoring frequency is once per month
Beaver Lake near Eureka Springs	07049690	USGS (COE)	1967-1990	Profile data available for temperature, conductivity, dissolved oxygen and pH. From 1975 through 1981, data for nitrogen fractions, phosphorous fractions, and chlorophyll a were collected at 8m and 20m . From 1982 through 1984, data were collected at 1, 8, and 30 m. The 1 m samples were collected intermittently. From 1985 through 1990, samples were collected consistently at 1, 8, and 30 m. Monitoring frequency is once per month.
Beaver Lake on Prairie Creek near Rogers	07049570	USGS (COE)	1975-1990	Partial record station **.
Beaver Lake near Avoca	07049590	USGS (COE)	1975-1990	Partial record station.
Beaver Lake @ Hwy 12 Bridge	07049500	USGS (COE)	1950-1990	Partial record station.
	11	BWD	1984-1990	BWD deactivated this site 1 August 1990. Monitoring frequency was monthly.
Beaver Lake @ Monte Ne.	07049230	USGS (COE)	1975-1990	Partial record station.
Beaver Lake @ Rogers Water Intake near Lowell	07049230	USGS (COE)	1977-1990	Depths at which samples were collected by USGS are variable. Prior to 1983 samples representative of surface condition were not collected. From 1983 to the present samples were collected at 1 m. Partial record station.
	1	BWD	1979-1990	BWD collects profile data weekly at intake structure. All sites are sampled at least once a month.
Beaver Lake @ War Eagle	07049050	USGS (COE)	1975-1990	Partial record station.
	9	BWD	1979-1990	Monitoring frequency is monthly.
Beaver Lake @ Hwy 68 Bridge	07048910	USGS (COE)	1984-1990	Partial record station.
Pond East of Parson's Landfill	12	BWD	1985-1990	Monitoring frequency is monthly.

Table a.10.1. Continued.

Station Description	Station Number	Responsible Agency	Period of Record	Comments
White River near Goshen	07048700	USGS (COE)	1975-1990	
	3	BWD	1979-1990	BWD deactivated this site 1 August 1990.
	050151 (WHI52)	ADPCE	1974-1990	Provide records to the USGS.
Richland Creek @ Goshen	0704880	USGS (COE)	1954 1956-1963 1963-1988	Partial record station. Also low flow partial record station. (Water quality collected water year 1989).
	4	BWD	1979-1990	BWD deactivated this site 1 August 1990.
White River below Fayetteville WWTP	13	BWD	1990-1990	Monitoring frequency is monthly.
White River @ Wyman Bridge	10	BWD	1982-1990	Monitoring frequency is monthly. Special study site 1986-1988 (5 sampling events).
West Fork White River East of Fayetteville 2.3 km upstream of the White River, 0.8 km north of Hwy 16	07048550	USGS		Monitoring frequency monthly. (Records furnished by ADPCE).
	050150 (WHI31)	ADPCE	1974-1990	Monitoring frequency monthly.
West Fork White River @ Dead Horse Mountain Road	8	BWD	1979-1980	Originally this site was sampled at the Hwy 16 bridge. Due to safety reasons this site was moved upstream to Dead Horse Mountain Road 27 March 1987. Dead Horse Mountain Road was renamed to Stone Bridge Road in 1989. Monitoring frequency is monthly.
Middle Fork White River @ Strain Church	7	BWD	1979-1990	Monitoring frequency once per month.
Main Fork White River @ Hwy 74 Bridge	5	BWD	1979-1990	Monitoring frequency once per month.
Main Fork White River @ Durham	6	BWD	1979-1990	BWD deactivated this site 1 August 1990. Monitoring frequency was monthly.

* USGS collects and analyses the water samples for the COE - Little Rock.

** Water quality partial record stations are particular sites where data are collected systematically over a period of years for use in hydrologic analyses but the data are collected less than monthly.

Table a.10.2. A list of water quality stations monitored in the Beaver Lake Watershed and a summary of the parameters monitored.

Agency	Station I.D.#	Station Name	Sampling Depth	IM*	IA*	Chl*	M*	N*	FC*
USGS	07048700	White River near Goshen	1/2 of depth	Y	Y	a&b	Y	Y	Y
USGS	07048800	Richland Cr @ Goshen	1/2 of depth	Y	Y	a&b	N	Y	Y
USGS	07048910	Beaver Lake @ Hwy 68	1/2 of depth	Y	Y	a&b	N	Y	Y
USGS	07049050	Beaver Lake @ War Eagle	1/2 of depth	Y	Y	a&b	N	Y	Y
USGS	07049200	Beaver Lake @ BWD Intake	.2 & .8 of depth	Y	Y	a&b	Y	Y	Y
USGS	07049230	Beaver Lake @ Monte Ne	1/2 of depth	Y	Y	a&b	N	Y	Y
USGS	07049500	Beaver Lake @ Hwy 12	.2 & .8 of depth	Y	Y	a&b	Y	Y	Y
USGS	07049570	Beaver Lake @ Prairie Cr	1/2 of depth	Y	Y	a&b	Y	Y	Y
USGS	07049590	Beaver Lake near Avoca	1/2 of depth	Y	Y	a&b	Y	Y	Y
USGS	07049690	Beaver Lake near Eureka Springs	25 ft & 100 ft	Y	Y	a&b	Y	Y	Y
BWD	1	Beaver Lake @ BWD Intake	elev. of open valve +	Y	N	N	Y	Y	Y
BWD	2	Beaver Lake @ Hwy 68	elev. of open valve +	Y	N	N	Y	Y	Y
BWD	3	Beaver Lake @ Hwy 45**	elev. of open valve +	Y	N	N	Y	Y	Y
BWD	4	Richland Cr @ Hwy 45**	surface	Y	N	N	Y	Y	Y
BWD	5	White River @ Hwy 74	surface	Y	N	N	Y	Y	Y
BWD	6	White River @ Durham**	surface	Y	N	N	Y	Y	Y
BWD	7	Middle Fork @ Strain Church	surface	Y	N	N	Y	Y	Y
BWD	8	West Fork @ Stone Bridge Rd	surface	Y	N	N	Y	Y	Y
BWD	9	War Eagle Cr @ War Eagle Mill	surface	Y	N	N	Y	Y	Y

Table a.10.2. Continued.

Agency	Station I.D.#	Station Name	Sampling Depth	IM*	IA*	Chl*	M*	N*	FC*
BWD	10	White River @ Wyman Bridge**	surface	Y	N	N	Y	Y	Y
BWD*	11	Beaver Lake @ Hwy 12**	e. of open valve +	Y	N	N	Y	Y	Y
BWD	13	White River below Fay. WWTP	surface	Y	N	N	Y	Y	Y
ADPC&E	WHI51	West Fork E. of Fayetteville	5' or 1/2 depth	Y	Y	N	Y	Y	Y
ADPC&E	WHI52	White River near Goshen	5' or 1/2 depth	Y	Y	N	Y	Y	Y

\+ usually 1104 NGVD. There are valves at 1104, 116, 1092, 1077, 1055, 1050, 1042, also temp & d.o. profiles at these sites weekly until August 1990 the rest of the stations are sampled monthly

** Station deactivated 1 August 1990

IM* In situ Measurements: conductivity, pH, dissolved oxygen, temperature, secchi transparency (USGS) or depth of pond

IA* Inorganic Analyses: BOD_5, alkalinity, COD, color, sulfate, chloride, total dissolved calcium, total dissolved magnesium

Chl* Chlorophyll

M* Metals: USGS measures total aluminum, arsenic, chromium, copper, lead, iron, manganese, mercury, nickel, zinc
ADPC&E measures total & dissolved arsenic, chromium, copper, lead, iron, manganese, cadmium, selenium, zinc
BWD measures soluable manganese, copper, iron, and occaisonally magnesium

N* Nutrients: nitrite, nitrate, nitrite+nitrite, ammonia, TKN, phosphorous, orthophosphorous (ADPC&E and EPA) ADPC&E does not measure orthophosphorous

FC* Fecal Coliform

st\301-320\t-3-1.wp

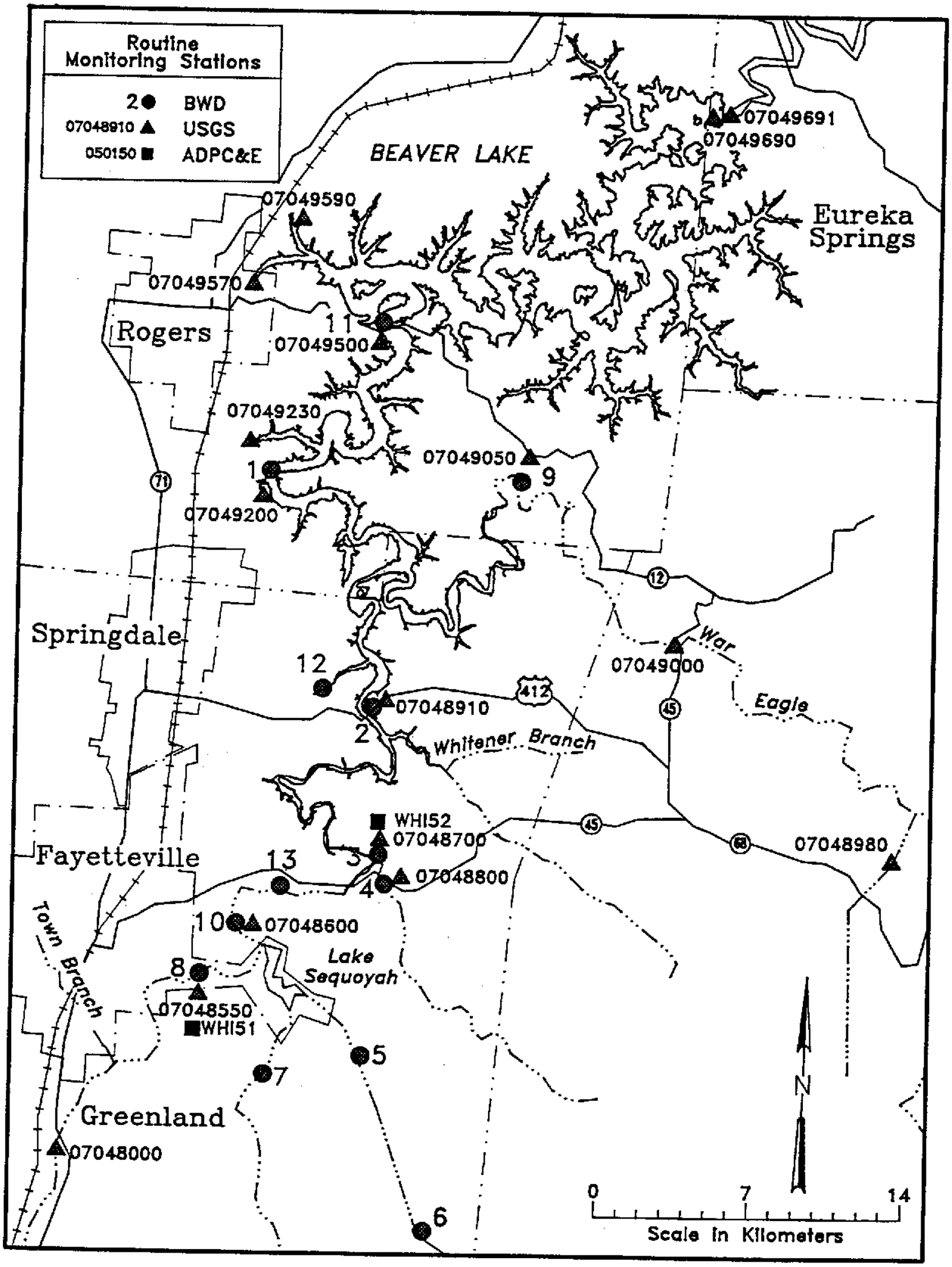

Figure a.10.1. Location of routine monitoring stations.

Table a.10.3. Special studies conducted on Beaver Lake.

Study	Year	Purpose	Sample Locations
A Preimpoundment Study of the Fishes, Their Distribution and Abundance, in the Beaver Lake Drainage of Arkansas W.E. Keith	1964	Determine the fish population existing in the White River before impoundment (1962 - 1963)	White River drainage system
Preimpoundment Studies of the Aquatic Insect Fauna of the Beaver Reservior Basin, 1963 to 1964 L.O. Warren	1964	Identify major groups represented in existing bottom fauna, and the numbers of adults present	White River drainage area
The Physical-Chemical Limnology of a New Reservior (Beaver) and a Fourteen Year Old Reservior (Bull Shoals) Located on the White River, Arkansas, and Missouri J.W. Mullan, R.L. Applegate	1965	Compare the physical-chemical limnologies of Beaver and Bull Shoals reservoirs	Beaver Lake and Bull Shoals
Food of the Black Bullhead *(Ichtalurus melas)* in a New Reservoir R.L. Applegate, J.W. Mullan	1966	Determine food habits of black bullheads during filling of Beaver Lake (1965 - 1966)	Beaver Lake
Water quality in Beaver Reservoir Watershed Postimpoundment Investigations, July 1964 to July 1966 M.E. Horn, J.S.Runsick	1966	Characterize water quality of Beaver Lake and its tributaries	15 sampling sites on Beaver, Lake
Bottom Fauna of Beaver Reservoir F.D. Miner, L.O. Warren	1967	Document seasonal variation of bottom fauna in the filling reservoir	Beaver Lake
Centrarchid Food Habits in a New and Old Reservoir During and Following Bass Spawning J.W. Mullan, R.L. Applegate	1967	Determine the foods utilized by centrarchids during and following bass spawning	Beaver Lake and Bull Shoals

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Food of Young Largemouth Bass, *Micropterus salmoides*, in a New and Old Reservoir R.L. Applegate, J.W. Mullan	1967	Determine differences in foods utilized by bass in Beaver and Bull Shoals Lakes	Beaver Lake and Bull Shoals
Zooplankton Standing Crops in a New and an Old Ozark Reservoir R.L. Applegate, J.W. Mullan	1967	Zooplankton populations in the two reservoirs were recorded and compared for 1964 - 1966	Beaver Lake and Bull Shoals
Bottom Fauna Development in Beaver Reservoir Northwest Arkansas, During the Period of Filling, 1964 to 1966 J.S. Dendy	1968	Monitor and evaluate the early development of benthic fauna to see how benthic fauna changes as the river becomes a reservoir	Beaver Lake
Distribution of Young Gizzard and Threadfin Shad in Beaver Reservoir N.F. Netsch	1968	Determine distribution of young gizzard and threadfin shad in Beaver Lake	Beaver Lake
Food of the Young-of-the-Year Largemouth and Spotted Bass During the Filling of Beaver Reservoir, Arkansas R.G. Hodson, K. Strawn	1968	Determine the foods being utilized by largemouth and spotted bass young-of-the-year	Beaver Lake
Standing Crops of Dissolved Organic Matter, Plankton, and Seston in a New and an Old Ozark Reservoir R.L. Applegate, J.W. Mullan	1968	Estimate dissolved organic matter, plankton and seston in Beaver and Bull Shoals Lakes 1963 - 1966	Beaver Lake and Bull Shoals
Fecundity of the Gizzard Shad, *Dorosoma cepedianum (Lesueur)*, in Beaver and Bull Shoals Reservoirs R.V. Kilambi, R.E. Baglin	1969	Determine relationships between fucundity, age, weight, and length of shad	Beaver Lake and Bull Shoals

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Fecundity of the Threadfin Shad, *Dorosoma petenense*, in Beaver and Bull Shoals Reservoirs R.V. Kilambi, R.E. Baglin	1969	Determine production of mature eggs by threadfins in the two reservoirs 1967 - 1968	Beaver Lake and Bull Shoals
Food Habits of Five Centrarchids During Filling of Beaver Reservoir 1965 to 1966 J.W. Mullan, R.L. Applegate	1970	Determine foods utilized by largemouth and spotted bass, bluegills, and green and longear sunfish in Beaver Lake	Beaver Lake
Pre- and Postimpoundment Ichthyoparasite Succession in a New Arkansas Reservoir D.A. Becker	1970	Look at studies of ichthyoparasites in Beaver Lake 1962 - 1964	Beaver Lake
Estimates of Young-of-Year Shad Production in Beaver Reservoir A. Houser, N.F. Netsch	1971	Develop models of gizzard and threadfin shad populations using data from 1968 - 1970	Beaver Lake
Impoundment effects on Water Quality as Reflected in Parasitism of Reservoir Basses D.A. Becker	1971	Qualitative and quantitative survey of pre and post impoundment helminth and crustacean parasites of black basses, attempt to identify correlations between water quality and bass parasitism, and determine effect of infection intensity on fish plumpness	Beaver Lake
Population Estimates and Growth of Largemouth Bass in Beaver and Bull Shoals Reservoirs H. Bryant, A. Houser	1971	Estimate population and growth rates of largemouth bass using data from April 1969 and 1970	Beaver Lake and Bull Shoals

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Summer Benthos in Newly Flooded Areas of Beaver Reservoir during the Second and Third Years of Filling, 1965 to 1966 L.R. Aggus	1971	Determine benthic population composition in newly flooded areas at Beaver Lake	Beaver Lake
Eutrophic Potential of Beaver Reservoir Influents G.L. Carnhan	1972	Determine the eutrophic potential of water from White River, War Eagle Cr and septic tank leaching	White River, War Eagle Creek, and Beaver Lake
Limnetic Zooplankton Population Dynamics in Beaver and Bull Shoals Reservoirs: Composition, Seasonal Abundance, Structure and Vertical Migration S. Damico	1972	Compare limnetic zooplankton populations of the two reservoirs four years after Beaver has filled	Beaver Lake and Bull Shoals
A Eutrophication Model of the White River Basin Above Beaver Reservoir in Northwest Arkansas R.A. Gearheart	1973	Determine rate of nutrient accumulation, identify major nutrient contributors, and develop a eutrophication model to predict future levels of eutrophy	White River
A Study: Effects of Geology and Nutrients on Water Quality Developments L.J. Stone	1973	Determine initial water quality of White River and War Eagle Cr and relate water quality to land use	White River and War Eagle Creek
Septic Tank Pollution of Beaver Reservoir. S.J. Stone	1973	Determine if bacteria and nutrient rich water entering Beaver Reservoir from septic tanks in soils poorly suited to septic tank functioning.	War Eagle, Hickory Cr, BWD intake, Monte Ne, Prairie Cr, Van Hollow Cr, and seep draining to the lake
The Bacterial and Algal Activity in the Metalimnion of Beaver Reservoir D.D. Drury	1973	Find a relationship between minimum dissolved oxygen and activity of algae and bacteria in the metalimnion	Beaver Lake

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
The Economic Impact of Beaver Lake Reservoir: A Cost Benefit Study D. Market	1973	Determine the economic impact of Beaver Lake reservoir on Washington, Benton, Carroll and Madison counties	
Biochrome Analysis Method for Assessing Phytoplankton Dynamics Phase I. R.L. Meyer.	1974	Develop procedure to determine phytoplankton populations by pigment analysis for use in eutrophication studies.	War Eagle Cr and cove, Hoffmans Pt Angle, Blue Springs, Friendship Cr, White River, Hickory Cr, BWD Water Works, Prairie Cr
Limnetic Zooplankton Dynamics in Beaver Reservoir Including an Inventory of Copepod Species and an Evaluation of Vertical Sampling Methods. E.H. Schmitz.	1974	Contribute to understanding of reservoir life histories by describing seasonal zooplankton and copepod dynamics in Beaver Lake 1972-1973.	Upper lake, mid-lake dam
Limnetic Zooplankton Dynamics in Beaver Reservoir Including a Preliminary Report on Vertical Distribution Patterns E.D. Short	1974	Report limnetic zooplankton dynamics in Beaver Lake 1973 - 1974	Beaver Lake
An Initial Assessment Contamination and Pollution of Beaver Reservoir Property Development H.C. Russell	1975	Determine amount of rural property development in lake area and its effect on lake water quality, and develop initial estimate of effects of continued development on lake quality	Beaver Lake
Biochrome Analysis as a Method for Assessing Phytoplankton Dynamics, Phase II R.L. Meyer	1975	Conclude one year of sampling and analyze interactions between phystochemical parameters and phytoplankton populations.	War Eagle Cr and cove, Hoffman's Point, Angle, Blue Springs, Friendship Cr, White River, Hickory Cr, BWD Water Works, Prairie Cr

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Dynamics of Feeding Ecology of Larval Shad, *Dorosoma*, in Beaver Reservoir, Arkansas R.V. Kilambi, L.E. Barger	1975	Determine food habits of larval shad in Beaver Lake, and relationship between feeding and algal densities	Beaver Lake
Pathogenic Free-Living Amoebae in Arkansas Recreational Waters. L.W. Bone, D.A. Becker.	1975	Attempt to isolate *Naegleria gruberi* in selected Arkansas Recreational waters and relate occurrence to water quality.	Recreation areas
Production of Largemouth Bass in Beaver and Bull Shoals Lakes A. Houser, W.C. Rainwater	1975	Summarize largemouth bass production for 1968 - 1973	Beaver Lake
Selected Aspects of the Limnology of Zooplankton in Beaver and Degray Reservoirs, Arkansas, with Emphasis on the Development of a Method for the Estimation of Zooplankton Biomass. E.H. Schmitz. J.T. McCraw, P.J. Williams	1975	Continuation of program of seasonal studies of zooplankton on Beaver Lake with emphasis on development of a method to estimate zooplankton contribution to biomass. Also initial zooplankton inventory on DeGray Lake for the comprehensive fisheries production research program.	Upper lake, mid-lake dam
An Aqueous Environmental Simulation Model for Mid-South Lakes and Reservoirs. L.G. Thibodeaux.	1976	Develop a mathematical model of the biological, chemical and physical phenomena associated with lakes and reservoirs in mid-south states to provide a method of assessing effects of current or projected conditions on lake water quality.	Segment of the lake from Hwy 45 to BWD intake was modeled
Freshwater Sponges in Beaver Reservoir T.O. Duncan	1977	Report existence of freshwater sponges in Beaver Lake and their disappearance as the lake filled	Beaver Lake

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Effects of Rotenone on Zooplankton in an Ozark Reservoir Cove J.I. Meinecke	1978	Determine percent kill of various species as a result of rotenone application, recolonization rates, and importance of various recolonization sources	Pine Creek and cove
Pre & Post Impoundment Ichthyoparasite succession in a New Arkansas Reservoir. D.A. Becker, W.D. Carr, R.G. Heard, D.C. Cloutman, P.D. Holmes, W.A. Evans, M.D. Norman, W.D. Owens Jr.	1978	Survey helminth and crustacean parasites of basses 1962-1969 to document changes in populations as a result of impoundment, as part of furthering understanding of the effects of stream impoundment.	Pre impoundment - White River drainage area Post impoundment - Beaver Lake
The Composition and Abundance of Vegetation Inhabiting the Water Fluctuation Zones of Veaver and Bull Shoals Lakes E.E. Dale, J. Sullivan	1978	Determine the relationship between microenvironment factors, composition and abundance of organic mulch and succession of plant communities in the fluctuation zones of Beaver Lake	Beaver Lake and Bull Shoals
Zooplankton Limnology of Beaver and DeGray Reservoirs in Arkansas E.H. Schmitz	1978	Continuation of study of seasonal changes in zooplankton abundance and biomass in the two reservoirs 1975 - 1976	Beaver Lake and DeGray Lake
Feeding Ecology of Larval Shad, *Dorosoma*, in Beaver Reservoir, Arkansas L.E. Barger, R.V. Kilambi	1980	Determine food habits of larval shad in Beaver Lake summer of 1972	Beaver Lake

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Water Quality Study of Beaver Lake, Arkansas Black and Veatch	1982	Identify, quantify and estimate the effect of pollutants of BWD water quality because of increasing difficulty treating water to acceptable levels.	Used data from BWD, R.L. Meyer, USGS, Fish & Wildlife
Water Quality Assessment of White River Between Lake Sequoyah and Beaver Reservoir, Washington County, Arkansas. J.E. Terry, E.E. Morris, C.T. Bryant.	1983	Determination of the assimilative capacity of White River for waste treatment plant effluent to satisfy EPA Program requirements Memorandum 79-7.	West Fork, 11 locations on White River 684.7 - 675.8, and Richland Cr
The Application of the Algal Assay Bottle Test to Define Potential Algal Production through Time and Space in Beaver Lake. R.L. Meyer, W.G. Green.	1985	Determining limiting factors that may be affecting algal growth in Upper Beaver Lake to assist in development of appropriate management practices.	Upper Beaver Lake and tribs.
A Study of Erosion, Animal Wastes and Nutrient Transport Associated with Agricultural Areas Within the Beaver Lake Watershed Area, Arkansas USDA, SCS, FS, ASWCC	1986	Identify magnitude of existing erosion, determine confined animal production and amounts of animal waste produced, evaluate existing agricultural management systems, and develop alternatives to deal with identified problems and methods to implement these alternatives. The study was requested as a result of water quality problems caused by nutrients and sediment.	1 out of every 10 1 km^2 cells of the Beaver Lake watershed
Algal Growth Potentials and Heavy Metal Concentrations of the Primary Streams to Upper Beaver Lake. R.L. Meyer, W.R. Green, K.F. Steele, D. Wickliff.	1986	Determine source of heavy metals inhibiting algal growth in upper Beaver Lake discovered by Meyer & Green (1984).	White River and Upper Beaver Lake

Table a.10.3. Continued.

Study	Year	Purpose	Sample Locations
Master Planning Study for Beaver Water District. James M. Montgomery Consulting Engineers.	1987	Establish plan to ensure water of adequate amounts and quality to meet increasing public demands and regulations requirements.	Various BWD & USGS sampling data, period of record.
Feasibility Study for Animal Waste Processing Facility in Northwest Arkansas FTN Associates, Ltd.	1989	Evaluate feasibility of construction operation of animal waste processing facility in Beaver Lake watershed.	
Water Quality Demonstration Project Beaver Lake, Arkansas U.S. Army Corps of Engineers	1989	Determine cost effectiveness of improving Beaver Lake water quality by reducing nonpoint source discharges	Federal, state and local agencies provided documents and data used in this report

Table a.10.4. List of theses and dissertations.

Amores-Serrano, R.R. 1978. Life Histories and Seasonal Population Dynamics of Two *Cyclopoid Copepods* in Beaver Reservoir, Arkansas, Including Some Observations of Their Post-Embryonic Development. University of Arkansas, Fayetteville.
Baglin, R.E. Jr. 1968. Fecundity of the Gizzard Shad, *Dorosom cepedianum (Le Sueur)*, and the Threadfin Shad, *Dorosoma petenese (Gunther)*, in Beaver and Bull Shoals Reservoirs. University of Arkansas, Fayetteville.
Baker, C.D. 1968. Comparative Studies of the Food Habits of the Gizzard Shad *Dorosoma cepedianum (Lesueur)*, and the Threadfin Shad, *Dorsoma petenese (Gunther)*, in Beaver and Bull Shoals Reservoirs. University of Arkansas, Fayetteville.
Ball, R.L. 1972. The Feeding Ecology of the Black Crappie, *Pomoxis nigromaculatus*, and the White Crappie, *Pomoxis annularis*, in Beaver Reservoir, Arkansas. University of Arkansas, Fayetteville.
Barnes, J.M. 1977. The Sustained Swimming Ability of Larval and Juvenile Gizzard Shad, *Dorosoma cepedianum (Le Sueur)*, and Threadfin Shad, *D. petenese (Gunther)*, as Related to Entrainment and/or Impingement by Water Intake Structures of Power Stations. University of Arkansas, Fayetteville.
Bennett, W.D. 1970. The Effect of Impoundment on the Water Quality and Microbial Ecology in Beaver Reservoir from June, 1968 to June, 1969. University of Arkansas, Fayetteville.
Carr, W.D. 1975. A Comparative Pre- and Postimpoundment Survey of the Helminth and Crustacean Parsites of *Micropterus punctulatus (Rafinesque)* and *M. salmoides (Lacepede) (Perciformes)* in Beaver Reservoir, Arkansas. University of Arkansas, Fayetteville.
Cheng, K.C. 1976. Deterministic Lake Ecosystem Simulation Model With Application to Beaver Reservoir. University of Arkansas, Fayetteville.
Drach, R.F. 1970. Pre- and Postimpoundment Trends and Possible Effects of Helminth and Crustacean Parasites of Black Basses in Beaver Reservoir, Arkansas. University of Arkansas, Fayetteville.
Drury, D.D. 1973. The Bacterial and Algal Activity in the Metalimnion of Beaver Reservoir. University of Arkansas, Fayetteville.
Evans, W.A. 1968. A Comparative Preimpoundment and Early Postimpoundment Survey of the Helminth and Copepod Parasites of *Micropterus dolomieui lacepede, M. punctulatus (Rafinesque)*, and *M. salmoides (Lacepede) (Perciformes)* of Beaver Reservoir in Northwestern Arkansas. University of Arkansas, Fayetteville.
Feeney, P.K. 1971. The Nutrient content of the Benthal Deposits in Beaver Reservoir. University of Arkansas, Fayetteville.

Table a.10.4. Continued.

Heard, R.G. 1965. A Preimpoundment Survey of the Helminth and Copepod Parasites of _Micropterus dolomieui lacepede, M. punctulatus (Rafinesque)_, and _M. salmoides (Lacepede) (Perciformes)_ of Beaver Reservoir in Northwest Arkansas. University of Arkansas, Fayetteville.
Heinrichs, S.M. 1979. Ontogenetic Changes in the Digestive Tract of the Larval Gizzard Shad, _Dorosom cepedianum (Le Sueur)_. University of Arkansas, Fayetteville.
Hodson, R.G. 1967. The First Year Life History of the Largemouth Bass, _Micropterus salmoides (Lacepede)_, and the Spotted Bass, _Mocropterus punctulatus (Rafinesque)_, in Beaver Reservoir, Arkansas. University of Arkansas, Fayetteville.
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Table a.10.4. Continued.

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the White River by the City of Fayetteville and land application of animal waste in the Beaver Lake watershed.

a.10.1.3 Limnological Investigations

The locations of USGS, ADPCE and BWD monitoring stations are shown in Figure a.10.1. Figures a.10.2 through a.10.4 show examples of sampling locations used during special studies (Gearheart 1973, Mitchell and Stevens 1973, and EPA 1977). The monitoring stations used by EPA (1977) during the National Eutrophication Survey (NES) are described in Table a.10.6. The purpose of these figures and tables is to show that monitoring of water quality has occurred throughout the Beaver Lake Watershed and Lake.

The major issue with these data collection efforts is that each study was designed for specific purposes, which may or may not be complementary. In order to understand the water quality of Beaver Lake, however, this combination of special studies and routine monitoring data was evaluated to assess the general patterns of water quality in Beaver Lake.

a.10.1.3.1 Status of Existing Data

Quality Assurance and Quality Control:

Quality assurance (QA) refers to programs and procedures designed to assure that data are reliable whether collected in the field or measured by analytical procedures in a laboratory. Quality control (QC) is a part of an overall QA program. QC refers to the routine procedures used to regulate measurements and to produce data of satisfactory results (Friedman and Erdman 1982).

Data for Beaver Lake came from several sources: the USGS, ADPCE, BWD, and special studies. The USGS has several publications that describe proper procedures for takin in-situ measurements, for collecting water samples, and for the analysis of the sample (Friedman and Erdman 1982, USGS 1987, USGS 1989, and Ward and Harr 1990).

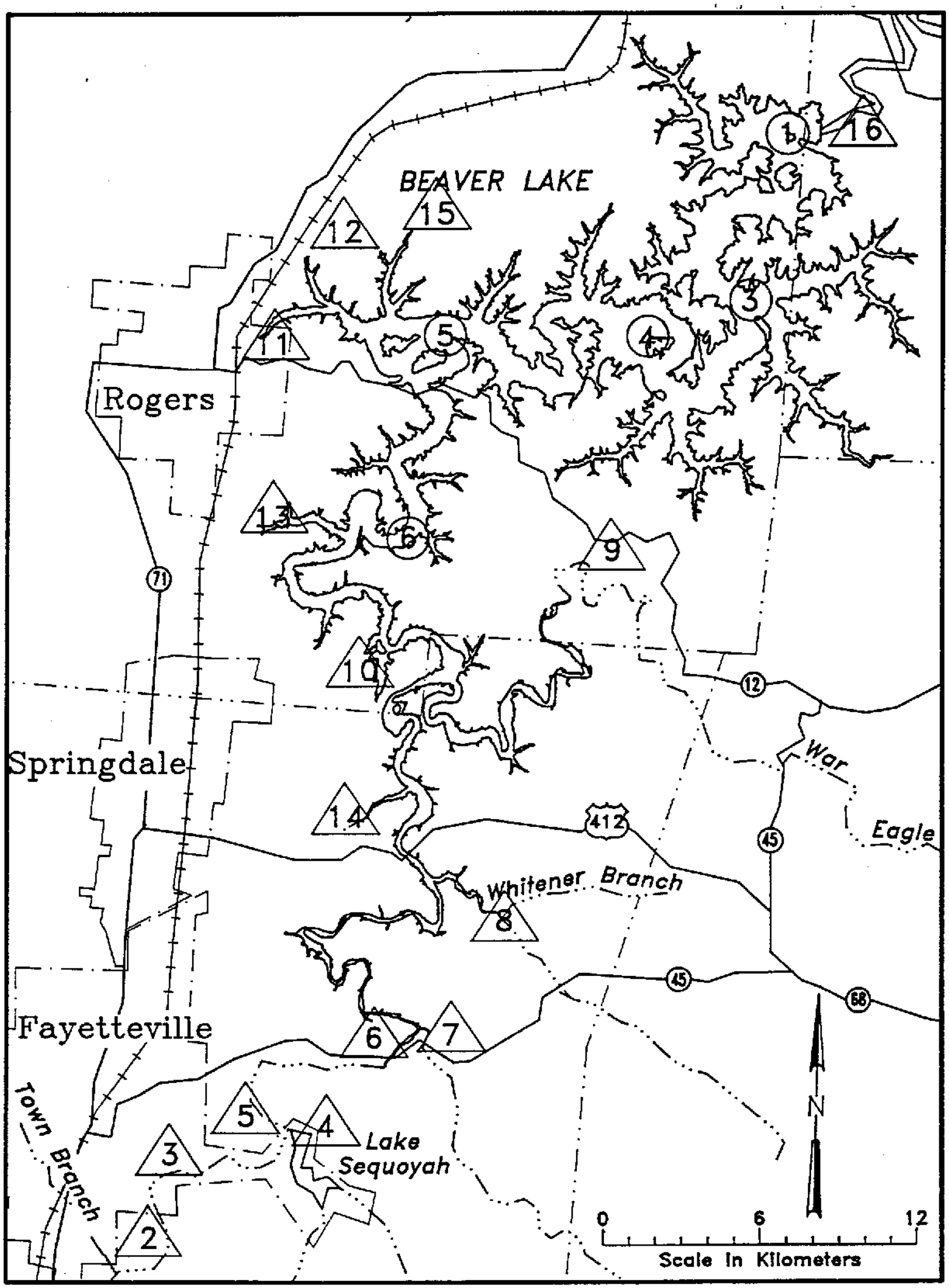

Figure a.10.2. Locations of sampling stations (Gearheart 1973).

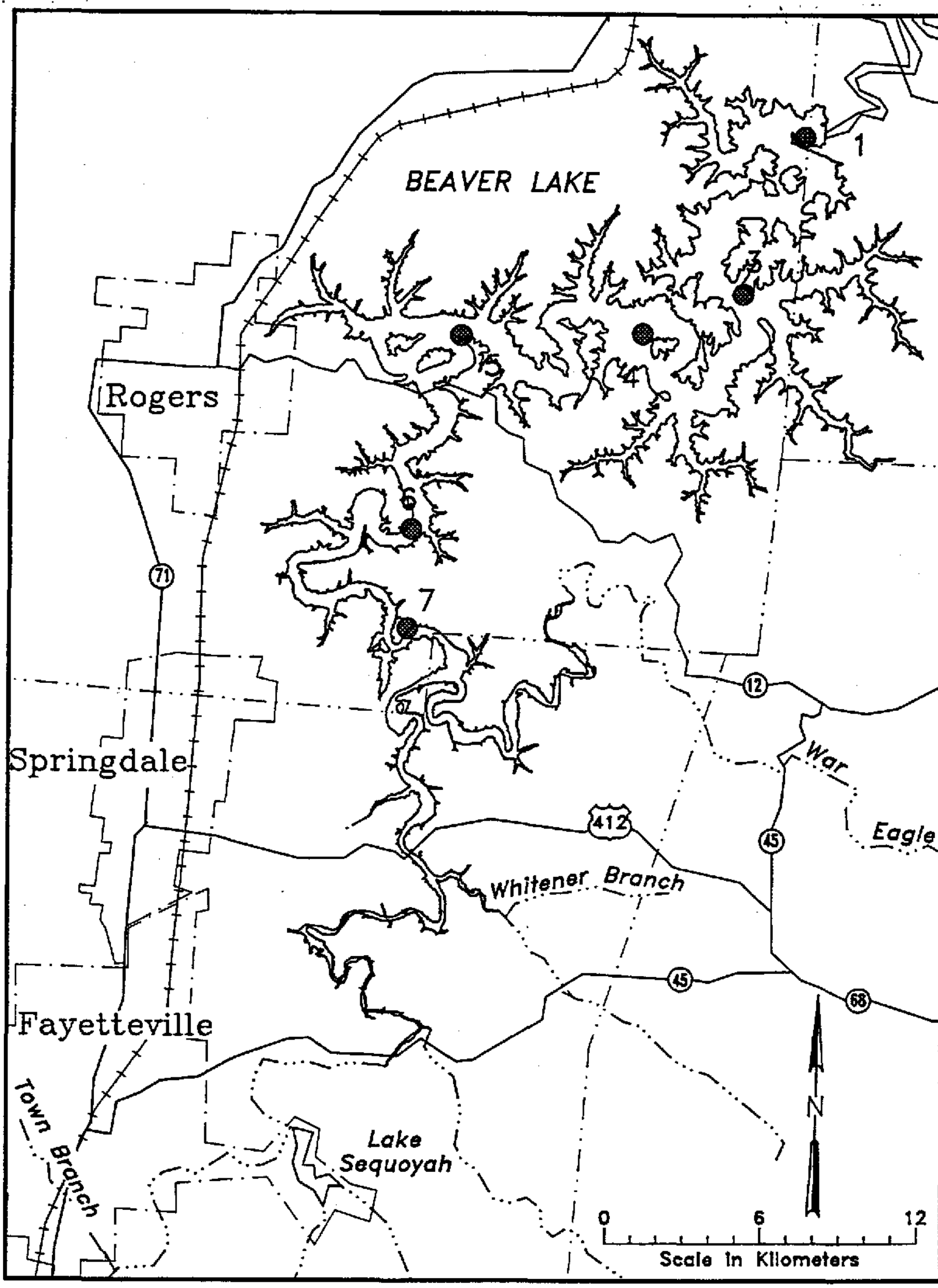

Figure a.10.3. Locations of sampling stations (Mitchell and Stevens 1973).

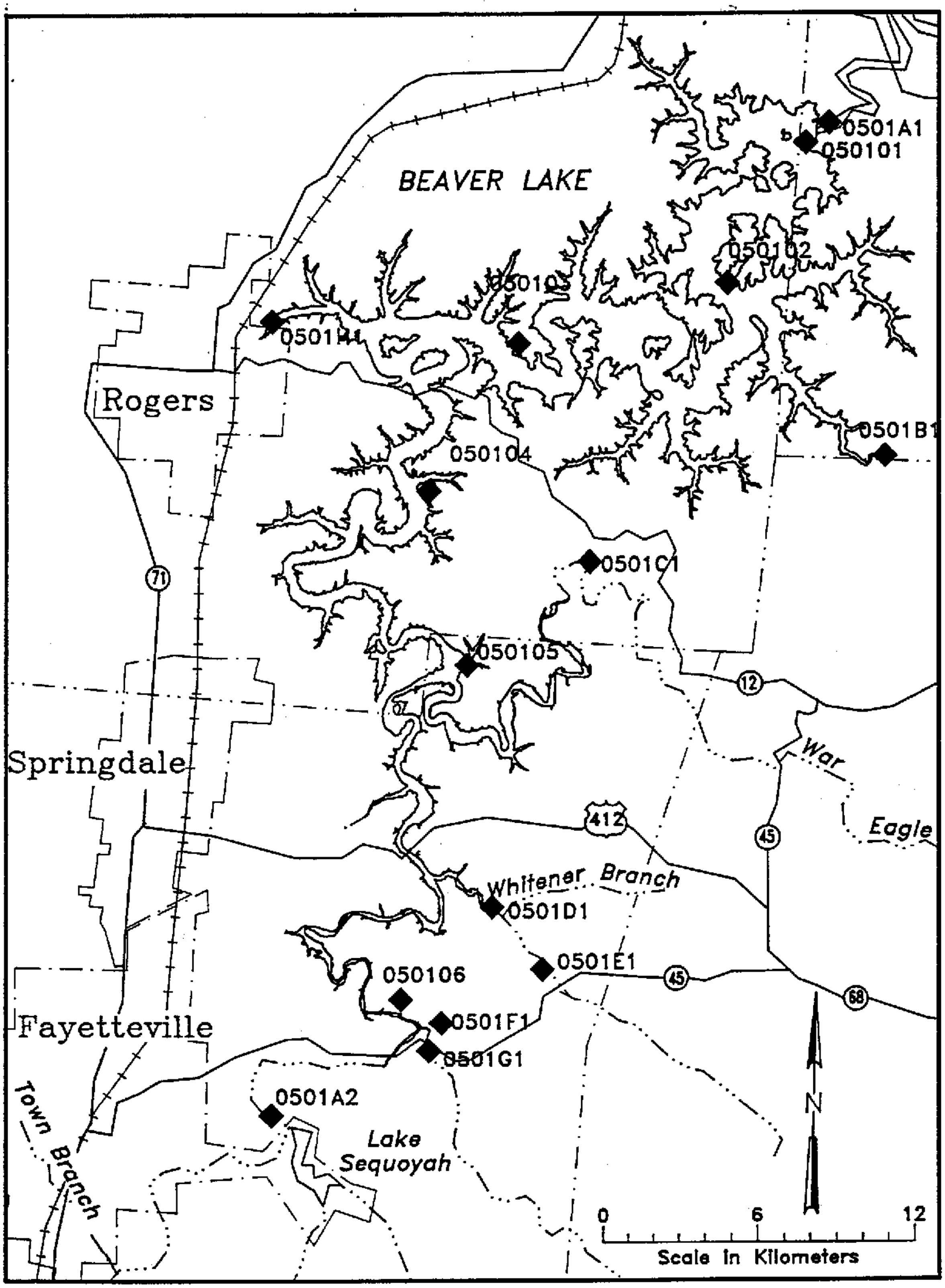

Figure a.10.4. Location of EPA sampling locations during National Eutrophication Survey (EPA 1977).

Table a.10.6. A list of water quality stations monitored in Beaver Lake Watershed during the EPA NES.

Agency	Station I.D.#	Station Name	Sampling Depth	IM*	IA*	Chl*	M*	N*	FC*
EPA	0501A2	White River (above Fay. WWTP)	varies, max 45'	N	N	N	N	Y	N
EPA	0501G1	Richland Cr near Goshen	varies, max 55'	N	N	N	N	Y	N
EPA	0501F1	Dry Cr	varies, max 49'	N	N	N	N	Y	N
EPA	050106	White River (D/S Richland Cr)	profile	Y	total alka-linity	a	N	Y	N
EPA	0501E1	Brush Cr	varies, max 50'	N	N	N	N	Y	N
EPA	0501D1	Whitner Cr	varies, max 50'	N	N	N	N	Y	N
EPA	0501YA	Holman Cr	varies, max 45'	N	N	N	N	Y	N
EPA	0501C1	War Eagle Cr	varies, max 45'	N	N	N	N	Y	N
EPA	050105	Beaver Lake @ War Eagle Cr	profile	Y	total alka-linity	a	N	Y	N
EPA	050104	Beaver Lake @ Horseshoe Bend	profile	Y	total alka-linity	a	N	Y	N
EPA	0501H1	Beaver Lake S of Hwy 12	varies, max 30'	N	N	N	N	Y	N
EPA	050103	Beaver Lake @ Shaddox Br	profile	Y	total alka-linity	a	N	Y	N
EPA	0501B1	Big Clifty Cr	varies, max 45'	N	N	N	N	Y	N

Table 10.6. Continued.

Agency	Station I.D.#	Station Name	Sampling Depth	IM*	IA*	Chl*	M*	N*	FC*
EPA	050102	Beaver Lake near Hall Spring Br	profile	Y	total alka-linity	a	N	Y	N
EPA	050101	Beaver Lake @ Beaver Dam	profile	Y	total alka-linity	a	N	Y	N
EPA	WHI70	Holman Cr Below Huntsville	5' or 1/2 depth	Y	BOD_5 COD	N	Y	Y	Y

IM* In situ Measurements: conductivity, pH, dissolved oxygen, temperature, secchi transparency (USGS) or depth of pond (EPA)

IA* Inorganic Analyses: BOD_5, alkalinity, COD, color, sulfate, chloride, total dissolved calcium, total dissolved magnesium

Chl* Chlorophyll

M* Metals: USGS measures total aluminum, arsenic, chromium, copper, lead, iron, manganese, mercury, nickel, zinc
ADPC&E measures total & dissolved arsenic, chromium, copper, lead, iron, manganese, cadmium, selenium, zinc
BWD measures soluble manganese, copper, iron, and occasionally magnesium

N* Nutrients: nitrite, nitrate, nitrite+nitrate, ammonia, TKN, phosphorus, orthophosphorus (ADPC&E and EPA). ADPC&E does not measure orthophosphorus.

FC* Fecal Coliform

The ADPCE also has a written QA plan for ambient water quality and compliance sampling (ADPCE 1988). The data collected by ADPCE is used to supplement the USGS records. Because data collected by ADPCE is used by the USGS, ADPCE participates in the USGS's round-robin reference sampling program. Based on personal communications with Dick Cassatt, the Director of Technical Services at ADPCE, the department's QA/QC program has been documented since the early 1980's. Prior to the 1980's the data are of unknown quality.

There is no formal QA/QC program for the BWD. BWD indicated that QC samples are rarely prepared and only when there appears to be an obvious problem. Sample preparation is inconsistent. Some samples are filtered while others are not, depending on the turbidity of the sample. The BWD is certified by Arkansas Department of Health for fecal coliform analyses. For field equipment, BWD uses two point (i.e., pH 7 and 10 su) calibration for pH meter; specific conductance (Hach meter) is calibrated once a month; and the DO meter is air calibrated before use. BWD data are considered to be adequate for a general qualitative description of the water quality in Beaver Reservoir and its tributaries.

In general, special studies on Beaver Lake report the methodologies used but do not discuss any QA/QC protocol. Therefore, the data falls into the category of unknown quality. One exception was EPA's National Eutrophication Survey data. The QA/QC program is described by EPA (1977), but results of spikes, duplicate samples and blank analyses are not presented.

As part of an effort to evaluate the response of the Beaver Reservoir to the implementation of a number of proposed management schemes, the Aquatic Processes and Effects Group of the U. S. Army Corps of Engineers Waterways Experiment Station was contracted to model long-term responses in Beaver Reservoir (COE 1989). The model selected to evaluate the responses was BATHTUB. Four data sets were potentially available for inclusion in the model: the USGS, BWD, Black and Veatch, and NES.

The data collected by the USGS and BWD were not adequate to address loading rates to Beaver Reservoir. Although the USGS data were representative of water quality, the information was insufficient to generate reasonable estimates of nutrient loads. The

BWD data set lacked variables needed to run the model and the Black and Veatch data were considered to be less complete in providing lake water quality data and the resolution of the loading data were less than that provided by NES.

A disadvantage of the NES data was that it was over fourteen years old. However, Gaugush (COE 1989) compared NES water quality to USGS data for the period 1980 through 1986. Mean total phosphorus and chlorophyll a concentrations, and Secchi disc transparency depth measurements were not significantly different between the 1974 NES data and the 1980-1986 USGS data. Two of four nitrogen comparisons were significantly different. However, because of the general lack of significant differences, the NES data were used to project future changes in Reservoir water quality as nonpoint and point source loads are reduced.

In general, it is recommended that existing data be used to determine patterns. Comparisons of data between data sets such as the USGS and the BWD data would not be appropriate because of the differences in the QA/QC programs.

a.10.1.3.2 Tributary Studies

The major tributaries to Beaver Lake include the West, Middle, and Main Forks of the White River and Richland and War Eagle Creeks. Agencies that have routinely monitored tributaries to Beaver Lake include:

- Arkansas Department of Pollution Control and Ecology (ADPCE)
- Beaver Water District (BWD)
- United States Environmental Protection Agency (EPA), and
- United States Geological Survey (USGS).

Because of the different sampling protocols and analytical techniques, comparisons between specific points are not made unless it is a situation where one agency (e.g., ADPCE) is providing data to another agency (e.g. USGS). The monitoring data are evaluated for general patterns and trends in and among tributaries. Table a.10.7

Table a.10.7. Summary of water quality constituents in tributaries to Beaver Reservoir.

	Secchi Disk, m	DO, mg/L	pH, su	Alkalinity mg/L	Orthophosphate mg/L	Total Phosphorous mg/L	Total Ammonia mg/L	Nitrite+ Nitrate mg/L	TKN mg/L
West Fork USGS 07048550 BWD 8	--	8.9 (3.1-14.3) 8.8* (3.9-13.8)	7.6 (6.9-9.6) 7.6* (7.2-8.4)	5.9 (30-107) 67.1* (30-270)	0.042* (0-0.600)	0.91 (0.010-0.870)	0.099 (0.010-2.50) 0.312* (0-3.1)	0.450 (0.01-6.1) 0.285+ (0-1.7)	0.514 (0-1.70)
White River at Durham BWD 6	-	9.4* (3.8-14.8)	7.3* (6.1-8.4)	24.5* (10-108)	0.039* (0-0.740)	--	0.156* (0-1.3)	0.341+ (0-1.8)	--
White River at Hwy. 74 BWD 5	--	8.8* (4.6-13.4)	7.3* (6.0-8.3)	30.7* (7-75)	0.40* (0-0.750)	--	0.228* (0-1.09)	0.367+ (0-2.25)	--
Middle Fork at Strain Church BWD 7	--	9.1* (4.3-13.6)	7.4* (6.8-8.4)	44.3* (23-81)	0.39* (0-1.08)	--	0.167* (0-1.3)	0.380+ (0-2.26)	--
White River at Wyman Bridge BWD 10	--	9.1* (5.6-13.4)	7.6* (7.0-8.1)	50.1* (16-126)	0.023* (0-0.380)	--	0.278* (0-0.860)	0.25+ (0.01-0.75)	--
White River below Fayett. WWTP BWD 13	--	8.3* (7.8-9.0)	7.6* (7.3-8.0)	63.8* (49-89)	0.083* (0.01-0.280)	--	0.365* (0.23-0.60)	0.935+ (0-2.6)	--
Goshen USGS 07048700 BWD 3	0.545 (0.06-1.2)	7.19 (1.2-13.4) 7.8* (1.4-12.5)	7.29 (6.2-8.12) 7.5* (6.9-8.7)	53.4 (12-140) 53.7* (21-121)	0.76 (0.02-4.6) 0.665* (0-16.0)	1.01 (0.05-6.8)	1.07 (0-7.9) 0.873* (0-6.80)	0.78 (0.16-2.2) 0.671+ (.04-4.07)	2.3 (0.29-12.0)
Richland Creek USGS 0704880 BWD 4	0.66 (0.06-1.8)	10.04 (6-12.7) 10.3* (5.7-43.8)	7.55 (7.3-8.5) 7.8* (7.0-9.1)	55.16 (33-98) 70.2* (24-120)	0.042 (0.01-0.22) 0.054* (0-2.1)	0.066 (0.01-0.32)	0.25 0.203* (0-1.80)	0.71 (0.1-1.3) 0.513+ (0-3.51)	.70
War Eagle USGS 07049050 BWD 9	0.7 (0-1.8)	9.5 (6-14.6) 9.2* (5.9-14.6)	(6.1-8.1) 7.8* (7.2-8.5)	79 (39-124) 84.8* (24-131)	0.024 (0.01-0.21) 0.040* (0-0.640)	0.047 (0.01-0.25)	0.06 0.171* (0-1.69)	0.88 (0.30-1.70) 0.539+ (0-1.8)	2.0

* Beaver Water District (BWD) monitoring data.
\+ Beaver Water District (BWD), nitrate only.
** Maximum and minimum values measured.

summarizes tributary water quality. The period of record for each station is listed in Table a.10.1.

The upper White River includes three sub-basins: the Main Fork of the White River basin, the Middle Fork of the White River Basin, and the West Fork of the White River. The lower White River basin consists of the White River downstream of the confluence of the three sub-basins to the upper end of the Beaver Lake pool.

In the West Fork of the White River, DO and pH levels were generally adequate to support aquatic biota. pH exceeded 9.0 su, the upper limit to protect aquatic biota (ADPCE 1988), on only one occasion.

The ADPCE (1991) recommends that total phosphorus concentrations in streams should not exceed 0.1 mg/L. In the upper White River, total orthophosphate concentrations generally do not exceed the 0.1 mg/L guideline but this does not mean that total phosphorus concentrations might not exceed 0.1 mg/L. The only fork of the White River for which total phosphorus data were available was the West Fork. The average total phosphorus concentration in the West Fork of the White River was less than 0.1 mg/L (i.e., 0.09 mg/L), but the 0.1 mg/L guideline was frequently exceeded (Figure a.10.5). Figure a.10.5 also shows that there have been no changes in phosphorus concentrations in the system since 1974 (i.e. slope of reggression line is 0.0).

In general, maximum nitrate plus nitrite concentrations occur in the winter with minimum concentrations in the summer (e.g., Figure a.10.6). However, in the West Fork of the White River, annual maximum concentrations sometimes occurred in the summer. Nitrate nitrogen concentrations occasionally were greater than 1.0 mg/L.

Based on BWD data, ammonia concentrations were generally higher in the West Fork of the White River than in the Main or Middle Forks of the White River (Table a.10.7).

Total iron concentrations in the upper White River Basin frequently exceeded EPAs (1986) criteria of 0.3 mg/L for domestic water supply and the EPA (1986) criteria of 1.0 mg/L to protect aquatic life from chronic toxicity (e.g. Table a.10.8). Although average concentrations of manganese exceeded the 0.05 mg/L EPA (1986) criteria for domestic water supply, the average concentrations are driven by occasional high

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WHITE RIVER SW LOWER MISSISSIPPI

665 PHOS-TOT MG/L P

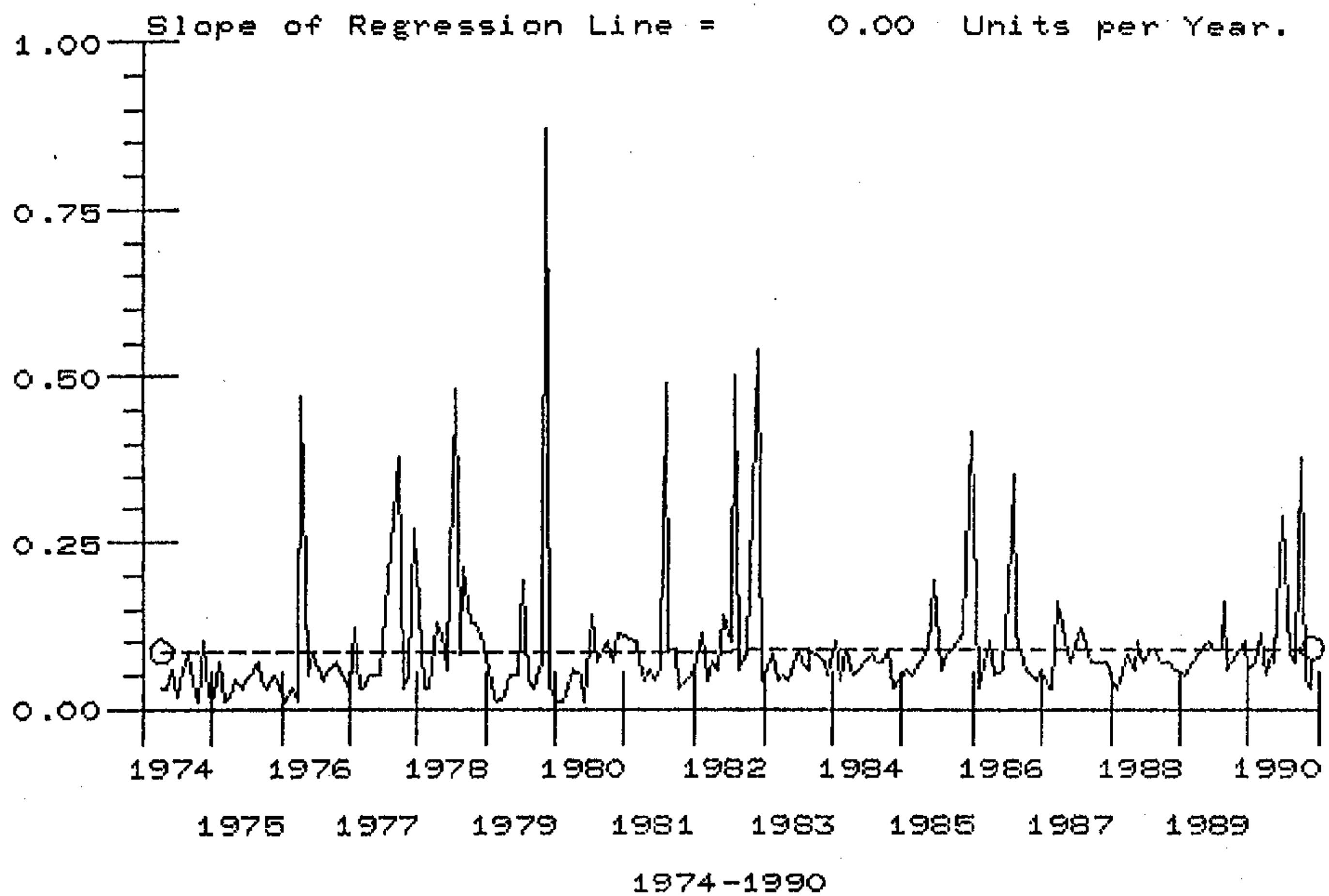

Figure a.10.5. Total phosphorus concentrations in the West Fork of the White River.

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W FORK WHITE RIVER E OF FAYETTEVILLE, ARK 05143 ARKANSAS
W
WHITE RIVER SW LOWER MISSISSIPPI

630 NO2&NO3 N-TOTAL MG/L

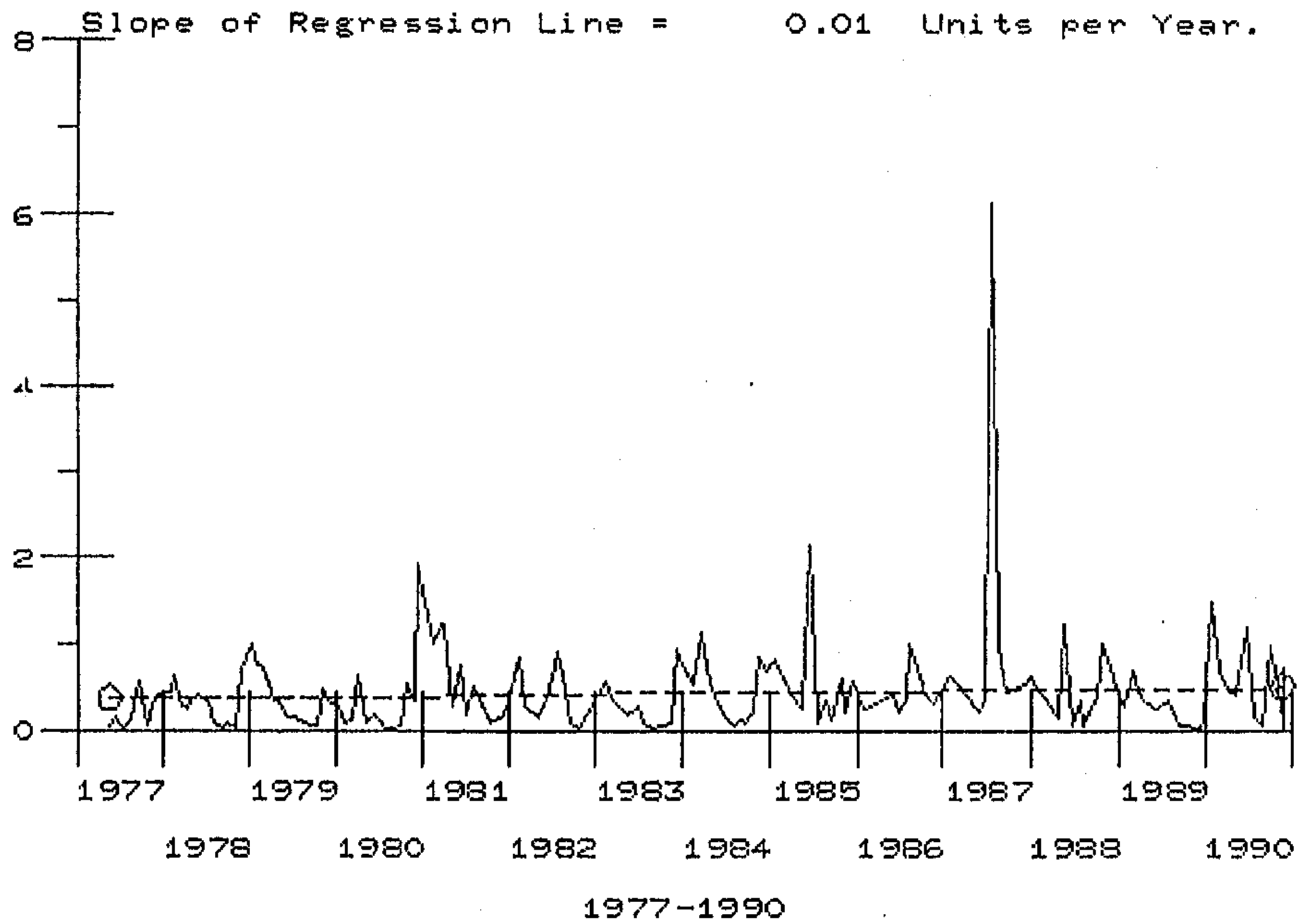

Figure a.10.6. Nitrite plus nitrite nitrogen concentrations in the West Fork of the White River.

Table a.10.8. Summary of heavy metal concentrations in tributaries to Beaver Lake.

	Arsenic ug/L	Cadmium ug/L	Chromium ug/L	Copper ug/L	Iron ug/L	Lead ug/L	Manganese ug/L	Nickel ug/L	Zinc ug/L	Aluminum ug/L	Mercury ug/L	Selenium ug/L
West Fork APDC&E WHI51 BWD 8	4.93 (5-28)	1.66 (0-17)	2.95 (0-31)	21.4 (0-414) 3.0* (0-50)	1079 (25-6990) 373* (0-2200)	16.0 (0-200)	166 (8-666) 42.0* (0-1100)	–	31.1 (0-324)	–	0.562 (0.3-1.0)	5.68 (5-10)
White River at Durham BWD 6	–	–	–	7.0* (0-590)	237* (0-1880)	–	15* (0-1300)	–	–	–	–	–
White River at Hwy. 74 BWD 5	–	–	–	2.0* (0-90)	288* (0-1420)	–	6.0* (0-170)	–	–	–	–	–
Middle Fork at Strain Church BWD 7	–	–	–	3.0* (0-120)	246* (0-2800)	–	28.0* (0-1000)	–	–	–	–	–
White River at Wyman Bridge BWD 10	–	–	–	3.0* (0-100)	386* (0-1210)	–	60.0* (0-720)	–	–	–	–	–
White River below Fayett. WWTP BWD 13	–	–	–	3.0* (0-10)	243* (70-580)	–	0*	–	–	–	–	–
White River at Goshen ADPC&E WHI52 BWD 3	1.87 (1-15)	5.65 (0-20)	8.62 (0-40)	9.61 (2-80) 4.0* (0-100)	1064 (180-4500) 405* (0-2000)	4.17 (0-19)	352.3 (40-1600) 107.0* (0-2990_	7.83 (1-50)	47.24 (10-290)	447 (100-2100)	0.19 (0-0.5)	5.86 (3-10)

Table a.10.8. Continued.

	Arsenic ug/L	Cadmium ug/L	Chromium ug/L	Copper ug/L	Iron ug/L	Lead ug/L	Manganese ug/L	Nickel ug/L	Zinc ug/L	Aluminum ug/L	Mercury ug/L	Selenium ug/L
Richland Creek BWD 4	--	--	--	3.0* (0-90)	176* (0-1540)	--	15.0* (0-350)	--	--	--	--	--
War Eagle BWD 9	--	--	--	5.0* (0-150)	187* (0-900)	--	17.0* (0-590)	--	--	--	--	--

* BWD soluble metals
** ADPC&E data
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concentrations. Actual exceedences of EPA (1986) criteria were infrequent and intermittent.

Meyer and Green (1984), using algal assay bottle tests (Green et al. 1978), attributed the inhibition of algal growth potential in upper Beaver Lake to heavy metals. Further investigations by Meyer et al. (1986) added additional support to this hypothesis. However, correlation between algal biomass and specific heavy metals was not possible because of low production of algal biomass. Meyer et al. (1986) attribute heavy metal concentrations to local geology (especially shale and relief) and groundwater hydrology.

USGS and ADPCE have monitored heavy metal concentrations in the West Fork of the White River (Table a.10.8). Based on EPA (1986) criteria and using average hardness concentrations of 80 mg $CaCO_3$/L for the West Fork of the White River and 61 mg $CaCO_3$/L for the White River near Goshen obtained from STORET, total metal concentrations for cadmium, copper, lead, zinc and mercury may occasionally exceed the EPA (1982) acute or chronic criteria. However, the analyses were based on total recoverable metal concentrations. Although EPA (1986) based the criteria on "acid soluble" values, EPA recommends that criteria be based on total recoverable metals because "acid soluble" analytical methods have not been approved. Therefore criteria based on total recoverable methods may or may not be overly protective.

The BWD collects water samples downstream of the confluence of three forks of the White River (i.e., BWD Station 10 at Wyman Bridge). This station is upstream of the City of Fayetteville's Waste Water Treatment Plant (WWTP). Nutrient concentrations were expected to reflect some intermediate value representing the contribution of the three Forks. However, mean orthophosphate and nitrate concentrations were lower at Wyman Bridge than in the three forks of the White River (Table a.10.7). This decrease probably reflects the incorporation of nutrients by biota and settling in Lake Sequoyah which receives the inflow from the White River and the Middle Fork of the White River. Ammonia concentrations at Wyman Bridge were intermediate between the West Fork of the White River and other two Forks.

BWD Station 13 is downstream of the City of Fayetteville WWTP. However, the period of record is short because BWD starting monitoring in 1990. There is another downstream station that has a longer period of record near Goshen, AR. The White River near Goshen is monitored by the USGS (Station 07048700) and/or the ADPCE (Station WH152) and the BWD (Station 3). Both the BWD and USGS/ADPCE data show higher nutrient concentrations (e.g., phosphorus and ammonia) than upstream stations (e. g. compare Figure a.10.5 to Figure a.10.7). These higher concentrations have been attributed to the City of Fayetteville WWTP discharge. Ammonia concentrations were potentially at levels that could cause toxic conditions for aquatic biota, depending on concurrent pH and temperature (Figure a.10.8).

Further evidence of the City's discharge impacting water quality of the White River is frequent DO concentrations less than 6.0 mg/L, (Figure a.10.9) the primary and critical DO standard for the Ozark Highlands Ecoregion (ADPCE 1988). The summer minimum concentrations are lower near Goshen than in the West Fork of White River (compare Figures a.10.9 and a.10.10). Impacts associated with the Fayetteville WWTP were observed during two synoptic surveys (24 September 1980 and 7 October 1980) conducted by the USGS in conjunction with the ADPCE. Dissolved oxygen was depressed downstream of WWTP and concentrations of ammonia nitrogen, nitrate nitrogen, and total phosphorus increased significantly (USGS 1983).

By July 1988, the City of Fayetteville had upgraded their WWTP and divided the waste stream flows between the Beaver Lake drainage basin and the Illinois River drainage basin. There are indications that water quality improvements are being attained. Figures a.10.5 and a.10.8 indicate total phosphorus and ammonia nitrogen concentrations are less since the treatment plant came on line. In addition, Figure a.10.9 indicates the summer DO minima are not as low as past summer lows.

a.10.1.3.3 Other Tributaries

Two additional major drainages to Beaver Lake are the Richland Creek and War Eagle Creek drainage basins. Both the USGS and BWD monitor Richland and War Eagle Creeks.

DO concentrations at War Eagle Creek and Richland Creek were adequate to support aquatic biota (Table a.10.7). BWD total orthophosphate and USGS total

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WHITE RIVER NR GOSHEN ARK 05143 ARKANSAS
W
WHITE RIVER SW LOWER MISSISSIPPI

665 PHOS-TOT MG/L P

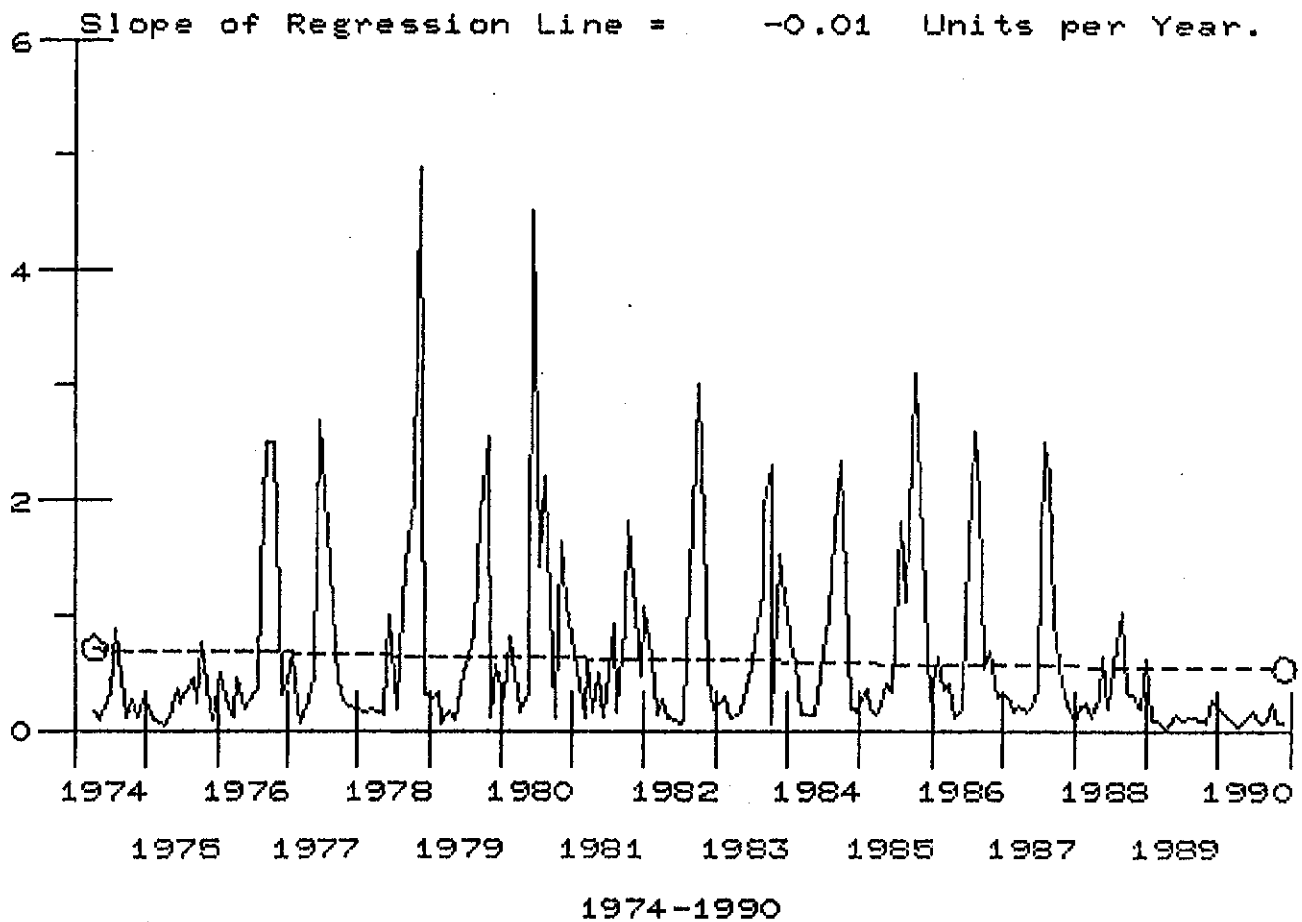

Figure a.10.7. Total phosphorus concentrations in the White River near Goshen, AR.

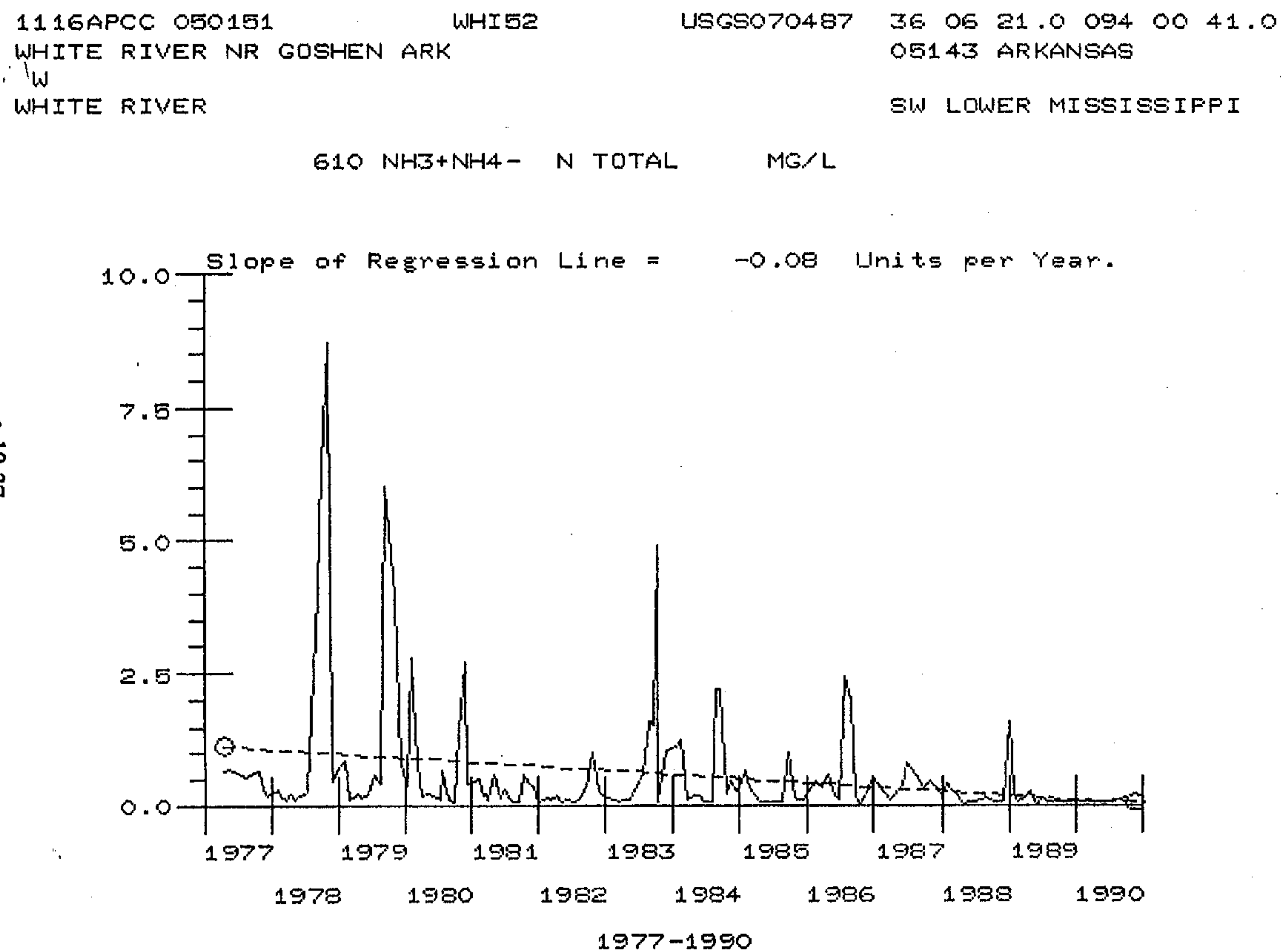

Figure a.10.8. Total ammonia-nitrogen concentrations in the White River near Goshen, AR.

1116APCC 050151 WHI52 USGS070487 36 06 21.0 094 00 41.0
WHITE RIVER NR GOSHEN ARK 05143 ARKANSAS
\W
WHITE RIVER SW LOWER MISSISSIPPI

300 DO MG/L

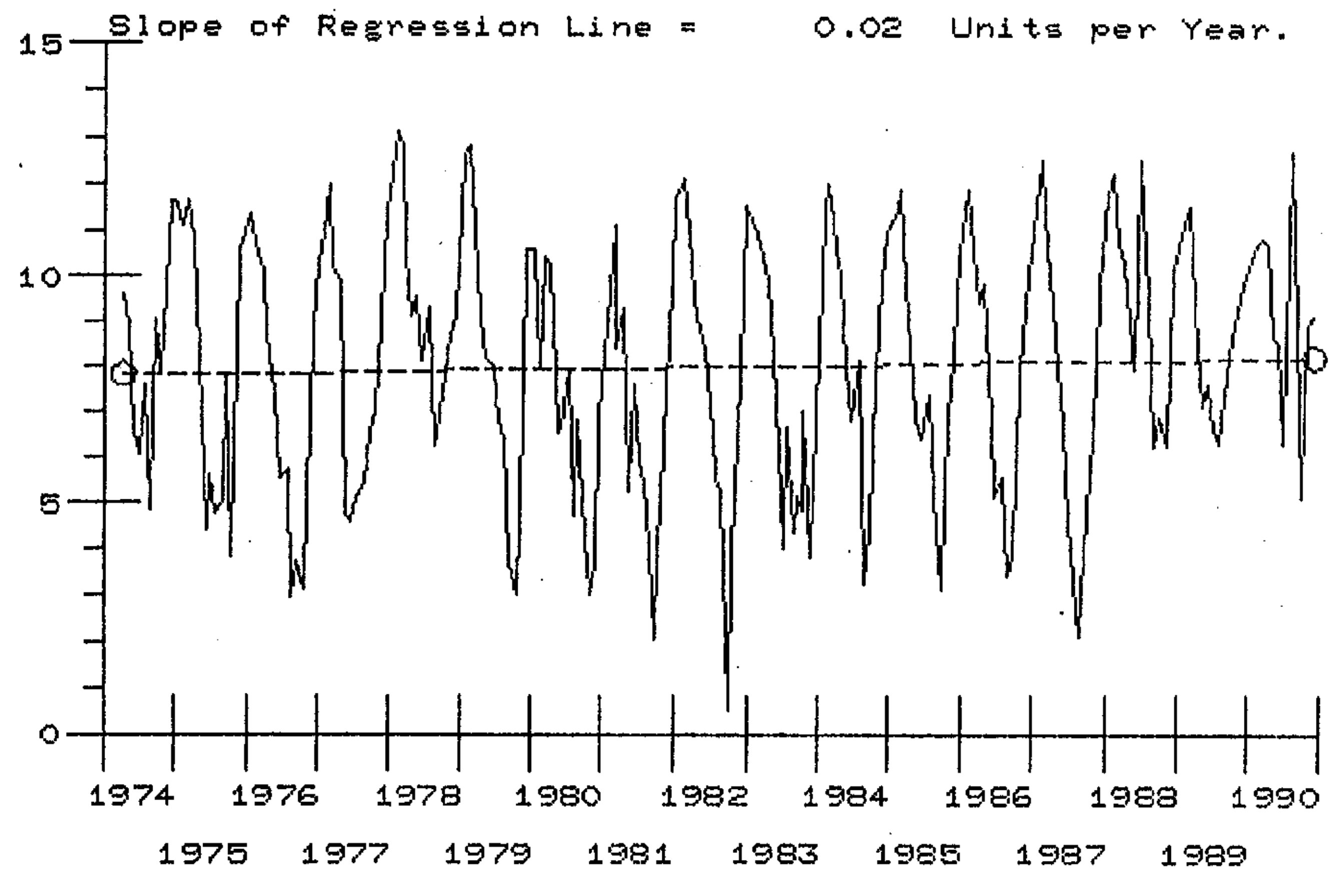

Figure a.10.9. DO concentrations in the White River near Goshen, AR.

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W
WHITE RIVER SW LOWER MISSISSIPPI

300 DO MG/L

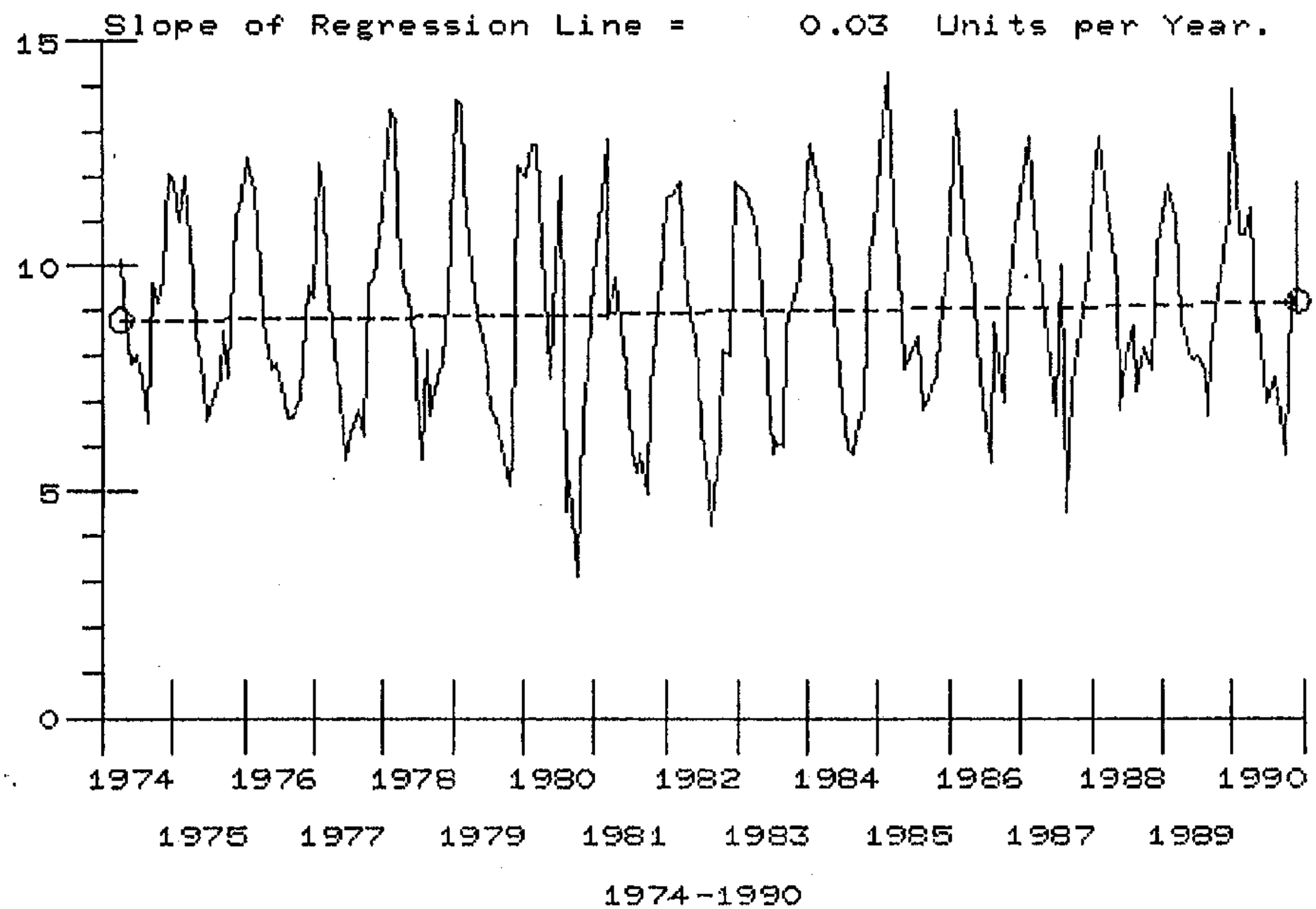


Figure a.10.10. DO concentrations in the West Fork of the White River.

phosphorus concentrations were generally within the State's guideline of 0.1 mg/L of total phosphorus (ADPCE 1988) at War Eagle. However, higher values did occur on occasion (e.g. Figure a.10.11). Excursions of total phosphorus at Richland Creek seem to occur more frequently than at War Eagle. However, the period of record is too short for Richland Creek (1984-1988) and samples were collected too infrequently at the surface to draw a conclusion (Figure a.10.12).

Nitrate concentrations were generally at maximum concentrations in the winter and at minimal concentrations in the summer as in the upper White River drainage basins (Figure a.10.13). A seasonal pattern was not apparent for ammonia concentrations.

Fecal coliforms in War Eagle Creek occasionally exceeded the primary contact standard of 200 colonies/100 mL. The mean number of colonies per 100mL was 131 and the maximum was 1500 colonies/100mL. However, the data were collected too infrequently to make a determination of significance.

Iron and manganese concentrations occasionally exceeded the EPA (1986) domestic water supply criteria of 0.3 mg/L and 0.05 mg/L, respectively (Table a.10.8).

a.10.1.3.4 In-Lake Studies

In-Situ Profiles: The USGS routinely measures temperature, DO, pH and conductivity vertical profiles near the dam (Station 07049690). Other profile studies have been conducted by Mitchell and Stevens (1973), Meyer (1974) and EPA (1977). The limnological characteristics exhibited by the reservoir are generally similar between these studies. Figures a.10.14 through a.10.25 show NES temperature and DO profile data from the headwaters of Beaver Lake to the dam. These figures provide an idea of the longitudinal variability in temperature and DO in the reservoir. Figures a.10.26 through a.10.31 show temperature and DO profile data for Beaver Lake near the dam during the months February, April, August (or September) and October (or November in 1974, 1981, and 1988.

In the winter, temperatures and DO concentrations are generally homogenous throughout the water column. By April, the reservoir is beginning to stratify from the upper pool to the dam. A metalimnetic DO minimum occurs in the lower reach of the

112WRD 07049050
BEAVER LK @ WAR EAGLE AR
B

36 16 03.0 093 56 35.0
05007 ARKANSAS

665 PHOS-TOT MG/L P

Slope of Regression Line = 0.00 Units per Year.

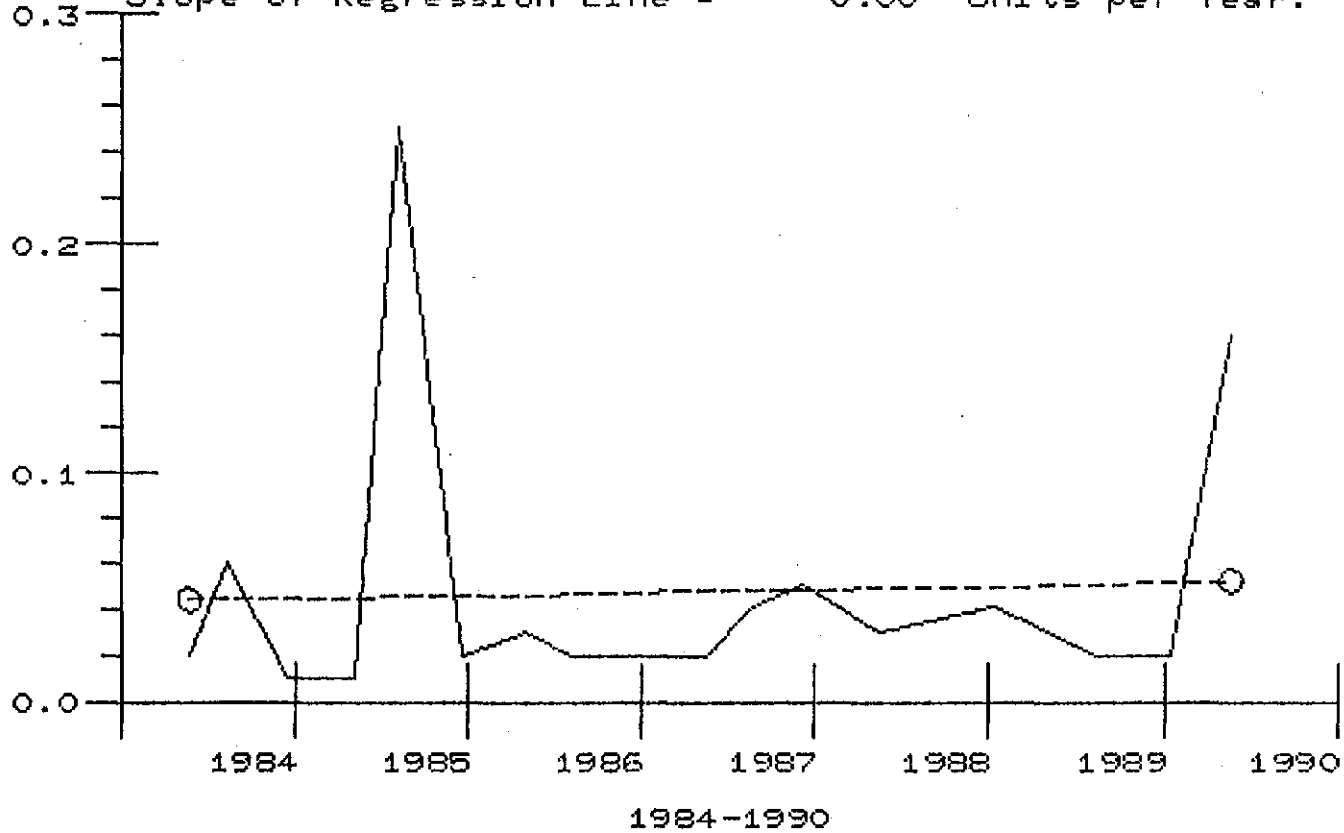


Figure a.10.11. USGS total phosphorus concentrations in War Eagle Creek at War Eagle, AR.

112WRD 07048800 00 00 00.0 000 00 00.0
RICHLAND CREEK AT GOSHEN, ARK. 05143 ARKANSAS
W

665 PHOS-TOT MG/L P

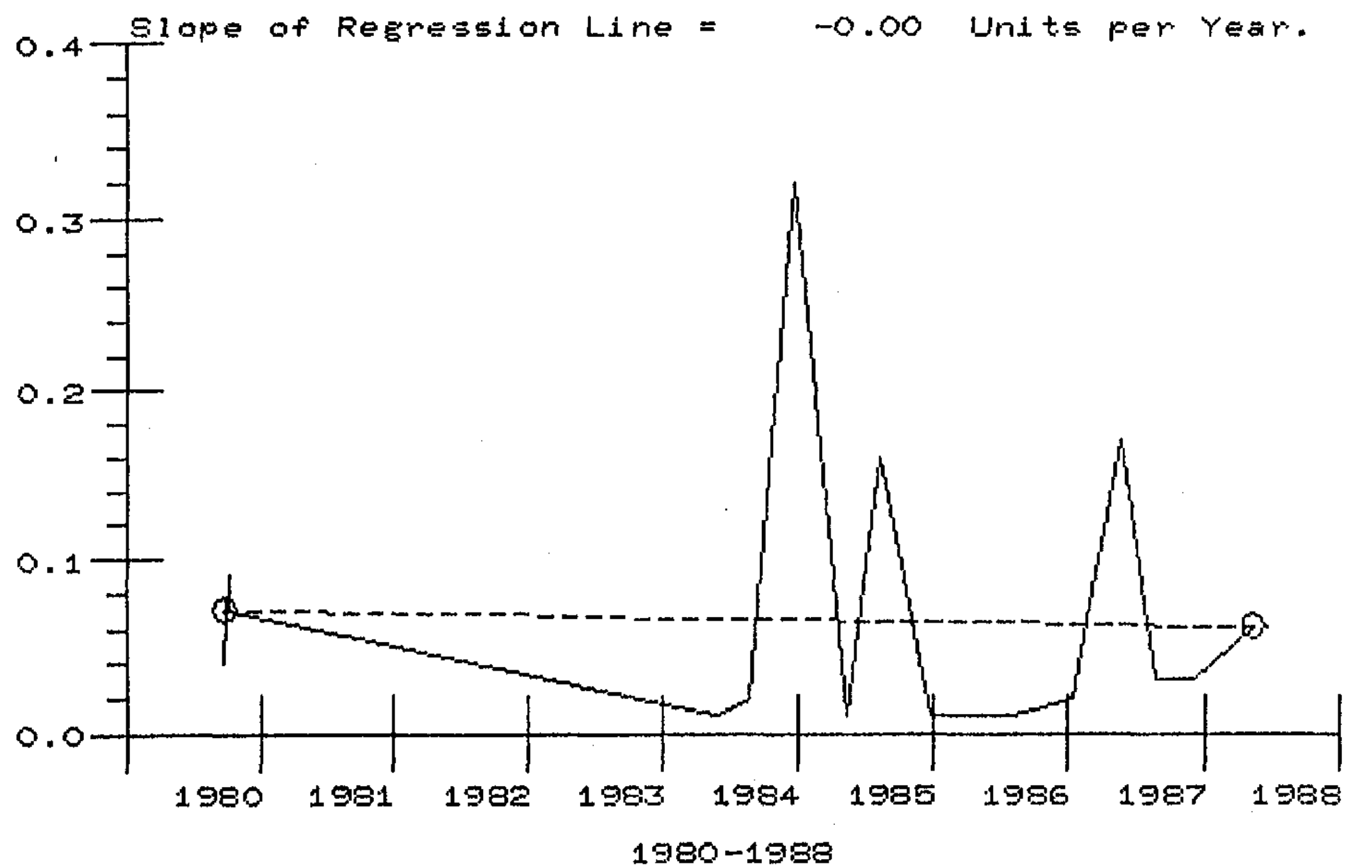


Figure a.10.12. Total phosphorus concentrations in Richland Creek near Goshen, AR.

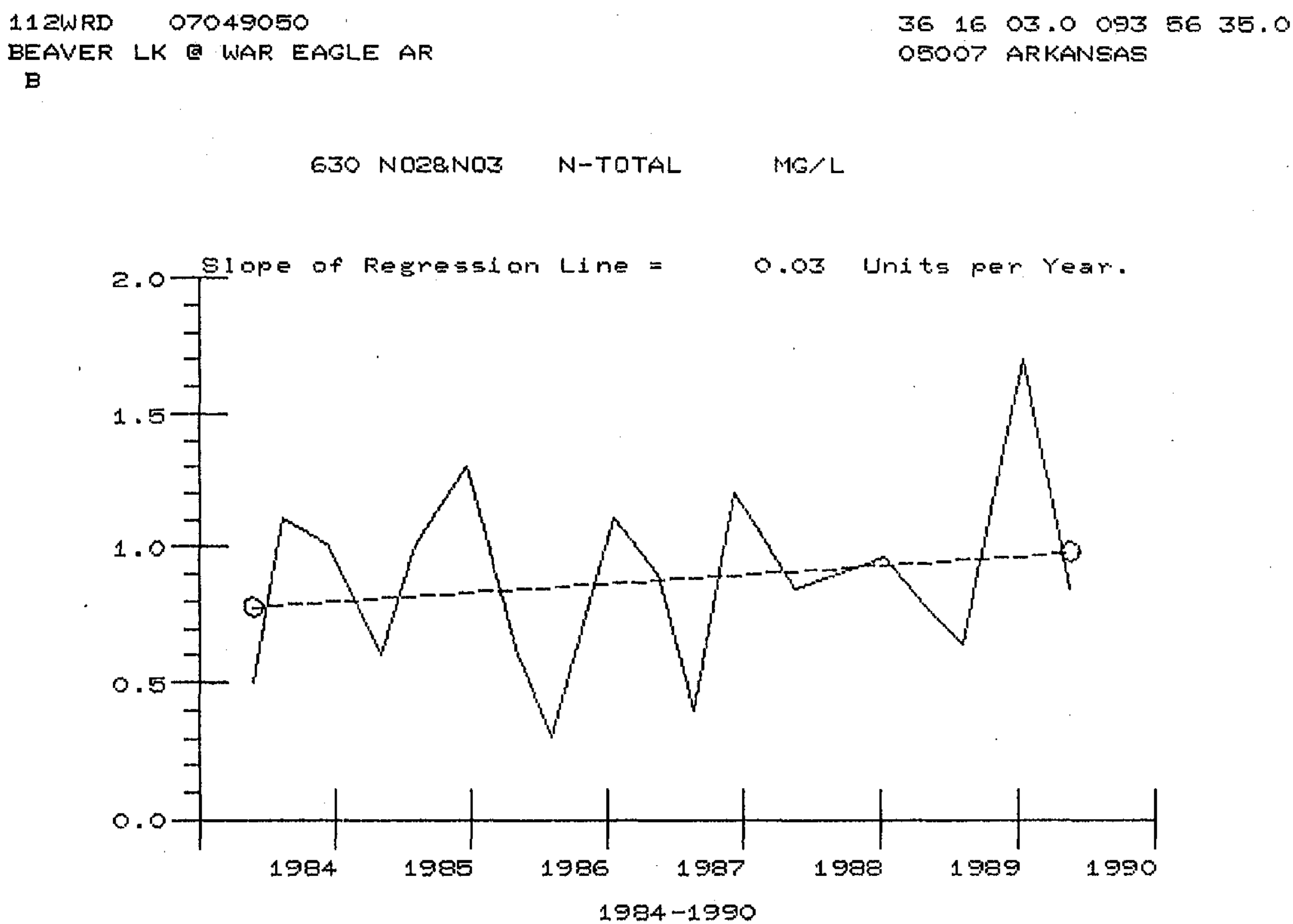
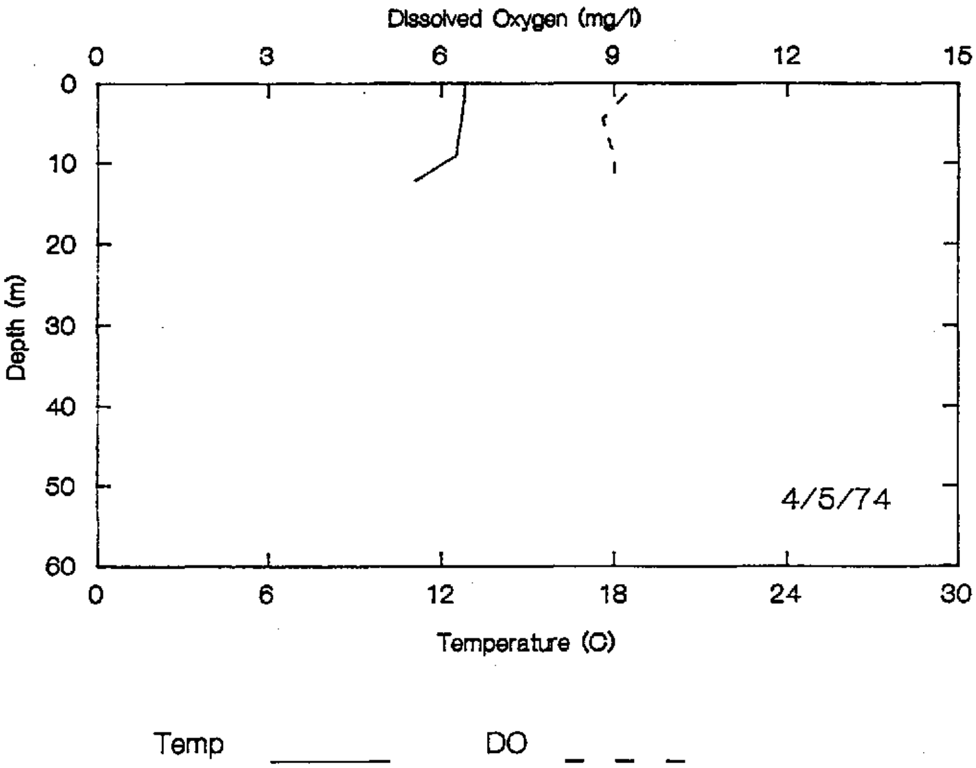


Figure a.10.13. Nitrate plus nitrite concentrations at War Eagle.



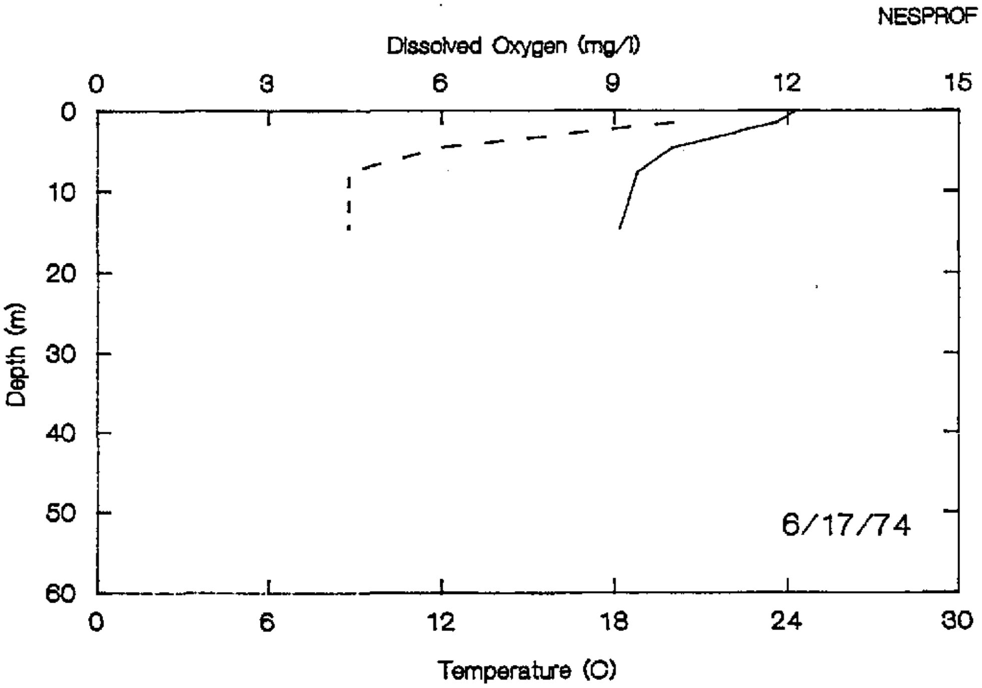


Figure a.10.14. Temperature and DO profiles for April and June 1974 at EPA Stations 050106 in the White River downstream of Goshen.

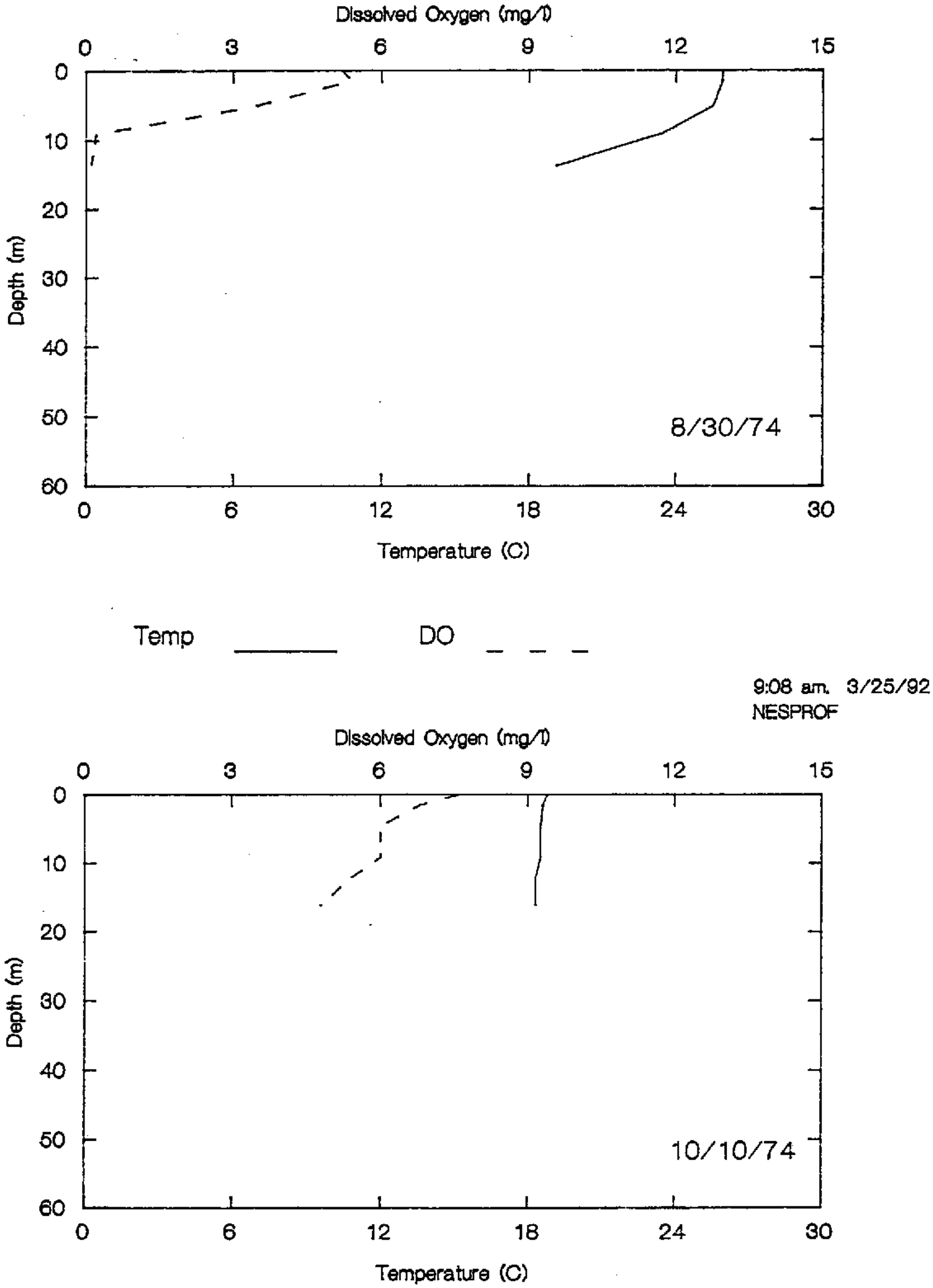


Figure a.10.15. Temperature and DO profiles for August and October 1974 at EPA Station 050106 in the White River downstream of Richland Creek.

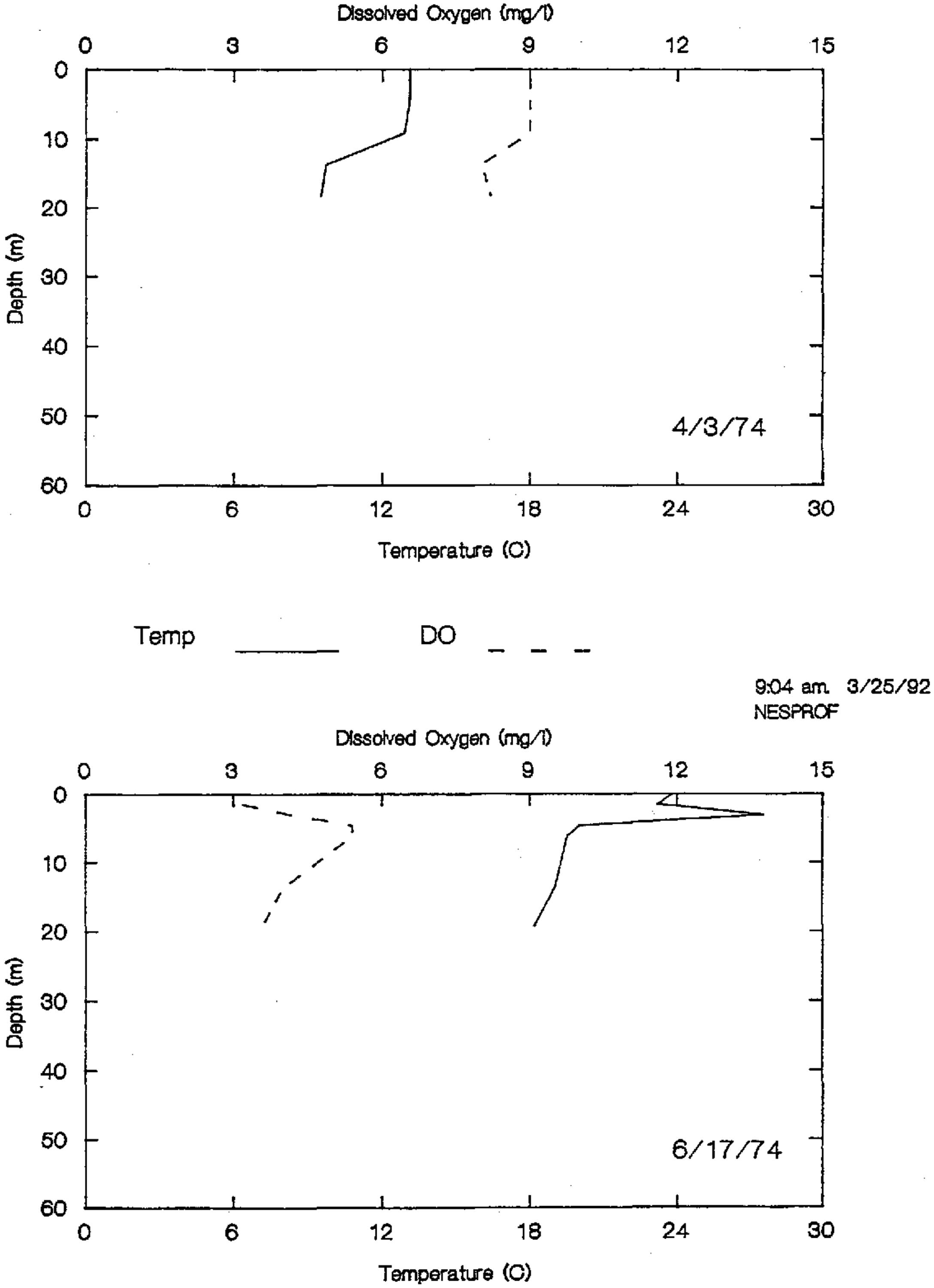


Figure a.10.16. Temperature and DO profiles for April and June 1974 at EPA station 050105 in Beaver Lake near War Eagle Cove.

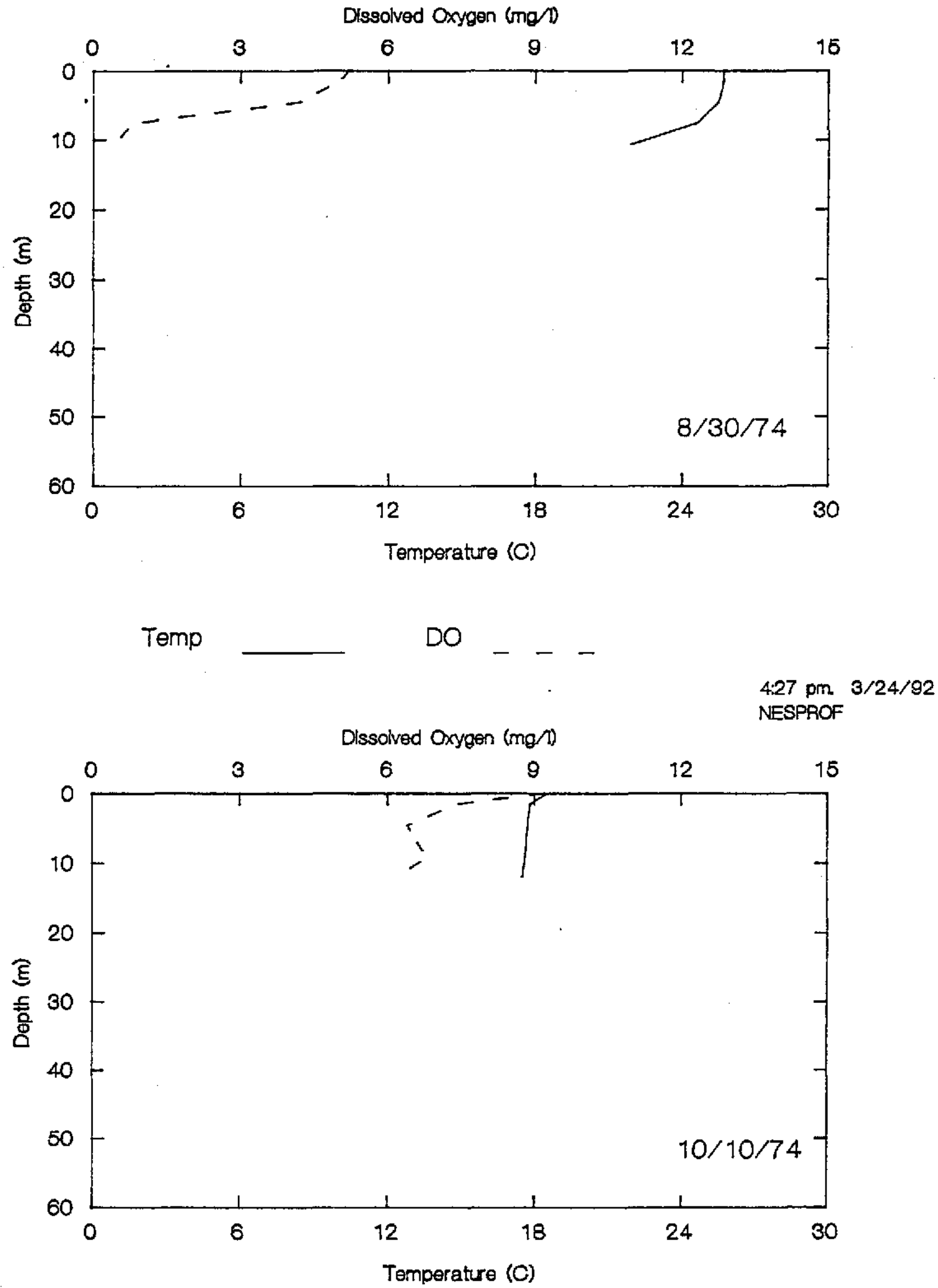


Figure a.10.17. Temperature and DO profiles for August and October 1974 at EPA Station 050105 in Beaver Lake Near War Eagle Cove.

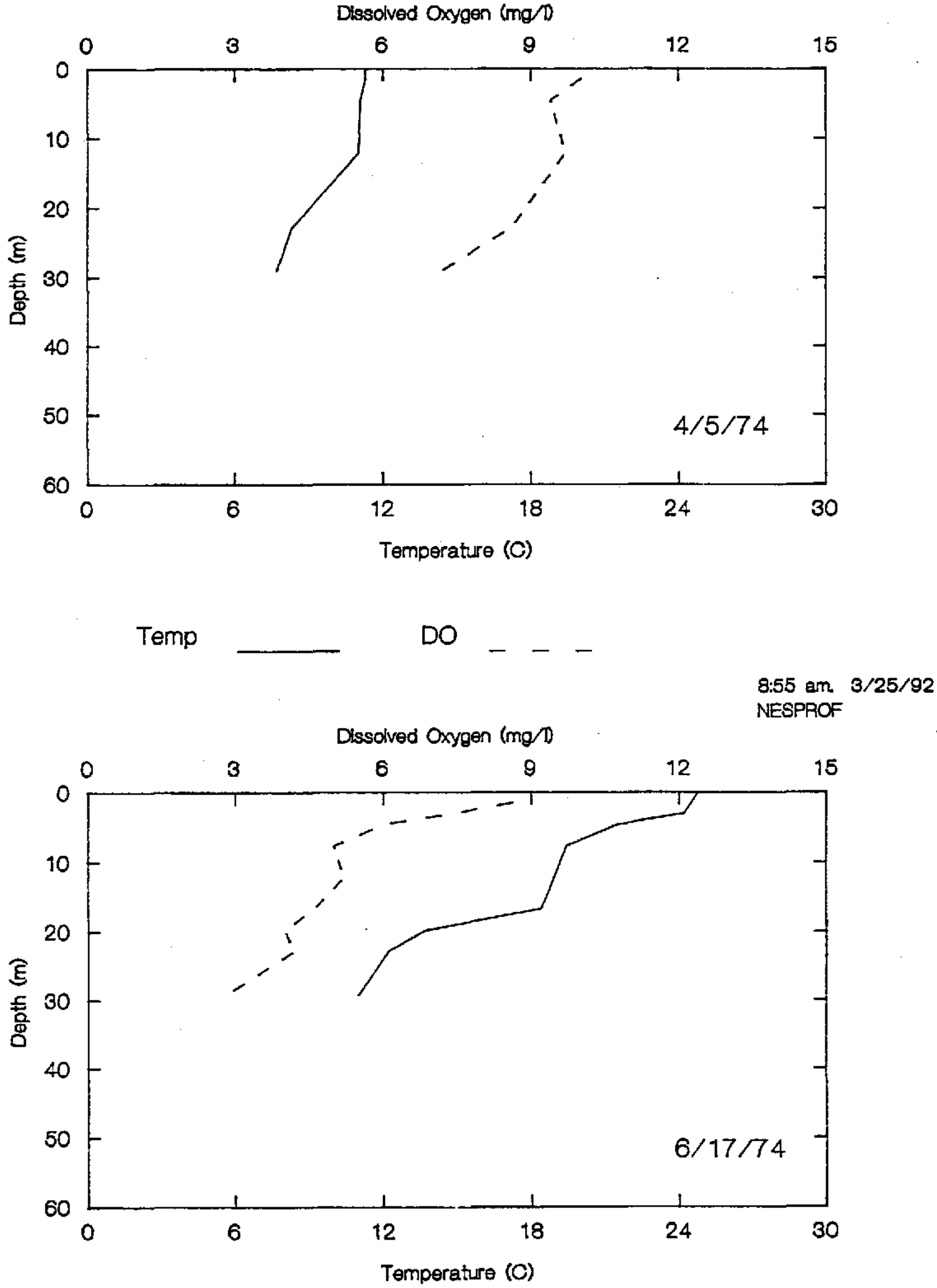


Figure a.10.18. Temperature and DO profiles for April and June 1974 at EPA Stations 050104 in Beaver Lake near Horseshoe Bend.

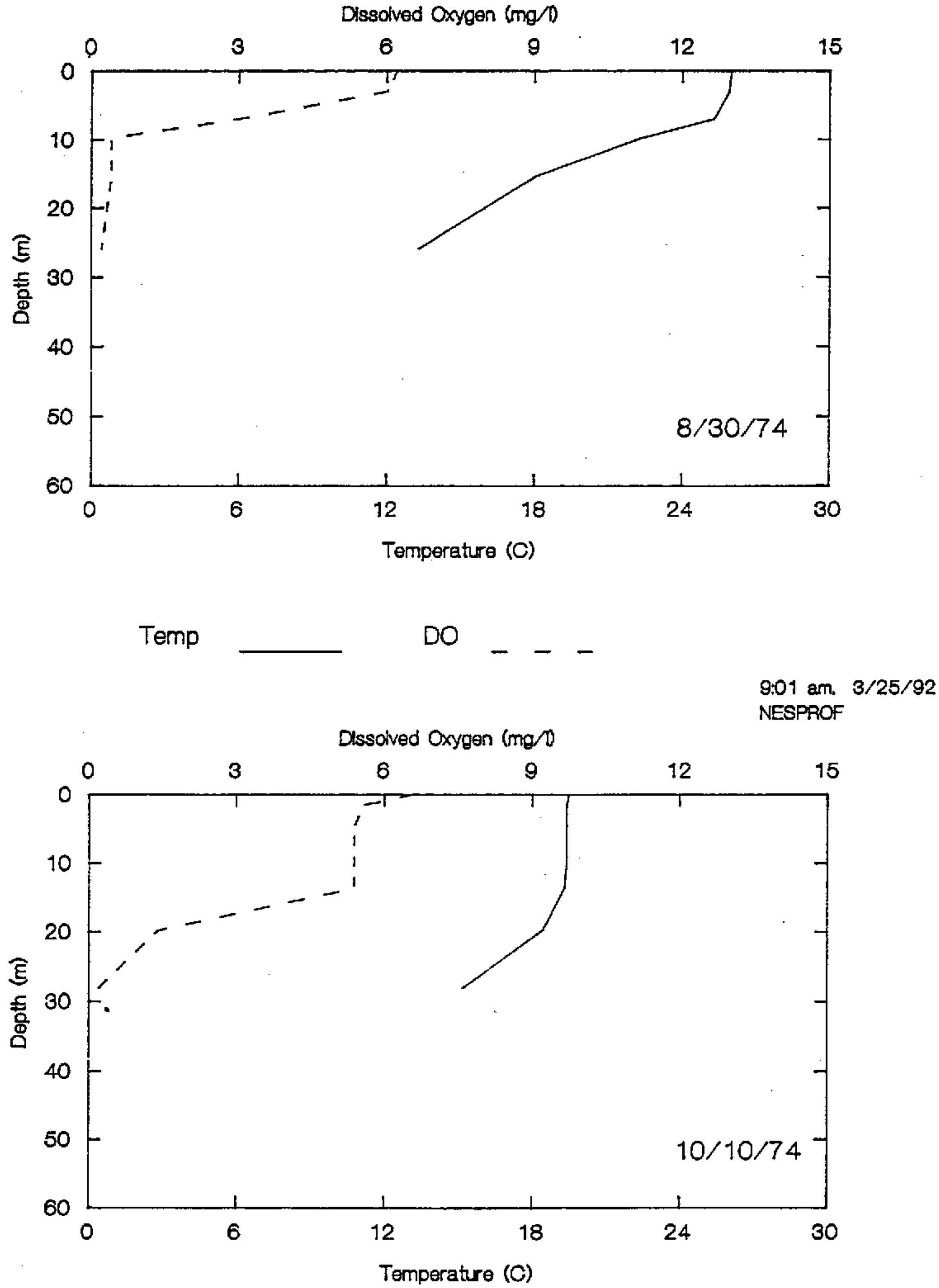


Figure a.10.19. Temperature and DO profiles for August and October 1974 at EPA Station 050104 in Beaver Lake near Horseshoe Bend.

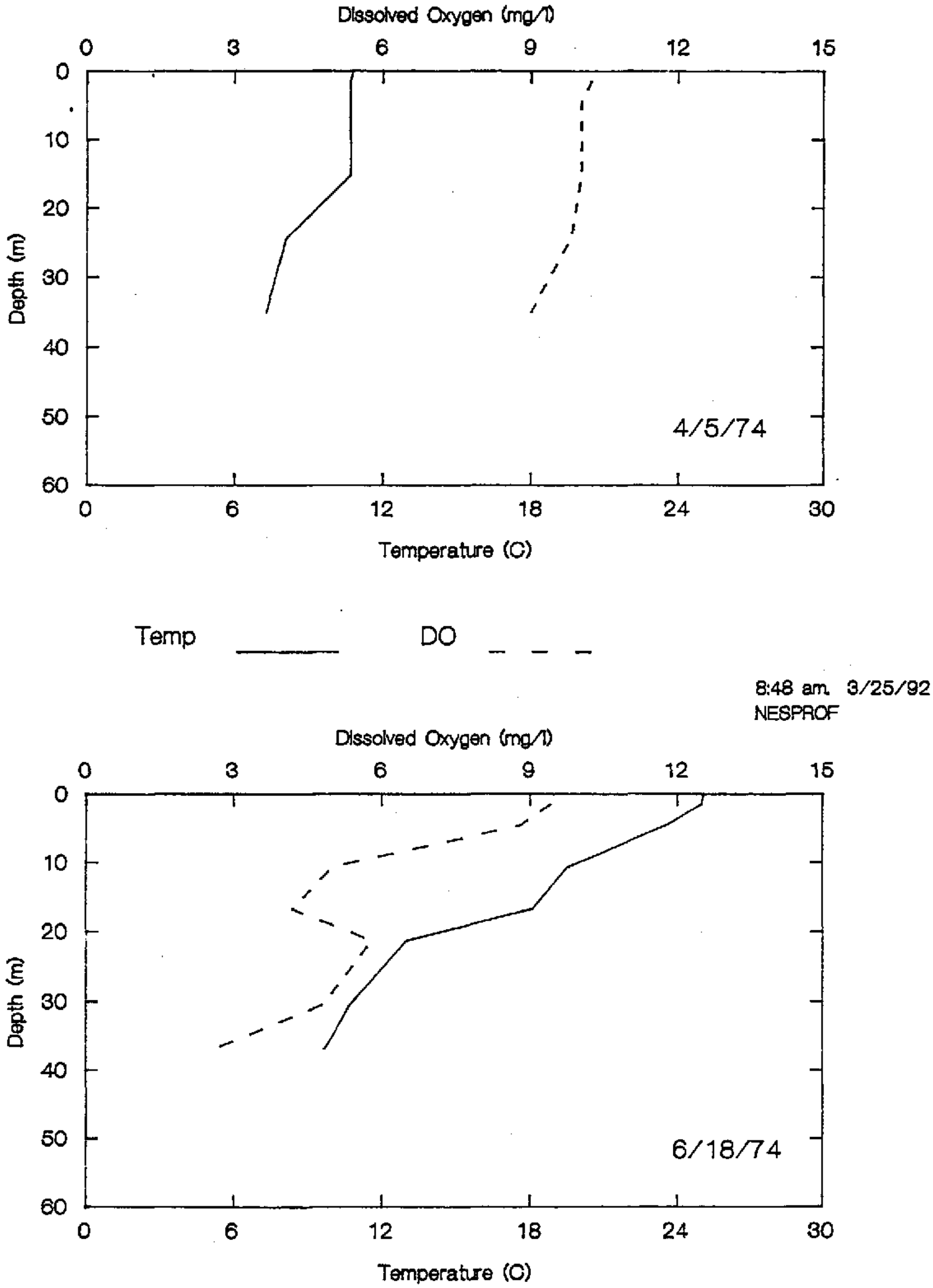


Figure a.10.20. Temperature and DO profiles for April and June 1974 at EPA Station 050103 in Beaver Lake near Shaddox Branch.

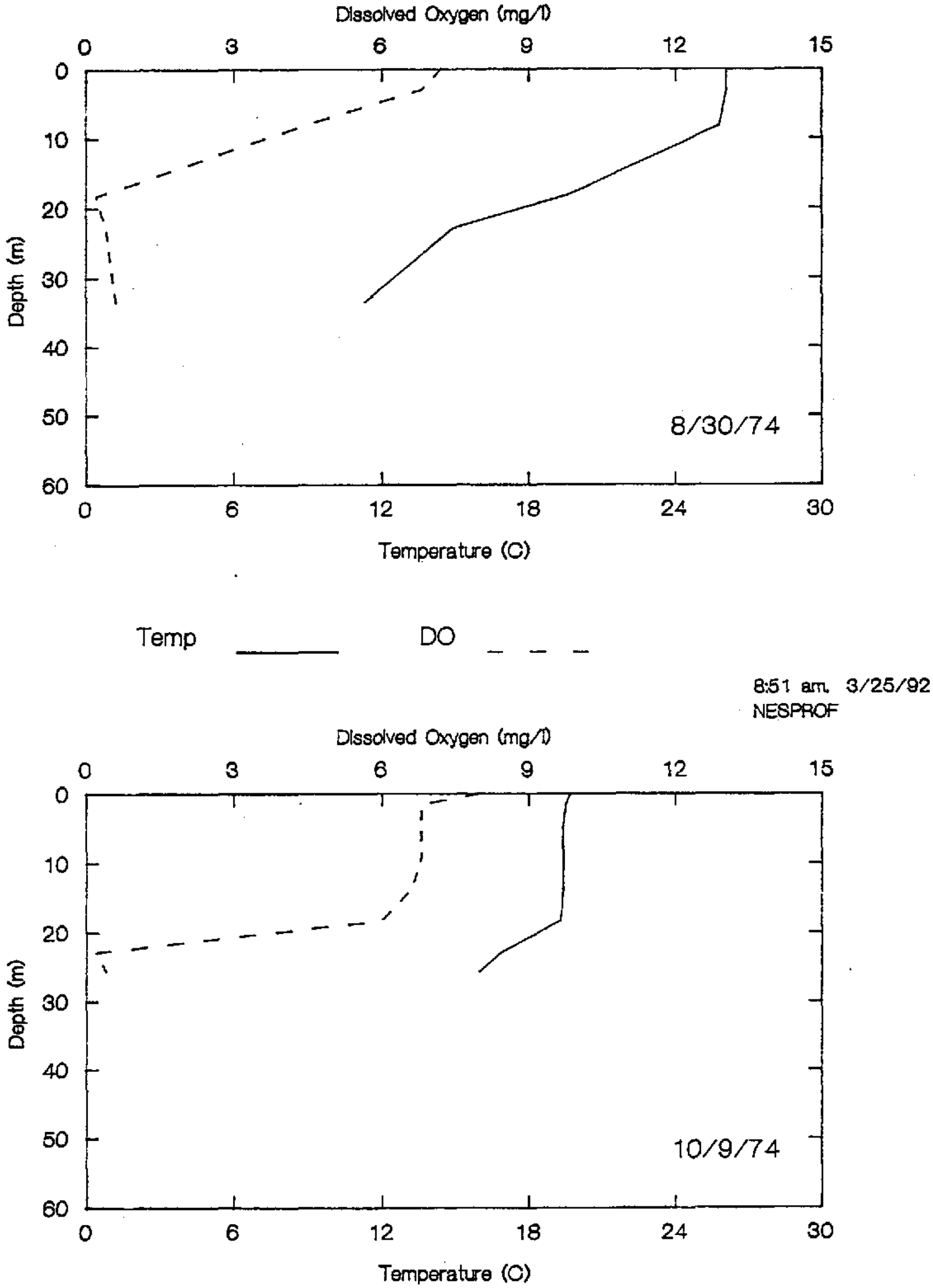


Figure a.10.21 Temperature and DO profiles for August and October 1974 at EPA Station 050103 in Beaver Lake near Shaddox Branch.

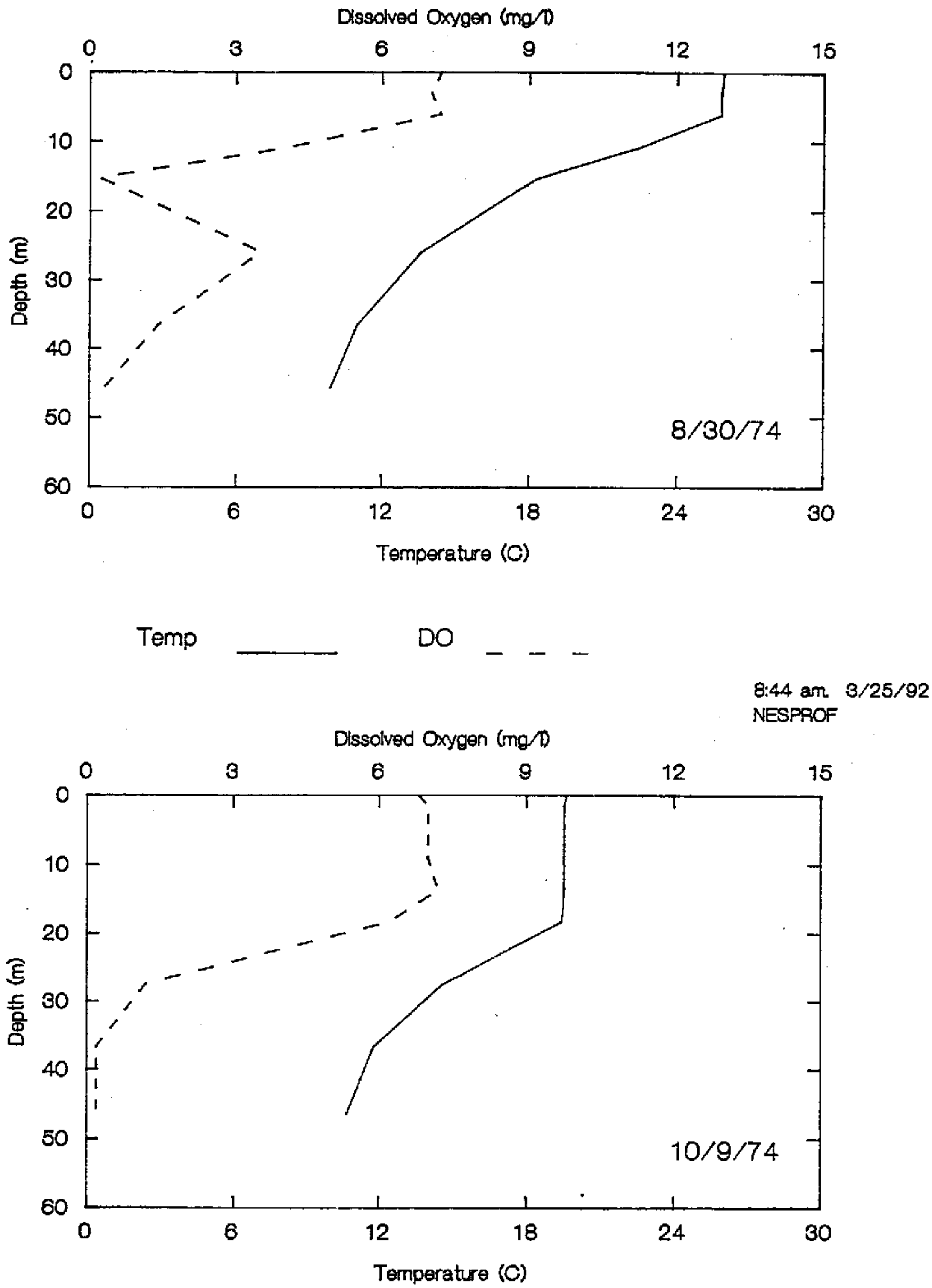


Figure a.10.22. Temperature and DO profiles for August and October 1974 at EPA Station 050102 in Beaver Lake near Hall Spring Branch.

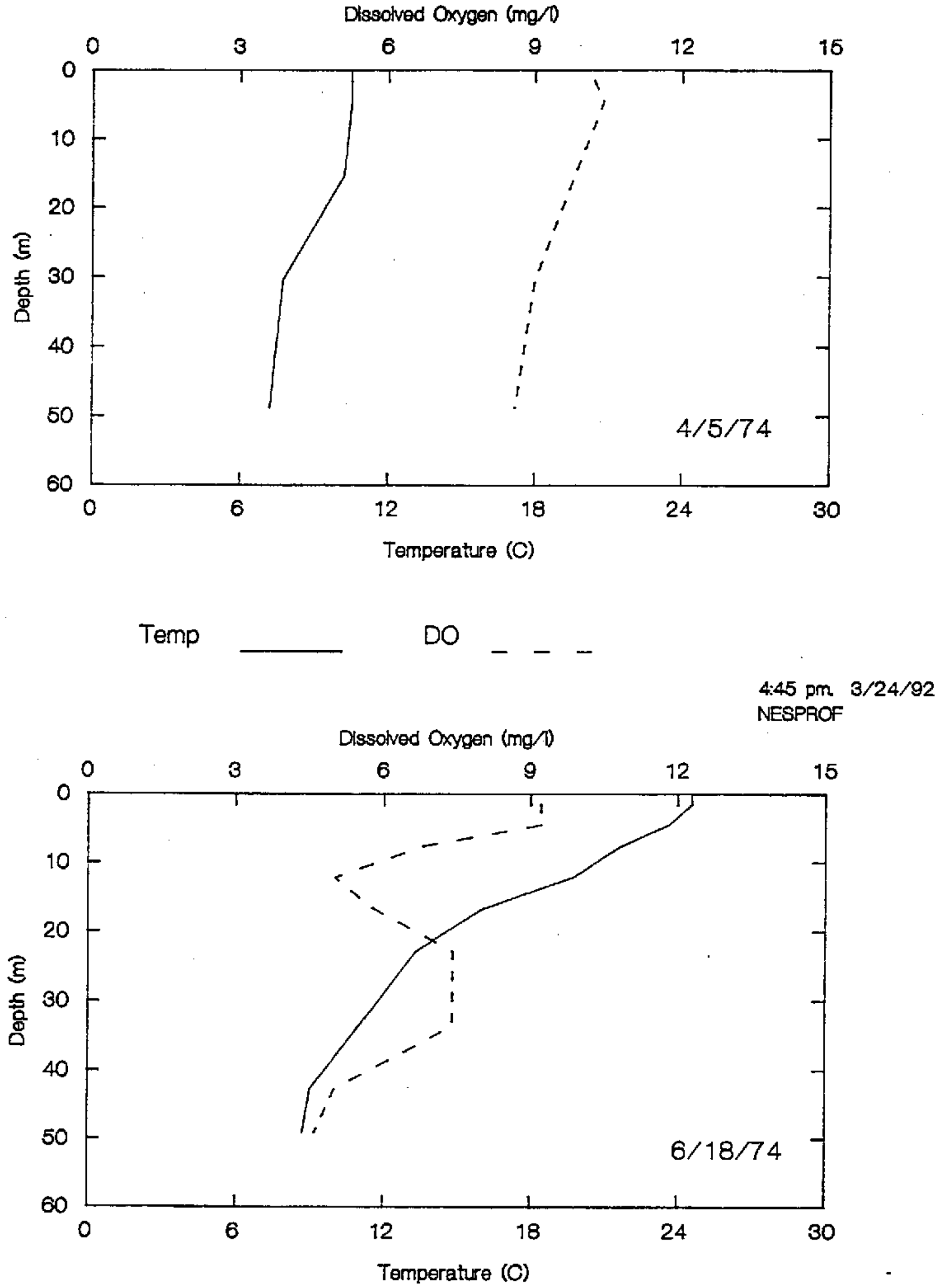


Figure a.10.23. Temperature and DO profiles for April and June 1974 at EPA Station 050102 in Beaver Lake near Hall Spring Branch.

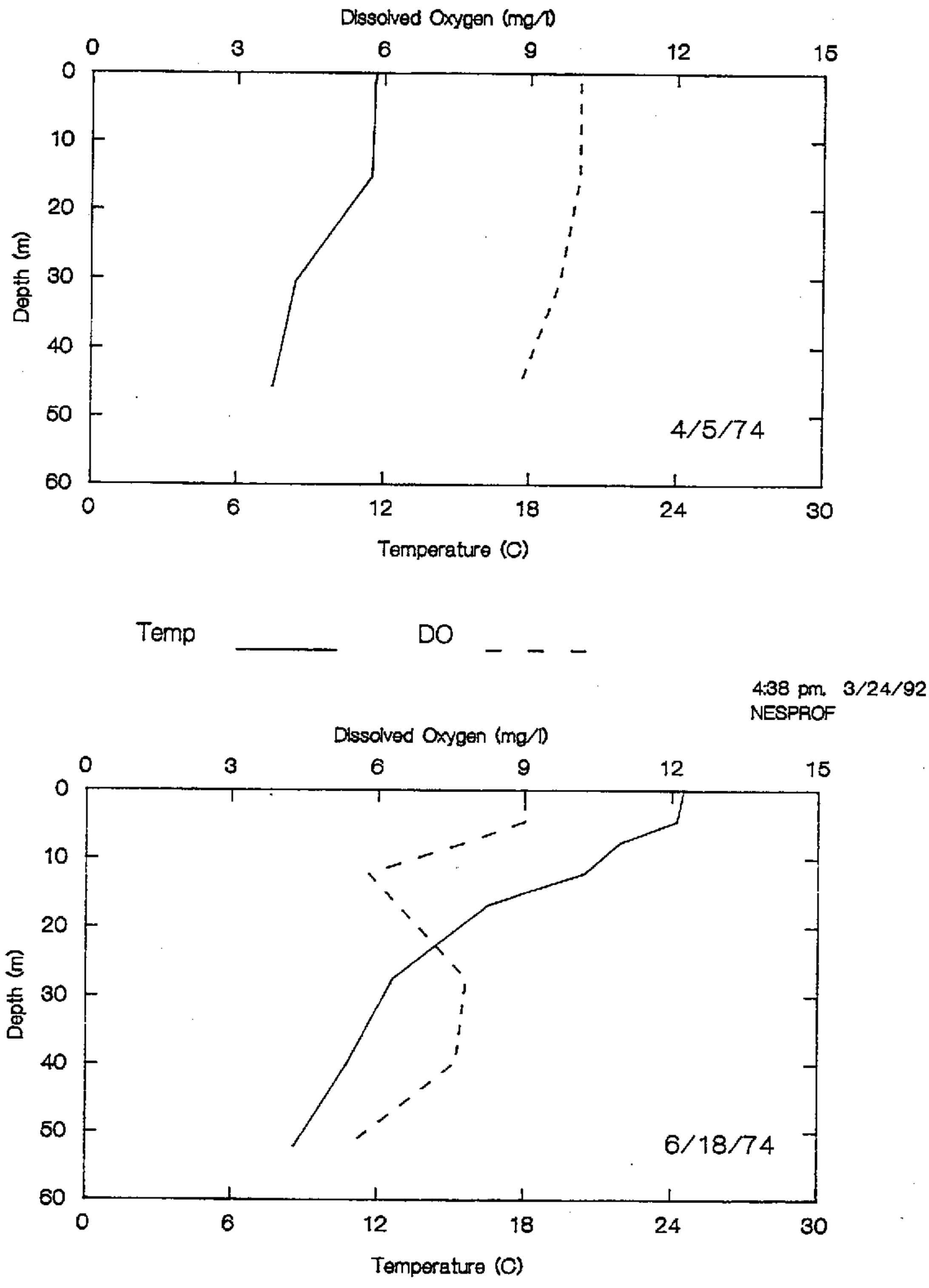


Figure a.10.24. Temperature and DO profiles for April and June 1974 at EPA Station 050101 in Beaver Lake near Beaver Lake Dam.

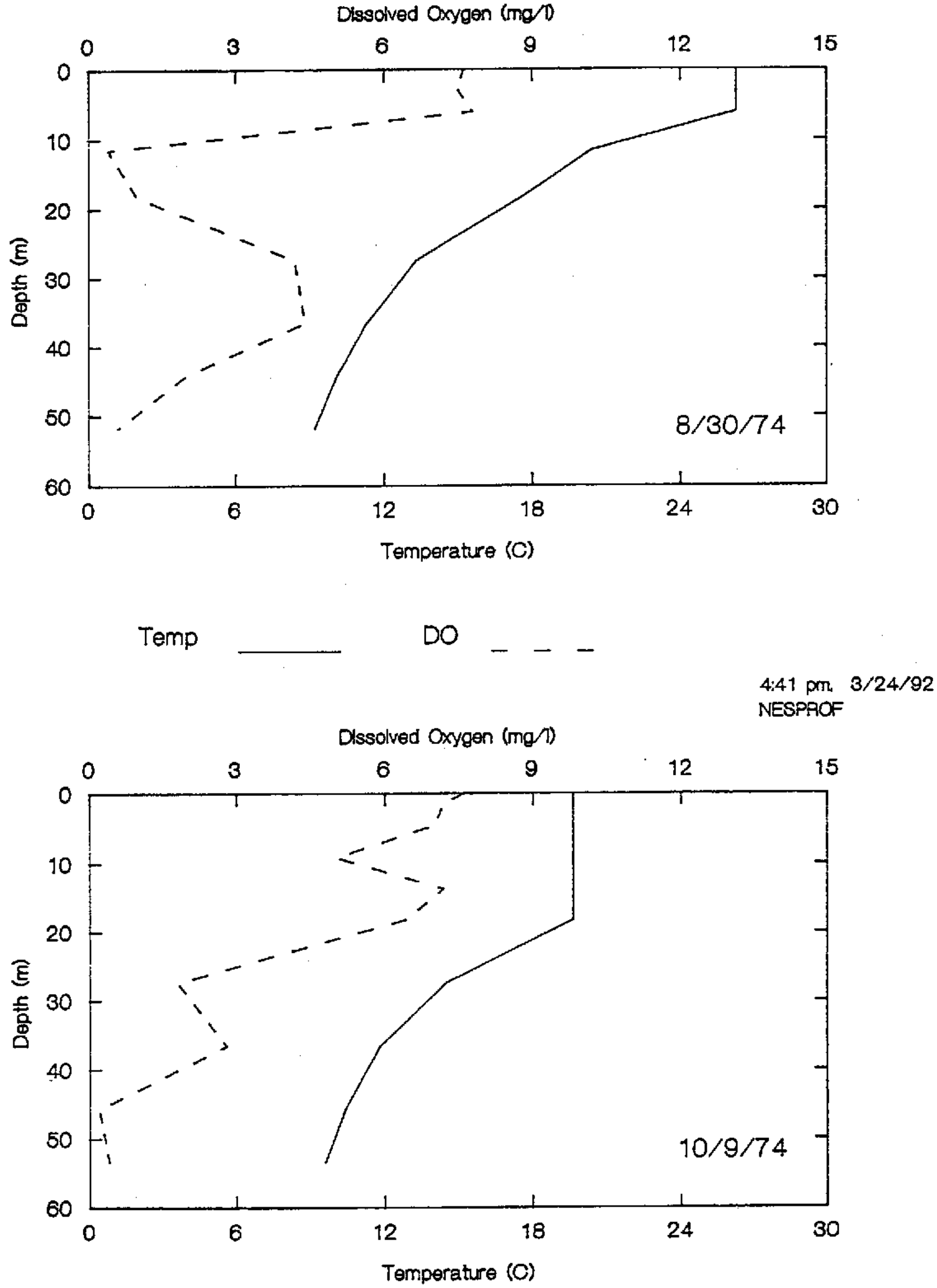


Figure a.10.25. Temperature and DO profiles for August and October 1974 at EPA Station 050101 in Beaver Lake near Beaver Lake Dam.

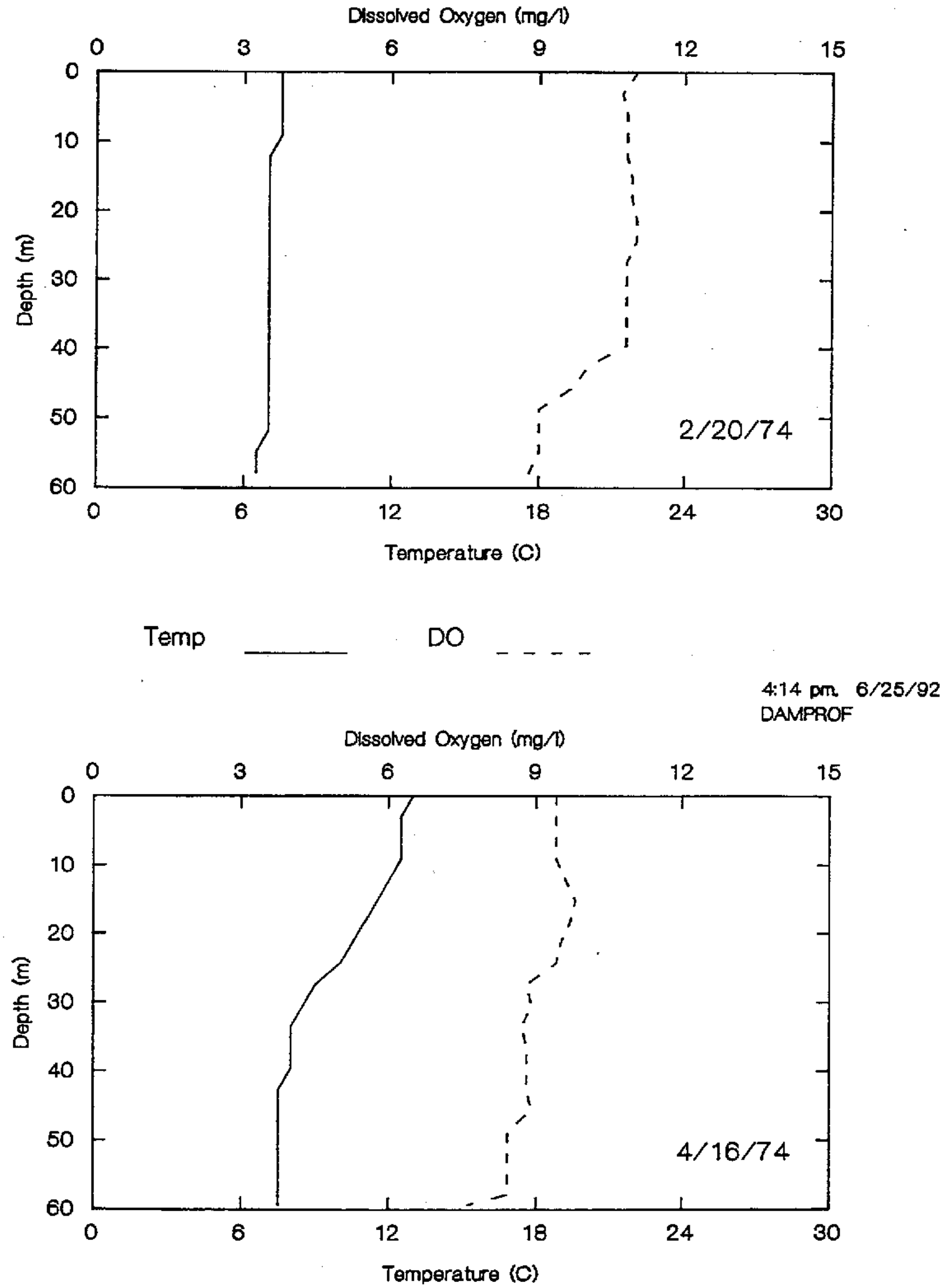


Figure a.10.26. Temperature and DO profiles for February and April 1974 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.

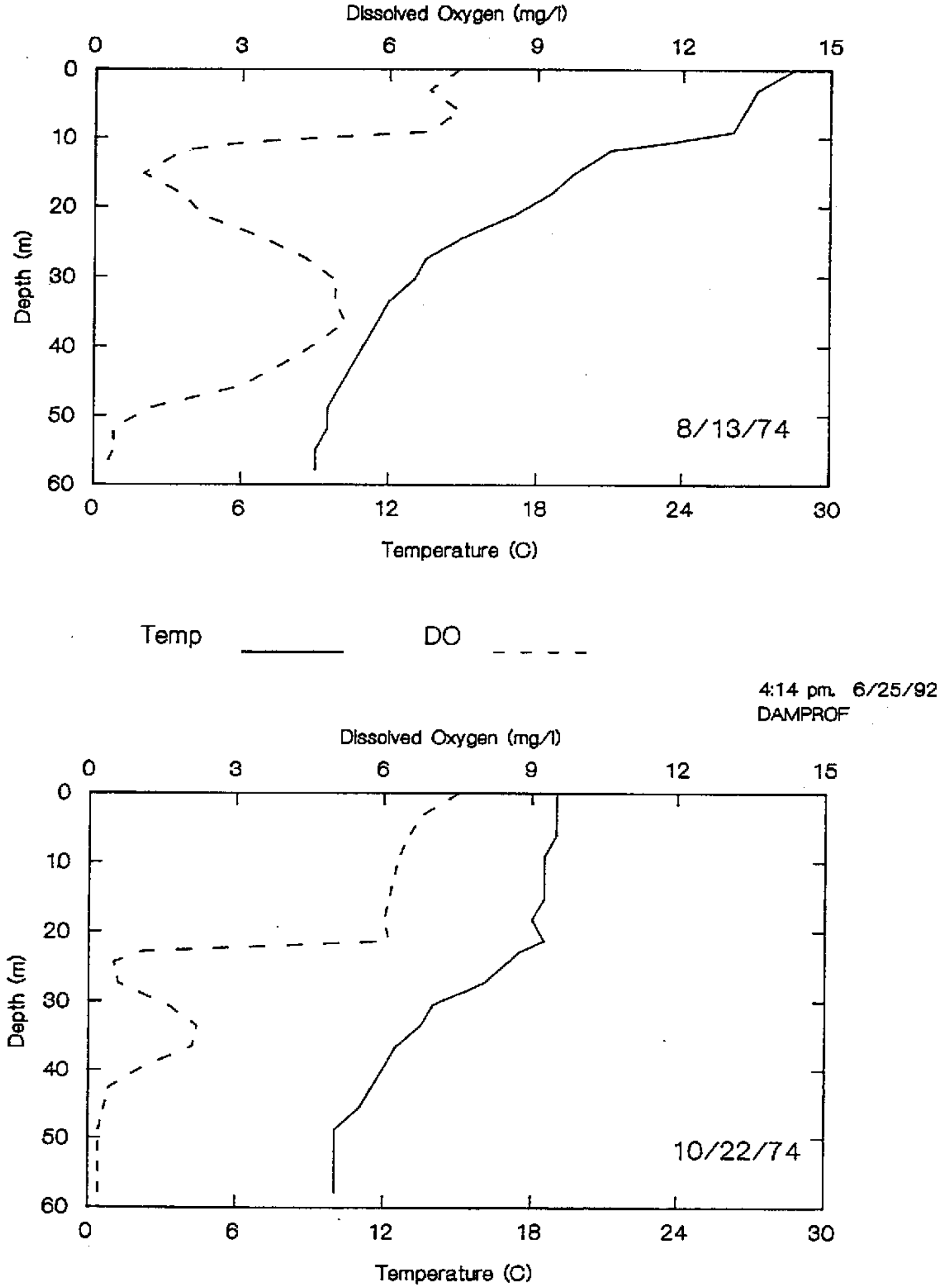


Figure a.10.27. Temperature and DO profiles for August and October 1974 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.

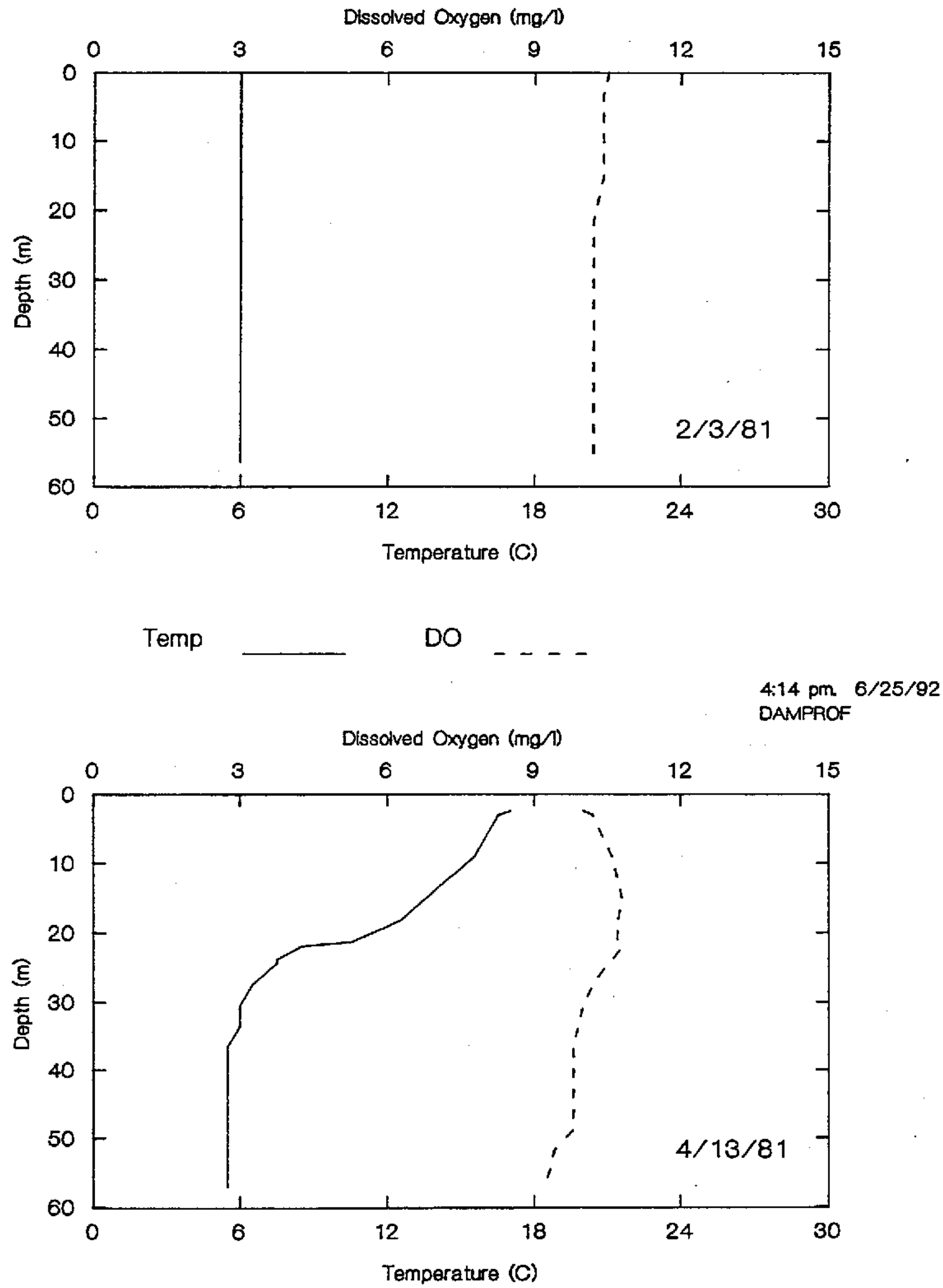


Figure a.10.28 Temperature and DO profiles for February and April 1981 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.

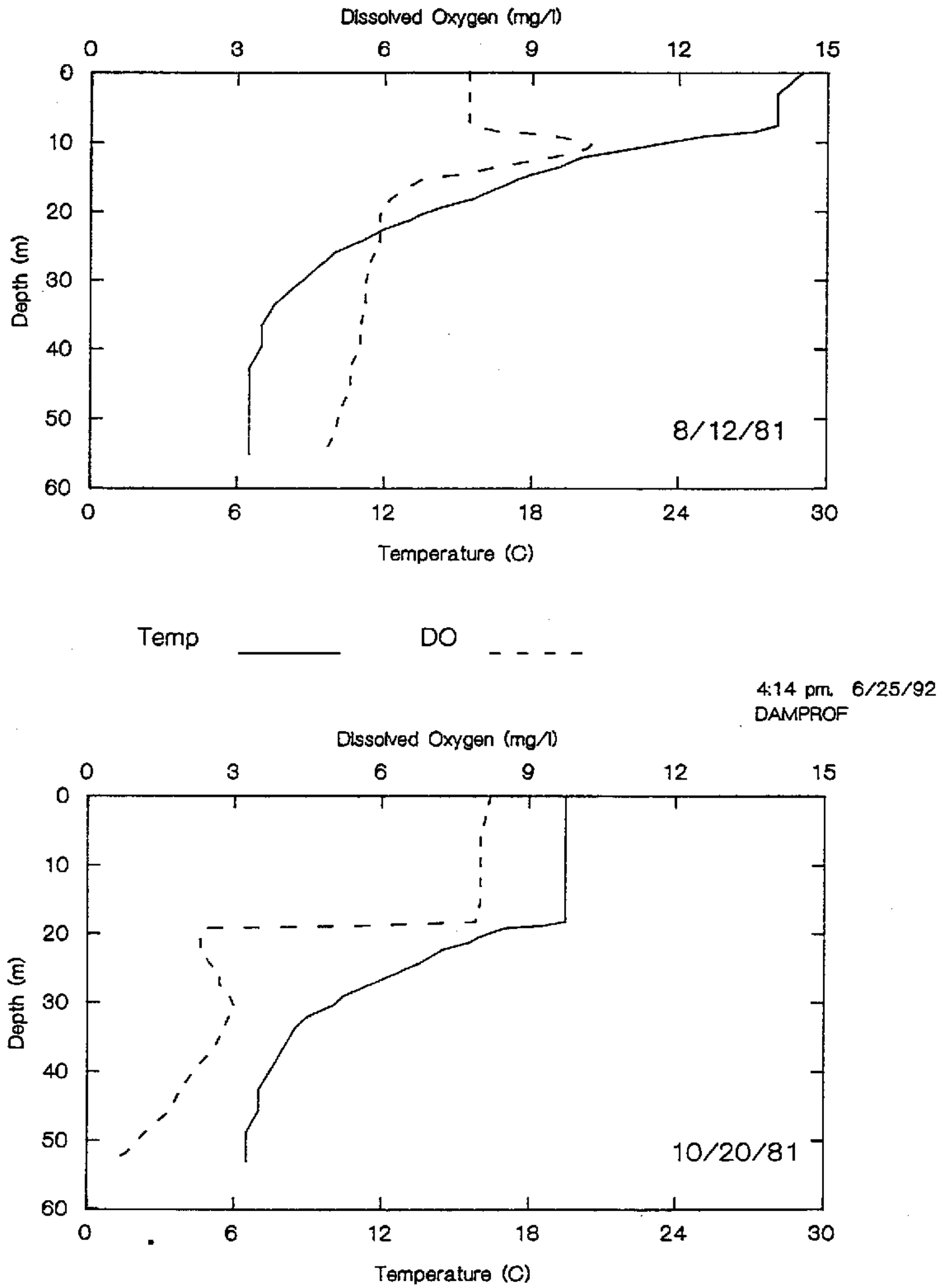
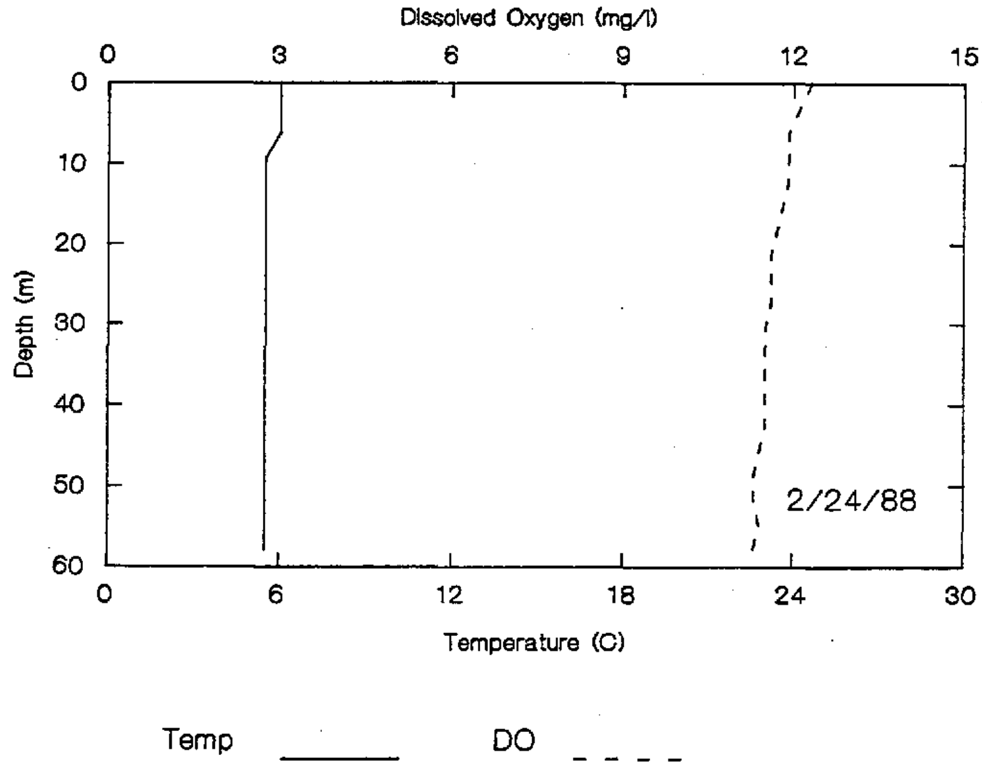


Figure a.10.29. Temperature and DO profiles for August and October 1981 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.



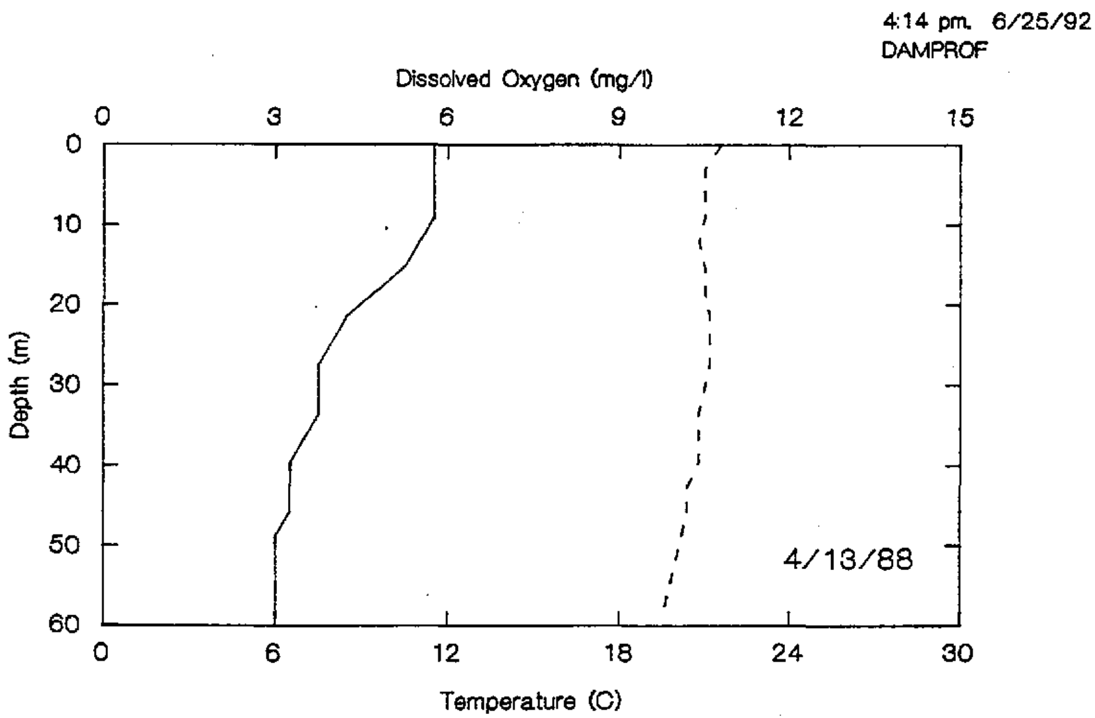


Figure a.10.30. Temperature and DO profiles for February and April 1988 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.

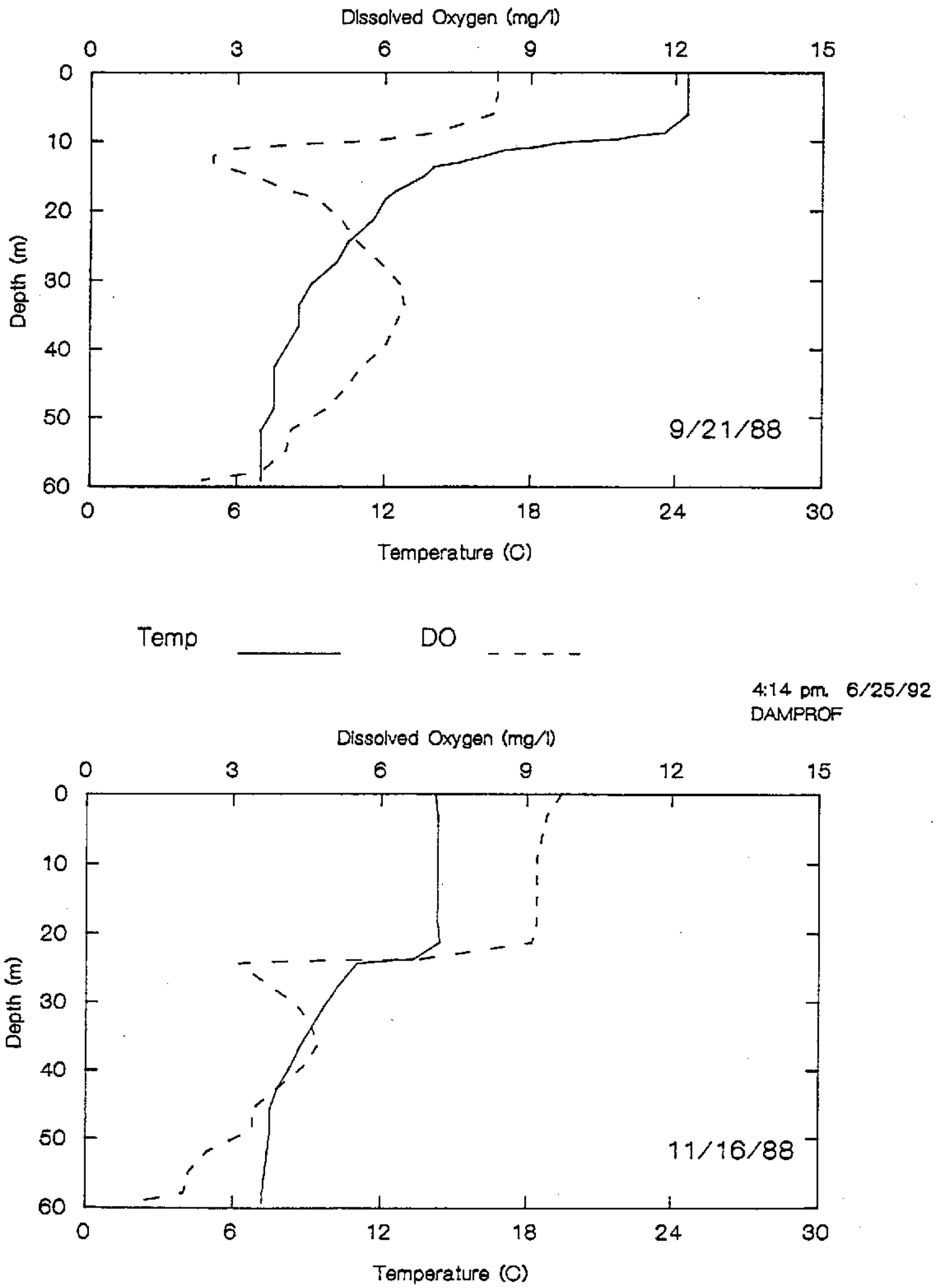


Figure a.10.31. Temperature and DO profiles for September and November 1988 at USGS Station 07049690 in Beaver Lake near Beaver Lake Dam.

pool by June and between June and August the metalimnetic minimum intensifies. By August, the metalimnetic minimum is anoxic or approaching anoxic conditions. This general pattern was consistent in 1974 and 1988. Based on studies of DeGray Lake (Nix 1981) and other reservoirs (Cole and Hannah 1990), the metalimnetic minimum are probably the results of interflows that move through the reservoir.

In addition to the metalimnetic minima, the hypolimnion generally becomes anoxic during the summer. The anoxic hypolimnion characteristically extends from the upper end of the pool to the dam by the end of the summer stratification period (compare August and October profiles Figures a.10.15 through a.10.25).

In October, Beaver Lake starts to mix at the relatively shallow stations in the upper pool where turnover may be complete by the end of October. In the deeper portions of the lake toward the dam, the thermocline begins to deepen by October but turn over is not complete until later in the winter.

a.10.1.3.5 Surface Water Quality in the Reservoir

The surface water quality for Beaver Lake and laterals (coves) to Beaver Lake are summarized in Table a.10.9. The summary is restricted to water samples collected between the surface and a depth of 1.5 m. The period of records for the data are summarized in Table a.10.1.

DO concentrations were adequate to support aquatic life and the data exhibited the expected pattern of higher concentrations in the winter than in the summer based on differences in DO solubility due to temperature (e.g., Figure a.10.32). pH was also generally in the range to support aquatic life (i.e. 6.0 to 9.0 su). Occasionally, however, pH measurements greater than 9.0 su occurred (e.g. near the dam and the Avoca lateral Table (a.10.9) The reason for the high pH measurement near the dam is not known since chlorophyll a concentrations do not indicate a high level of algal productivity that might result in high pH levels.

Nutrient data for the surface water of Beaver Lake are somewhat limited, although the USGS and the BWD routinely collect water samples in the reservoir. These agencies, however, have not consistently collected surface water samples for nutrient

Table a.10.9. Summary of Beaver Lake surface water quality.

Station	Secchi Disk m	DO mg/L	pH, su	Alka-linity mg/L	Ortho-P mg/L	Total-P mg/L	Total NH_3 mg/L	Fecal Coli.** colonies /100 ml	Chl a** ug/L	Nitrite+ Nitrate mg/L	TKN mg/L
Hwy 68 USGS 07048910 BWD 2	2.6 (0.3-30.0)	7.6* (0.0-12.8)	7.6* (6.9-9.4)	52.9* (6-96)--	0.076* (0-1.0)	–	0.407* (0-2.12)	59 (0-390) 134.5* (0-2680)	11.7 (0.1-46.0)	0.414+ (0-2.40)	–
BWD Water Intake USGS 07049200 BWD 1	1.3 (0.0-2.8)	1.5* (0.2-3.4)	7.6* (6.6-9.2)	52.6* (22-78)	0.045* (0-0.510)	–	0.282* (0-2.5)	4.2 (0-24) 49.4* (0-1500)	5.6 (0.2-32.0)	0.301* (0-1.8)	–
Monte Ne USGS 07049230	1.2 (0.2-1.9)	9.6 (7.7-12.5)	(6.3-9.0)	72 (32-130)	0.01 (0.01-0.02)	0.03 (0.01-0.06)	–	23 (0-370)	5.3 (1.2-24.0)	0.54 (0.04-1.50)	–
Hwy 12 USGS 07049500 BWD 11	1.8 (0.2-4.9)	8.5* (3.3-14.2)	7.9* (7.1-9.4)	52.0* (28-86)	0.025* (0-0.50)	–	0.238* (0-2.7)	2 (0-20) 27.0* (0-720)	2.6 (0.4-7.7)	0.197+ (0-0.60)	–
Prairie Creek USGS 07049570	1.1 (0.3-1.8)	9.6 (7.0-13.4)	(6.2-9.0)	70 (40-240)	0.02 (0.01-0.30)	0.03 (0.01-0.09)	–	9 (0-95)	4.1 (0.1-14.0)	0.53 (0.02-1.4)	–
Avoca USGS 07049590	1.3 (0.2-2.2)	9.5 (6.7-13.2)	(6.6-9.3)	61 (42-128)	0.018 (0.0-0.11)	0.035 (0.01-0.18)	0.07 (0-0.33)	10 (0-180)	5.4 (0.1-14.0)	0.03 (0-1.3)	0.54 (0.1-1.6)
Beaver Lake nr. Eureka Springs USGS 07049690	4.7 (2.1-11.7)	9.19 (6.1-14.0)	(6.2-9.8)	–	0.012 (0.01-0.05)	0.018 (0.01-0.07)	0.05	10 (0-350)	1.2 (0.1-4.4)	0.17 (0.02-0.4)	0.50
White River at Beaver Dam USGS 07049691	–	12.01 (11.9-12.2)	7.8 (7.8-7.81)	–	–	–	–	10 (0-350)	–	–	–

* Beaver Water District (BWD) monitoring data.
\+ Beaver Water District (BWD), nitrate only.
** Less than values are treated as actual values.

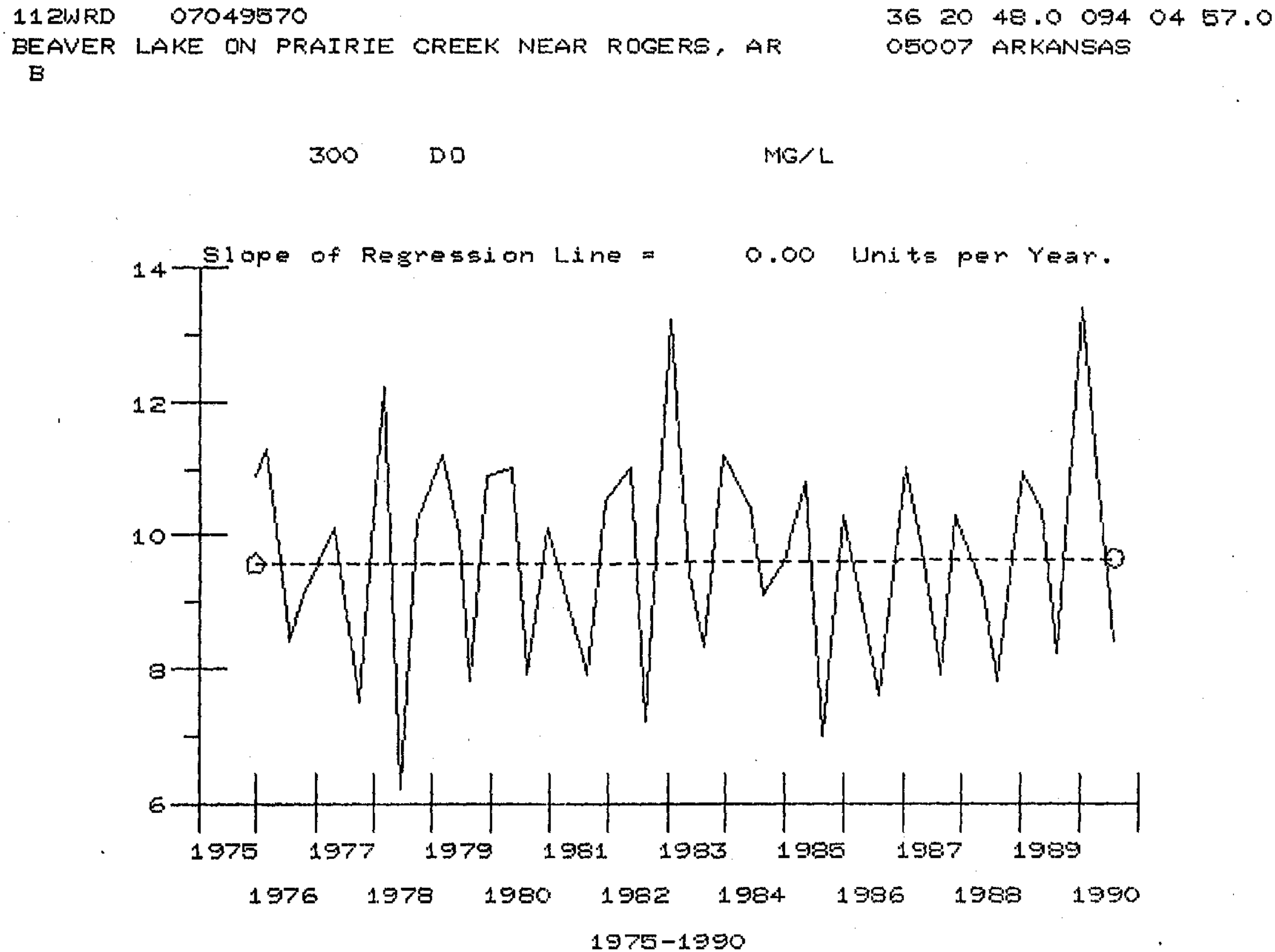


Figure a.10.32. An example of surface water DO concentrations over time.

analyses. The USGS began analyzing surface water samples for nutrients in 1982-83 (see Table a.10.1). The BWD sometimes collects samples from the surface, but samples are generally collected at the approximate level of the BWD's intake structure.

In general, nutrient (e.g. phosphorus, ammonia-nitrogen and nitrate nitrogen) concentrations decrease from the upper pool to the dam. The decrease in nutrients is reflected by increasing Secchi transparency depths (Figures a.10.33 and a.10.34) and decreasing chlorophyll a concentrations (Figures a.10.35 and a.10.36). In 1974, EPA (1977) concluded that, overall, Beaver Lake was mesotrophic. The recent USGS data (Table a.10.9) indicates that, in general, Beaver Lake is still mesotrophic.

Laterals to Beaver Lake, such as Monte Ne, Prairie and Avoca, generally indicated mesotrophic conditions based on mean phosphorus and chlorophyll a concentrations, and eutrophic conditions based on Secchi transparency (Wetzel 1983). However these laterals are sometimes eutrophic based on the maximum total phosphorus and chlorophyll a concentrations and minimum Secchi transparency depths.

Fecal coliform counts were higher in the reservoir headwaters than near the dam (Figures a.10.37 and a.10.38). Fecal coliform counts in the War Eagle Creek were similar to counts in the reservoir headwaters (Figures a.10.37 and a.10.39) whereas fecal coliform counts in Avoca and Prairie Creek Coves were intermediated between the headwater and dam stations (Figures a.10.40 and a.10.41).

Special studies on Beaver Lake that included surface water sampling were conducted by Bennett (1970), Gearheart (1973), Mitchell and Stevens (1973), Meyer (1974), EPA (1977) and Meyer et al. (1986). In general, the results of these studies indicate similar patterns. Although there have been several water quality studies on Beaver Lake, comparisons among variable at various monitoring locations are not attempted because of differences in sampling methodologies, analytical procedures, and levels of quality assurance and control. The data are useful, however, in determining the general patterns in water quality.

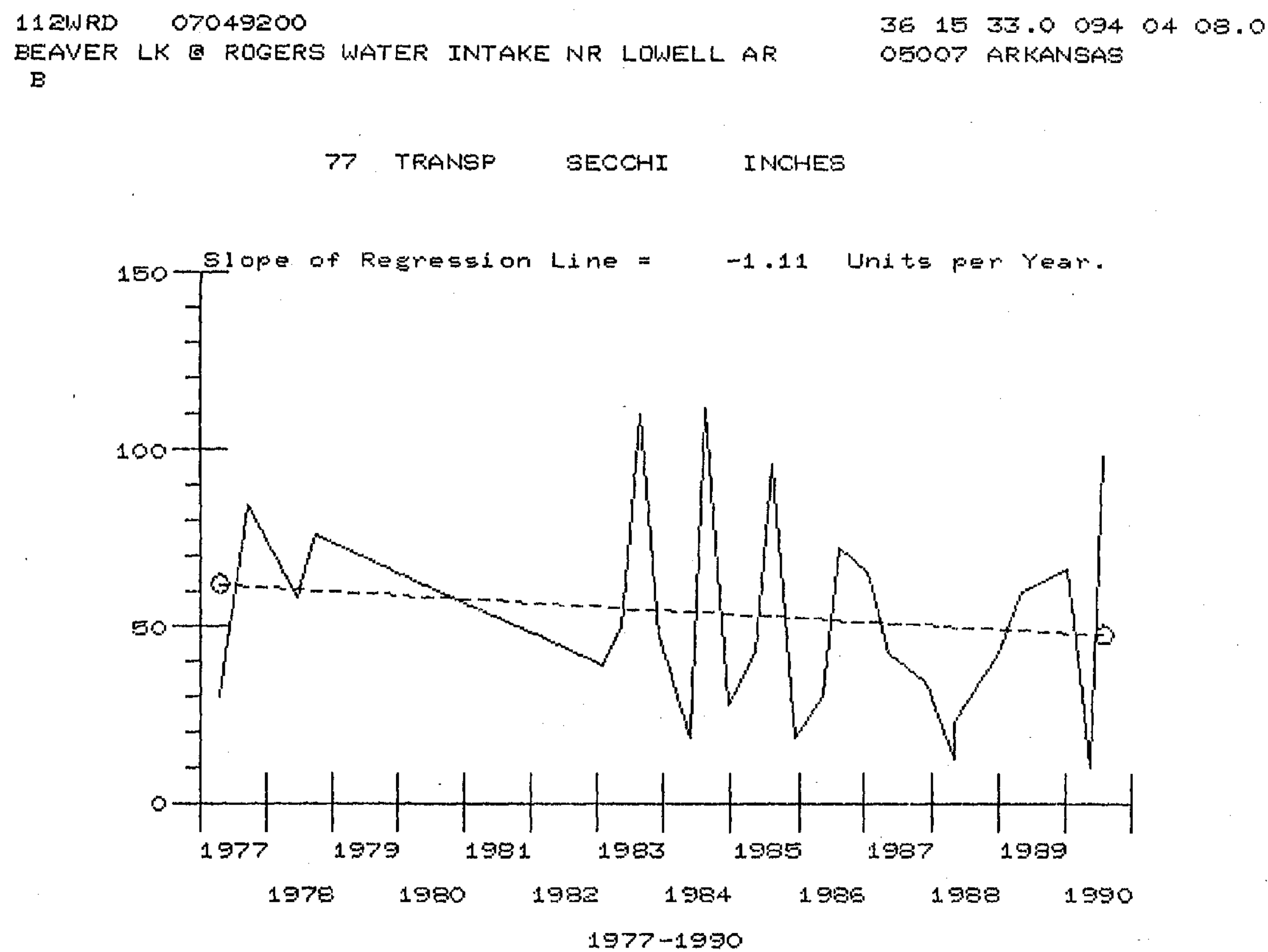


Figure a.10.33. Secchi transparency in Beaver Lake at the BWD intake near Lowell, AR.

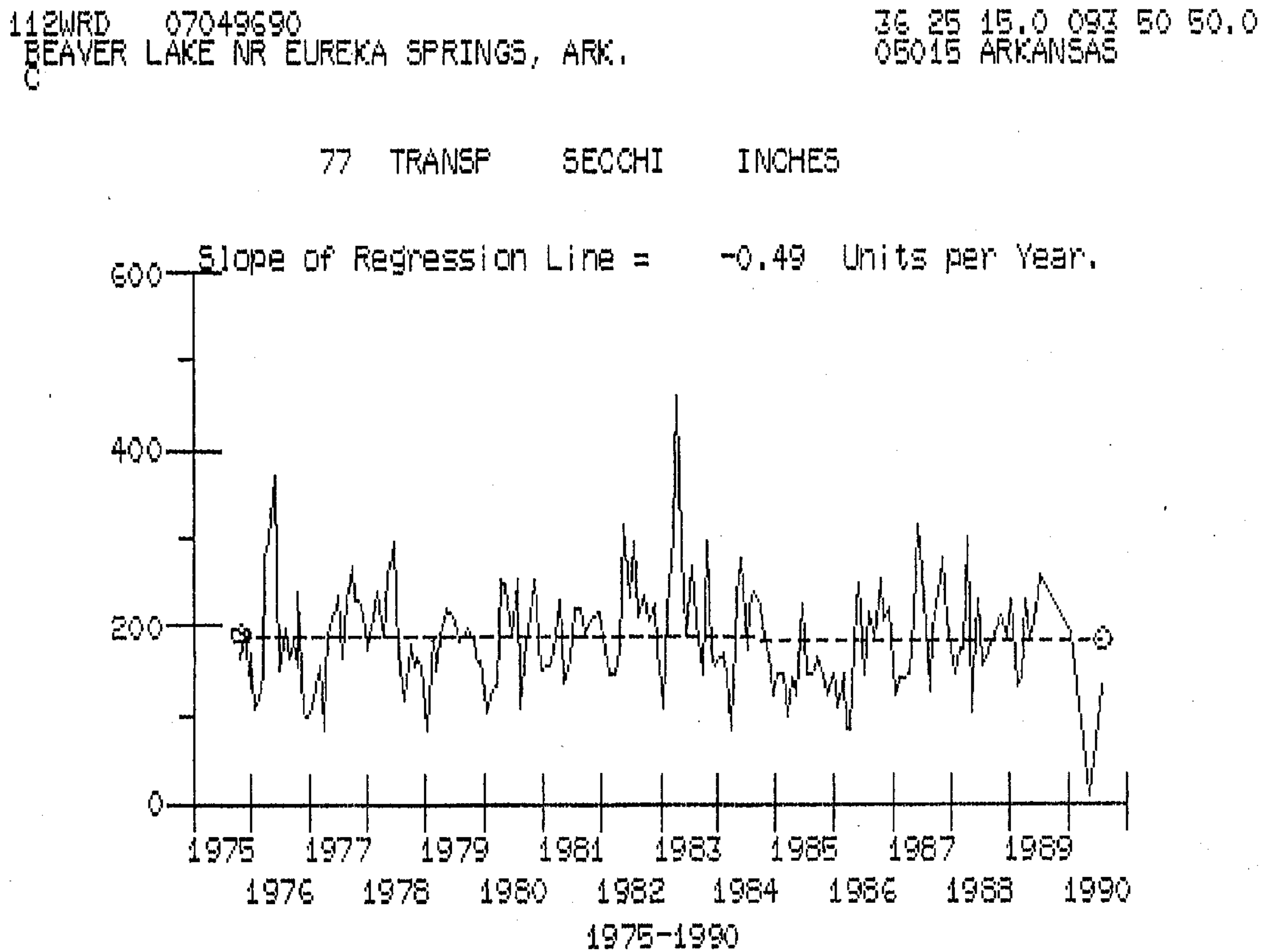


Figure a.10.34. Secchi transparency in Beaver Lake over time near Beaver Lake Dam.

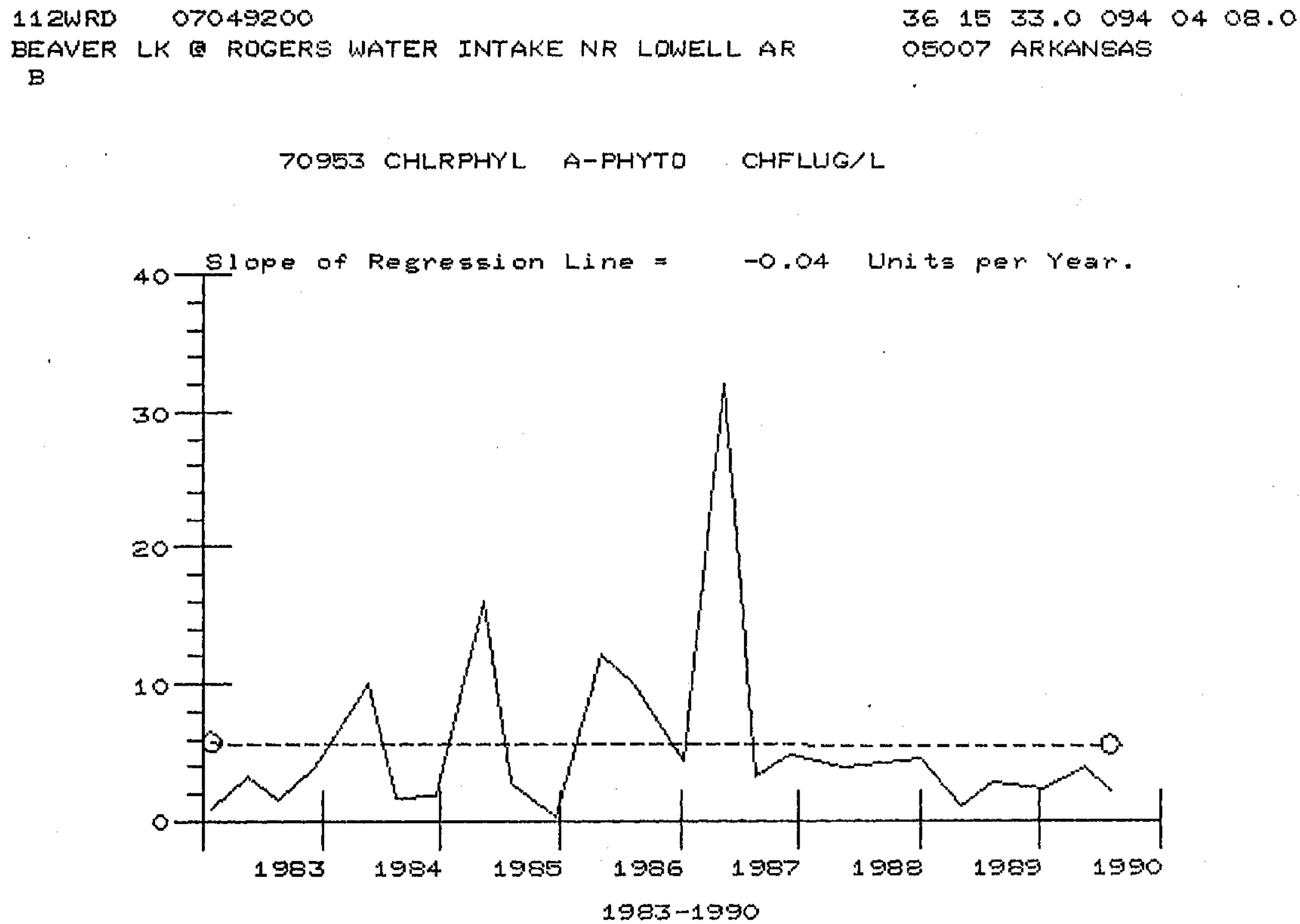


Figure a.10.35. Chlorophyll a concentrations in Beaver Lake at the BWD intake structure near Lowell, AR.

112WRD 07049690 36 25 15.0 093 50 50.0
BEAVER LAKE NR EUREKA SPRINGS, ARK. 05015 ARKANSAS
C

70953 CHLRPHYL A-PHYTO CHFLUG/L

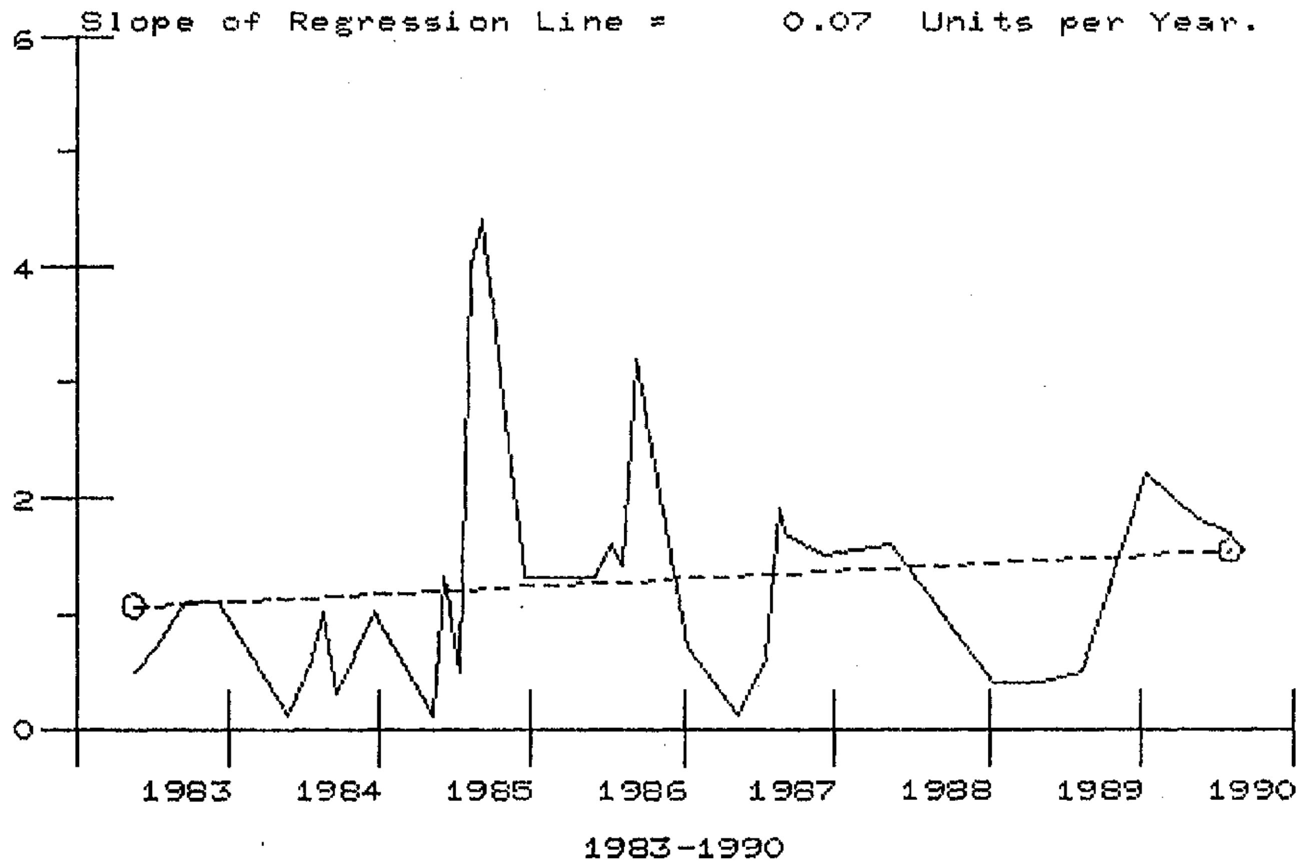


Figure a.10.36. Chlorophyll a concentrations in Beaver Lake at the Beaver Lake Dam.

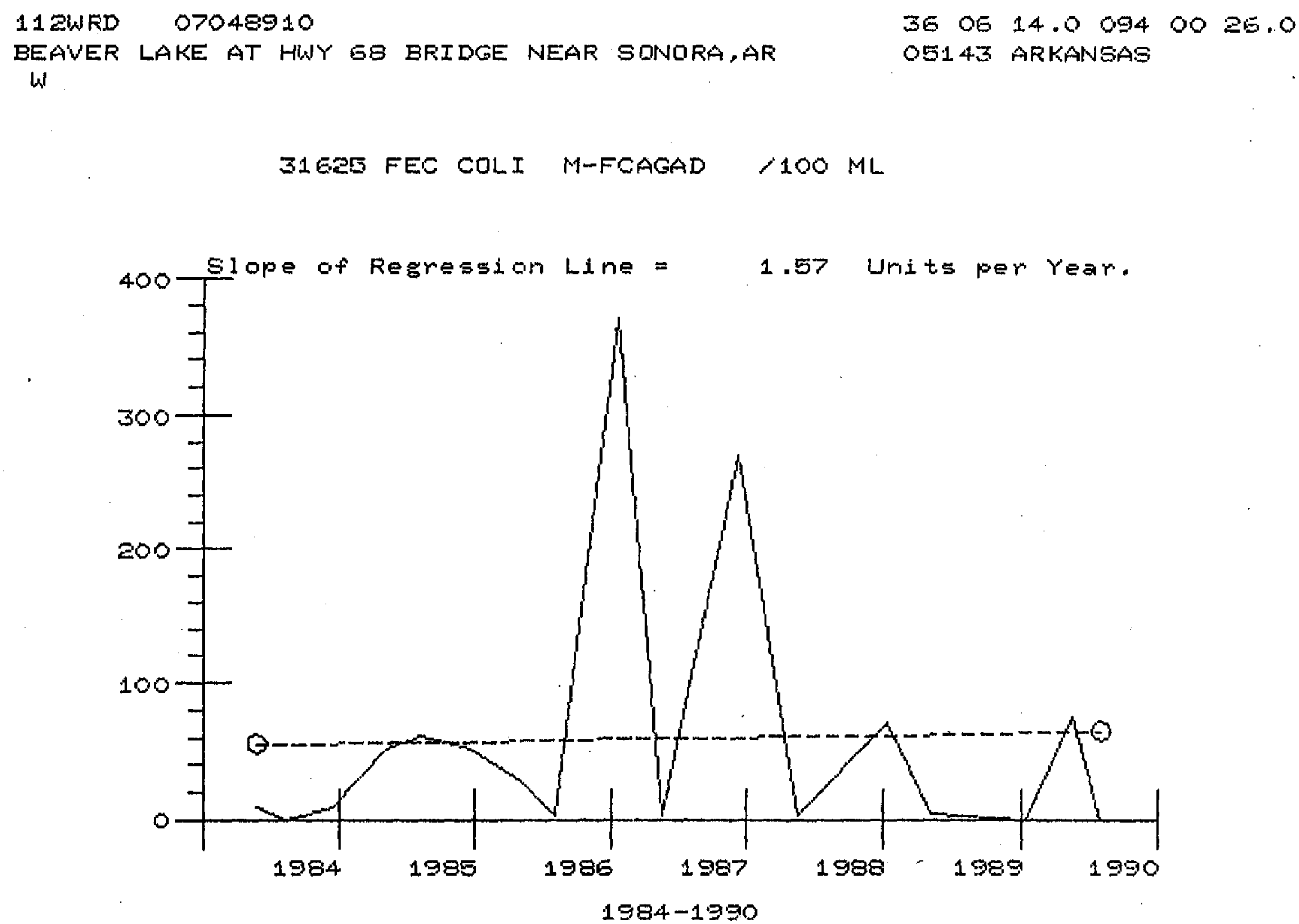


Figure a.10.37. Fecal coliform counts in Beaver Lake at the Highway 68 bridge near Sonora, AR.

112WRD 07049500 36 19 56.0 094 01 08.0
BEAVER LK @ HWY 12 BRIDGE NR ROGERS AR 05007 ARKANSAS
B

31625 FEC COLI M-FCAGAD /100 ML

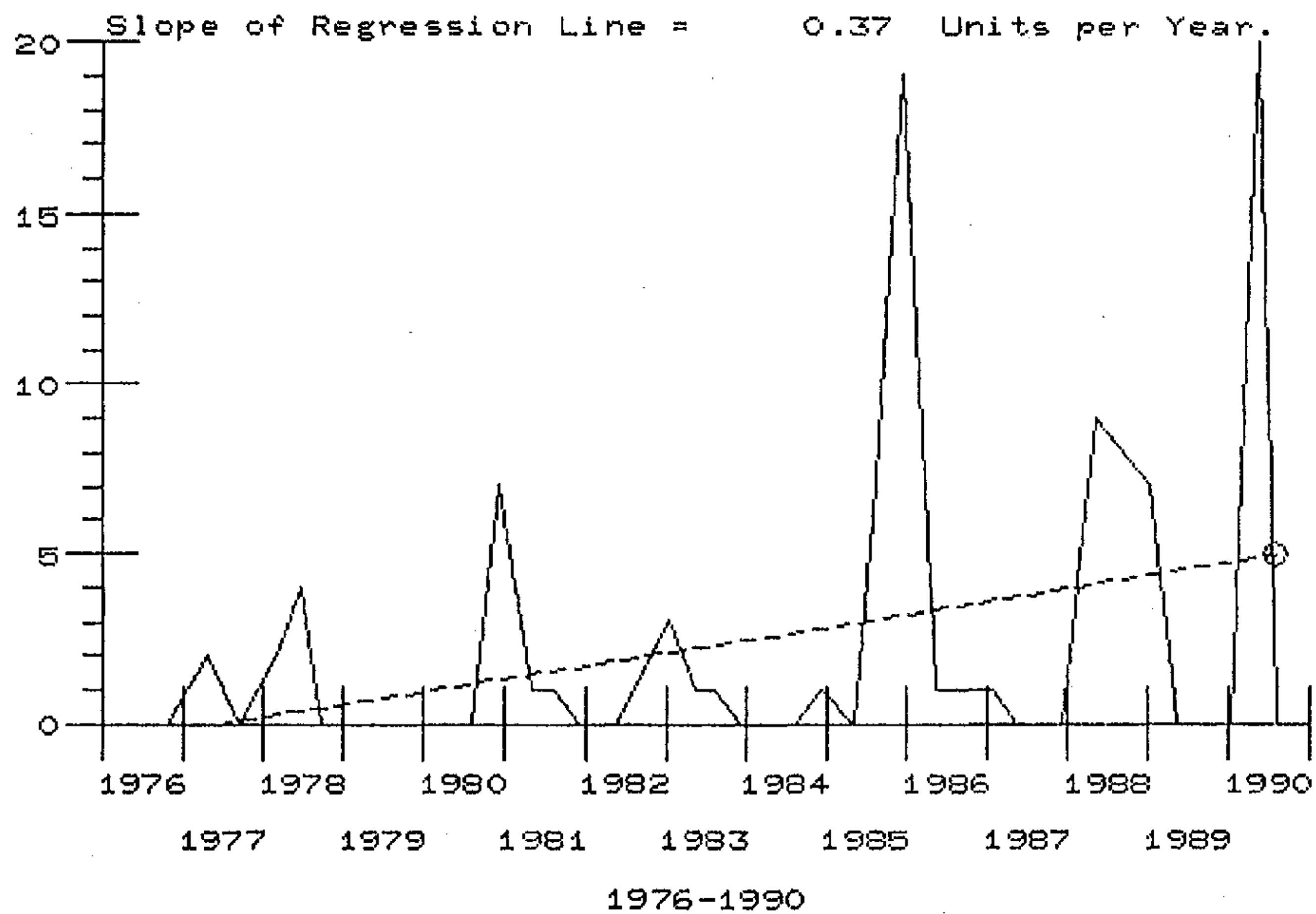


Figure a.10.38. Fecal coliform counts in Beaver Lake at Highway 12 bridge near Rogers, AR.

112WRD 07049570 36 20 48.0 094 04 57.0
BEAVER LAKE ON PRAIRIE CREEK NEAR ROGERS, AR 05007 ARKANSAS
B

31625 FEC COLI M-FCAGAD /100 ML

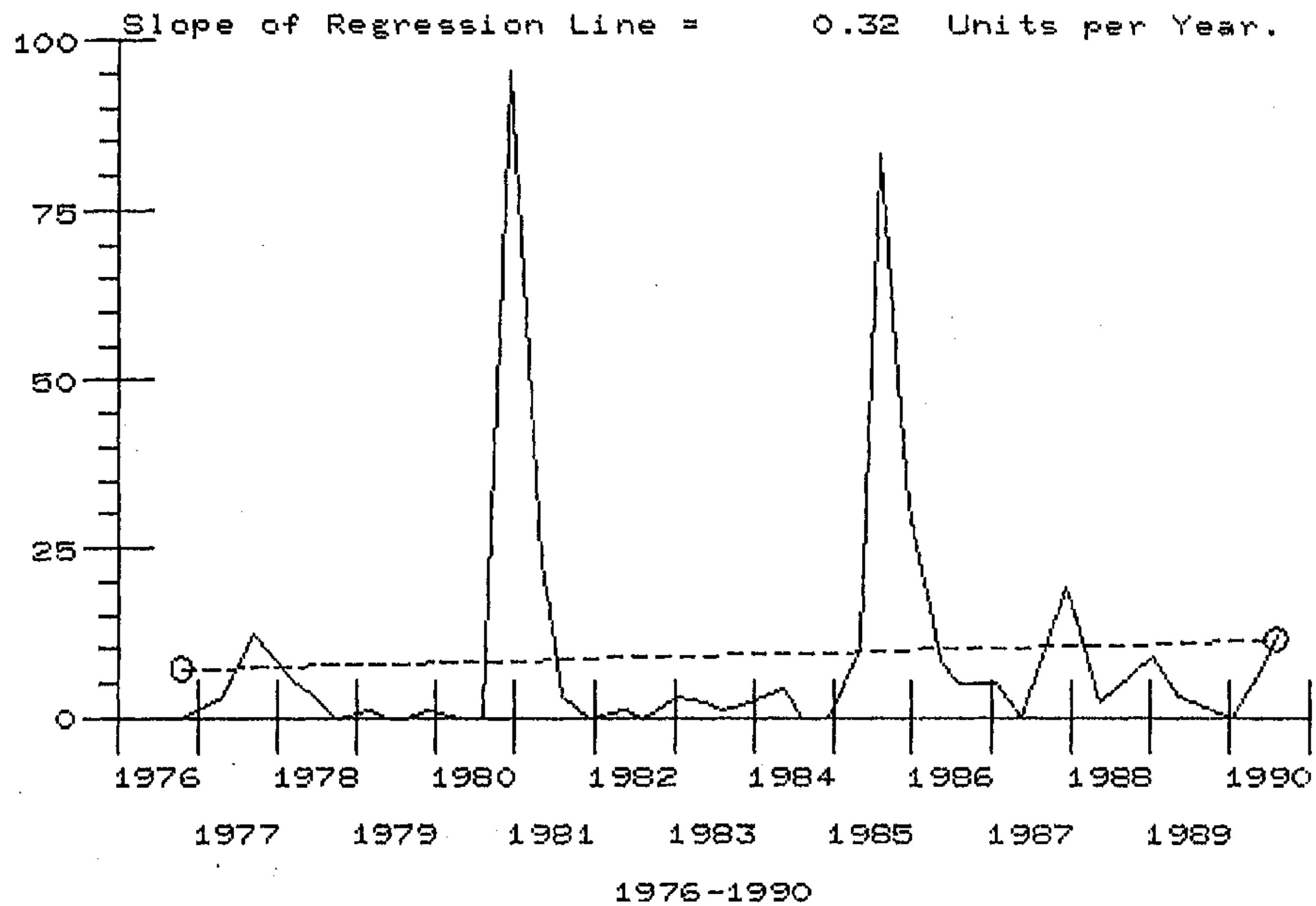


Figure a.10.41. Fecal coliform counts in Prairie Creek lateral to Beaver Lake.

a.10.2 Present Conditions

The morphometric data for Beaver Reservoir are listed in Table a.10.10. Beaver Reservoir was sampled and monitored on a routine basis from 6 April 1991 through 5 December 1991. The routine water quality sampling and monitoring locations are shown in Figure a.10.42. Analytical parameters, methods and detection are summarized in Table a.10.11. The data from routine sampling are provided in Appendix A.

a.10.2.1 Monitoring Program Design

The approach taken to monitor Beaver reservoir was a nested design of routine fixed station monitoring, combined with synoptic surveys and re-sampling NES sites.

a.10.2.1.1 Routine, Fixed Monitoring Stations

Sampling stations consisted of: 1) four primary lake stations; 2) two secondary lake stations; and 3) six stream stations (Figure a.10.42). The purpose for each of these stations is listed in Table a.10.12. Routine sampling consisted of taking in-situ measurements at all stations and collecting water quality samples at the four primary Lake stations and all the stream stations. In-situ measurements only were made at the secondary Lake stations. Estimates of discharge and water quality data from Beaver Lake were obtained from the USGS sampling program below Beaver Lake.

The depth intervals for in-lake water quality samples were 0, 3, 5, 10, 20, 30, 40 and 50m with maximum depth being determined by the depth of the lake over the river channel at each station. In-situ measurements were made at one meter intervals to a depth of fifteen meters and then every two meters to the bottom. Stream samples were collected at 0.6 depth. The water quality parameters that were measured are listed in Table a.10.11. The methods and quality assurance protocols to be used for field sample collection and preservation, laboratory analyses, data management, and analyses are described in the QA/QC Plan, submitted under separate cover.

Fourteen routine sampling trips were made between April and December 1991 plus one trip in March for the sampling crews to familiarize themselves with the Lake and its tributaries, to establish sampling stations and to determine a suitable location for

Table a.10.10. Beaver Lake morphometric data.

Drainage Area, km^2	3,072
Surface Area, km^2	114
Conservation Pool Elevation, m	341
Maximum Depth, m	79
Mean Depth, m	18
Residence Time, yr	1.8
Volume, m^3	2,034,450,000
Shoreline Development Ratio	19.1
Outlet Depth, m	42.7
Average Annual Pool Level Fluctuation, m	4.6
Thermocline Depth, m	7.6

From Aggus, L.R. 1985

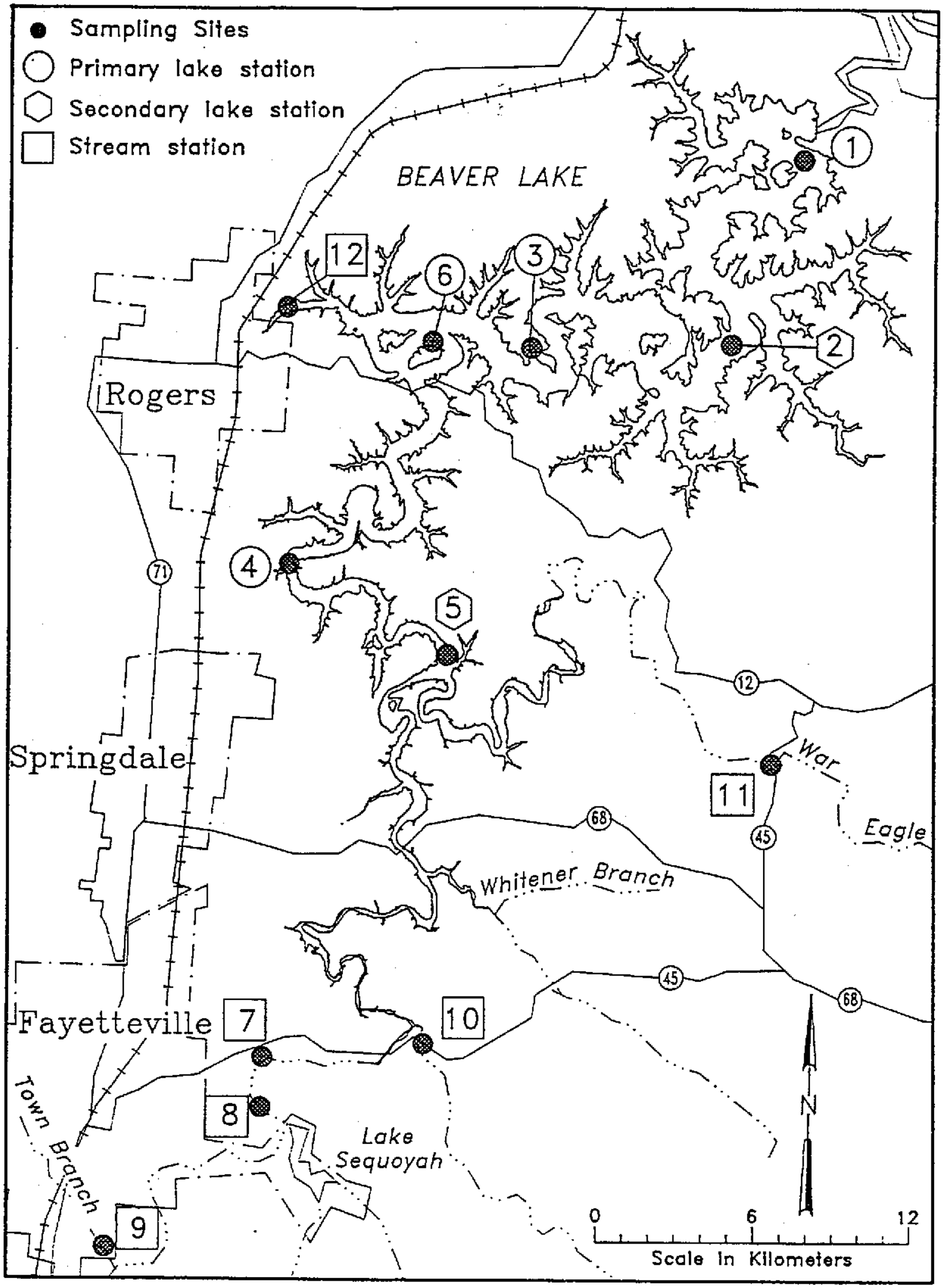


Figure a.10.42. Sampling Locations.

Table a.10.11. Parameter table and analytical methods.

Parameter	Method and Reference	Detection Limits
In-Situ Parameters:		
pH		0.1 Su
Conductivity		2 µS
Temperature		0.1°C
Dissolved Oxygen		0.2 mg/L
Water Quality Indicators:		
Alkalinity	Electrometric titration EPA 310.1 (EPA 1970)	0.5 mg/L
Calcium	Flame AA, EPA 215.1 (EPA 1970)	0.1 mg/L
Iron	Flame AA, EPA 236.1 (3) (EPA 1970)	0.05 mg/L
Manganese	Flame AA, EPA243.1 206.2 (EPA 1970)	0.02 mg/L
Sulfide	Ion Chromatography (Waters 1985)	0.2 mg/L
Total Organic Carbon	Ion Chromatography (Waters 1985)	0.2 mg/L
Nitrite-nitrogen	Ion Chromatography (Waters 1985)	0.01 mg/L
Nitrate-nitrogen	Ion Chromatography (Waters 1985)	0.01 mg/L
Ammonia-nitrogen	Specific ion electrode EPA 350.3 (EPA 1970)	.01 mg/L
Total Kjeldahl Nitrogen	Digestion, EPA 341.1 modified for manual determination (EPA 1970)	0.1 mg/L
Total Phosphorus	Persulfate digestion, spectrophotometric, EPA 365.4, modified for manual determination (EPA 1970)	0.002 mg/L

Table a.10.11. Continued.

Parameter	Method and Reference	Detection Limits
Soluble Reactive Phosphorus	Spectrophotometric EPA 365.4 modified for manual determination (EPA 1970)	0.002 mg/L
Chlorophyll a	Trichromatic (APHA 1989)	0.1 mg/L
Total Suspended Solids	Gravimetric, drying at 105°C (APHA 1989)	2 mg/L
Turbidity	Nephelometric (APHA 1989)	0.1 NTU

Table a.10.12. Purpose of sampling locations.

Station No.	Purpose
Reservoir 1, 3, 5, 6	Longitudinal, vertical gradients in water quality, pool versus cove water quality
2, 4	In-situ profiles, supplemental gradients
Tributary 7, 8	Downstream, upstream of Fayetteville WWTP
9	Urban runoff, upstream land use
10, 11	Agricultural land use
12	Real Estate Developments

a mobile laboratory and boat storage. The purpose of each sampling trip was to characterize a particular hydrometeorological or limnological period. The frequency of sampling and the rationale for this frequency is described in Table a.10.13.

An 11m mobile laboratory equipped with wet laboratory benches, sample preparation and processing equipment, and living facilities for three people was located at Hickory Creek Marina and used to prepare for field sampling and to process water quality samples after collection. Samples were returned to Ouachita Baptist University for analysis.

a.10.2.1.2 Synoptic Surveys

Extensive surface sampling of the reservoir was conducted on 19 June and 7 September 1991 during the summer months. The sampling periods corresponded to periods when water quality problems have historically been noted in Beaver Lake. Samples were distributed to represent all major regions of the Lake, including the main channel, coves of different sizes and surrounding land use, recreational areas, highly developed areas, marinas and other similar considerations (Figure a.10.43). During these synoptic surveys, Secchi transparency and in-situ parameters were measured and 2 m integrated surface water samples were collected for chlorophyll a and fecal coliform analyses. In addition, the water samples were also analyzed for total nitrogen, total phosphorus and total suspended solids, as time and funding permitted.

a.10.2.1.3 NES Re-Sampling

The sampling station locations, sampling frequency, water quality parameters and sampling protocol permitted sampling at similar locations and times as the 1974 NES sampling of Beaver Lake. This permitted subsequent comparisons of water quality patterns during 1991 with water quality patterns during 1974 to determine if there has been a change in the trophic status of Beaver Lake during this seventeen year period.

Based on the Corps of Engineers-Little Rock district inflow data to Beaver Reservoir, the inflow during the NES study (20 July 1974 - 11 May 1975) was 1,733 x

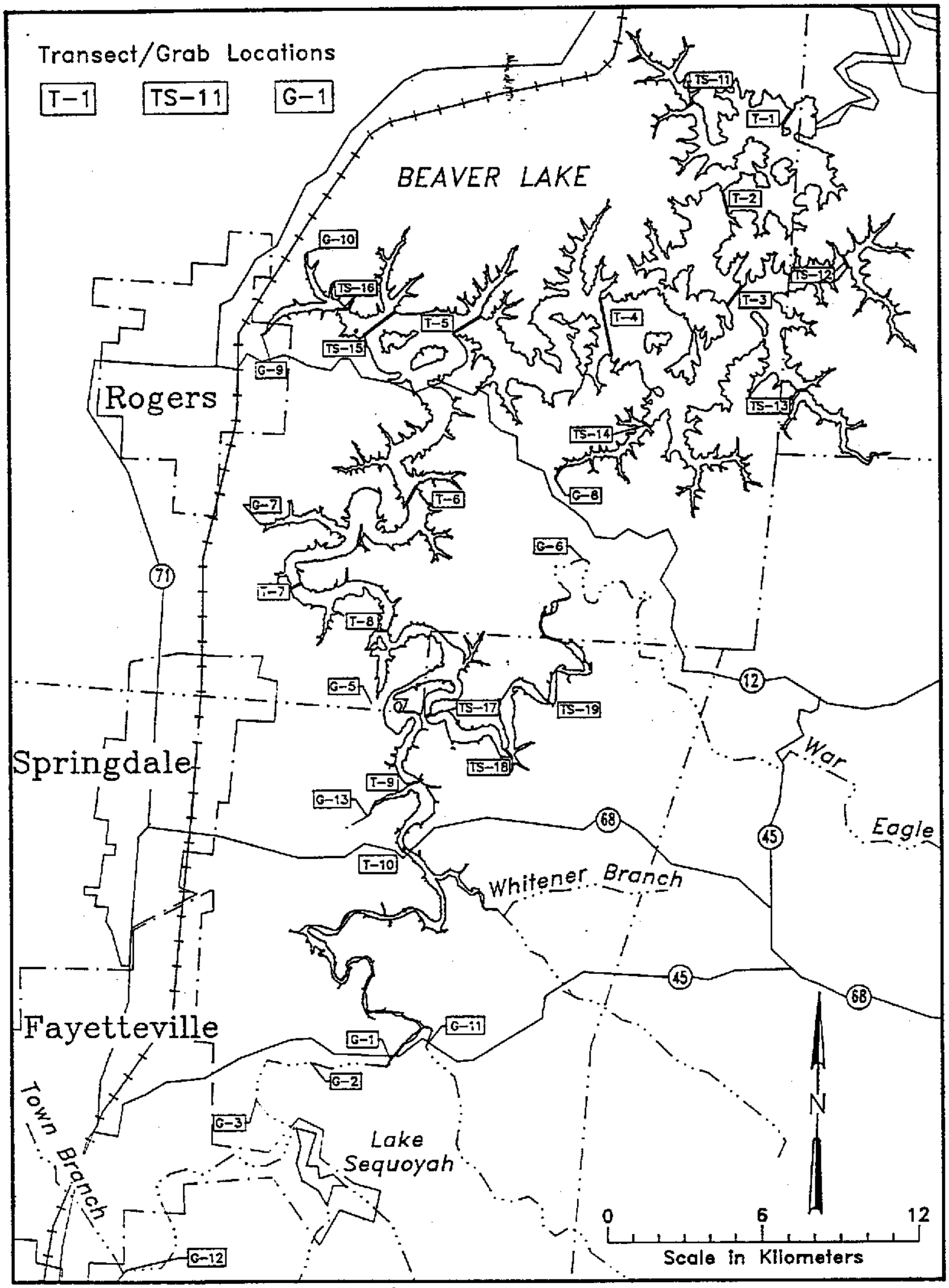


Figure a.10.43. Synoptic survey locations.

Table a.10.13. Sampling frequency.

Date and Number of Samples	Limological Factor
April 1991 (2)	Isothermal conditions followed by elevated flows
May 1991 (2)	Early growing season
June 1991 (2)	Increased biological activity and public uses
July 1991 (2)	Strong stratification, low runoff
August 1991 (2)	Potential phytoplankton blooms
September 1991 (1)	Potential phytoplankton blooms, minimum flow
October 1991 (2)	Deepening of thermocline
December 1991 (1)	Fall overturn

10^6 m^3/yr, and during this study it was 1,495x 10^6 m^3/yr. The inflows were within 14% for the two study periods.

a.10.2.1.4 Quality Assurance and Quality Control

The quality assurance and quality control (QA/QC) program for the Beaver Lake clean lake study is described in the document "Quality Assurance Project Plan: Beaver Clean Lake Diagnostic Feasibility Study for the State of Arkansas" (FTN 1991), and control charts for the constituents monitored are presented in Appendix B.

In addition to the QA/QC activities described in the "Quality Assurance Project Plan," the Beaver Lake Clean Lake Study data were reviewed in-house to address the following questions:

1. Were the data consistent (e.g. were temperature and DO values generally inversely related, keeping in mind that metalimnetic minima can occur)?
2. Were there any potential outliers (i.e. very high or very low data points)?
3. Were pH values in the range expected for surface waters?
4. Were total phosphorus values greater than soluble reactive phosphorus values?
5. Were Total Kjeldahl Nitrogen values greater than corresponding ammonia nitrogen values?
6. Were total iron and manganese values greater than corresponding dissolved iron and manganese values?

Questionable data points were reviewed by the laboratory and corrections made as appropriate. In general, differences in constituents were related to levels of detection and precision at very low concentration. The data presented in Appendix B are of known quality

a.10.2.2 Tributary Water Quality

The tributary water quality data are available in Appendix A and summary statistics for the tributary sites are presented in Table a.10.14. As stated in Section a.10.1.2, major water quality concerns associated with the tributaries are the reduction of DO downstream of the Fayetteville WWTP and excessive nutrient inputs to the reservoir. The following topics will be discussed:

- The water quality of the upper White River with emphasis on the influence of the Fayetteville WWTP;
- The water quality of Town Branch because of water quality problems observed during this study; and
- The water quality of the remaining tributaries monitored compared to historical water quality data.

a.10.2.2.1 Upper White River

During this study, sampling stations were established upstream of the WWTP (Sampling Station B8 at the Wyman Bridge) and approximately 2.3 and 3.4 km downstream of the WWTP (Sampling Station B7) on the White River. The purpose of data collection efforts at these stations was to assess the influence of the Fayetteville WWTP discharge on the White River.

Historical data showed that the DO concentrations could be depressed for at least 9.0 km downstream of the WWTP (Terry et. al 1983; Section a.10.1.3.1). The data from sampling stations monitored during this study showed the DO concentrations were slightly higher downstream than upstream of the WWTP (Table a.10.14). These data are in agreement with BWD data (BWD-13; Table a.10.7) collected since 1990. During this study, forty-three percent of DO measurements upstream of the WWTP and eight percent of the DO measurements downstream of the WWTP were less than 6.0 mg/L, the primary and critical DO standard for the Ozark Highland Ecoregion.

The WWTP's discharge was apparently increasing nutrient concentrations in the White River. Median total phosphorus, soluble reactive phosphorus, and nitrate nitrogen concentrations were 5, 35 and 2 times, respectively, greater downstream than upstream.

Table a.10.14. Summary statistics for tributary sites.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Parameter: Temperature								
White River - D/S WWTP	12	5.9	16.2	21.3	26.5	28.4	20.4	6.9
White River - Wyman Brdg	14	6.0	15.9	23.9	26.2	27.8	20.7	6.6
Town Branch	14	2.5	13.5	21.1	24.0	25.4	18.5	6.3
Richland Creek - Hwy 45	14	6.3	15.7	22.0	25.8	29.0	20.4	6.6
War Eagle	14	7.5	15.8	22.3	25.8	30.1	20.9	6.5
Prairie Creek	14	10.5	14.2	20.8	25.0	28.0	20.7	5.1
Parameter: Dissolved Oxygen								
White River - D/S WWTP	12	5.5	6.4	7.2	8.9	10.6	7.5	1.5
White River - Wyman Brdg	14	5.1	5.3	6.5	7.5	9.4	6.6	1.4
Town Branch	14	3.3	5.0	6.0	7.3	9.0	6.2	1.7
Richland Creek - Hwy 45	14	6.9	7.2	8.1	9.0	9.4	8.1	0.9
War Eagle	14	6.3	7.0	7.8	8.9	10.2	7.9	1.2
Prairie Creek	14	6.4	6.9	7.6	8.3	8.8	7.6	0.8
Parameter: pH								
White River - D/S WWTP	12	6.4	6.8	6.9	7.3	7.5	7.0	0.3
White River - Wyman Brdg	14	6.5	6.6	6.8	6.9	7.4	6.8	0.2
Town Branch	14	6.5	6.7	6.9	7.2	7.3	6.9	0.3

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Richland Creek - Hwy 45	14	6.7	6.9	7.1	7.3	7.5	7.1	0.2
War Eagle	14	6.7	6.9	7.3	7.4	7.6	7.2	0.3
Prairie Creek	14	6.8	7.2	7.3	7.4	7.7	7.3	0.2
Parameter: Specific Conductivity								
White River - D/S WWTP	12	70	75	186	268	380	187	110
White River - Wyman Brdg	14	62	81	106	168	215	125	50
Town Branch	14	223	325	387	402	532	371	76
Richland Creek - Hwy 45	14	96	107	174	222	293	176	66
War Eagle	14	100	129	239	283	313	211	76
Prairie Creek	14	241	255	261	284	309	267	19
Parameter: Turbidity								
White River - D/S WWTP	12	6.8	10.2	21.0	31.8	53.0	22.5	14.2
White River - Wyman Brdg	14	3.3	6.9	14.0	31.0	77.0	21.8	20.2
Town Branch	14	5.7	13.0	22.0	30.0	710.0	71.9	184.1
Richland Creek - Hwy 45	14	2.9	4.2	6.6	16.5	53.0	12.7	13.8
War Eagle	14	2.7	3.2	4.8	18.3	29.0	9.1	5.6
Prairie Creek	14	1.1	1.7	2.3	2.8	3.3	2.3	0.7

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Parameter: Total Suspended Solids								
White River - D/S WWTP	12	2	4	14	19	38	14	10
White River - Wyman Brdg	14	2	6	10	17	45	13	11
Town Branch	14	4	9	20	41	505	56	130
Richland Creek - Hwy 45	14	2	5	8	14	30	10	8
War Eagle	14	2	3	5	11	26	8	7
Prairie Creek	14	1	2	4	4	7	3	2
Parameter: Total Phosphorus								
White River - D/S WWTP	12	0.032	0.042	0.187	0.251	0.365	0.171	0.128
White River - Wyman Brdg	14	0.026	0.030	0.037	0.059	0.071	0.044	0.015
Town Branch	14	0.016	0.022	0.038	0.053	0.570	0.098	0.167
Richland Creek - Hwy 45	14	0.008	0.017	0.022	0.026	0.046	0.023	0.009
War Eagle	14	0.002	0.019	0.024	0.038	0.044	0.026	0.013
Prairie Creek	14	0.010	0.013	0.019	0.025	0.076	0.022	0.017
Parameter: Soluble Reactive Phosphorus								
White River - D/S WWTP	12	0.001	0.005	0.141	0.190	0.265	0.112	0.099
White River - Wyman Brdg	14	0.001	0.002	0.004	0.009	0.030	0.006	0.008
Town Branch	14	0.007	0.010	0.016	0.025	0.038	0.018	0.009

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Richland Creek - Hwy 45	14	0.001	0.002	0.005	0.010	0.023	0.008	0.007
War Eagle	14	0.001	0.003	0.007	0.014	0.046	0.011	0.012
Prairie Creek	14	0.005	0.008	0.010	0.012	0.033	0.012	0.009
Parameter: Total Kjeldahl Nitrogen								
White River - D/S WWTP	12	0.2	0.3	0.5	0.9	1.1	0.6	0.3
White River - Wyman Brdg	14	0.2	0.4	0.5	0.6	0.8	0.5	0.2
Town Branch	14	0.4	0.4	0.5	0.6	2.3	0.6	0.5
Richland Creek - Hwy 45	14	0.1	0.2	0.3	0.4	0.9	0.3	0.2
War Eagle	14	0.1	0.2	0.3	0.3	0.6	0.3	0.1
Prairie Creek	14	0.1	0.1	0.1	0.2	0.5	0.2	0.1
Parameter: Nitrate Nitrogen								
White River - D/S WWTP	12	0.03	0.24	0.56	1.91	3.33	1.06	1.06
White River - Wyman Brdg	14	0.04	0.12	0.27	0.34	0.83	0.28	0.22
Town Branch	14	0.05	0.19	0.74	1.48	1.99	0.85	0.66
Richland Creek - Hwy 45	14	0.02	0.08	0.29	0.41	0.79	0.27	0.22
War Eagle	14	0.01	0.35	0.62	0.90	1.48	0.67	0.43
Prairie Creek	14	0.01	1.06	1.31	1.44	1.79	1.15	0.52

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Parameter: Nitrite Nitrogen								
White River - D/S WWTP	12	0.01	0.01	0.01	0.01	0.01	0.01	0
White River - Wyman Brdg	14	0.01	0.01	0.01	0.01	0.01	0.01	0
Town Branch	14	0.01	0.01	0.01	0.01	0.01	0.01	0
Richland Creek - Hwy 45	14	0.01	0.01	0.01	0.01	0.01	0.01	0
War Eagle	14	0.01	0.01	0.01	0.01	0.01	0.01	0
Prairie Creek	14	0.01	0.01	0.01	0.01	0.01	0.01	0
Parameter: Ammonia Nitrogen								
White River - D/S WWTP	12	0.02	0.03	0.04	0.05	0.21	0.05	0.05
White River - Wyman Brdg	14	0.02	0.03	0.08	0.13	0.42	0.10	0.10
Town Branch	14	0.04	0.05	0.07	0.11	0.21	0.09	0.06
Richland Creek - Hwy 45	14	0.01	0.02	0.04	0.05	0.08	0.04	0.02
War Eagle	14	0.01	0.02	0.03	0.05	0.07	0.03	0.02
Prairie Creek	14	0.01	0.02	0.02	0.05	0.07	0.03	0.02
Parameter: Silica								
White River - D/S WWTP	12	3.48	5.08	6.16	6.60	7.52	5.94	1.10
White River - Wyman Brdg	14	4.67	5.57	6.27	6.61	7.39	6.10	0.70
Town Branch	14	2.49	3.81	4.32	6.15	7.62	4.72	1.51

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Richland Creek - Hwy 45	14	3.80	5.08	6.33	6.79	8.47	6.02	1.27
War Eagle	14	3.01	5.60	6.49	7.28	8.20	6.37	1.37
Prairie Creek	14	7.12	8.11	8.55	9.11	10.38	8.70	0.86
Parameter: Total Organic Carbon								
White River - D/S WWTP	12	1.74	2.90	5.40	6.90	13.40	5.53	3.32
White River - Wyman Brdg	14	1.60	2.50	3.85	5.55	20.40	4.98	4.69
Town Branch	14	3.77	4.27	5.40	6.78	10.60	5.83	1.90
Richland Creek - Hwy 45	14	1.68	1.87	2.55	3.57	5.80	2.84	1.19
War Eagle	14	1.60	2.06	2.80	3.35	4.80	2.88	1.00
Prairie Creek	14	0.08	1.04	1.60	2.55	8.90	2.23	2.36
Parameter: Alkalinity								
White River - D/S WWTP	12	18	22	48	64	84	46	22
White River - Wyman Brdg	14	19	29	47	69	85	48	22
Town Branch	14	52	105	120	132	437	137	89
Richland Creek - Hwy 45	14	29	37	82	102	114	76	31
War Eagle	14	35	52	103	110	116	85	32
Prairie Creek	14	106	112	117	124	138	119	10

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Parameter: Calcium								
White River - D/S WWTP	12	6.12	7.06	16.50	26.40	30.00	16.29	9.13
White River - Wyman Brdg	14	5.70	7.73	11.60	23.15	28.50	14.77	7.93
Town Branch	14	5.04	39.11	45.91	55.03	65.20	43.95	15.04
Richland Creek - Hwy 45	14	6.20	12.64	29.37	40.43	44.40	27.42	13.70
War Eagle	14	6.29	19.15	36.75	38.91	44.10	30.18	12.44
Prairie Creek	14	8.33	36.38	41.75	45.00	51.00	39.41	10.20
Parameter: Total Manganese								
White River - D/S WWTP	12	0.07	0.09	0.13	0.20	0.26	0.14	0.06
White River - Wyman Brdg	14	0.08	0.13	0.26	0.51	1.31	0.41	0.41
Town Branch	14	0.07	0.09	0.14	0.17	0.63	0.16	0.14
Richland Creek - Hwy 45	14	0.03	0.04	0.07	0.09	0.16	0.07	0.04
War Eagle	14	0.04	0.05	0.07	0.09	0.14	0.07	0.03
Prairie Creek	14	0.02	0.02	0.03	0.04	0.08	0.03	0.02
Parameter: Dissolved Manganese								
White River - D/S WWTP	12	0.02	0.04	0.07	0.10	0.19	0.07	0.05
White River - Wyman Brdg	14	0.02	0.04	0.07	0.30	1.31	0.27	0.42
Town Branch	14	0.03	0.08	0.11	0.13	0.14	0.10	0.03

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Richland Creek - Hwy 45	14	0.01	0.02	0.05	0.07	0.08	0.05	0.03
War Eagle	14	0.01	0.02	0.04	0.06	0.08	0.04	0.03
Prairie Creek	14	0.01	0.01	0.03	0.04	0.08	0.03	0.02
Parameter: Total Iron								
White River - D/S WWTP	12	0.19	0.38	0.68	1.08	1.34	0.72	0.39
White River - Wyman Brdg	14	0.04	0.41	0.65	1.12	1.60	0.75	0.46
Town Branch	14	0.14	0.45	0.70	0.99	18.05	1.93	4.66
Richland Creek - Hwy 45	14	0.01	0.21	0.32	0.56	1.50	0.44	0.39
War Eagle	14	0.02	0.16	0.23	0.64	1.03	0.39	0.32
Prairie Creek	14	0.03	0.08	0.11	0.13	1.18	0.18	0.29
Parameter: Dissolved Iron								
White River - D/S WWTP	12	0.06	0.13	0.17	0.31	0.45	0.21	0.12
White River - Wyman Brdg	14	0.07	0.09	0.19	0.33	0.43	0.21	0.12
Town Branch	14	0.07	0.08	0.13	0.24	0.84	0.19	0.20
Richland Creek - Hwy 45	14	0.03	0.08	0.10	0.22	0.38	0.15	0.11
War Eagle	14	0.06	0.07	0.08	0.21	0.46	0.14	0.12
Prairie Creek	14	0.04	0.06	0.07	0.09	0.22	0.08	0.05

Table a.10.14. Continued.

Site Name	Number Cases	Minimum	25 %	50 %	75 %	Maximum	Mean*	Standard deviation
Parameter: Total Coliforms								
White River - D/S WWTP	12	24	274	2098	6402	17000	4024	4902
White River - Wyman Brdg	14	18	165	1915	6681	73500	9273	19954
Town Branch	14	35	455	2368	20157	240500	24155	62983
Richland Creek - Hwy 45	14	72	347	4043	11627	30750	7664	9506
War Eagle	14	15	248	1715	8013	31500	5386	8286
Prairie Creek	14	92	341	1869	6065	29000	5912	9373
Parameter: Fecal Coliform								
White River - D/S WWTP	12	16	24	123	190	670	182	222
White River - Wyman Brdg	14	18	36	141	326	3100	389	809
Town Branch	14	29	171	441	1501	8700	1551	2668
Richland Creek - Hwy 45	14	31	131	187	296	2285	397	613
War Eagle	14	7	53	126	325	1040	229	276
Prairie Creek	14	34	69	145	429	1590	310	419

* The minimum detection level value was used as the actual constituent value in computing the mean.

Generally, the higher concentrations occurred from June through October when the discharge from the WWTP is contributing a greater proportion of the White River flow (e.g. Figures a.10.44 through a.10.46). Mean concentrations for total phosphorus and nitrate nitrogen (Table a.10.14) were less than historical mean concentrations for samples collected at the Goshen Bridge (Table a.10.7) corresponding with improved WWTP discharge to the White River. Although phosphorus concentrations have decreased, the concentration periodically exceed the 0.1 mg/L guideline for streams. This guideline is to minimize objectionable algal growth.

The new WWTP also has apparently reduced ammonia nitrogen concentrations to the White River. When the historical mean concentration at the Goshen Bridge (Table a.10.7) is compared to the mean concentration at the White River monitoring station downstream of WWTP, and when data from the USGS (1983) synoptic survey are compared to this study's data, ammonia concentrations downstream of the WWTP have decreased. During this study ammonia concentrations downstream of the WWTP are slightly lower than they are upstream of the WWTP.

Fecal coliform concentrations were generally lower downstream of the WWTP than upstream, but there were exceedences of the 200 colonies/100 mL guideline for primary contact recreation at both sites (ADPCE 1991). However, these exceedences cannot be construed as violations of water quality standards because not enough samples were collected during a 30 day period to calculate a geometric mean.

a.10.2.2.2 Town Branch

Town Branch receives runoff from the City of Fayetteville and from Fayetteville's Industrial Park. This site was selected for further discussion because of the poor water quality observed in this stream.

The minimum DO concentrations and the maximum total suspended solids occurred in this stream. The criteria DO Standard (ADPCE 1991) for an Ozark Highland stream with a watershed of 10 to 100 sq mi is 5 mg/L. During June, July and August three out of six DO measurements were less than 5 mg/L.

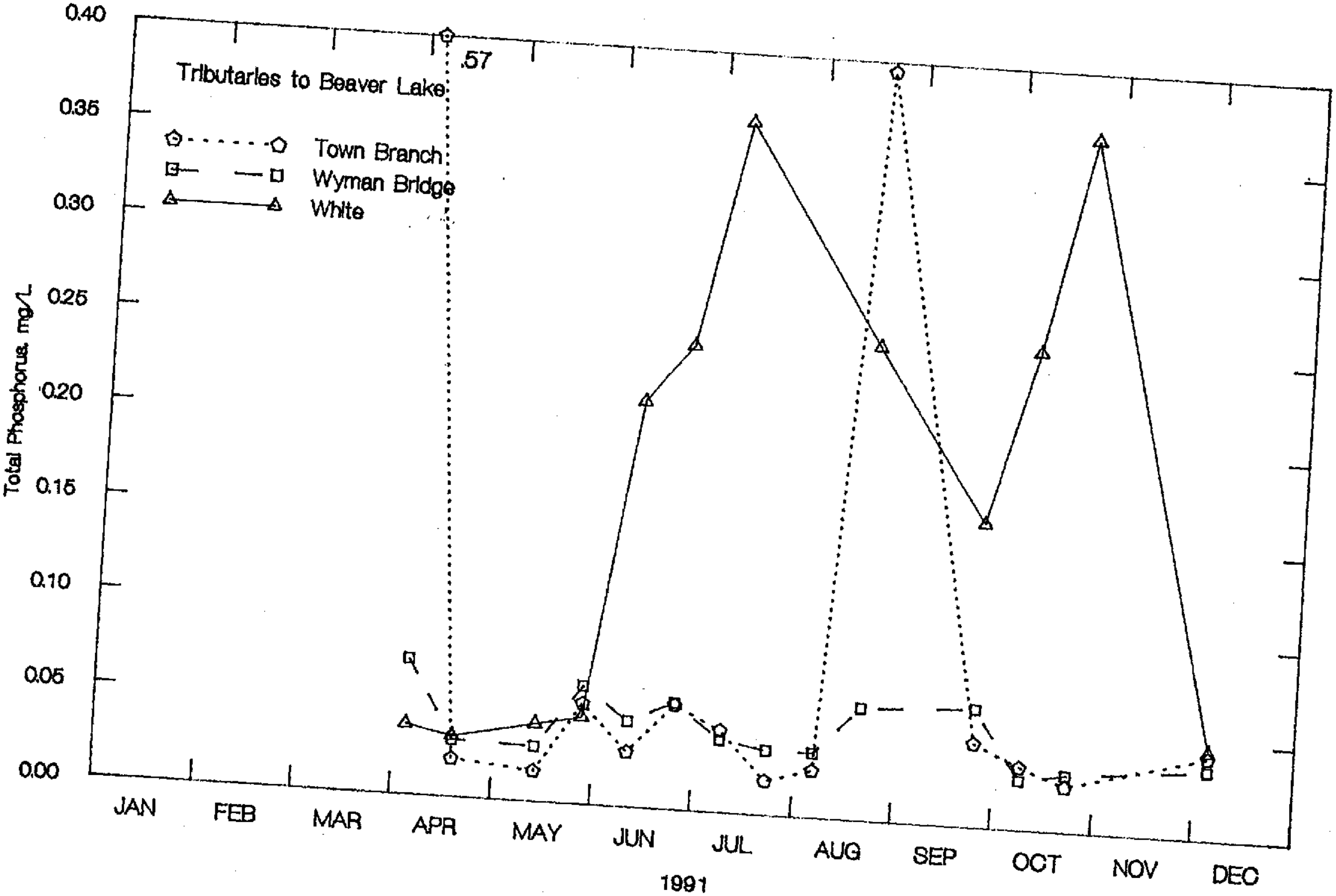


Figure a.10.44. Total phosphorus concentration in the upper White River Basin.

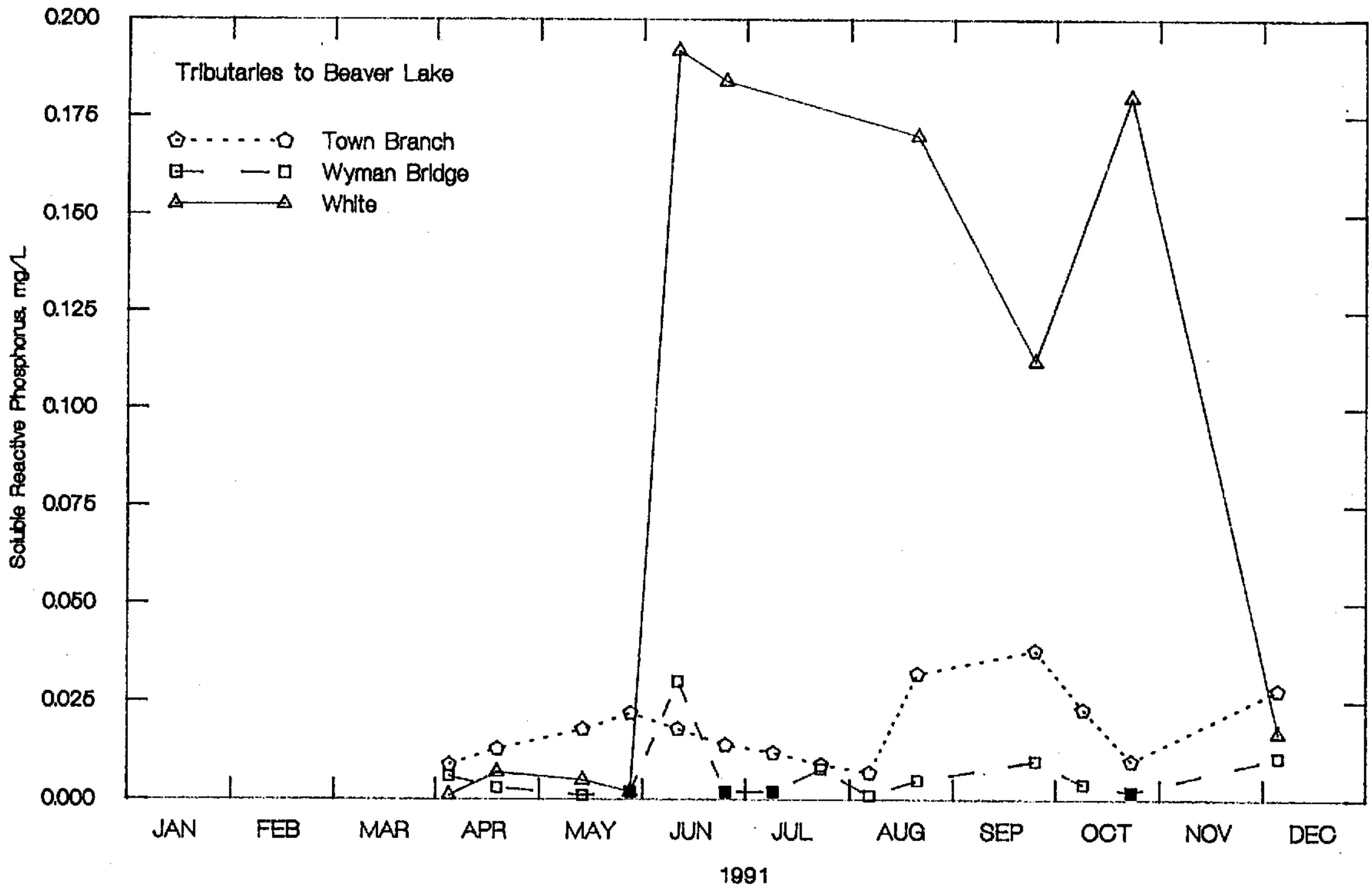


Figure a.10.45. Soluble reactive phosphorus concentrations in the upper White River Basin.

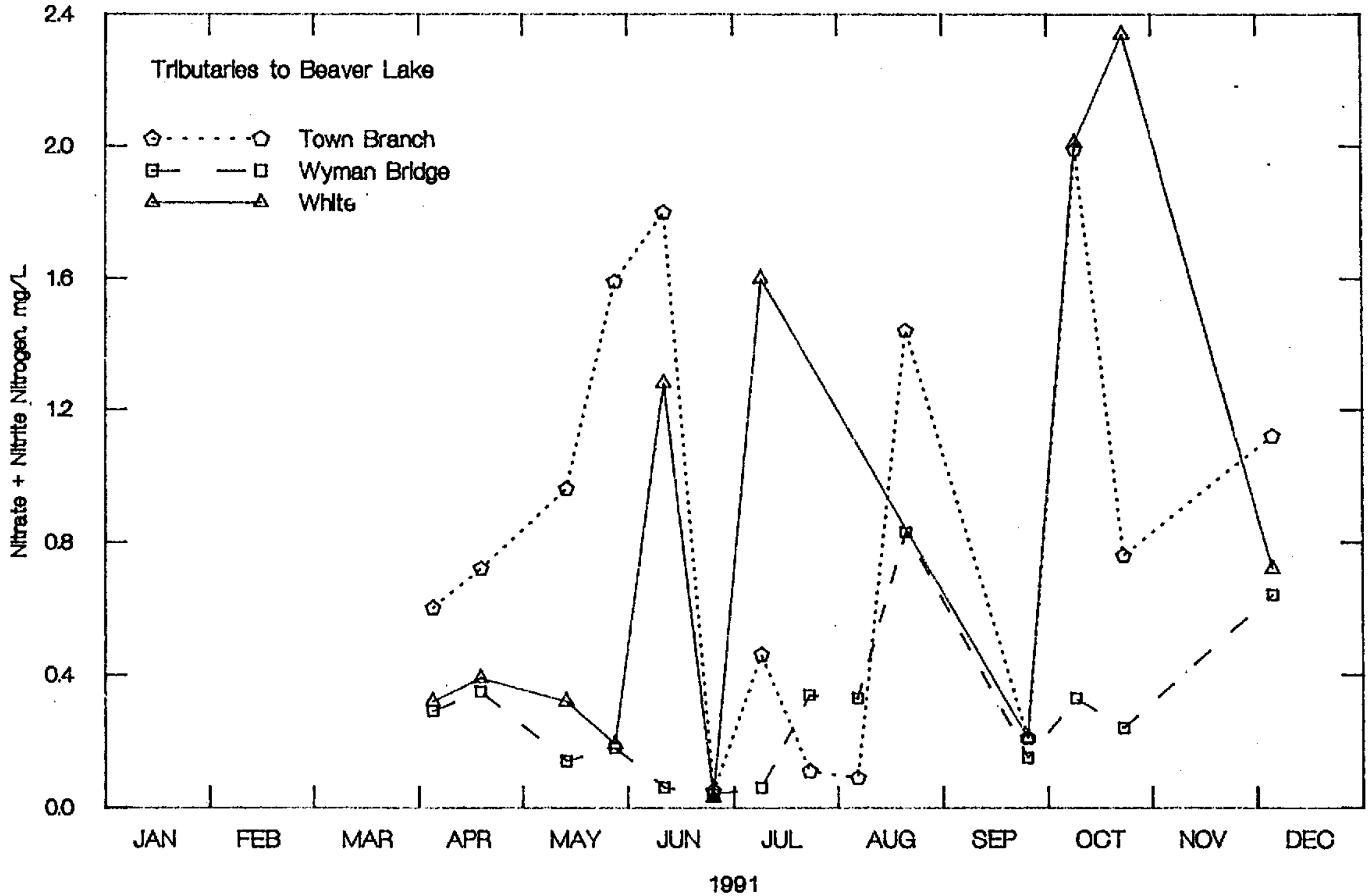


Figure a.10.46. Nitrate plus nitrogen concentrations in the upper White River Basin.

The turbidity guideline for streams in the Ozark Highland Ecoregion is 10 NTU (ADPCE 1991). Thirteen out of 14 measurements in Town Branch exceeded 10 NTU.

The second highest mean total phosphorus, soluble reactive phosphorus and nitrate plus nitrate nitrogen concentrations occurred in Town Branch. The highest means were downstream of the WWTP plant. The high mean concentrations resulted from occasional pulses of high concentrations of these constituents in Town Branch (Figure a.10.44 through Figure a.10.46). The reasons for the poor water quality observed in Town Branch are not known but may be related to urban runoff and/or construction runoff from the Highway 71 Bypass.

a.10.2.2.3 War Eagle, Richland and Prairie Creek

War Eagle and Richland Creeks were selected for monitoring because they drain watersheds where agricultural activities take place. Prairie Creek was selected for monitoring because it drains a watershed where development activities have occurred.

DO concentrations and pH were adequate to support aquatic biota and were within the range expected for an Ozark Highland Ecoregion stream.

Turbidity values for Richland and War Eagle Creeks were occasionally higher than the State's standard of 10 NTU, especially in spring. During the summer, the turbidity values were less than 10 NTU. In Prairie Creek, the turbidity values were also less than 10 NTU.

Total phosphorus concentrations were less then the state guideline of 0.1 mg/L in the three tributaries throughout the study. There was no consistent pattern of total phosphorus or soluble reactive phosphorus being higher in one creek or the other.

Nitrate plus nitrate nitrogen concentrations were generally higher in Prairie Creek (>1.0 mg/L) than in Richland or War Eagle Creeks (Figure a.10.47). Nitrate nitrogen concentrations generally were higher in Prairie, Richland and War Eagle Creeks than in the White River at Wyman Bridge.

There were differences observed in water chemistry between War Eagle, Richland and Prairie Creeks and the White River at Wyman Bridge. Generally, turbidity, the metals iron and manganese, total organic carbon, suspended solids, total phosphorus and total Kjeldahl nitrogen were lower in War Eagle, Richland and Prairie Creeks than in the

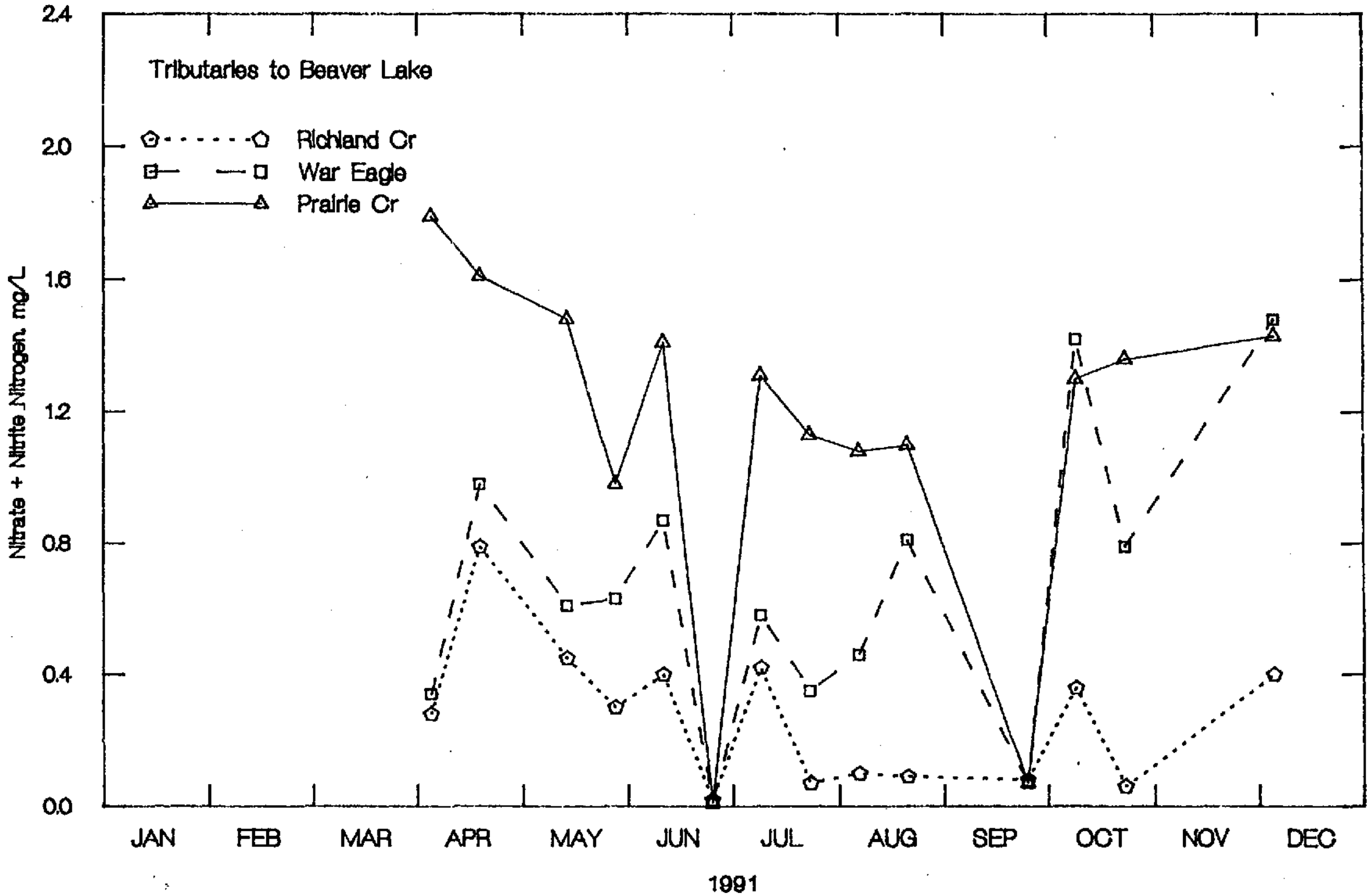


Figure a.10.47. Nitrate nitrogen concentrations in Richland, War Eagle, and Prairie Creeks.

White River at Wyman Bridge. Alkalinity and calcium concentrations were higher in War Eagle, Richland and Prairie Creeks than in the White River at Wyman Bridge. A partial explanation for the difference in alkalinity is that the White River drains the Boston Mountain Ecoregion which has little limestone whereas War Eagle, Richland and Prairie Creeks drain the Ozark Highland Ecoregion which is limestone rich and which would consequently contribute more calcium and carbonates to these surface waters.

In Table a.10.15, the median concentration, and minimum and maximum concentrations for nutrients measured at selected sites during the EPA NES Study are compared to median ranges determined during this study at similar sites.

The results indicate the nutrient concentrations between the two study periods were similar except that median nitrate plus nitrite nitrogen concentrations were higher during this study than during the NES study in the White River at Wyman Bridge and War Eagle Creek. In addition, the median total ammonia nitrogen also was higher during this study than during the NES survey in the White River at Wyman Bridge.

a.10.2.3 In-lake Water Quality

Water quality concerns listed in Table a.10.5 that are relevant for Beaver Reservoir include:

1) Oxygen depletion in the lower levels of Beaver Reservoir;
2) Lake eutrophication;
3) Elevated levels of iron and manganese;
4) Formation of trihalomethanes;
5) High turbidity levels causing coagulation problems at the Beaver Water District Plant; and
6) Fecal coliform levels periodically exceeding State Standards.

a.10.2.3.1 Stratification and Oxygen Depletion

The temperature isopleth presented in Figure a.10.48 is representative of the temperature profile throughout the reservoir. When sampling was initiated on 6 April 1991, Beaver Reservoir was already starting to stratify. Stratification intensified over

Table a.10.15. A comparison of median, and minimum and maximum concentrations from the NES and this Beaver Clean Lake Study.

	Total Phosphorus (mg/L)		Soluble Reactive Phosphorus (mg/L)		Total Ammonia (mg/L)		Nitrate Plus Nitrite Nitrogen (mg/L)	
	NES*	BCL**	NES	BCL	NES	BCL	NES	BCL
White River @ Wyman Bridge	0.05 (0.02-0.12)***	0.04 (0.03-0.07)	0.008 (0.005-0.020)	0.006 (0.001-0.030)	0.03 (0.01-0.07)	0.08 (0.02-0.42)	0.18 (0.08-0.38)	0.28 (0.04-0.83)
War Eagle Creek	0.04 (0.01-0.16)	0.03 (0.002-0.04)	0.03 (0.005-0.045)	0.010 (0.002-0.046)	0.06 (0.005-0.43)	0.03 (0.01-0.07)	0.42 (0.20-0.62)	0.67 (0.01-1.48)
Richland Creek	0.03 (0.01-0.06)	0.02 (0.008-0.05)	0.010 (0.005-0.025)	0.008 (0.001-0.023)	0.02 (0.008-0.04)	0.04 (0.01-0.08)	0.42 (0.22-0.64)	0.27 (0.02-0.79)
Prairie Creek	0.02 (0.01-0.05)	0.02 (0.01-0.08)	0.008 (0.005-0.012)	0.013 (0.005-0.033)	0.02 (0.005-0.05)	0.03 (0.01-0.07)	1.78 (0.02-2.40)	1.15 (0.01-1.79)

* NES National Eutrophication Survey (EPA 1977)
** BCL Beaver Clean Lake Study
*** ( ) Minimum to maximum concentrations

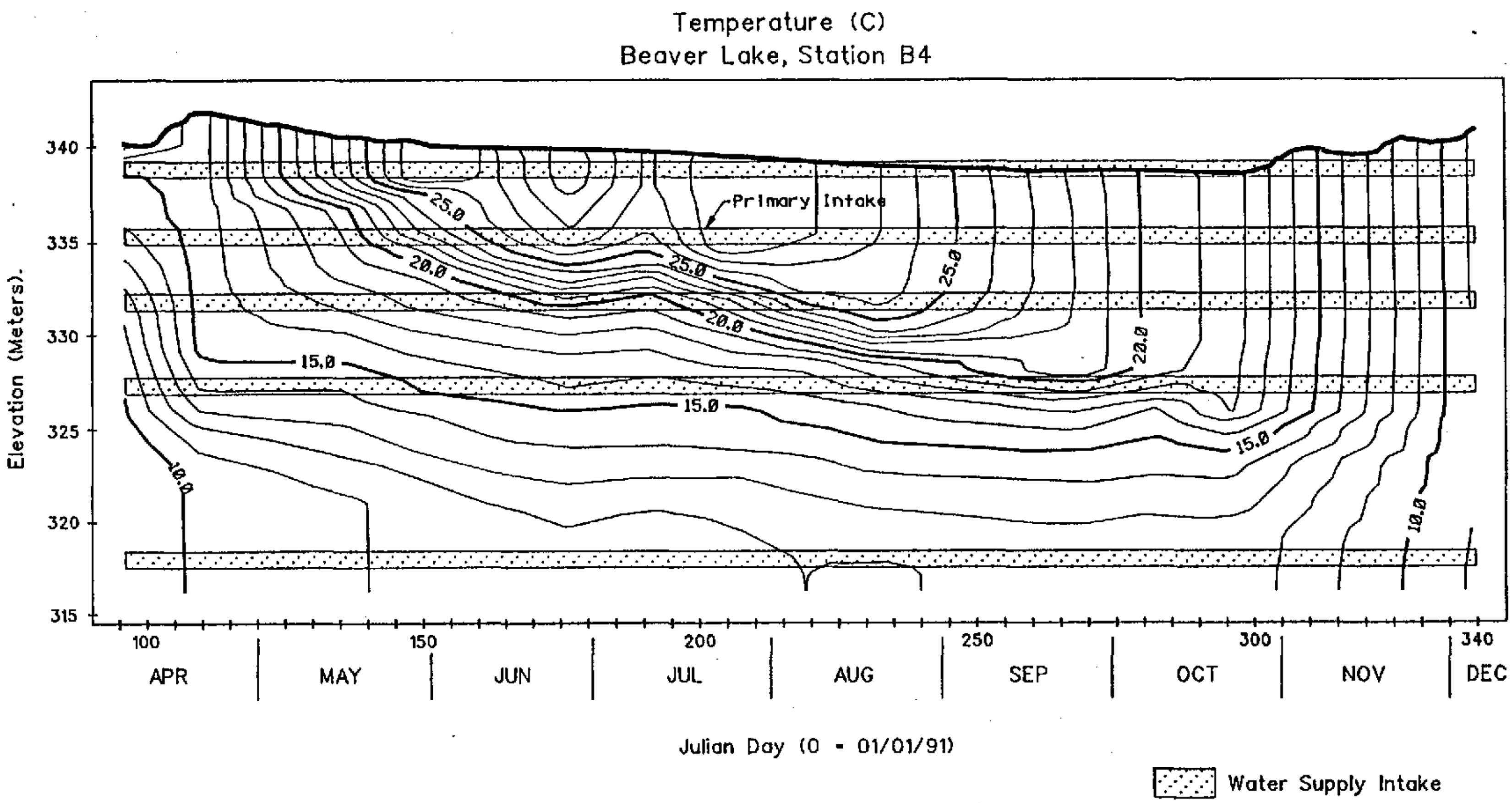


Figure a.10.48. Temperature isopleths for Station B4 near the Beaver Water District intake structure.

the summer and as the summer progressed the epilimnion deepened, depressing the metalimnion deeper into the Lake. By the end of December, the Reservoir was mixed except in the deeper areas such as near the Beaver Reservoir Dam (Appendix A).

Dissolved oxygen (DO) isopleths were related to the temperature isopleths in the Reservoir (Figure a.10.49). Following stratification in April, DO concentrations in the metalimnion and hypolimnion began to decrease. There was a pronounced metalimnetic DO minima by early June. By late June, the hypolimnion near the BWD intake was anoxic. The hypolimnetic anoxic conditions lasted from mid-June through the latter part of October and extended from the bottom of the reservoir to within approximately 1.5 m of the BWD primary intake (elevation 336.4m). Generally, the primary intake structure was at a level where DO concentrations were 6.0 mg/L or greater, but DO concentrations did decrease rapidly just below the primary intake. The results obtained during this study were compared to similar time periods during the 1974 Beaver Reservoir NES study. Anoxic conditions appear to be more intense at the intake structure in 1991 than during the NES. In June 1974, DO concentrations less than 1.0 mg/L were not measured either at the War Eagle site up reservoir of the BWD intake or at Horseshoe Bend down reservoir of the BWD site (Figures a.10.16 and a.10.18). DO concentrations less than 1.0 mg/L did exist by August at the Horseshoe Bend site. Anoxic conditions started between 8.0 and 18.0 m and extended to the bottom (Figure a.10.19). During the 1991 study, DO concentrations less than 1.0 mg/L were measured at 8 m. There is not a sufficient difference, however, to determine whether the volume of the hypolimnion affected by anoxic conditions in August is different during this study than during the NES.

Near the dam, DO concentrations did not reach anoxic conditions until the latter part of September (Figure a.10.50). Although anoxic conditions still persisted when monitoring was terminated, the Lake was close to being completely mixed as evidenced by the isopleths. During the NES, anoxic conditions were measured at 57 m at the end of August. During the 1991 study, DO was measurable to 50 m. This difference in anoxic conditions between the two study periods is not considered significant.

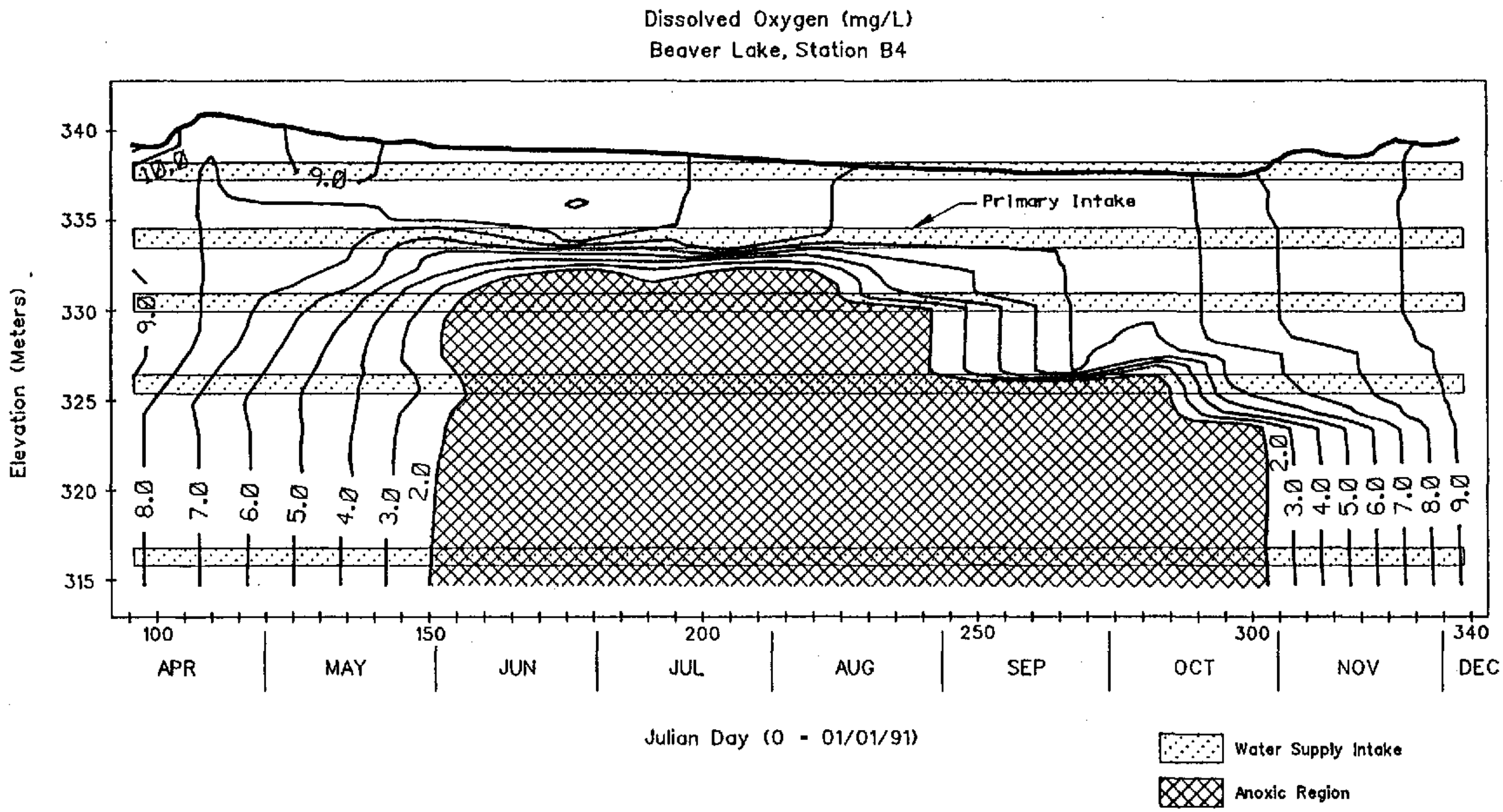


Figure a.10.49. DO isopleths for Station B4 near the Beaver Water District intake structure.

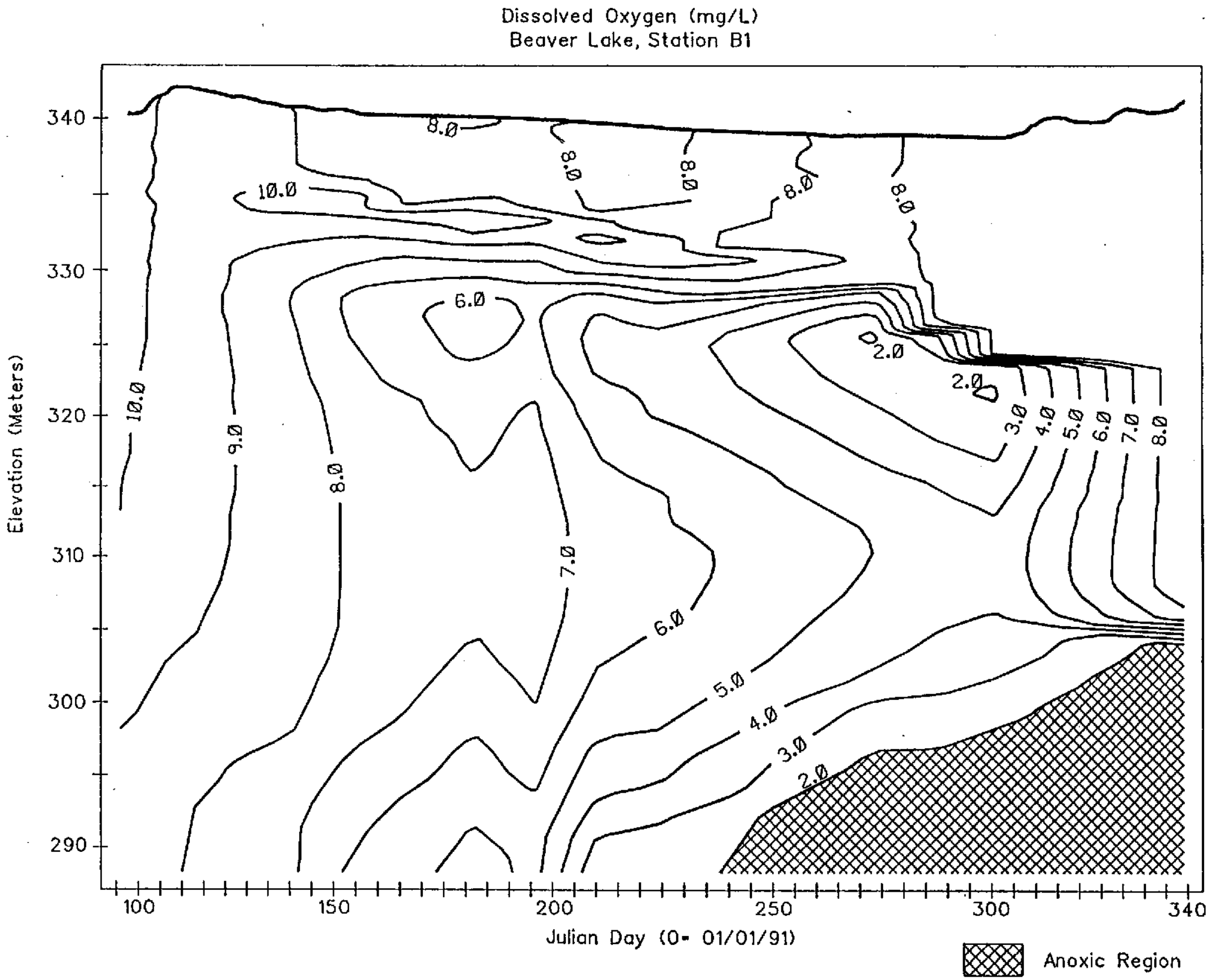


Figure a.10.50. DO isopleth for Station B1 near the Beaver Lake Dam.

Figure a.10.51 shows the conditions that existed in a cove to the Reservoir during this study. In the Prairie Creek Cove, a DO minima occurred at the bottom of the metalimnion (Figure a.10.51). The DO minima started in late April/early May and as the summer progressed, the DO concentrations continued to decrease in this minima until anoxic conditions occurred in mid-July. By mid-July, anoxic conditions were also starting to occur toward the bottom of the hypolimnion. By the end of July, the anoxic conditions in the hypolimnion had extended upward and converged with the anoxic conditions in the metalimnetic minima. The DO pattern observed for the remainder of the study was similar to the DO pattern observed at the other two stations located in the Reservoir. After mid-July, the epilimnion deepened until complete mixing occurred in October.

As part of the synoptic surveys conducted in June and September, temperature and DO measurements were taken at 10 stations that ranged from just downstream of Highway 68 (Transect 10) to the dam (Transect 1) (Figure a.10.43). The major difference between the two longitudinal temperature plots (Figures a.10.52 and a.10.53) was the increase in the depth of the epilimnion by September, a pattern also observed in the individual station plots. The longitudinal DO plots (Figures a10.54 and a10.55) shown that over the summer, anoxic conditions extended from the upper reservoir to at least river kilometer 195 (Ventris site). As the summer progressed, anoxic conditions progressed down toward the dam.

a.10.2.3.2 Lake Eutrophication

Water Chemistry: A major water quality concern has been that Beaver Reservoir is becoming more eutrophic because of point and nonpoint pollution inputs. One approach to evaluating this concern is to compare the data collected during the NES almost 20 years ago (i.e. 1974) with the data collected at comparable time periods during this study (i.e. 1991). Table a.10.16 summarizes the results of the comparisons for the epilimnion and hypolimnion. Insufficient data points were available to compare metalimnetic data. In Table a.10.16, the median parameter value for the four NES sampling dates is compared to the median parameter value for four comparable sampling

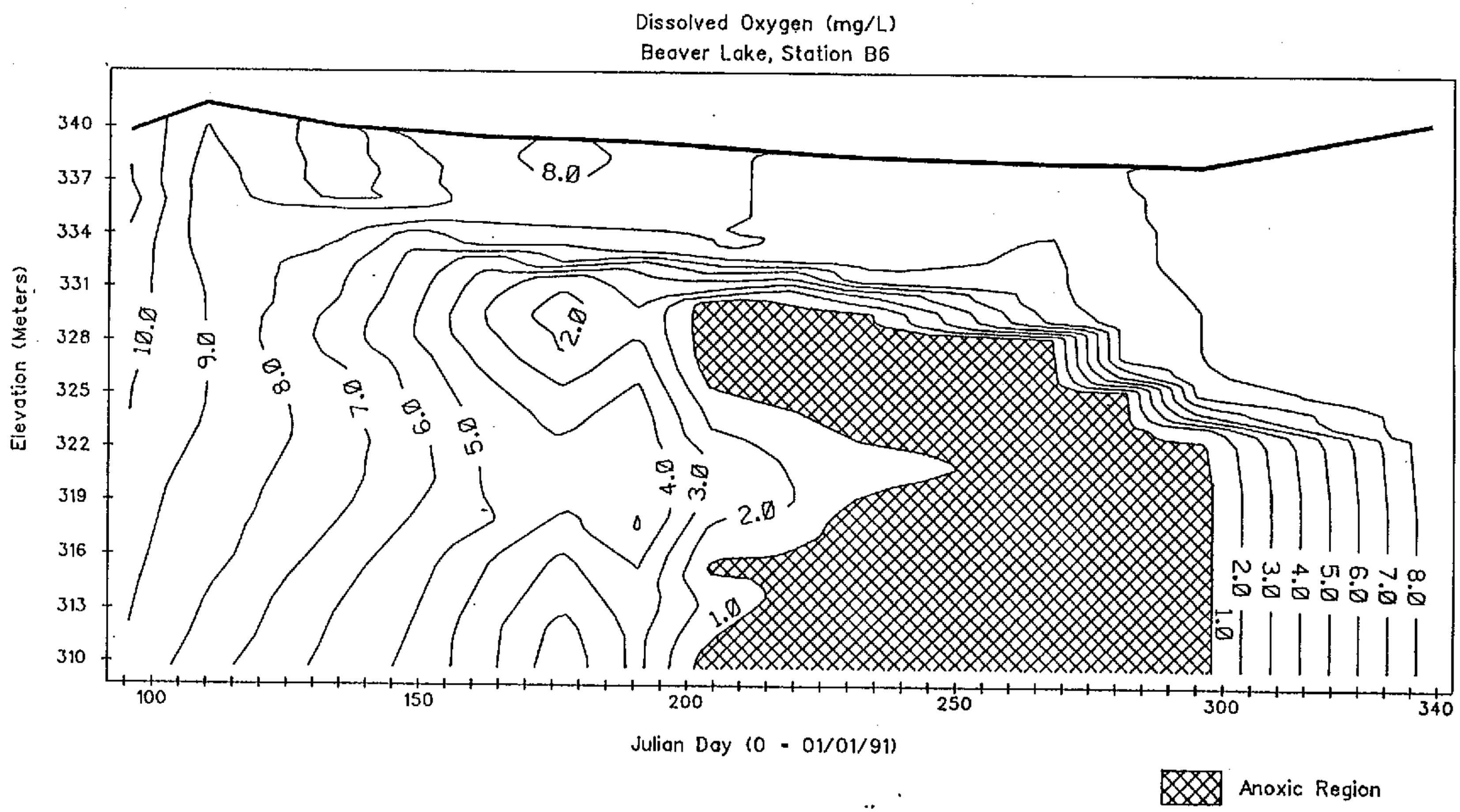


Figure a.10.51. DO isopleth for Station B6 located in the Prairie Creek Cove.

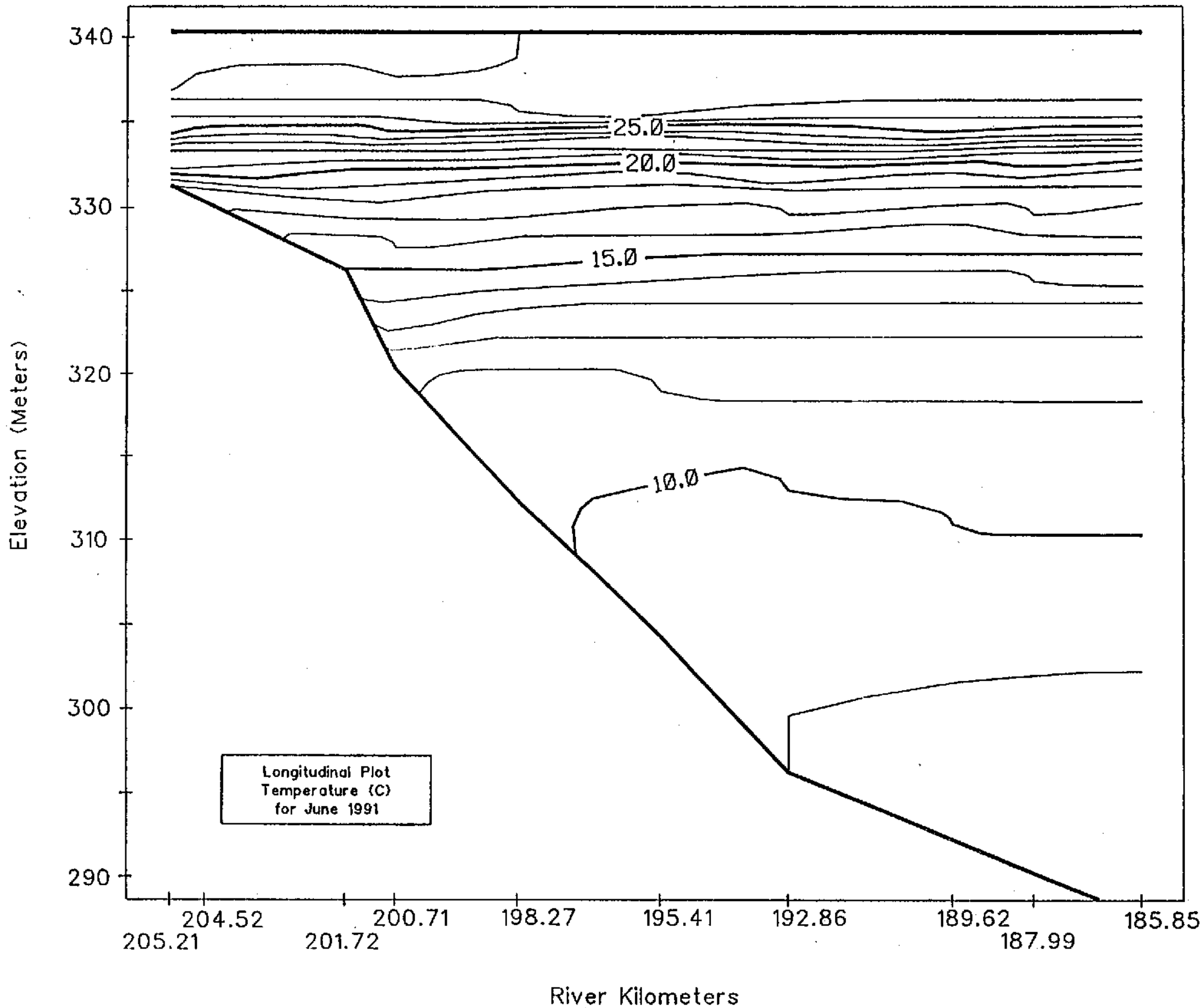


Figure a.10.52. Longitudinal temperature gradients in Beaver Lake during the June synoptic survey.

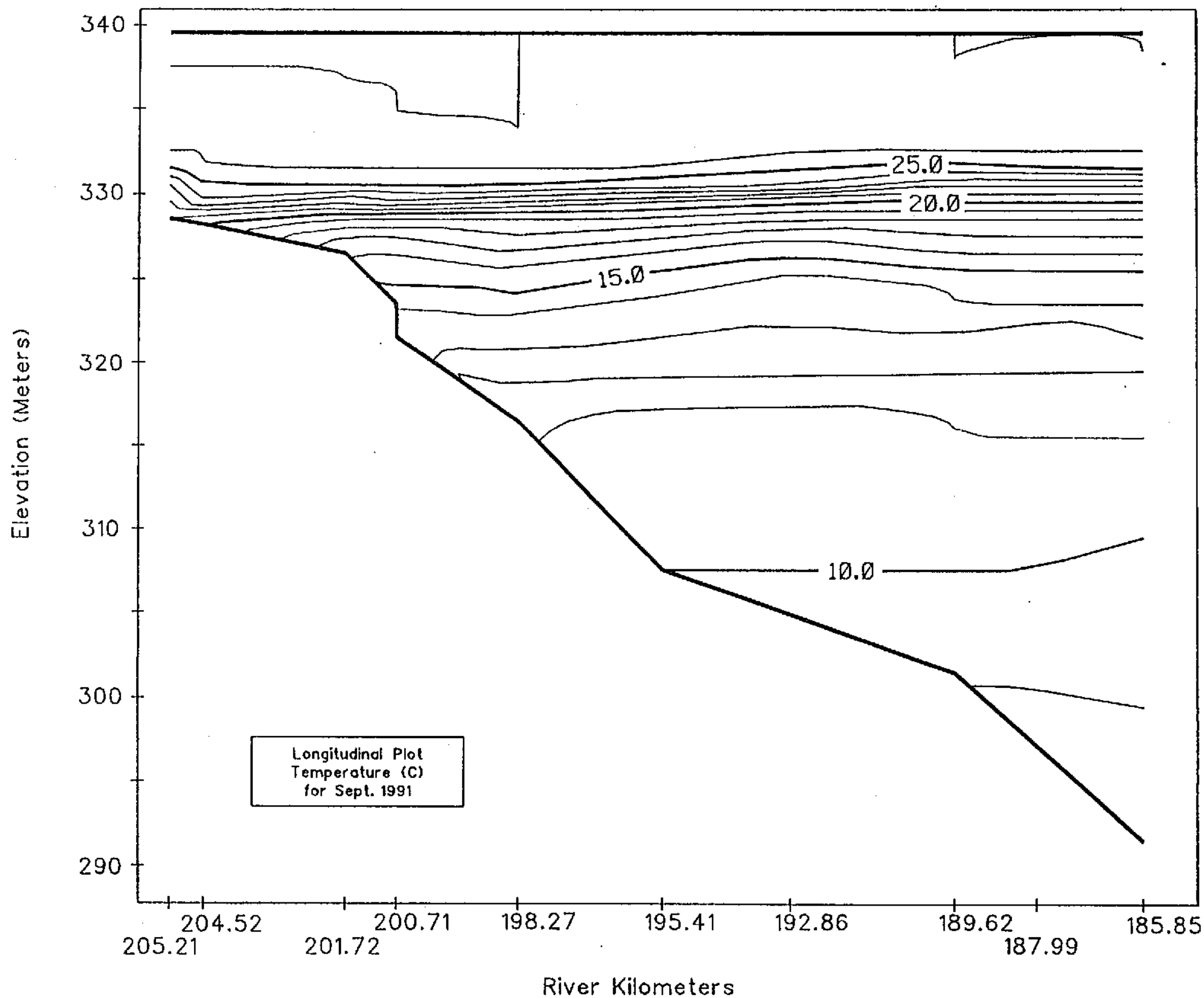


Figure a.10.53. Longitudinal temperature gradients in Beaver Lake during the September synoptic survey.

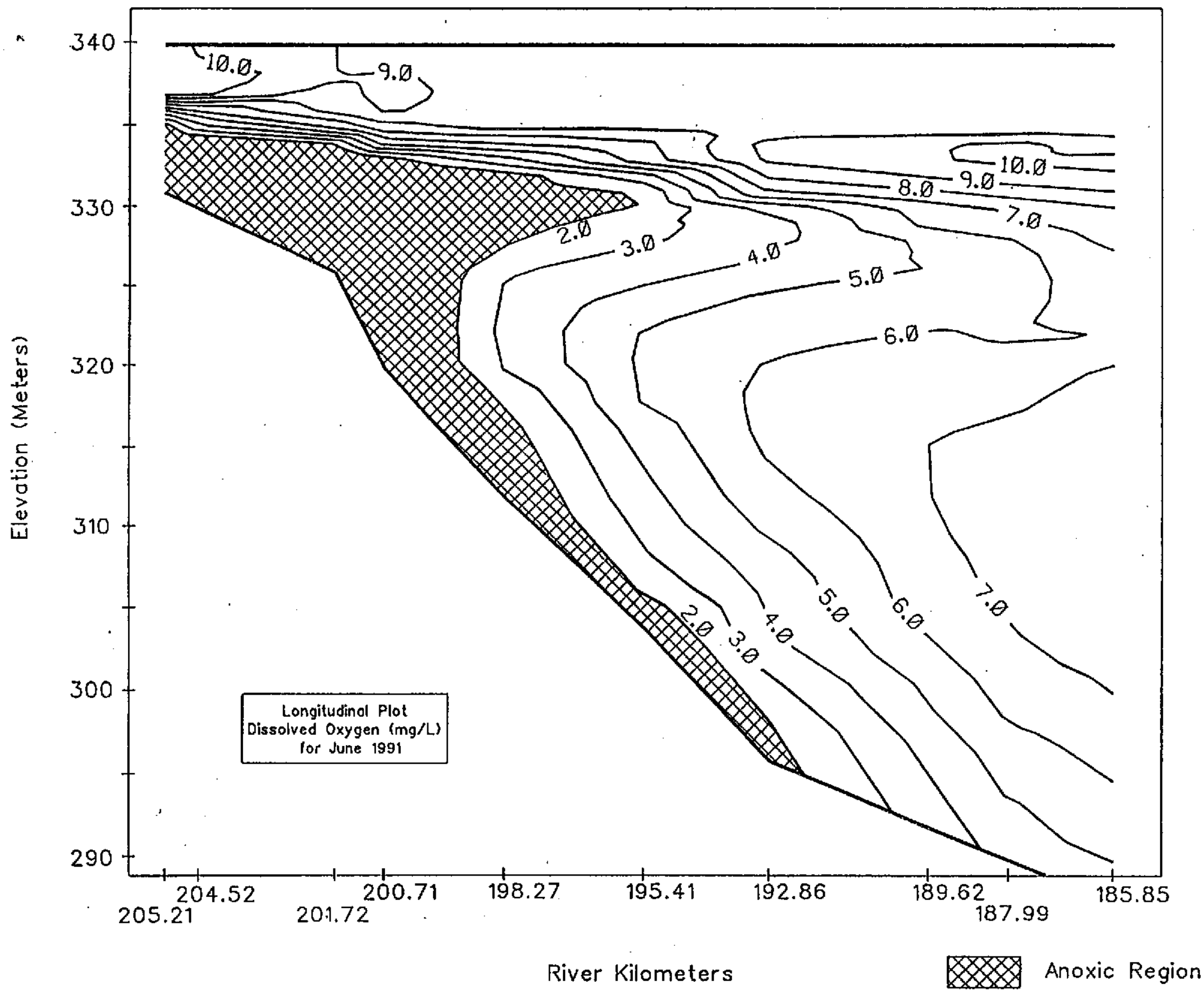


Figure a.10.54. Longitudinal DO gradients in Beaver Lake during the June synoptic survey.

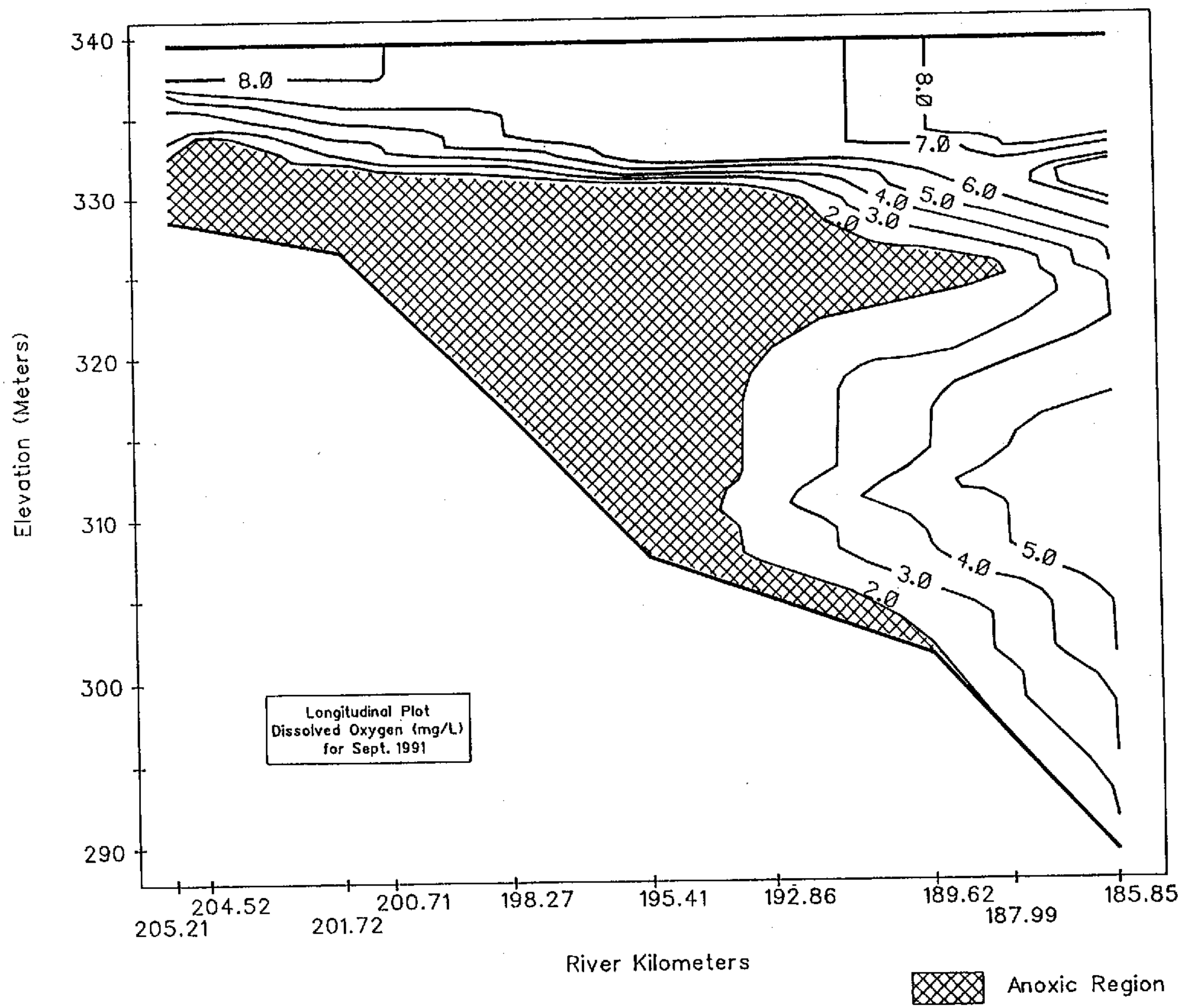


Figure a.10.55. Longitudinal DO gradient in Beaver Lake during the September synoptic survey.

Table a.10.16. A comparison of median epilimnion and hypolimnion values from this survey and the NES.

	Total Phosphorus (mg/L)		Soluble Reactive Phosphorus ** (mg/L)		Total Ammonia-N (mg/L)		Nitrate Plus Nitrite-N (mg/L)		Secchi Transparency (m)		Chlorophyll a	
	NES**	BCL+	NES	BCL	NES	BCL	NES	BCL	NES	BCL	NES (µg/L)	BCL (µg/L)
Dam Site												
Epilimnion	0.010	0.004	0.004	<0.002	0.03	0.02	0.07	0.17	4.5	5.5	2.9	1.3
	(0.008-0.016)*	(<0.002-0.005)	(0.002-0.010	(<0.002-0.005)	(<0.02-0.06)	(0.01-0.04)	(0.02-0.24)	(0.03-0.53)	(2.3-5.5)	(2.7-8.1)	(1.7-3.5)	(<0.1-1.5)
Hypolimnion	0.012	0.003	0.004	<0.002	0.03	0.04	0.36	0.42				
	(0.007-0.100)	(<0.002-0.011)	(<0.002-0.013)	(<0.002-0.005)	(<0.02-0.27)	(0.01-0.05)	(0.19-0.52)	(0.28-0.60)				
Ventris												
Epilimnion	0.016	0.006	0.004	<0.002	0.05	0.03	0.04	0.04	2.4	4.0	3.5	2.6
	(0.011-0.040)	(<0.002-0.014)	(0.002-0.015)	(<0.002-0.002)	(0.03-0.06)	(<0.01-0.05)	(<0.02-0.60)	(0.03-0.73)	(1.0-3.2)	(1.7-7.1)	(1.0-6.5)	(0.1-3.2)
Hypolimnion	0.042	0.015	0.008	0.002	0.07	0.002	0.46	0.69				
	(0.018-0.136)	(0.004-0.039)	(0.003-0.025	(<0.002-0.007)	(0.03-0.37)	(<0.01-0.34)	(0.16-0.67)	(0.29-0.88)				

Table a.10.16. Continued.

	Total Phosphorus (mg/L)		Soluble Reactive Phosphorus ** (mg/L)		Total Ammonia-N (mg/L)		Nitrate Plus Nitrite-N (mg/L)		Secchi Transparency (m)		Chlorophyll a	
	NES**	BCL+	NES	BCL	NES	BCL	NES	BCL	NES	BCL	NES (µg/L)	BCL (µg/L)
Beaver Water District vs Horseshoe Bend												
Epilimnion	0.022	0.012	0.005	<0.002	0.06	0.02	0.15	0.04	1.5	2.2	3.4	3.0
	(0.020-0.042)	(0.007-0.031)	(0.004-0.016)	(<0.002-0.008)	(0.04-0.16)	(0.01-0.03)	(<0.02-0.58)	(0.01-0.53)	(0.6-2.6)	(0.8-2.6)	(2.2-6.0)	(0.7-5.6)
Hypolimnion	0.062	0.029	0.012	0.002	0.10	0.01	0.30	0.70				
	(0.021-0.212)	(0.027-0.127)	(0.006-0.023)	(<0.002-0.005)	(0.03-1.27)	(0.01-1.30)	(0.03-0.74)	(0.01-0.98)				

* ( ) Minimum and maximum values
** Dissolved ortho phosphourus NES
*** NES - National Eutrophication Survey 1977
\+ BCL - Beaver Clean Lake Study

dates during this study. The values in parentheses are the minimum and maximum values observed.

With the exception of a few nitrate plus nitrite nitrogen concentrations, there is no indication that Beaver Reservoir is becoming more eutrophic, at least from the BWD intake monitoring site to the dam monitoring site. In general, the median and the minimum and maximum values were comparable or slightly lower for total phosphorus, soluble reactive phosphorus (dissolved orthophosphorus), ammonia as nitrogen, and chlorophyll a during this study than during the NES survey. In addition, Secchi disc transparency was greater during this study than during the NES. Nitrate plus nitrite nitrogen concentrations were greater in the hypolimnion near the BWD site and near Ventris. At the dam site, nitrate plus nitrite concentrations were higher in both the epilimnion and the hypolimnion. The minimum and maximum concentrations are similar in the hypolimnion between the studies, but the maximum concentration in the epilimnion is about 2X greater than it was in 1974.

Phytoplankton: The relative abundance of phytoplankton, based on organism units, is shown in Figures a.10.56 and a.10.57. At both the BWD intake site and near the dam the bacillariophytes (diatoms) typically contributed the most organisms to the community. The cryptophytes were generally the next most abundant group. Near the BWD intake structure, pulses of cyanophytes (bluegreens) did occur in late May and early August.

James M. Montgomery, Consulting Engineers, Inc (JMM) (1987) reported taste and odor problems occurred occasionally each year. The cause of the odor problems had not been identified but actinomycetous (bacteria) were suspected because of an earthy/musty odor (JMM 1987). There are algae present in Beaver Lake that can cause taste and odor problems. However, odor-causing algae did not occur in large numbers. The filter clogging diatom, *Fragillaria*, was the dominant algae near the BWD intake structure throughout most of the summer. The maximum number of cells recorded was 645/mL during July. Other organisms were present in the Reservoir that can cause taste and odor problems or that can clog filters (e.g. *Peridinium, Anabaena,* and *Trachelomonas*), but they were in low-numbers.

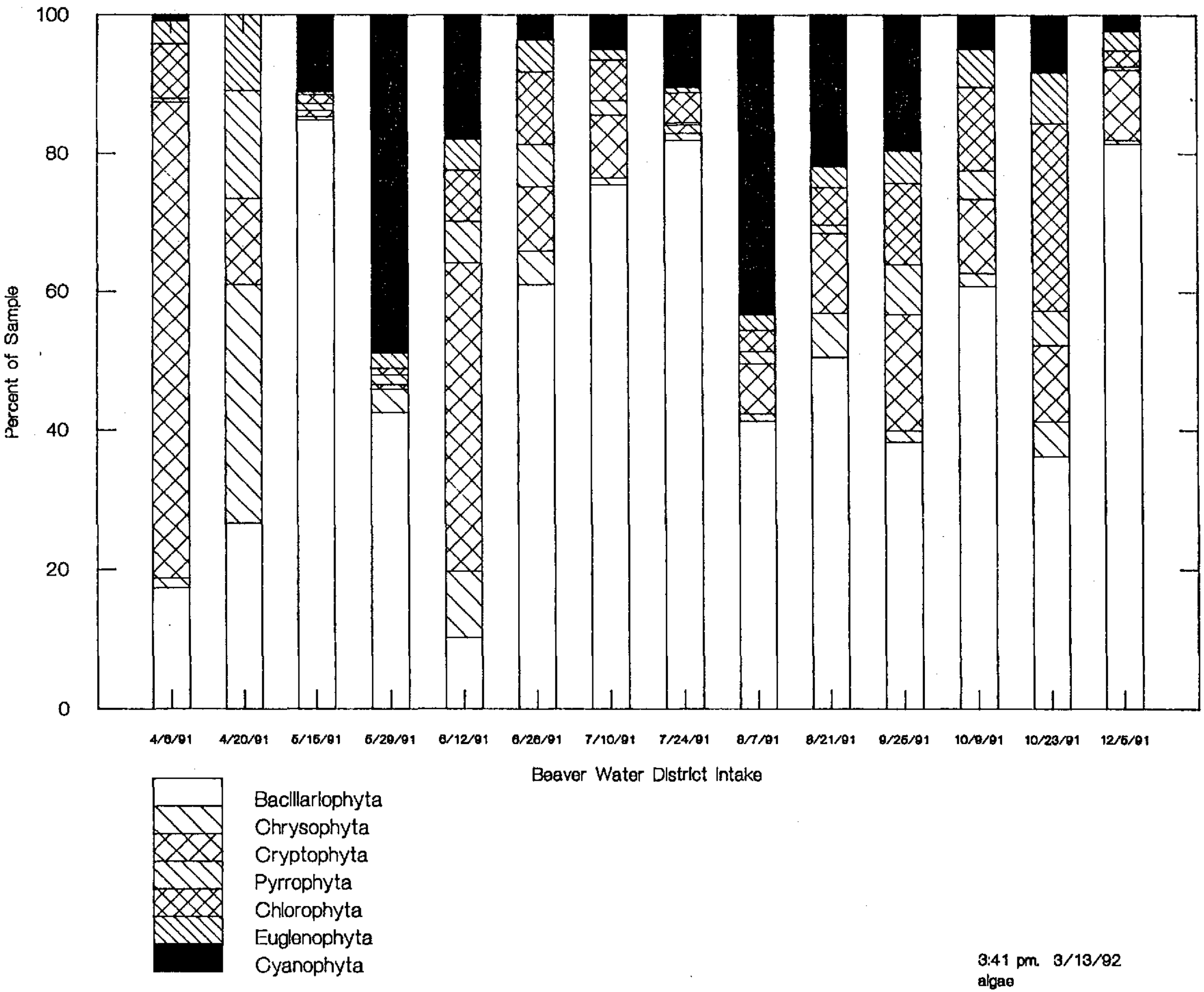
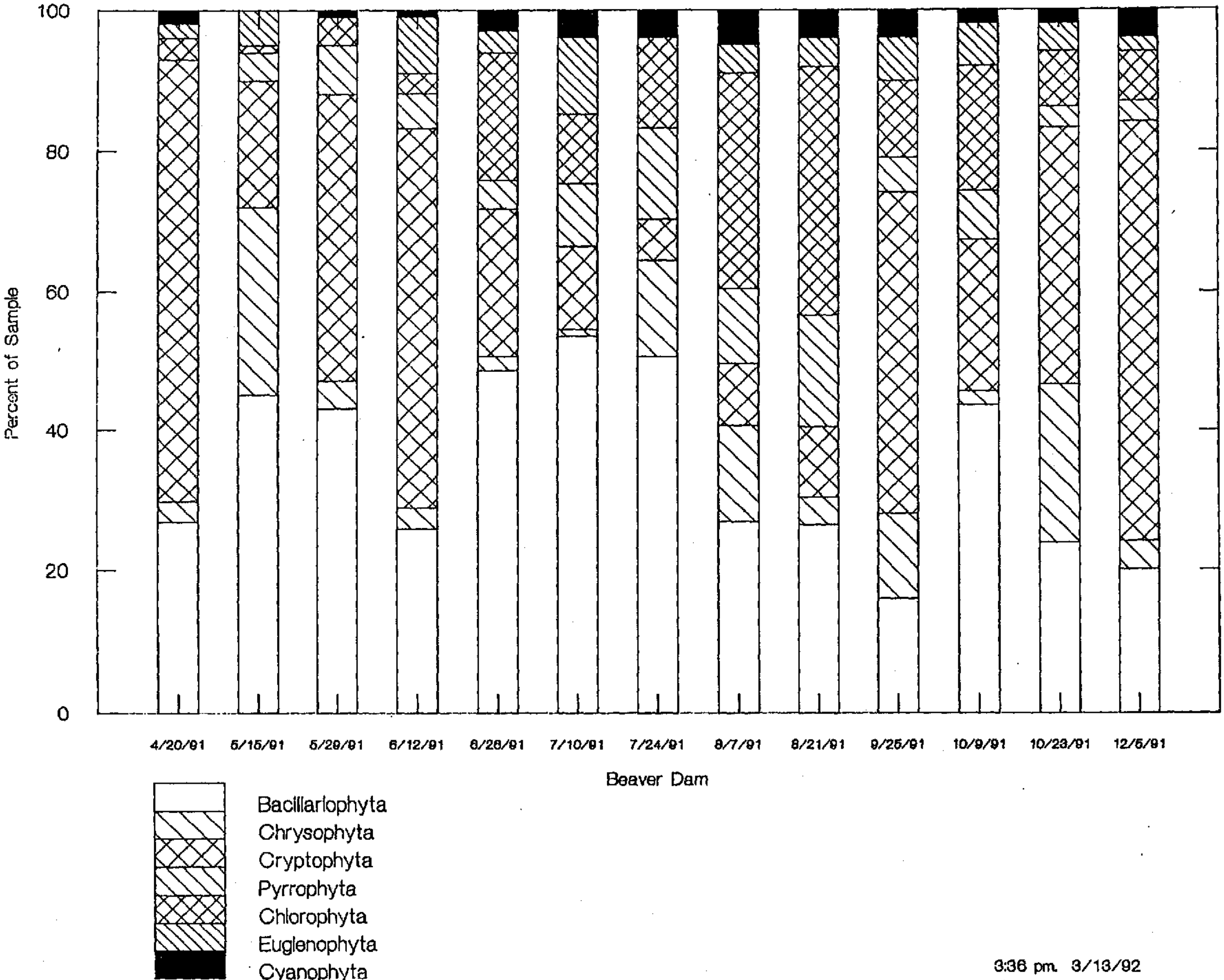


Figure a.10.56. Relative abundance of phytoplankton collected near the Beaver Water District Intake.



3:36 pm. 3/13/92
algae

[redacted] abundance [redacted] phytoplankton [redacted] collected near [redacted] Beaver R[redacted]oir [redacted]

In Table a.10.17, the dominant phytoplankton present at the dam site during the NES are compared to the dominant phytoplankton found during this study. The results for April are similar between the two studies. In August, a green algae and a dinoflagellate were the two dominant groups during this study while a bluegreen and a diatom were the two dominant groups during the NES based on algal organism units. The types of algae present in October were similar although different genera are listed.

In Table a10.18, a series of indices are summarized based on the phytoplankton collected during the NES and this study (EPA 1977 and Hilgert et al. 1977). These indices include Nygaard's Trophic State Indices (Nygaard 1949) that were adopted from Hutchinson (1967), Palmer's Organic Pollution Indices (Palmer 1969). Nygaard's indices are based on the assumption that certain algal groups are indicative of nutrient enrichment levels. For example, it is generally accepted that Cyanophyta, Euglenophyta, centric diatoms and members of chlorococcales are found in nutrient rich (eutrophic waters), whereas desmids and many pennate diatoms cannot tolerate high nutrient levels.

Palmer's indices are based on the tolerance of 20 algae genera or species to organic pollution. To algae of known tolerance, a pollution index was assigned ranging from one for moderately tolerant forms to six for extremely tolerant forms. A score of 20 is evidence of high organic pollution while a score of 15 to 19 is probable evidence of organic pollution.

The Nygaard Trophic State Indices indicate that the phytoplankton at the dam site were more representative of oligotrophic conditions during this study than during the NES except in October when the phytoplankton communities indicated eutrophic conditions. Occasionally, the Nygaard Trophic State Index could not be calculated because algae representative of nutrient poor conditions were not present but algae representative of nutrient rich conditions were present. By definition, the algae were considered to represent eutrophic conditions.

Palmer's organic pollution index indicates that during both studies, organic pollution at the dam site was not a problem.

Additional comparisons made between this study and the NES study included the Shannon-Weiner diversity index, total number of taxa, and total number of individuals

Table a.10.17. A comparison of dominant phytoplankton collected during the NES survey and during this survey.

*NES**		*BCL***			
4/5/74		*4/20/91*			
Dominant Genera	Algal Units Per mL	*Dominant Genera*	Algal Units Per mL	*Dominant Genera*	Algal Units Per mL
Cryptomonas	475	*Cryptomonas*	10	*Cryptomonas*	20
Melosira	412	*Fragilaria*	3	*Melosira*	13
Chroomonas	380	*Synedra*	1	*Fragilaria*	3
Stephanodiscus	190	*Ochromonas*	1	*Ochromonas*	3
Dactylococcopsis	95	*Scenedesmus*	1	*Pondoria*	2
*NES**		*BCL***			
8/30/74		*8/21/91*			
Dominant Genera	Algal Units Per mL	*Dominant Genera*	Algal Units Per mL		
Lyngbya	549	*Peridinium*	11		
Synedra	549	*Scenedesmus*	14		
Chroomonas	335	*Navicula*	9		
Nitzschia	335	*Cryptomonas*	7		
Melosira	244	*Fragilaria*	7		

Table a.10.17. Continued.

*NES**		*BCL***			
4/5/74		*4/20/91*			
Dominant Genera	Algal Units Per mL	*Dominant Genera*	Algal Units Per mL	*Dominant Genera*	Algal Units Per mL
Centric Diatom	172	*Fragilaria*	15		
Melosira	172	*Crytomonas*	14		
Skeletonema	103	*Cyclotella*	12		
Cryptomonas	69	*Scenedesmus*	6		
Tetraedon	69	*Peridinium*	4		

* NES - National Eutrophication Survey 1977
** BCL - Beaver Clean Lake Study

Table a.10.18. A comparison of indices determined from NES phytoplankton data and from this study's data.

NYGAARD Trophic State Indices						
	5 April 74	20 April 91	30 August 74	23 August 91	9 October 74	9 October 91
Myxophycean	02/0 (E)*	0/0 (0)**	3.50 (E)	0.25 (0)	5.00 (E)	1.5 (E)
Chlorophycean	02/0 (E)	0/0 (0)	6.50 (E)	1.0 (E)	7.00 (E)	2.0 (E)
Euglenophyte	0.50 (E)	2/0 (E)	0.30 (E)	0.2 (0)	0.67 (E)	0.29 (E)
Diatom	0.83 (E)	0.33 (E)	0.50 (E)	0.25 (0)	1.40 (E)	0.35 (E)
Compound	11/0 (E)	3/0 (E)	14.5 (E)	2.5 (E)	27.0 (E)	6.0 (E)
Palmer's Organic Pollution Indices						
	5 April 74	20 April 91	30 August 74	23 August 91	9 October 74	9 October 91
No. of Genera	1	1	10	4	1	0
Species Diversity And Abundance Indices						
	5 April 74	20 April 91	30 August 74	23 August 91	9 October 74	9 October 91
Shannon-Wiener Diversity	2.91	1.72	3.38	3.45	3.10	3.24
Number of Taxa	23	9	51	19	39	21
Total Number of Individuals/mL	1680	64	2925	259	721	259

* Eutrophic
** Oligotrophic

per mL. The Shannon-Weiner diversity indices were similar between the two studies. However, both the number of taxa and the total number of individuals per mL were lower during this study than during the NES.

Chlorophyll a can be used as a measure of phytoplankton biomass and as an estimate of the trophic status of a lake or reservoir (EPA 1988, Moore and Thornton 1988). During this study, the median chlorophyll a concentrations for all sampling dates were 1.1 μg/L the dam and 2.6 μg/L near the BWD intake structure. Both median values indicate oligotrophic conditions. However, 43% of the chlorophyll a concentrations near the BWD intake indicate mesotrophic or eutrophic conditions (primarily mesotrophic). The two intensive surveys clarify the chlorophyll a concentration pattern and distribution. In both June and September, chlorophyll a concentrations were less than 4.0 μg/L from the vicinity of Horseshoe Bend (Transect 6, Figure a.10.43) to the dam. Up reservoir from the BWD intake chlorophyll a concentrations were >4.0 to 10.0 μg/L (mesotrophic) or > 10 μg/L (eutrophic) (Figures a.10.58 and a.10.59). The upper White River and War Eagle Creek had areas of high chlorophyll a concentrations in September.

Based on the above results, Beaver Reservoir does not appear to be significantly more eutrophic now than it was during the 1974 NES.

a.10.2.3.3 Elevated Iron and Manganese

Black and Veatch (1982) reported that iron and manganese had stained the basin walls and troughs and shortened filter runs at the BWD treatment plant. In Table a.10.19, the iron and manganese concentrations for the period 1976 through 1981 are compared to the average and median epilimnetic concentrations in 1991. In 1991, the average concentrations of iron and manganese were greater than average concentrations reported by Black and Veatch (1982).

Although the average concentrations were higher in 1991, it cannot be assumed that iron and manganese concentrations are increasing. The Black and Veatch (1982) concentrations are based on daily values over a six year period. High concentrations that tend to skew average concentrations calculated from small data sets such as the 1991 data

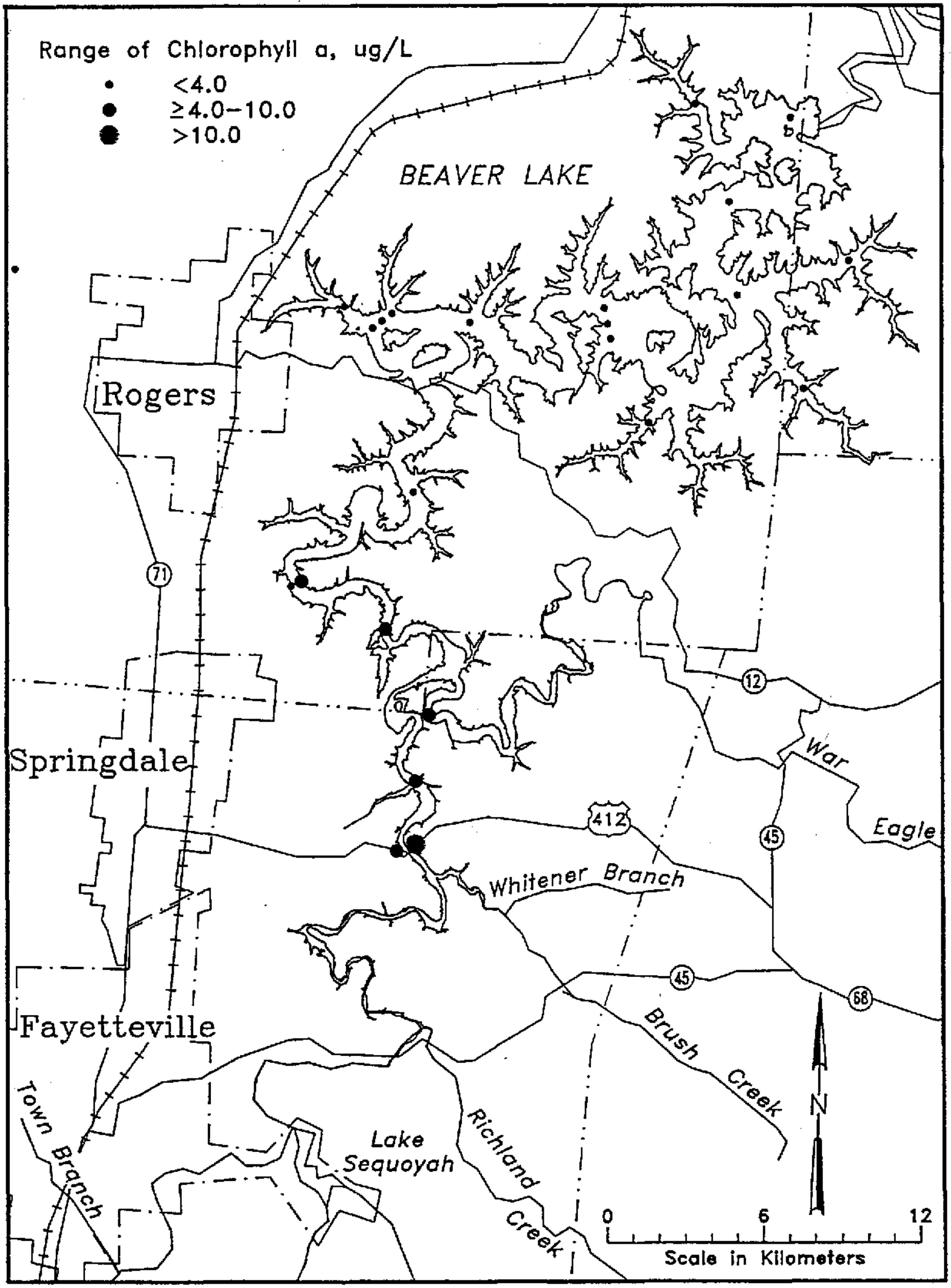


Figure a.10.58. Chlorophyll a results from the June synoptic survey.

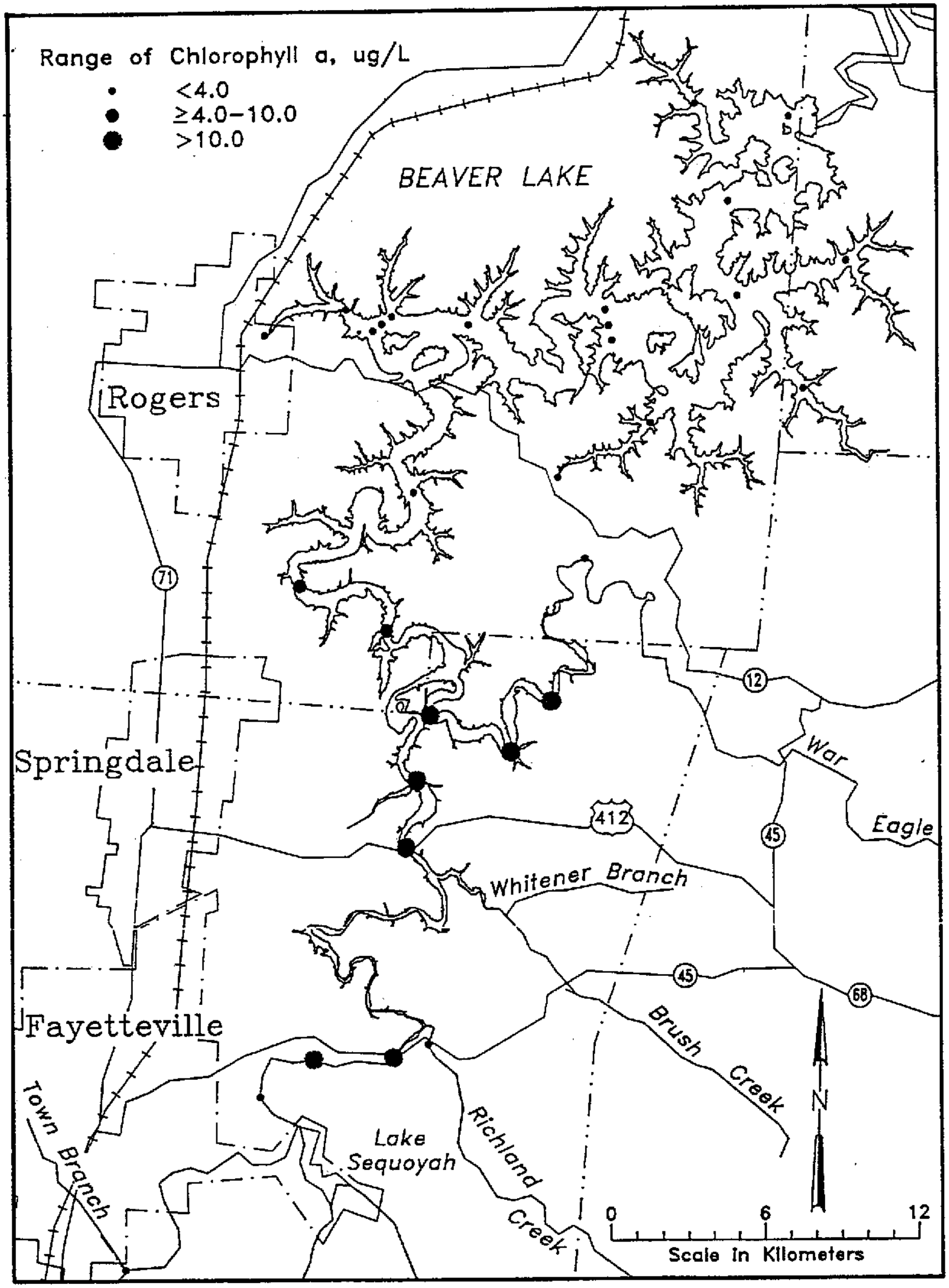


Figure a.10.59. Chlorophyll a results from the September synoptic survey.

Table a.10.19. Total iron and total manganese concentrations during this study compared to BWD operating record.

BWD Iron (mg/L)	Iron (mg/L) Beaver Clean Lake Study	
Mean	Mean	Median
0.18	0.33	0.14
Manganese (mg/L)	Manganese (mg/L) Beaver Clean Lake Study	
BWD		
Mean	Mean	Median
0.02	0.07	0.04

set would be minimized by a large data set such as the one Black and Veatch had available. Assuming that the median concentration for the large Black and Veatch data set would be similar to the average concentration, the median concentrations in 1991 would be similar to the Black and Veatch median concentration for the period 1976 through 1981.

a.10.2.3.4 Trihalomethane Formation

Trihalomethane (THM) concentrations were first monitored by the BWD in 1981 (Black and Veatch 1982). At that time, the THM concentrations were less than 0.1 mg/L, which is now the National Secondary Drinking Water standard. Black and Veatch (1982) expressed the concern that with continued organic loadings and increases of algae, the THM concentrations in finished drinking water would exceed the 0.1 mg/L standard.

Kavanaugh et al. (1980) and Singer (1981) reported that the chlorination of raw water sources with total organic concentrations (TOC) greater than 4 mg/L could result in THM concentrations that exceed the 0.1 mg/L standard. Near the intake structure, the median TOC concentration was 3.4 mg/L and the 75th percentile concentration was 4.0 mg/L with a maximum concentration of 5.6 mg/L.

TOC data were not available from the NES. Therefore, TOC concentrations were estimated from NES total phosphorus and chlorophyll a concentrations using relationships developed by Walker (1983). Formulas used to estimate TOC concentrations from the NES data were:

$$TOC = 0.56\ P^{0.63} \quad (R^2 = 0.85)$$

and

$$TOC = 2.31\ Chl^{0.40}\ (R^2 = 0.56)$$

where TOC is in mg/L and chlorophyll a and total phosphorus are in mg/L.

Table a.10.20 summarizes the results. Between the NES study and this study there is no indication that the risk of THM formation from chlorination of raw water is any greater now than in 1974. Organic loadings appear similar between these two periods.

Table a.10.20. A comparison of estimated TOC concentrations from the NES and TOC concentrations in Beaver Reservoir during this study.

NES			Beaver Clean Lake Study	
TOC (mg/L)			TOC (mg/L)	
Date	Estimated from Total Phosphorus	Estimated from Chlrophyll a	Date	
5 April 1974	5.8	4.7	4 April 1991	4.9
18 June 1974	5.9	3.2	12 June 1991	2.3
30 August 1974	3.8	4.0	28 August 1991	3.6
9 October 1974	4.9	3.5	9 October 1991	4.0

From November 1983 to November 1984, 15 TOC samples were collected at the intake structure (JMM 1987). These 15 samples combined with 5 additional samples collected in October 1985 showed the TOC concentrations near the intake structure ranged from 0.0 to 15.0 mg/L. The average concentration at the primary intake structure was 6.0 mg/L. During the study, the average concentration was 3.5 mg/L.

a.10.2.3.5 Turbidity

Black and Veatch (1982) reported that the BWD was experiencing turbidity problems. The problem was attributed to variations in raw water turbidity, temperature and pH variations outside the optimum range of efficient coagulation.

The ADPCE turbidity standard for reservoirs is 25 NTU. Turbidity exceeded 25 NTU in the upper surface waters during the latter part of April and again in December. During the latter part of April, turbidity exceeded 40 NTU. Through October, NTU in the upper waters of the Lake were typically less than 10 NTU.

Between February 1982 and March 1987, the average turbidity at the elevation of the primary water intake structure was 19 NTU and the maximum was 180 NTU based on BWD samples (JMM 1987). The mean turbidity was 10.4 NTU and the median was 3.6 NTU in the epilimnion during 1991.

a.10.2.3.6 Fecal Coliforms

For primary contact recreation, the State's standard is 200 colonies/100 mL based on the geometric mean of samples collected during a 30 day period. During this study, there were not enough samples collected to compute a geometric mean during a 30 day period. However the 200 colonies/100 mL can be used as a guideline to identify potential problems.

During the routine monitoring, no potential problems with fecal coliform concentrations were identified (Appendix A). In addition, no potential problems with fecal coliforms were monitored in the lake or the coves to the lake during the synoptic surveys in June and September (Figures a.10.60 and a.10.61; respectively). Fecal coliform concentrations greater than 200 colonies/100mL occurred in Town Branch, the

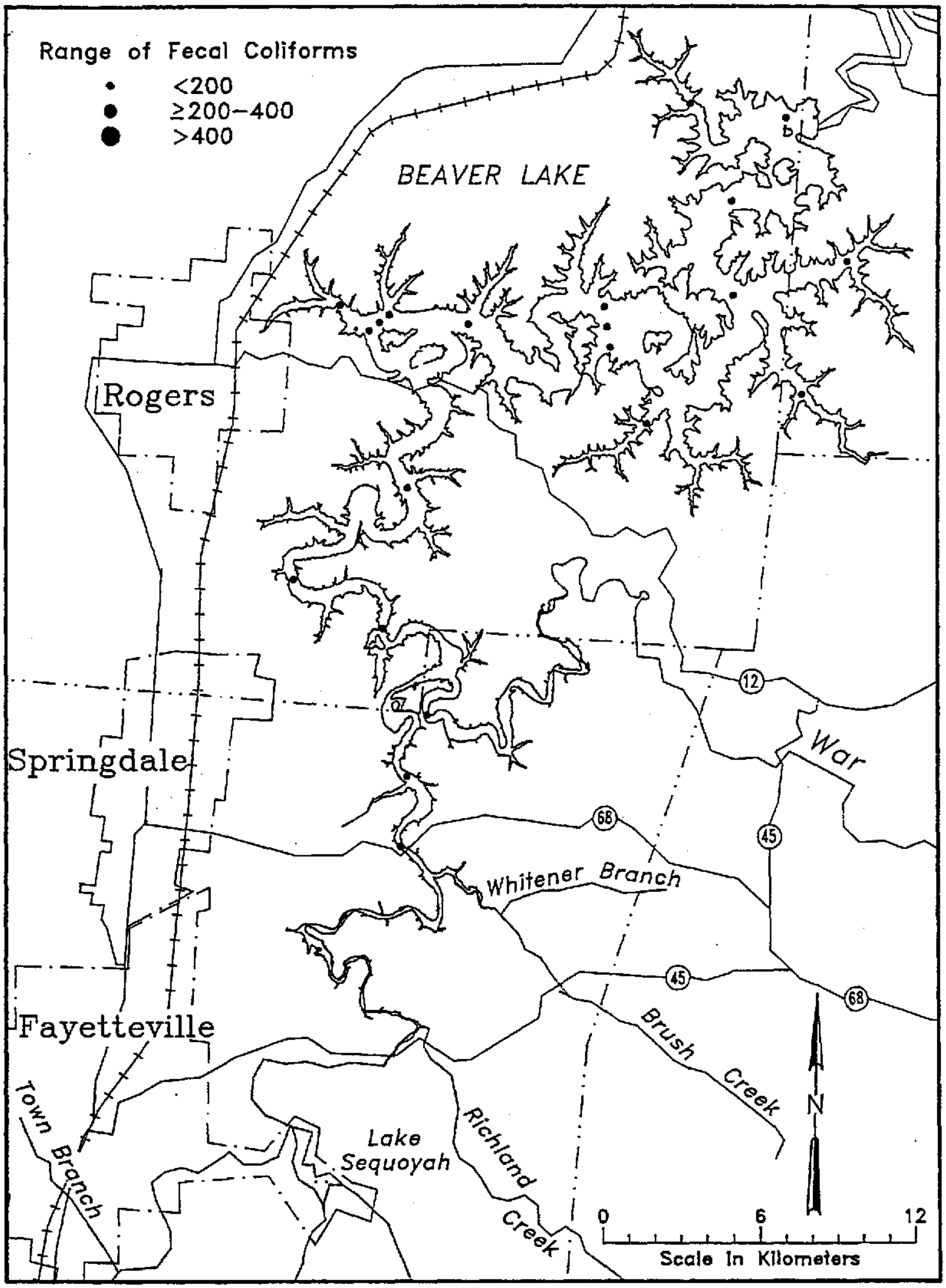


Figure a.10.60. Fecal coliform colonies/100 mL during the June 1991 synoptic survey.

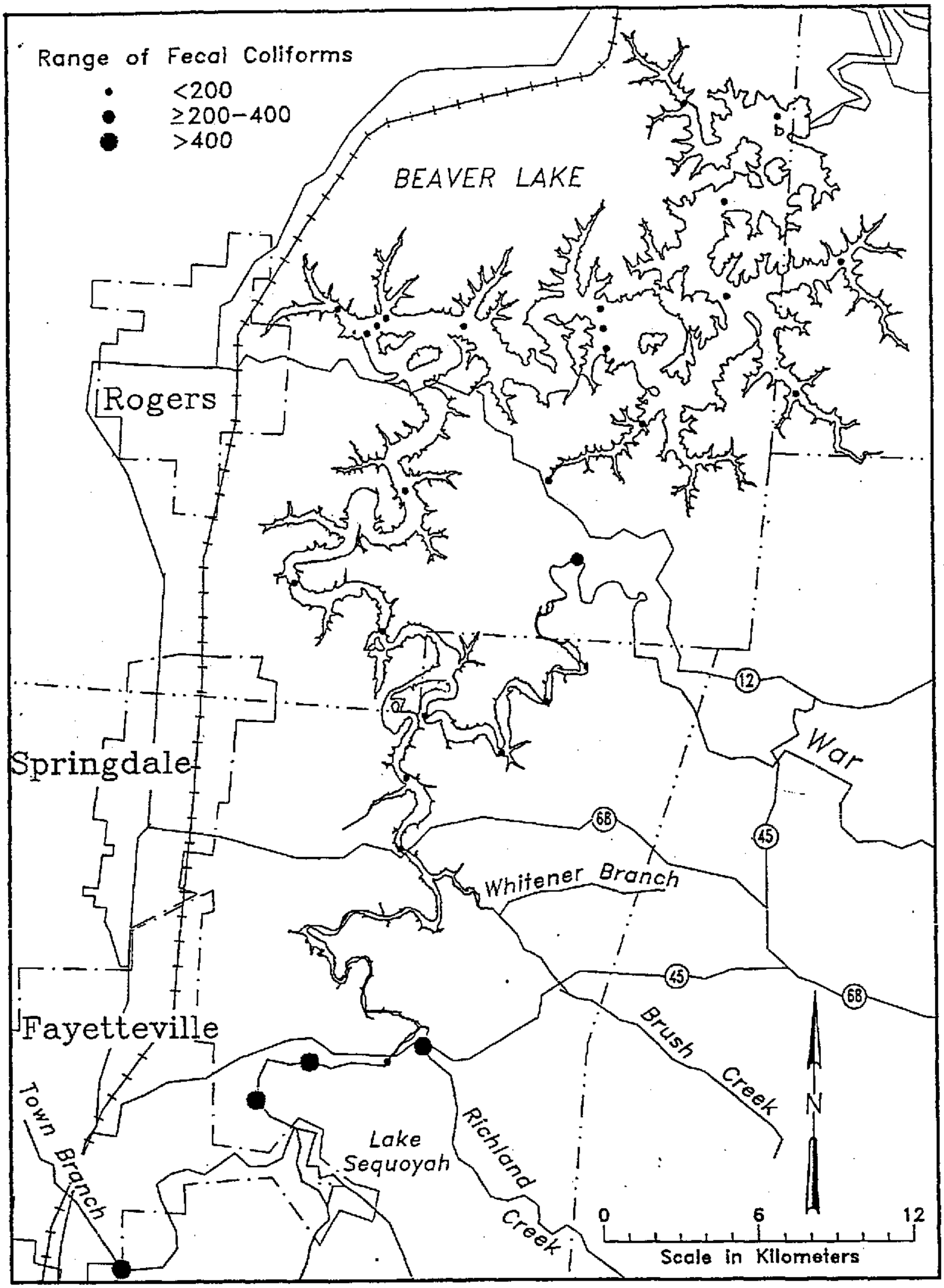


Figure a.10.61. Fecal coliform colonies/100 mL during the September 1991 synoptic survey.

White River upstream and downstream of the Fayetteville WWTP, and in War Eagle Creek (Figure a.10.61).

a.10.3 Limiting Nutrient

During the NES, algae assays (EPA 1971) were conducted to determine the limiting nutrient(s) in Beaver Reservoir. Water samples tested were collected on 5 April 1974 (EPA 1977). The results of the algae bioassays showed phosphorus was the limiting nutrient.

In addition to the algae bioassay results, the limiting nutrient was estimated from NES data for the dam site (050101) and Horseshoe Bend site (05103) by dividing surface total nitrogen concentrations by surface total phosphorus concentrations. Four estimates per site could be made from the available data. A ratio greater than 15:1 indicates phosphorus limitation and a ratio less than 15:1 indicates nitrogen limitation. The further the estimated ratio is from 15, the greater the confidence that phosphorus or nitrogen is limited. The calculated ratios indicated phosphorus limitation near the dam. The ratios ranged from 29 to 41. At the Horseshoe Bend site, the ratios ranged from 14 to 35. During this study, phosphorus was the limiting nutrient at the dam site (Figure a.10.62). The ratios were more variable near the BWD intake site but phosphorus limitation typically occurs (Figure a.10.63).

a.10.4 Beaver Lake Water Budget

A monthly water budget was developed for Beaver Lake using historical data. The US Corps of Engineers Little Rock District collects data on basin average precipitation, precipitation at the dam, pan evaporation, lake releases, water supply withdrawals, water surface elevation, and storage for Beaver Lake. Using evaporation, releases, and water supply withdrawals, inflows to the lake are back-calculated. This Corps of Engineers monitoring data was used to develop a historical water budget as well as a water budget for the monitoring year, 1991. These budgets are summarized in Table a.10.21.

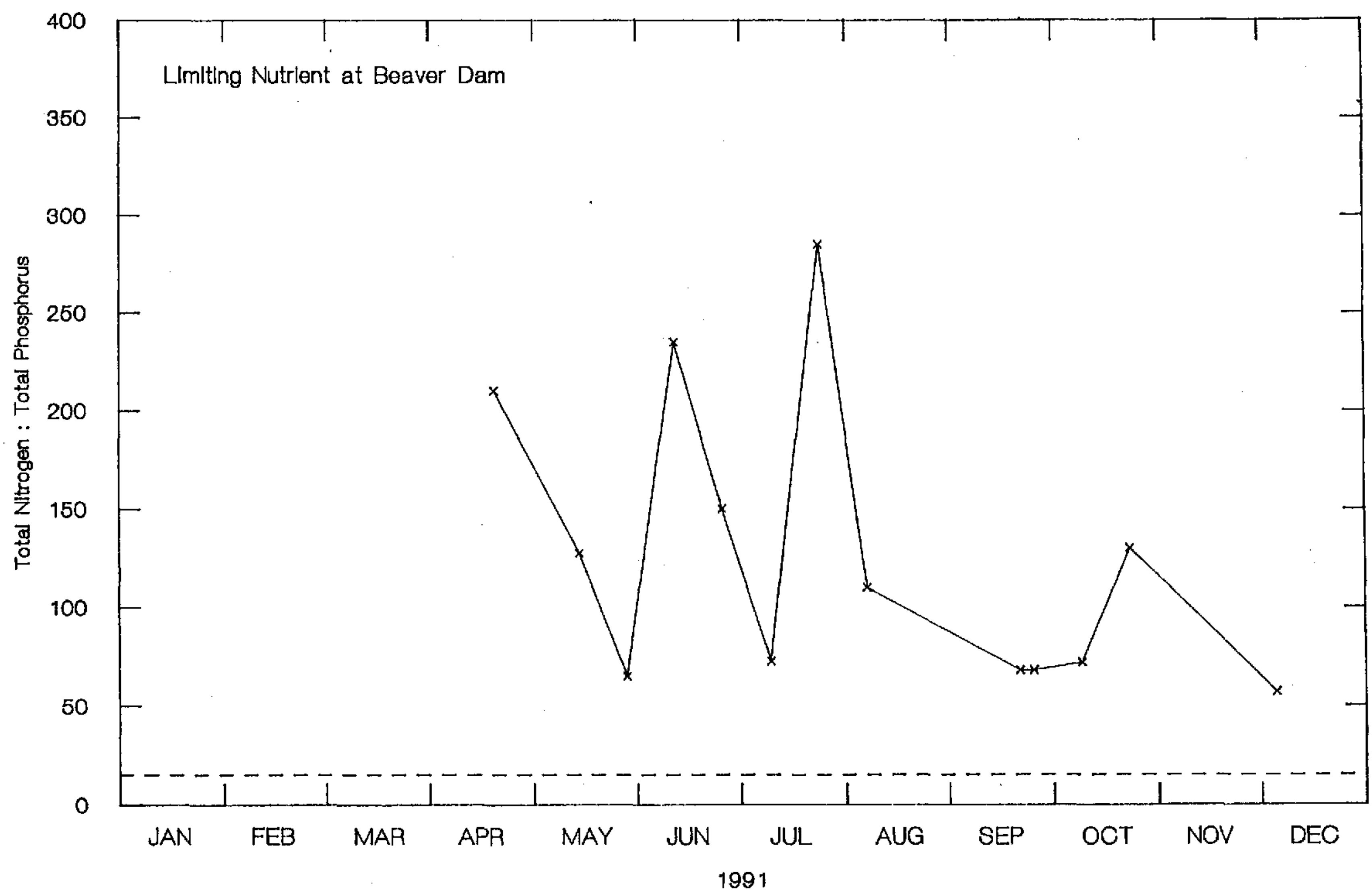


Figure a.10.62. Total nitrogen to total phosphorus ratio, near the Beaver Reservoir Dam (Station B1).

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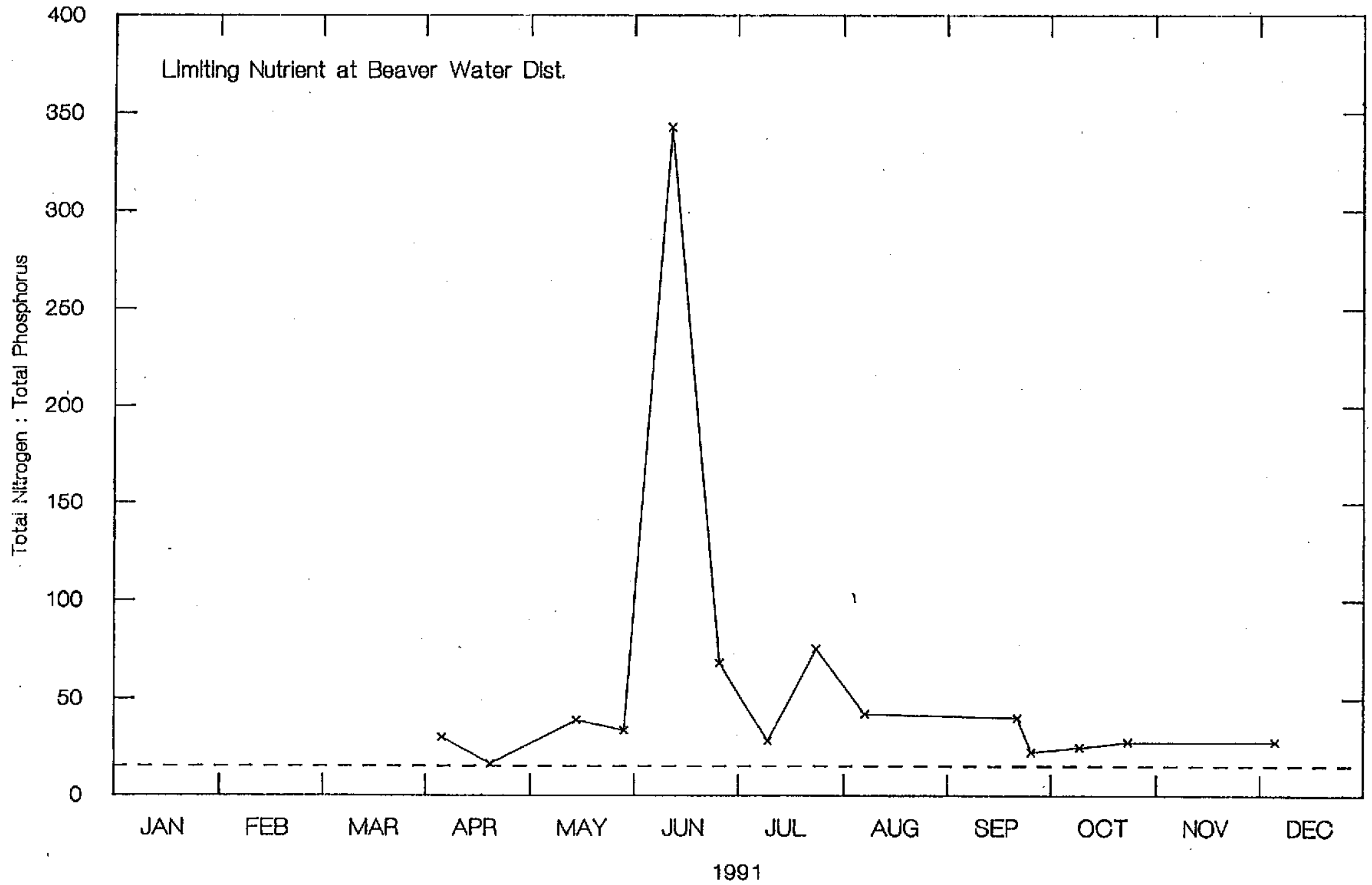

Figure a.10.63. Total nitrogen to total phosphorus ratios near the BWD intake structure (Station B4).

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Table a.10.21. Water budget for study year and historical average year.

	Flow ($10^6 m^3/yr$)		Percent of total	
	Study Year	Historical	Study Year	Historical
Sources				
Direct Precipitation	158	129	10	10
Inflows	1386	1239	91	93
Change in Storage	33	0	2	0
Error Term	-58	-29	-4	-2
Total	1519	1339	100	100
Sinks				
Evaporation	57	64	4	5
Releases	1416	1247	93	93
Withdrawals	46	29	3	2
Total	1519	1339	100	100

Table10.wp

Monthly totals of precipitation, inflow, pan evaporation, total releases, storage, and water supply withdrawals were obtained from the Corps of Engineers. The pan evaporation data was corrected using a pan correction factor of 0.7. The Corps inflows include direct precipitation. To determine inflows from tributaries and runoff, the monthly direct precipitation contributions were calculated and subtracted from the Corps monthly inflows. The change in storage was calculated by taking the difference between the storage reported for the first day of each month.

Monthly values for the historical water budget were determined by averaging the monthly totals for precipitation, inflow, pan evaporation, total releases and water supply withdrawals over the period of record. The storage values used to calculate change in storage were derived from the average water surface elevation for the first of the month. The period of record used to determine the historical water budget was 1968 to 1991. The pan evaporation and dam precipitation data only went back to 1970, but this should not result in significant inconsistencies. Basin precipitation data is recorded from 1977 to the present. When compared to the dam precipitation data, and historical precipitation records for Fayetteville and Eureka Springs, the period from 1977 to present is drier. Using data from only this time period would be inconsistent, so dam site precipitation from 1970 to 1977 is included in the calculation of the historical monthly precipitation total.

In the initial 1991 budget, inflow was negative for June, July and August. USGS and FTN monitoring records show that tributaries were flowing during those months, so zero inflows were not realistic. Inflows for these months were estimated using a runoff coefficient derived from the flow of the White River recorded by the USGS, multiplied by the drainage area of the lake. The resulting inflows were consistent with the historical flow pattern.

Water supply withdrawals for 1991 are close to twice the average historical withdrawals. The percentage of storage utilized for water supply is 2.3 compared to the historical 1.5. This is the result of increases in water supply demand. Prior to 1983, the BWD was the only entity making water supply withdrawals. In 1983, the Carroll-Boone Water District started making withdrawals also. This has increased the water supply withdrawals by roughly 10 percent for the last eight years. Increased use of lake water for irrigation of agricultural lands also may account for part of the observed increase in water supply withdrawals. 120 MGD is allocated for water supply in Beaver Lake, and currently 28 percent of this is being utilized.

In 1991 the percent of storage for precipitation, inflow, and outflow is also greater than for the historical budget. The higher total precipitation for 1991 indicates that it was a wetter year than the average for the Lake, so this accounts for the higher percentages for precipitation and inflow. The slightly higher percentage for outflow may also be a function of the wetter year, or a function of changes in power generation. Most releases from Beaver Lake are the result of power generation. Prior to 1982, the amount of power generated at Beaver Dam was variable, ranging from approximately 25,000,000 kwh to 305,000,000 kwh. Since 1982, power generation has remained between 100 mkwh and 300 mkwh. The variability in historical power generation, which likely resulted in highly variable releases, would result in a lower overall average release than would occur in the present.

For the most part, change in storage calculated from the inputs and outputs is greater than the change in storage calculated from storage based on water surface elevation. The instances where the storage calculated from the inputs and outflows is less than the change in storage based on water surface elevation occur at the same parts of the year in both the 1991 and the historical water budgets. This seems to indicate a seasonal relationship in the error where the storage calculated from inputs and outflows tends to overestimate the change in storage in the summer and early winter, and underestimate the change in storage in late winter - spring, and late summer - early fall. This method of calculating change in storage also overestimates the annual change in storage.

a.10.5 Beaver Lake Nutrient Budget

The 1991 nutrient budget set up for Beaver Lake is summarized in Table a.10.22 along with the NES nutrient budget for the Lake (EPA 1977). Nutrient inputs consisted of tributary inflows, point sources discharging directly to the Lake, and atmospheric

Table a.10.22.. A comparison of NES annual phosphorus and nitrogen budgets to phosphorus and nitrogen budgets from this study (BCL).

	Total Phosphorus, kg/yr (%)		Total Nitrogen, kg/yr (%)	
Sources	NES	BCL	NES	BCL
Tributaries				
White River	10,360 (13)	22,700 (40)	443,410 (28)	399,000 (29)
War Eagle Creek	12,065 (15)	12,700 (22)	390,825 (24)	439,000 (32)
Richland Creek	3,570 (4)	3,800 (7)	113,485 (7)	98,000 (7)
Minor Tributaries and immediate drainage	8,145 (10)	10,600 (19)	377,325 (24)	271,000 (20)
Point Sources				
Fayetteville	43,545 (53)	6,190 (11)	154,805 (10)	38,900 (3)
West Fork	920 (1)		2,755 (<1)	
Huntsville	1,395 (2)		2,225 (<1)	
Other point Sources		173 (<1)		104 (<1)
Septic tanks:				
Domestic		122 (<1)		4,580 (<1)
Parks/Resort	10 (<1)	61 (4)	385 (<1)	2,290 (<1)
Atmospheric Precipitation	2,000 (2)	524 (<1)	123,290 (8)	103,000 (8)
Total Inputs	82,010	56,900	1,608,505	1,360,000
Sinks				
Lake Releases	18,580	5,800 (87)	1,110,180	918,000 (97)
Beaver Water District Withdrawals		820 (12)		24,200 (3)
Carroll-Boone Withdrawals		18 (<1)		2,280 (<1)
Total Outputs	18,580	6,640	1,110,180	944,000
Net Annual Accumulation	63,430	50,300	498,325	416,000

Tab-10-2.wp

contributions. Losses consisted of Lake releases from the dam, and water supply withdrawals by the BWD and the Carroll-Boone Water Supply District.

The only gaging station in the watershed is on the White River at Wyman Bridge, and data is available for January through September 1991. White River flows for the remainder of 1991 were estimated. Flows for Richland and War Eagle Creeks and the Beaver laterals were also estimated. Flows were estimated using runoff coefficients based on land use and precipitation determined from average annual surface runoff from different land uses reported in the EPA National Urban Runoff Study. The coefficients were then multiplied by the 1991 precipitation and amount of area devoted to each land use to determine flows for the ungaged watersheds and the remainder of 1991 for the White River. Comparison of the White River gage data to estimate White River flows for the same time period showed good correlation between observed and estimated flows.

Nutrient inputs from the three main tributaries were derived by multiplying the land use based flows and nutrient concentrations from 1991 field data. Field data was not available for January through March and for November. For the months field data were not available, the average concentration of all the field data was used. To estimate the nutrient loadings from the Beaver Lake laterals, a land use based approach was used as described in Section a.9.3.

Not all of the point sources in the Beaver Lake watershed were included in the nutrient budget. It was felt that the nutrient contribution from West Fork STP would be accounted for in the field measurements from the White River at Wyman Bridge, and nutrient contributions from Huntsville STP would be included in the field measurements from War Eagle Creek. Fayetteville WWTP was included because it is located downstream from Wyman Bridge and not accounted for in the White River loadings.

For Fayetteville WWTP, flow and total phosphorus and ammonia nitrogen concentrations were taken from 1991 DMRs and multiplied together to derive loadings. Total nitrogen was calculated based on the per capita loading: 7.5 lb N/capita/yr, and 1990 census data.

Centark discharges May through October only. Flow was available for the entire period from DMRs. Ammonia nitrogen was also available from DMRs, but not for the entire period. For the months that data was not available, the average of the available data was used.

Flows were available for the entire year for the Village from DMRs. Total phosphorus and ammonia nitrogen were not available for the entire period. For the months data was not available, the average of the available data was used.

Only flows were available from DMRs for Heritage Bay. December flow was not available, so it was estimated.

Flows and some ammonia nitrogen data were available from DMRs for Lost Bridge through November. December flow was estimated, and the average of available ammonia nitrogen concentrations was used for the months that actual data was not available.

The Village is the only one of these four point sources that monitored phosphorus in 1991. Since these point sources are all extended aeration package plants, it was felt that the phosphorus concentrations from the Village would be a good estimate for the rest.

Included in Heritage Bay's NPDES permit is an analysis of their effluent which reports total organic nitrogen and nitrate plus nitrite nitrogen concentrations. Again, since the plants are similar, these concentrations were felt to be a reasonable estimate of conditions at all four point sources. To estimate total nitrogen, these concentrations were added to the existing ammonia data for the point sources, and this concentration was used to estimate the total nitrogen loading.

Atmospheric loadings for phosphorus and inorganic nitrogen in milliequivalents/m2/yr were taken from Wagner and Steele (1983) and converted to mg/L. To estimate wet fallout, the reported loadings were divided by the corresponding reported precipitation, and then multiplied by the 1991 precipitation and the surface area of the Lake.

Nutrient contributions from septic tanks were also estimated for the budget using the methodology outlined for the NES (EPA 1975). The number of domestic septic systems that may be contributing to the lake was estimated by counting the number of houses within 100m of the shore on 1976 USGS Quadrangle maps. Each of these systems was assumed to serve an average of 2.5 people/day annually and release 0.1134 kg phosphorus/capita/yr and 4.263 kg nitrogen/capita/yr (EPA 1975). The COE campgrounds on the Lake are also served by septic systems. To estimate the number of people served by these systems, it was assumed that 2.5 people/day used each campsite annually. There are very few users at these parks before April or after October, therefore the yearly load was multiplied by 7/12 to get a load for only the heavy use months.

Lake releases are taken from the 1991 water budget (Section a.10.4). The nutrient concentrations used to estimate the nutrient loads are field data from Station 1, near the dam, at a depth of 40m. This is the approximate location of the hydropower intake (most Lake releases are the result of hydropower generation). For months in which data were not available, the average of available data was used.

BWD withdrawals are from COE records for BWD. Nutrient concentrations from Station 4, the BWD intake, at a depth of 5m were used to estimate the nutrient loads. This is the approximate location of the intake they use most often. For months in which field data were not available, the average of available data was used.

Carroll-Boone withdrawals are from Carroll-Boone Water District records. Nutrient concentrations from Station 1, near the dam, at a depth of 3m were used to estimate the nutrient loads. The approximate location of the intake being used 3/12/92r is 3m.

A comparison of the 1991 and NES phosphorus budgets indicates Fayetteville WWTP is no longer the major contributor of phosphorus to the system. In the 1991 budget, the White River upstream of the WWTP has the greatest contribution (39.9%). The 1991 estimates of loadings from septic tanks are greater than those from the NES. The NES estimate is only for the COE parks and does not include domestic septic systems. The 1991 load from precipitation is approximately one fourth of that reported by NES. Rainfall was less in 1991, but the main reason for the difference is the fact that the NES literature values were used to estimate an average areal precipitation loading for the United States, while for the 1991 budget, precipitation loadings from a local study were used. The net accumulation of phosphorus is similar for both study periods, although the 1991 budget shows losses to be approximately half of those for the NES budget.

There is little difference between the two nitrogen budgets. The 1991 septic tank loadings are greater than those reported by the NES, for the reason outlined above. The Fayetteville WWTP is contributing much less nitrogen loading in 1991 than it did during the NES. The total nitrogen losses and net accumulation of nitrogen are similar for both budgets.

a.10.6 Trophic Condition of The Lake

To estimate the trophic condition of the Lake, the BATHTUB model was run. Gaugush's input deck for Beaver Lake based on NES data was used with 1991 precipitation, atmospheric nutrient loads, tributary flows and tributary nutrient concentrations (COE 1989). In the model, the Lake is separated into 12 segments, each approximately 10 km long. Water quality for each segment is estimated based on transport and sedimentation of nutrient input loads (tributary and atmospheric). The results from BATHTUB are presented in Table a.10.23. The trophic status of Beaver Lake ranges from eutrophic conditions in the headwaters to oligotrophic conditions near the dam based on chlorophyll a concentrations, Secchi disc transparency and Carlson's (1977) trophic state indices (TSI). This pattern is not atypical for a reservoir system. Nutrient concentration are generally higher in the riverine zone of reservoirs and decrease towards the dam. To assign an overall trophic status to Beaver Lake, therefore, must be approached with caution and understanding of other gradient.

Using the TSIs, it appears that non-algae turbidity affects the upper segments of the reservoir. Predicted Chlorophyll a TSIs are lower than predicted total phosphorus and Secchi disc transparency TSIs. If there was a linear relationship between Chlorophyll a, total phosphorus and Secchi transparency, then the predicted TSI values for each constituent would be expected to be similar. Predicted TSI values become similar as the dam is approached, indicating that algae turbidity is not as important as it is in the headwaters.

Table a.10.23. Summary of BATHTUB model results.

Segments*	Total P mg/m³	Total N mg/m³	Chl a mg/m³	Secchi Transparency m	TSI Total P	TSI Chl a	TSI Secchi Transparency
1**	145	1337	17	0.6	76	58	68
2	87	1015	13	0.7	69	55	65
3***	54	906	10	0.8	62	54	63
4	44	783	9	0.9	59	52	61
5	35	668	7	1.1	55	50	58
6****	28	564	6	1.4	52	49	55
7	23	491	6	1.7	50	47	52
8	19	428	5	2.2	47	46	49
9	16	368	4	2.5	44	44	47
10	13	304	3	3.0	41	41	44
11	11	263	2	3.7	38	39	41
12+	9	241	2	4.6	36	37	38

* Each reach is 10 km
** Segment 1 contains the inputs from the White River, Richland Creek, and Fayetteville
*** Segment 3 contains inputs from War Eagle Creek
**** Segment 6 contains the BWD intake
\+ Segment 12 is at the dam

a.10.7 Conclusions

Based on the results in Sections a.10.1 through a.10.6 the following conclusions are drawn:

1) Based on areal loads, the trophic status of Beaver Lake in 1991 is similar to the trophic status of the lake during the NES survey.

2) Although the trophic status of Beaver Lake based on loads was similar between the two studies, the Lake was not as mesotrophic in 1991 as it was in 1974.

3) Based on comparisons of nutrient data between 1991 and 1974 there are no indications that Beaver Lake is more eutrophic in 1991 as opposed to 1974 although the Lake may have become more eutrophic during the period between 1974 and when the City of Fayetteville's waste water treatment plant became operative.

4) Since the NES, phosphorus and nitrogen loads have decreased and DO concentrations have increased significantly after the new City of Fayetteville wastewater treatment plant went on-line.

5) Contributions of phosphorus and nitrogen in the White River upstream of the Fayetteville Waste Water Treatment Plant were greater in 1991 than in 1974 indicating a probable increase in nonpoint source pollution;

6) Of the major tributaries monitored, the White River and War Eagle Creek are the major contributors of phosphorus and nitrogen loads to Beaver Lake.

7) Urban or road construction runoff appears to be affecting the water quality of Town Branch which in turn affects the water quality of the West Fork of the White River.

8) Based on septic tank nutrient load estimates, septic tanks are not a significant source of nutrients to Beaver Reservoir, although septic tanks might contribute to load problems.

9) Based on the results of the intensive surveys, nutrients from the headwater tributaries of the White River and War Eagle Creek affect Beaver Lake at least to the BWD District intake structure.

10) There were no apparent major differences between the water quality in the vicinity of the BWD intake structure during this study and the 1974-1975 NES.

11) There are potential fecal coliform bacteria problems in the vicinity of Town Branch, the White River upstream and downstream of the Fayetteville wastewater treatment plant in the White River, and in War Eagle Creek.

a.11.0 BIOLOGICAL RESOURCES AND ECOLOGICAL RELATIONSHIPS

a.11.1 Lake Fish Fauna

Beaver Lake is managed as a sport fishery by the Arkansas Game and Fish Commission (Arkansas Game and Fish Commission and U.S. Fish and Wildlife Service 1980, Fourt and Moore 1988, 1989, and 1991). The Lake has been stocked with Spotted, Smallmouth, Striped, and Hybrid Bass; Blue and Channel Catfish; White Crappie; Threadfin Shad; and Paddlefish. Table a.11.1 summarizes stocking rates from 1986 through 1991. In addition, there is a nursery pond near Horseshoe Bend that is used to raise Smallmouth Bass and Blue Catfish that are released from the pond directly to the lake.

The fish species and density collected during a 1991 cove rotenone sampling in Beaver Lake are listed in Table a.11.2. The cove rotenone samples were collected during August in the lower, middle and upper reservoir (Fourt and Moore 1991). The cove rotenone sample results indicated Threadfin Shad level were low for the second year in a row. The reason for the low Threadfin Shad levels was attributed both to a Threadfin Shad kill during record cold spell in 1989 and large number of intermediate sized White Bass that prey on Threadfin Shad. The predator/prey ratios, however, indicate there is still adequate forage for all predators.

The Black Bass spawn was lower in 1991 than in 1990. The lower spawn was attributed to low water conditions in the spring and high numbers of intermediate Black Bass preying on the spawned fish.

Figure a.11.1 shows the 5 year sport fish biomass records for Beaver Reservoir. Although the forage base (Threadfin Shad) is down, the sport fish populations do not show trends of a declining fishery. Although the White Crappie biomass is down (muddy water contributed to low catch rates) compared to the population in 1987, the depressed population appears to be part of a cyclic pattern. Figure a.11.2 shows White and Black Crappie Biomass from 1967 through 1991. Figure a.11.3 shows estimates of the Largemouth Bass catch rates. There do not appear to be problems with the Beaver Reservoir sport fishery.

Table a.11.1. Fish Stocking Rates in Beaver Reservoir from 1986 through 1991.

Date Stocked	Number Stocked	Species	Size
06-20-86	10,000	Spotted Bass	Fingerling
11-05-86	9,194	Blue Catfish	Catchable
11-25-86	112,000	White Crappie	Fingerling
08-06-87	50,000	Striped Bass	Fingerling
10-28-87	31,452	Blue Catfish	Catchable
11-24-87	50,000	White Crappie	Fingerling
06-01-88	1,000,000	Smallmouth Bass	Fingerling
07-15-88	12,750	Striped Bass	Fingerling
07-15-88	500	Striped Bass	Fingerling
08-09-88	76,594	Striped Bass	Fingerling
08-25-88	26,892	Striped Bass	Fingerling
09-26-88	30,000	Blue Catfish	Catchable
11-16-88	100,000	White Crappie	Yearling
11-22-88	1,000	Channel Catfish	Catchable
06-19-89	300,000	Smallmouth Bass	Fingerling
07-11-89	72,000	Striped Bass	Fingerling
08-09-89	156,600	Striped Bass	Fingerling
10-06-89	30,000	Blue Catfish	Catchable
05-24-90	30,000	Threadfin Shad	Adult
05-30-90	50,000	Hybrid Bass	Fingerling
06-22-90	118,000	Smallmouth Bass	Fingerling
07-19-90	40,000	Striped Bass	Fingerling
07-26-90	23,875	Striped Bass	Fingerling
07-30-90	43,000	Hybrid Bass	Fingerling
10-18-90	100,000	White Crappie	Yearling
10-30-90	30,000	Blue Catfish	Catchable

Table a.11.1. Continued.

11-30-90	9,784	Paddlefish	Yearling
06-14-91	165,000	Smallmouth Bass	Fingerling
06-18-91	5,175	Striped Bass	Fingerling
06-25-91	113,250	Striped Bass	Fingerling
09-20-91	30,400	Blue Catfish	Yearling
11-01-91	100,000	White Crappie	Yearling

Table a.11.2. Mean number of fish collected during cove rotenone sampling in Beaver Lake in 1991 (Fourt and Moore 1991).

Species	No./ha
Largemouth Bass	58
Spotted Bass	296
Smallmouth Bass	5
White Bass	29
Blue Catfish	1
Channel Catfish	66
Flathead Catfish	23
White Crappie	41
Black Crappie	9
Longnose Gar	1
Green Sunfish	1,685
Warmouth	187
Bluegill	2679
Longear Sunfish	18,632
Redear Sunfish	2
Minnows (unid)	35
Golden Shiner	1
Steelcolor Shiner	5
Logperch	441
Stippled Darter	5
Orangethroat Darter	22
Gizzard Shad	522
Threadfin Shad	4,356
Slender madtom	8
Blackspotted Topminnow	197
Mosquitofish	39

Table a.11.2. Continued.

Brook Silverside	6,292
Central Stoneroller	1
Common Carp	39
Israeli Carp	1
River Redhorse	<1
Golden Redhorse	2
Quillback	1
Highfin Carpsucker	<1
Total	18,911

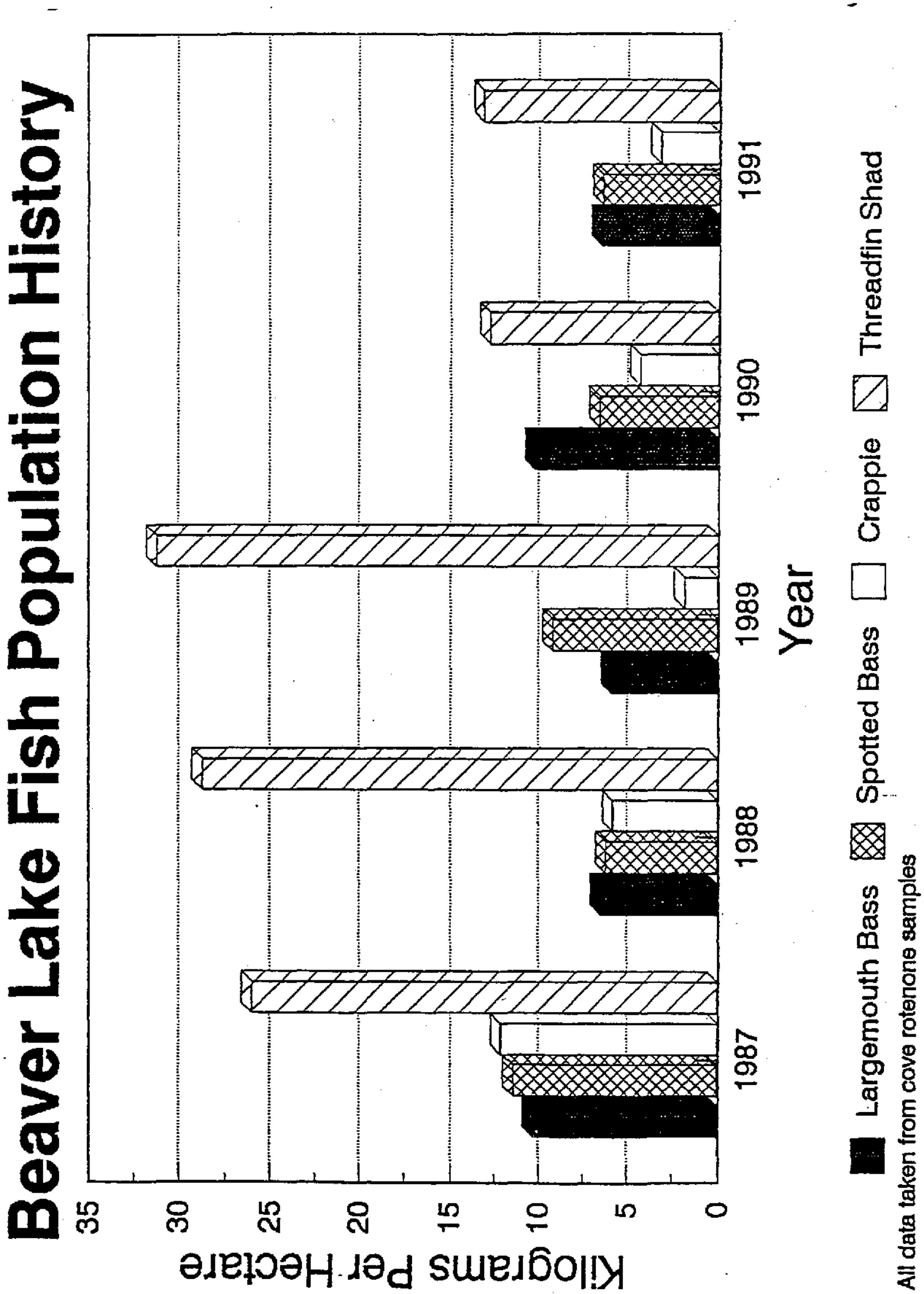

Figure a.11.1. Sportfish biomass for 1987 through 1991.

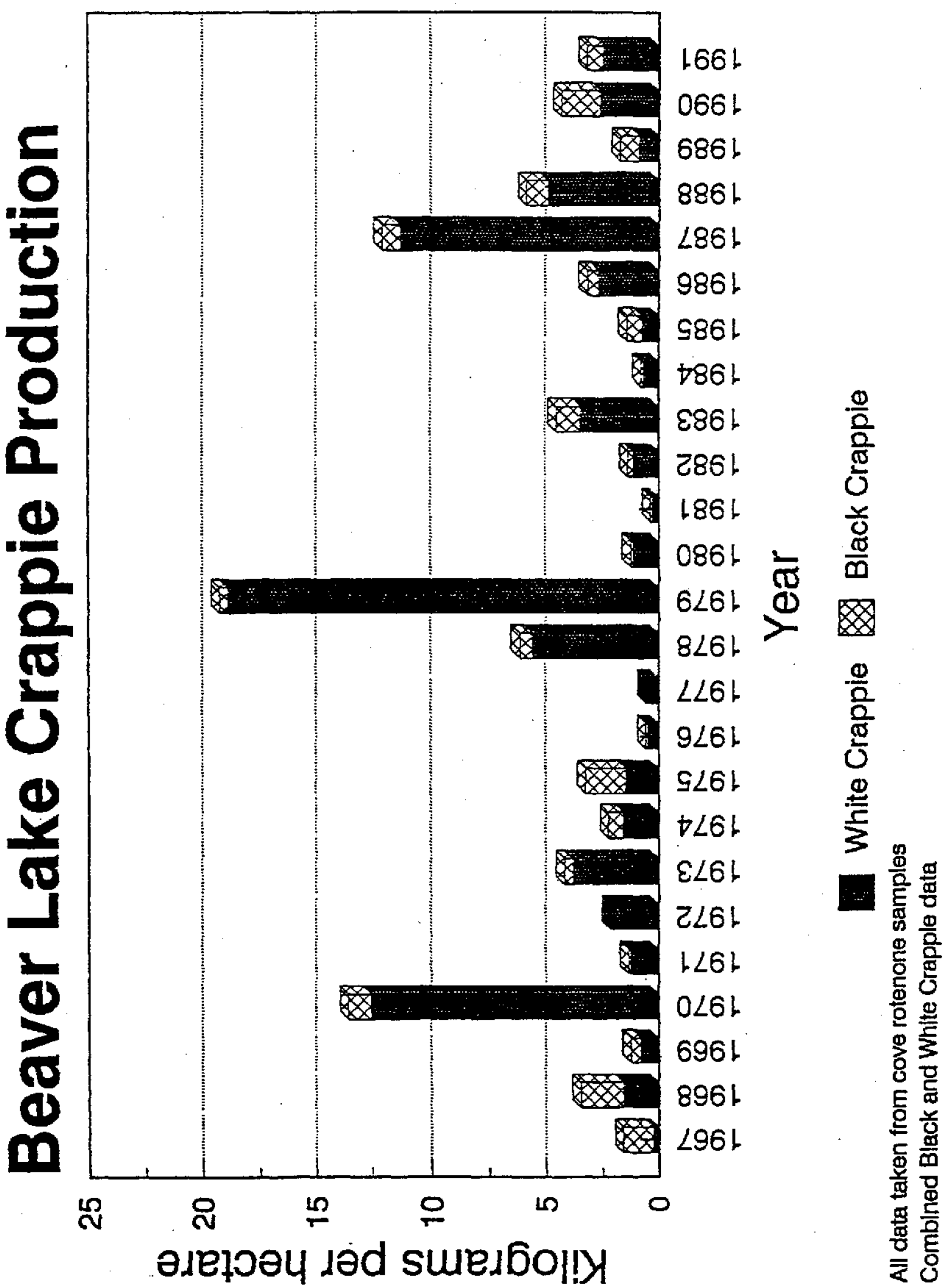

Figure a.11.2. Summary of Beaver Lake Crappie Production.

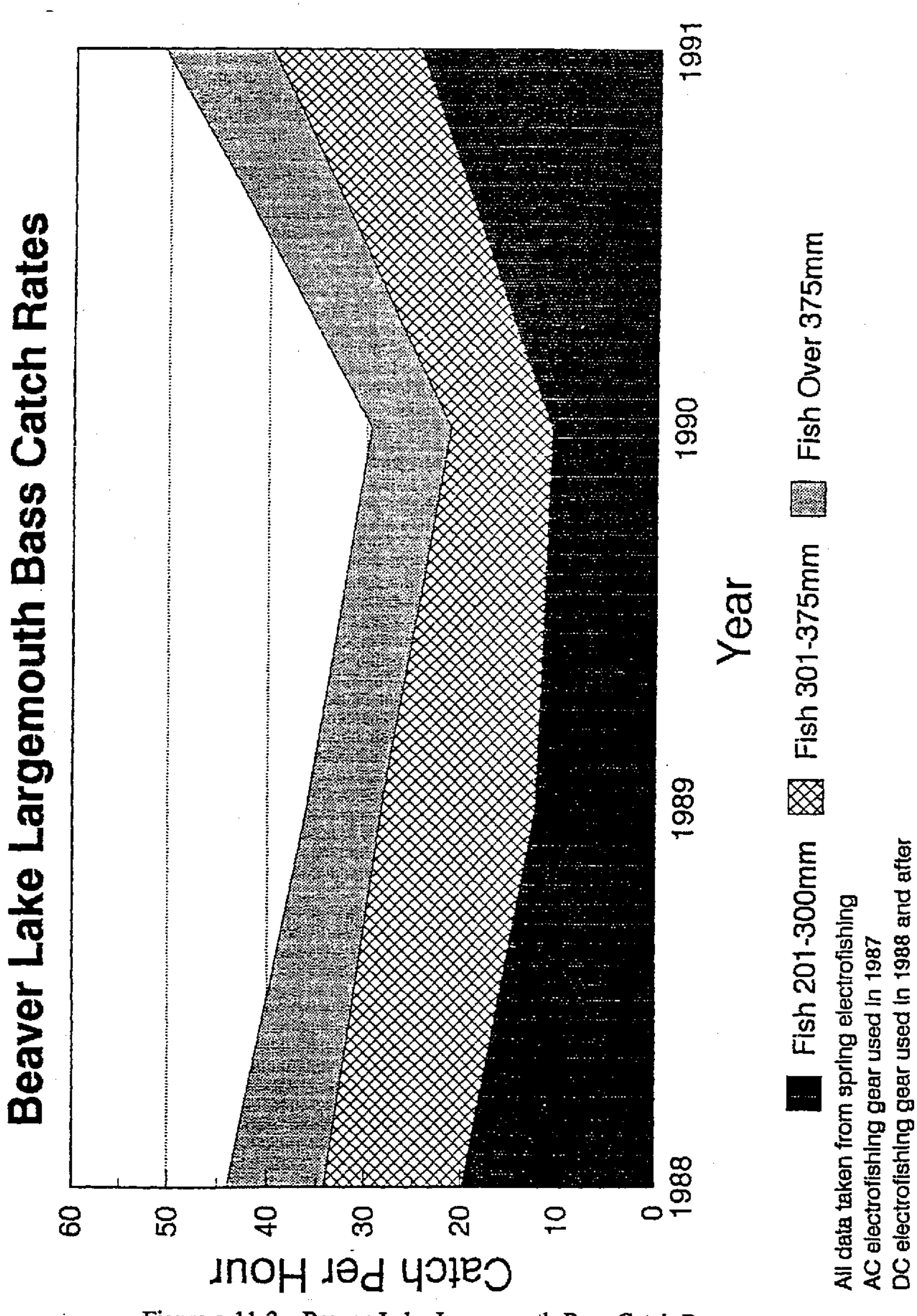

Figure a.11.3. Beaver Lake Largemouth Bass Catch Rate.

Striped Bass are an important component of the Beaver lake sport fishery. Fourt and Moore (1989) report that Beaver Lake is one of the best Striped Bass lakes in the country. In 1989, the captures of Striped and Hybrid Striped Bass were the best recorded. However, a possible reason for the better success was the use of new monofilament nets as opposed to old experimental panels. (Fourt and Moore 1989).

Fourt and Moore (1989) consider Beaver Lake to be a "remarkable inland fishery," and they feel that the aggressive Striped Bass program on the lake has improved and diversified the fishery.

a.11.2 Waterfowl

Information on waterfowl supported by Beaver Reservoir is limited. The Arkansas Game and Fish Commission does not have a waterfowl management program in Beaver Lake (Scott Yiach, Arkansas Game and Fish Commission Communication personal communications, 4 March 1992). Alan Blard (Ranger with the Army Corps of Engineers - Little Rock District (Resident Office in Rogers), personal communication, 4 March 1992), reported there is a resident flock of Canada Geese, but that the lake is primarily used by migratory waterfowl such as mergansers, mallards and pintails. The U.S. Fish and Wildlife Service also notes that Beaver Reservoir is used for a resting and feeding area during the winter season. (Appendix A; U.S. Army Corps of Engineers - Little Rock District 1989).

a.11.3 Other Wildlife Dependent on the Lake

The forest types that occur in the Beaver Lake watershed include the following:

- post oak - blackjack
- short pine - oak
- cedar
- white oak - black oak - northern red oak
- white oak

The trees and shrubs growing around the lake shore include: Persimmons, honey locusts, black walnuts, oaks, hickories, elms, maples, blackgums, ashes, cottonwoods, dogwoods, redbuds, snowberries, and sumacs. The general cover consists of green briars and native grasses.

The wildlife supported in the vicinity of Beaver Lake include: Whitetail deer, squirrels, bobwhite quails, rabbits, doves, wild turkeys, beavers, opossums, striped skunks, raccoons, minks, woodchucks, muskrats, foxes and bobcats. In addition, there are four endangered species including the Bald Eagle (*Haliaeetus leucocephalus*), the Gray Bat (*Myotis grisesens*), the Ozark Big-eared Bat (*Plecotus townserndii ingens*), and the Ozark Cavefish (*Amblyopsis rosae*).

Bald Eagles are dependent on Beaver Reservoir during the winter months (Bob McAnally, Arkansas Game and Fish Commission, personal communication) or at least winter in the vicinity of Beaver Reservoir. During the Corps of Engineers' annual Eagle count, 240 eagles were counted on Beaver Lake in January 1992. Seven individuals were identified as Golden Eagles with the remainder identified as adult and immature Bald Eagles. This is the highest eagle count in recent years on the Lake (Alan Blard, personal communication, 4 March 1992).

a.11.4 Fish, Waterfowl and Wildlife Relationships

Prior to the completion of the Beaver Reservoir Project, the U.S. Fish and Wildlife Services Bureau of Sport Fisheries estimated that 225 km (140 miles) of excellent fishing streams and 11,420 ha (28,220 ac) of our valuable wildlife habitat would be lost with the impoundment of the Reservoir. An additional 983 ha (2,430 ac) was estimated to be reduced in value by temporary inundation due to flood storage (letter report to the District Engineer, U.S. Army Corps of Engineer - Little Rock from U.S. Fish and Wildlife Services Regional Director, 23 September 1960). In the proposed project area deer populations were low but increasing and moderate to high population of quail, rabbits, squirrels, and other small game supported an annual harvest.

The area around Beaver Reservoir owned by the Corps of Engineers provides limited wildlife habitat and is not managed by the Arkansas Game and Fish Commission

(Bob McAnally, Arkansas Game and Fish Commission, personal communication, 5 March 1992). The majority of the habitat available to wildlife is away from the Reservoir on private land.

There is some concern by fisheries managers that if the nutrients to Beaver Reservoir are decreased, the existing productive fishery would decrease.

b.1.0 POLLUTION CONTROL AND RESTORATION ALTERNATIVES

b.1.1 Introduction

Existing uses in Beaver Reservoir that would be affected by water quality degradation include primary and secondary contact recreation, reservoir fishery, and domestic water supply. Because the purpose of EPA Clean Lakes Studies are to enhance water based recreation, the restoration alternatives proposed will be directed toward enhancing the recreational appeal of Beaver Reservoir. However, the alternatives proposed to improve water quality will also enhance the quality of water used for domestic water supply.

The restoration goal for the tributaries to Beaver Reservoir is to reduce total phosphorus, nitrate and ammonia concentrations to levels that are similar to concentrations observed in least disturbed streams in the Ozark Highlands Ecoregion (ADPCE 1987). By reducing nutrient concentrations to levels observed in least disturbed streams, nutrient loads would also be reduced to the lowest levels considered reasonably attainable. Table b.1.1 summarizes concentrations of these constituents by watershed for least disturbed streams as defined by ADPCE (1987). War Eagle Creek, a tributary to Beaver Lake monitored during this study, is one of the least disturbed streams. The minimum and maximum concentrations for nutrients analyzed in 1991 are compared with one spring and one summer measurement made, and reported on War Eagle Creek by the ADPCE (Table b.1.2). The maximum concentrations of total phosphorus and ammonia were either less than or similar to the maximum concentration measured during the ADPCE (1987) study. The maximum concentrations monitored during this study for turbidity and nitrate were greater than the maximum turbidity and ammonia concentrations monitored during the ADPCE study. One of the problems with using the ADPCE data for guidelines on nutrient concentrations expected in least disturbed Ozark Highland streams is that only two analytical measurements were made with no estimate of variability. However, the ADPCE data are based on the least disturbed streams in the Ozark Highland Ecoregion and are recommended guidelines for attainable water quality throughout the Beaver Lake watershed.

Table b.1.1. Concentrations of nutrients and chlorophyll a monitored during ADPCE least disturbed stream studies (ADPCE 1987).

Least Disturbed Streams - Ozark Highland Ecoregion	Drainage Area (km^2)	Total Phosphorus µg/L		Chlorophyll a µg/L		Turbidity NTU		Nitrate Plus Nitrite mg/L		Ammonia mg/L	
		Sp*	Su**	Sp	Su	Sp	Su	Sp	Su	Sp	Su
South Fork Spavinaw	47	10	10	1.7	0.5	2	2	1.51	0.92	0.04	0.01
Flint Creek	49	150	80	4.5	3.3	7	3	1.86	0.92	0.04	0.01
Yocum Creek	142	70	30	2.0	0.6	8	2	1.52	0.72	0.01	0.02
Long Creek	477	40	30		1.8	2	4	0.95	1.03	0.03	0.04
War Eagle Creek	681	30	50	2.1	5.0	4	6	0.62	1.15	0.07	0.01
Kings River	1362	20	90	6.4	1.5	3	7	0.19	0.38	0.08	0.01

* Sp - Spring
** Su - Summer

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Table b.1.2. Comparison of constituent concentrations monitored during ADPCE's least disturb stream study's in War Eagle Creek to concentrations monitored during this study in War Eagle Creek.

	ADPCE, 1987		1991 Study		
	Minimum	Maximum	Minimum	Mean	Maximum
Total Phosphorus, μg/L	30	50	2	26	41
Turbidity, NTU	4	6	3	9	29
Nitrate plus nitrite, mg/L	0.62	1.15	1	0.67	1.42
Ammonia, mg/L	0.01	0.07	0.01	0.03	0.07

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b.1.2 Alternatives Considered

A number of alternatives were considered and they can be grouped into the following categories:

- Watershed management techniques;
- In-lake restoration techniques;
- Regulatory considerations; and
- Lake management association.

b.1.2.1 Watershed Management Techniques

The watershed management techniques considered were the implementation of Best Management Practices (BMP) to minimize runoff, sediment losses and nutrients. The BMPs can be divided into several categories: agriculture, construction and urban, and silviculture.

b.1.2.1.1 Agriculture BMPs

As stated in Section a.9, pasture is a dominant land use (32%) in the Beaver Lake watershed. Only the forest land use is greater. Cropland accounts for less than 1% of the land use in the watershed.

In 1986, the SCS published a report that was based on a two year study that evaluated the effects of runoff, sediment and associated nutrients from grassland, direct deposits of manure from cattle wading in the streams, animal waste nutrients transported by stormflows from flood-prone soils, and runoff from areas where animals were confined. Based on the results of this study, the SCS recommended the kinds and numbers of BMPs needed to control erosion and nutrient transport, the cost of implementing the practices and the percent reduction of nutrients from different resource management systems. The following three alternative BMP plans were considered (U.S. Army Corps of Engineers-Little Rock District 1990):

- Alternative A: Projected conditions - "This alternative assumes that expansion of the watershed animal industry will continue and that BMPs will continue to be applied at the present rate under current cost share agreements."
- Alternative B: Full BMP installation - "This alternative includes all BMPs that combined would reduce nutrients a substantial degree. No consideration was given to how much nutrient reduction each practice was likely to contribute compared to the cost when selecting BMPs"
- Alternative C: Recommended BMP installation - This alternative "includes all the BMPs in Alternative B with the exclusion of some fencing and ponds that were not cost-effective. Alternative C does include some fencing and ponds needed to prevent direct deposits of manure in high nutrient stream areas."

The BMPs that the SCS recommended for inclusion, as needed, in any resource management system are listed and described in Table b.1.3. With the implementation of Alternative C, the expected nutrient reduction is about 44%. Table b.1.4 summarizes BATHTUB estimates of total phosphorus, total nitrogen and chlorophyll _a_ concentrations, and Secchi disc transparency under existing conditions and under nutrient load reductions of 40 and 50% into Beaver Lake. In the vicinity of the BWD intake structure, the estimated total phosphorus reductions ranged from 18 to 25%, the estimated total nitrogen reductions ranged from 25 to 33%, and the estimated chlorophyll _a_ reductions ranged from 17 to 33%. Secchi disc transparency increased about 7%.

The SCS study emphasized agricultural BMPs because the primary source of nutrients in the Beaver Lake watershed are associated with agricultural activities. The study did not consider the implementation of urban and construction, and silviculture BMPs.

Table b.1.3. Agricultural BMP's recommended.

Practice	Practice Description
Conservation Cropping Sequence	An adapted sequence of crops to provide organic residues to improve or maintain soils, reduce erosion, improve efficiency of water use and improve water quality.
Conservation Tillage	A planting system that reduces soil disturbance and water loss by retaining crop residues on the land and leaving the surface rough, porous or ridged.
Proper Grazing Use	Grazing at an intensity which will allow the maintenance or improvement of quality of desirable vegetation, and allow the accumulation of liter and mulch to increase infiltration and reduce runoff and sediment yields.
Terraces or Diversions	Ridges constructed across the slope of the land to control erosion.
Waste Management systems	Planned system to manage liquid and solid waste in a manner which does not degrade air, soil, or water resources.
Fertilizer/Nutrient Management	Judicious use of fertilizers (quantity & composition) to achieve increased productivity with minimal effect on water.
Integrated Pest Management	Combination of pest control methods, new and old to provide for pest control with minimal loss to water resources.
Deferred Grazing	Postponing grazing or resting grazing land will produce a variety of beneficial effects, including reducing soil loss and improving water quality.
Access Road	Access roads should be located to serve the intended purpose, facilitate control & disposal of water and utilize topographic features.
Critical Area Planting	Planting vegetation on highly erodible or critically eroding areas to stabilize soil and reduce damage form runoff and sediment downstream.
Debris Basins	A sediment basin may reduce pollution by providing for deposition and storage of sediments, agricultural wastes and other detritus from run off.

Table b.1.3. Continued.

Practice	Practice Description
Levee/Dike	Embankment constructed to protect land from inundation over overflow or facilitate water storage or control.
Field Border	Strip of perennial vegetation established a the edge of a field to control erosion, etc.
Grassed Waterway	A natural or constructed waterway established in suitable perennial vegetation to reduce runoff rates of surface water without causing erosion or flooding.
Fencing	Areas may be fenced that need to be protected from grazing, or as part of a grazing system (Proper Grazing use).
Irrigation Systems	Systems installed to efficiently convey and distribute water without excessive erosion or water loss.
Land Smoothing	Removing irregularities in the land surface to; improve surface drainage, provide more effective water management, improve terrace alignment of facilitate contour cultivation, etc.
Irrigation Water Management	Determining and controlling the rate, amount and timing of irrigation to promote desired crop response, minimize soil erosion and loss of plant nutrients, control water loss, and protect water quality.
Poultry Disposal Pits	Excavated pit or depression to provide suitable disposal for solid farm wastes to prevent pollution.
Spring Development	Improvement of spring or seep by excavating, cleaning, capping or providing collection and storage facilities, usually to improve distribution or increase water supply.
Strip Cropping	Growing close growing crops and tilled crops in alternating bands across the general slope or on contour to reduce erosion.

Table b.1.3. Continued.

Practice	Practice Description
Water Control Structures	Structures in irrigation or drainage systems that convey water, control direction or rate of flow or maintain a desired water elevation.
Establish and Manage Permanent Pasture and Hayland	Planting long-term stands of adapted species of forage plants, and implementing proper treatment and use of pasture or hayland to improve forage, protect soil and reduce water loss.
Farm Ponds	Impoundment constructed to provide water storage.

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Table b.1.4. Estimated reductions in concentrations of total phosphorus (TP), total nitrogen (TN) and chlorophyll a (Chla), and estimated increases in Secchi disc transparency (SD) based on BATHTUB model results with a 40% and 50% reduction in nutrient loads.

Segment	Existing Conditions				40% Reduction				50% Reduction			
	TP ((mg/m^3)	TN ((mg/m^3)	Chla ((mg/m^3)	SD (m)	TP ((mg/m^3)	TN ((mg/m^3)	Chla ((mg/m^3)	SD (m)	TP ((mg/m^3)	TN ((mg/m^3)	Chla ((mg/m^3)	SD (m)
1 (Upper White)	145	1,337	17	0.6	97	842	12	0.6	84	711	10	0.6
2	87	1,015	13	0.7	63	674	9	0.8	56	579	8	0.8
3	54	906	10	0.8	40	604	7	0.9	36	519	6	0.9
4	44	783	9	0.9	34	540	6	1.0	30	470	5	1.0
5	35	668	7	1.1	28	481	5	1.2	25	424	5	1.2
6 (BWD)	28	564	6	1.4	23	421	5	1.5	21	376	4	1.5
7	23	491	6	1.7	19	378	4	1.8	18	341	4	1.9
8	19	428	5	2.2	16	337	4	2.3	15	307	3	2.4
9	16	368	4	2.5	14	298	3	2.7	13	274	3	2.8
10	13	304	3	3.0	11	253	2	3.2	11	235	2	3.3
11	11	263	2	3.7	9	224	2	4.0	9	210	1	4.1
12 (DAM)	9	241	2	4.6	9	208	1	5.0	8	196	1	5.2

b.1.2.1.2 Construction and Urban BMPs

Examples of urban and construction BMPs are described in Table b.1.5. Although urban land use White River drainage basin accounted for only 2.0% of the land use in the Beaver Lake watershed, 17% of the phosphorus load, was estimated to come from urban sources in the White River drainage (Section a.9.0). As discussed in Section a.10, Town Branch is representative of a stream receiving urban runoff and it is located in the White River drainage. Samples collected in the Town Branch after a 2.0 cm (0.8 in.) rain recorded some of the highest nutrient and suspended solids concentrations measured during this study (i.e., total suspended solids = 505 mg/L, total phosphorus = 0.4 mg/L, nitrate plus nitrite nitrogen = 1.2 mg/L, and total organic carbon = 10.6 mg/L). Although the contribution of pollutants via urban runoff may be small, within the Beaver Lake watershed, urban runoff may be very important during storm events within the White River subbasin. Therefore, construction and urban BMPs are considered, although additional investigations are recommended within the White River watershed to specifically address urban runoff.

Although not specifically monitored during this study, road surfaces and road banks may be significant contributors of sediments to watercourses that drain into Beaver Reservoir. The SCS (1986) estimated that 42% of all erosion in the Beaver Lake watershed and 51% of the sediments entering Beaver Lake came from gravel and dirt road surfaces and road bank erosion. The dirt and gravel roads, and road banks are not urban problems per se since they occur predominately in the rural areas of the watershed. Problems with road banks include poor design and construction leaving side slopes at steep angles. In many cases, road right-of-ways are not wide enough to allow proper shaping of side slopes (SCS 1986). The implementation of urban (e.g., retention basins) and agriculture (e.g., vegetative stabilization) BMPs as well proper design of roads and adequate right-of-ways could significantly reduce erosion from road surfaces and road banks. The BMPs in Table b.1.5 also are applicable to the Town Branch watershed, which includes drainage from road surfaces and industrial areas.

Table b.1.5. Examples of urban and construction BMPs (EPA 1987).

Practice	Practice Description
Structural Controls	Structural controls are used when vegetative cover is inadequate to provide the protection desired or when flows concentrate in specific areas. Examples of structural controls include drop spillways, box inlet spillways, chute spillways, pipe drop inlets, filters, traps, basins, and diversions structures.
Nonvegetative Soil stabilization	Practices include using covers or binders to shield the soil surface from rainfall and runoff or bind the soil particles into a more resistant mass. Practices can be temporary or permanent.
Runoff Detention/Retention	These practices are used to prevent or reduce stormwater runoff and associated pollutants associated with stormwater runoff from entering combined sewers or surface water.
Street Cleaning	The purpose of street cleaning is to remove solids from the street to reduce pollutant loads that could reach receiving waters.
Surface Roughening	The purpose of surface roughening is to decrease the rate of water runoff by slowing the downhill movement of water. An example is scarification where grooves are cut along the contour of a graded slope that increasing the rate of infiltration.

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The SCS (1986) alternatives to reduce road surface erosion was to install ditches, graveling or paving, and the placing of numerous culverts. For roadbank erosion, measures considered to reduce roadbank erosion including shaping the roadbanks 3 to 1 or flatter, vegetating, and head water division to reroute runoff. These alternatives were not considered to be feasible alternatives by the SCS. The cost of reducing road erosion would be about equal to building new roads and the estimated costs of treating roadbanks was $15 million or about $100 per ton of sediment delivery reduction.

b.1.2.1.3 Silviculture BMPs

Examples of potential silviculture BMPS are listed in Table b.1.6. Forests are the dominant land use in the Beaver Lake watershed and most of the forest land is owned by private landowners. When trees are cut, the cuttings generally occur on 20 to 40 acre tracts and generally there is little reforestation other than natural regrowth (personal communication Jim Brigance, Arkansas State Forestry Commission, District 6, 3 April 1991). There are no concentrated areas of logging (e.g., extensive clearcuttings). Voluntary implementation of silviculture BMPs should be encouraged in the Beaver Lake watershed. An educational program for private landowners and loggers under the oversight of the Arkansas State Forestry Commission would be appropriate.

b.1.2.2 In-lake Restoration Techniques

Because the water quality of Beaver Reservoir is generally good, in-lake enhancement/restoration treatments were not considered for the entire reservoir. In-lake enhancement/restoration techniques, however, were considered in the vicinity of the BWD intake structure. The Little Rock District of the Army Corps of Engineers requested that the Army Corps of Engineers Waterways Experiment Station evaluate the following in-lake enhancement/restoration alternatives:

- Selective withdrawal in the water column by the Beaver Water District;
- Submerged weir;
- Hypolimnetic aeration/oxygenation; and
- Lake destratification.

Table b.1.6. Examples of siviculture BMPs. (EPA 1987)

Practice	Practice Description
Limiting Disturbed Areas	The control measures associated with this BMP are associated to limiting disturbances only to those areas where the work is actually occurring.
Log Removal Techniques	BMPs include methods to reduce soil disturbances from the transporting of logs.
Ground Cover	The purpose of this BMP is to maintain ground cover in disturbed areas.
Debris Removal	The purpose of the debris removal BMP is to keep tree tops and slash away from water courses. Accumulations of slash can deplete stream dissolved oxygen during decomposition.
Proper Design of Haul Roads and Trails	Practices included constructing haul roads away from water courses and according to recommended guidelines for gradient, drainage, soil stabilization and filters. Roads should be routed across slopes rather than up and down slopes.

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The selective withdrawal and the submerged weir alternatives are not considered to be lake restoration alternatives in this document because they do not improve the water quality of the lake. These techniques are considered to be enhancement techniques. On the other hand, hypolimnetic aeration/oxygenation and lake destratification are potential lake restoration techniques.

The criteria that were used to evaluate the effectiveness of the in-lake restoration techniques were:

- DO concentrations greater than or equal to 4 mg/L;
- Low or no concentrations of iron and manganese;
- Few or no algae;
- No concentrations of trihalomethanes; and
- Water temperature between 10°C and 21°C.

These criteria were set by the BWD (Little Rock Corps of Engineers 1989).

b.1.2.2.1 Selective Withdrawal

The numerical model SELECT was used to evaluate selective withdrawal. The model utilizes temperature and DO profiles, withdrawal rate, port elevation(s) and intake characteristics to predict a withdrawal distribution within the lake and the subsequent temperature and DO of the withdrawn water. Alternatives considered under the selective withdrawal alternative included:

- Existing conditions;
- Withdrawal through a higher port (el 338 m (1110 ft)); and
- Increasing withdrawal rates from 50 MGD to 80 MGD.

Under the existing conditions scenario, the port at elevation 336 m (1104 ft) was used exclusively. A significant quantity of the water withdrawn had DO concentrations less than 2.0 mg/L and the temperature of the withdrawal flow was higher than 21°C.

When the water was withdrawn from the higher port, the average DO concentration never fell below 5.0 mg/L although there was some low or zero DO water in the withdrawal distribution. The water temperatures were higher than under the existing conditions. A concern with this alternative is the possibility of algal blooms potentially clogging the filters in the treatment plant.

The withdrawal rates were increased to 80 MGD by withdrawing water from the ports at elevations 336 m (1104 ft) at a rate of 79 cfs and at elevation 338 m (1110 ft) at a rate of 45 cfs. The result was to draw higher than average temperature and DO concentration water into the ports. Again, the water withdrawal distribution did extend to water levels with DO concentrations less than 2.0 mg/L.

The recommended withdrawal operation if higher water temperature and the percentage of low DO water withdrawals was acceptable was to use port at elevation 336 m (1110 ft) under normal flows and both ports under high flows.

b.1.2.2.2 Submerged Weir

The following options were investigated under the submerged weir alternative:

- Modification of the trash rack to a weir under existing flow; and
- Expansion of the weir length to 120 ft under normal and maximum flow rates.

In general, the modification of the trash rack to a weir by plating did not offer an advantage over the other options considered above. The expansion of the weir length maintained the lower limits of the withdrawal in the oxygenated layer of the water column under normal flow conditions but, under maximum flow rates, the DO concentrations dropped to 0.03 mg/L for about one week.

b.1.2.2.3 Hypolimnetic Oxygenation

Under this alternative, either air or pure oxygen is injected into the hypolimnion through a diffuser. The diffuser head is made of a porous material that allows small bubbles to escape into the water column. The smaller the size of the bubbles, the greater the oxygen transfer rate between the bubbles and the anoxic hypolimnion. If temperature of water is a major concern, than a hypolimnetic oxygenation/aeration system is the best overall alternative.

b.1.2.2.4 Destratification

Options considered to destratify the water column in the vicinity of the BWD intake structure included:

- Pneumatic destratification; and
- Surface pump destratification.

The purpose of these options is to introduce a diffused bubble plume that induces a recirculation pattern by entraining water towards the surface where it is aerated and moves out laterally. Additional water moves in to replace the flow upward and a circulation cell is generated.

The design of the destratification device was based on guidelines for total lake destratification (Davis 1980). Four pneumatic destratification system were evaluated based on diffuser (pipe) requirements such as air required, inside diameter of pipe, length of pipe, and the radius from the intake. Depending on the sizing requirements "guaranteed" storage of acceptable water inside the radius from the intake ranged from 0.3 to 1.6 days.

The purpose of the surface pump option is to destratify the region directly in front of the BWD intake structure by jetting warm oxygenated water from the surface into the hypolimnion to replace the low DO water withdrawal. The pumps would be arranged in a semicircular pattern in front of the intake structure. The number of pumps and the size of pumps required depend on the required flow across the thermocline, and the desired penetration depth. With two pumps capable of discharging 7680 gpm the penetration depth is estimated to be 22 m (73 ft).

An additional option evaluated was side stream pumping. Under this option, water would be pumped from the lake up to a pool where the water would be allowed to cascade over a series of weirs to promote reaeration. An advantage of this methodology is cooler water could be pump from the lake.

Even though the destratification and the oxygenation of the hypolimnion alternatives can be considered to be lake restoration techniques, the benefits from these alternatives in this instance are primarily to the drinking water. If the hypolimnion is aerated, fish (e.g., smallmouth bass) will potentially benefit from the increase in oxygenated water at cooler preferable temperatures. However, the effect will be localized and will not benefit the reservoir fishery as a whole. Hatchery reared smallmouth bass released from Arkansas Game and Fish nursery ponds in the vicinity of Horseshoe Bend recreation areas will in all likelihood not be able to locate this refugia of cooler water because of the distance between BWD intake structure and the nursery pond (approximately 2 km).

b.1.2.3 Regulatory Considerations

Corps of Engineer reservoirs are different from other publicly owned lakes because the Corps controls activities that occur on the land which they own or have flowage easements. Around Beaver Reservoir the Corps acquire an area up to an elevation of 346 m (1135 ft). In addition, they tried to obtain flowage easements, where possible, between the elevations 346 m (1135 ft) and 350 m (1148 ft) on the upstream end of the reservoir (personal communication, Joe Craig, Little Rock District Corps of Engineers, Real Estate Division). In general, any structure to be built on Corps land has to be approved by the Corps and they will not approve any structure that could affect the operation of the reservoir. However outside of the Corps property or flowage easements, regulations can be an important part of a watershed-lake management plan.

A legal entity must be in place before regulations can be enacted. Once a legal entity is in place, regulations can be adopted for the following purposes (Thornton 1988):

- Prevention or reduction of erosion and pollution problems;
- Control of development to protect shoreline aesthetics, and benefits; and
- Regulate lake use to reduce user conflicts.

A variety of zoning regulations are available for lake management and protection. Types of zoning regulations are presented in Table b.1.7 and development regulations are outlined in Table b.1.8.

With zoning regulations, the types of buildings, densities and uses can be controlled. Within the context of protecting the water quality of Beaver Lake, the zoning regulations could be used to prevent or control the development of facilities that might discharge waste or result in storm water runoff that contained contaminants. By using development regulations such as minimum lot size, adequate land would be available for either septic tanks or holding tanks. Through a judicious use of zoning and development regulations, potential sources of pollutants to Beaver Lake would be controlled, and aesthetic appeal of the Lake maintained. Potentially, zoning and development regulations could increase property values.

b.1.2.3.1 Lake Associations

A lake association is critical to enhance restoration effects and to sustain improvement. One purpose of lake associations is to educate the public and to promote increased public involvement. The more informed people are about lake problems, alternative management procedures, and watershed effects, and more intelligent their decisions about selecting and implementing appropriate protection and maintenance procedures (Thornton 1988). A second purposes is to ensure that restoration efforts are implemented and that once implemented they are sustained. A publication by the North American Lake Management Society on how to start an effect lake association is provided in Appendix C.

Table b.1.7. A variety of zoning techniques (Public Technology, Inc. 1977, Thornton 1988).

Topic	Definition
Zoning	The regulation of building types, densities, and uses permitted in districts established by law.
Special Permits/ Secial Excepions/ Conditional Use Permits	Administrative permits for uses that are generally compatible with a particular use zone, but that are permitted only if certain specified standards and conditions are met.
Variances	Administrative permits for uses that are generally compatible with a particular use zone, but that are permitted only if certain specified standards and condition are met.
Floating Zones	Use zones established in the text of a zoning ordinance, but not mapped until a developer proposes and the legislative body adopts such a zone for a particular site.
Conditional Zoning	An arrangement whereby a jurisdiction extracts promises to limit the future use of land, dedicate property, or meet any other conditions. The arrangement is either stated in general terms in the zoning ordinance or imposed on a case-by-case basis by the legislative or administrative body, prior to considering a request for a rezoning.
Contract Zoning	An arrangement whereby a jurisdiction agrees to rezone specified land parcels subject to the landowner's execution of restrictive covenants or other restrictions to dedicate property or meet other conditions stated in the zoning ordinance or imposed by the legislative or administrative body.
Cyclical Rezoning	The periodic, concurrent consideration of all pending rezoning applications, generally as part of an ongoing rezoning program, focusing upon one district at a time.

Table b.1.7. Continued.

Topic	Definition
Comprehensive Plan	Provisions that require all zoning actions, and all other Consistency Government actions authorizing development, to be Requirement consistent with an independently adopted comprehensive plan.
Zoning Referendum	Ratification of legislatively approved land use changes by popular vote, before such changes become law.
Prohibitory Zoning	The exclusion of all multifamily, mobile, modular, industrialized, prefabricated, or other housing types from an entire jurisdiction, or from most of the jurisdiction.
Agricultural Zoning/	The establishment of "permanent" zones with large Large Lot Zoning/(that is multiacre) minimum lot sizes and/or a Open Space Zoning prohibition against all nonagricultural development (with the exception of single-family residences and, possibly selected other uses).
Phased Zoning/ Holding Zones/ Short-Term Service Area	The division of an area into (1) temporary holding zones closed to most nonagricultural uses and/or with large minimum lot sizes, and (2) service areas provided with urban services and open for development in the near term (for example 5 years).
Performance Zoning/ Performance Standards	An arrangement whereby all or selected uses are permitted in a district if they are in compliance with stated performance standards, that is, if they meet stated community and environmental criteria on pollution, hazards, public service demands, etc.
Flexible Zoning	Freedom from minimum lot size, width, and yardage regulations, enabling a developer to distribute dwelling units over individual lots in any manner the developer desires, provided (usually) that the overall density of the entire subdivision remains constant.

Table b.1.8. A variety of development options (Public Technology, Inc. 1977, Thornton 1988).

Topic	Definition
Planned Unit Developement (PUD)	A conditional use or floating zone regulated through specific design standards and performance criteria, rather than through the traditional lot-by-lot approach of conventional subdivision and zoning controls.
Subdivision Regulations	Procedures for regulating the division of one parcel of land into two or more parcels-usually including a site plan review, exactions, and the application of aesthetic, bulk, and public facility design standards.
Minimum Lot Size	The prohibition of development on lots below a minimum size.
Minimum Lot Size	A limitation on the maximum number of dwelling units Per Dwelling Lot permitted on a lot, based on the land area of that lot (usually applied to multifamily housing).
Minimum Lot Size	A limitation on the maximum number of rooms (or Per Room bedrooms) permitted on a lot, based on the land area of that lot (usually applied to multifamily housing).
Setback, Frontage, and Yard Regulations	The prohibition of development on lots without minimum front, rear, or side yards or below a minimum width.
Minimum Floor Area	The prohibition of development below a minimum building size.
Height Restriction	The prohibition of development above a maximum building size.
Floor Area Ratio (FAR)	The maximum square footage of total floor area permitted for each square foot of land area.
Land Use Intensity Rating	Regulations that limit the maximum amount of permitted floor space and require a minimum amount of open space (excluding parking areas), recreation space, and a minimum number of parking spaces (total and spaces reserved for residents only).

Table b.1.8. Continued.

Topic	Definition
Adequate Public Facilities Ordinance	The withholding of development permission whenever adequate public facilities and services, and defined by ordinance, are lacking, unless the facilities and services are supplied by the developer.
Permit Allocation System	The periodic allocation of a restricted (maximum) number of building permits or other development permits first to individual districts within a jurisdiction and then to particular development proposals.
Facility Allocation System	The periodic allocation of existing capacity in public facilities, especially in sewer and water lines and arterial roads, to areas where development is desired while avoiding areas where development is not desired.
Development Moratorium/Interim Development Controls	A temporary restriction of development through the denial of building permits, rezonings, water and sewer connections, or other development permits until planning is completed and permanent controls and incentives are adopted, or until the capacity of critically overburdened public facilities is expanded.
Special Protection Districts/Critical Areas/Environmentally Sensitive Areas	Areas of local, regional, or State-wide importance-critical environmental areas (for example, wetlands, shorelands with steep slopes); areas with high potential for natural disaster (for example, floodplains and earthquake zones); and areas of social importance (for example, historical, archaeological, and institutional districts) - protected by a special development review and approval process, sometimes involving State-approved regulations.

b.1.3 Feasible Alternative

The feasible alternatives include:

- BMPs;
- Regulatory considerations; and
- Lake association.

These alternatives have already been described in the previous section. The in-lake restoration alternatives are not considered to be feasible alternatives to improve the overall water quality in Beaver Reservoir. Water quality improvements would be localized and primarily benefit the drinking water supply use rather than recreation.

b.1.4 Expected Water Quality Improvements

b.1.4.1 BMPs

The purpose of BMPs is to decrease the generation of pollutants rather than to attempt to treat the pollutants once they are generated. BMPs are the only feasible means to control nonpoint source pollution. The primary weakness of BMPs is that there is not a good database to estimate effectiveness, in part, because the relationship between land use activities, land physiography, nonpoint pollution runoff and the resulting effects on the aquatic ecosystem is not fully understood. The effectiveness of selected BMPs, however, is summarized in Table b.1.9.

With the implementation of agricultural BMPS, the SCS expects a nutrient reduction in Beaver Reservoir of about 44%. With the aid of the model BATHTUB, effects of a 40 and 50% reduction in nutrient loads on in-lake concentrations were estimated. With a 40% reduction in nutrients, phosphorus, nitrogen and chlorophyll a concentrations would be reduced approximately 33, 37 and 29%, respectively, in the upper end of the reservoir that includes the White River and Richland Creek drainages. With a 50% nutrient load reduction, phosphorus, nitrogen and chlorophyll a concentrations would be reduced approximately 42, 47 and 41%, respectively in the upper end of the reservoir. Changes in Secchi disc transparency would probably not be

Table b.1.9. Estimates of effectiveness of select BMPs in reducing nutrient (EPA 1987, Olem et al. 1990).

AGRICULTURAL BMPs	EFFECTIVENESS
Conservation Tillage	Effectiveness estimates for reducing sediment loads and phosphorus and pesticide transport range from 40 to 90%
Waste Management	Can reduce phosphorus runoff from 50 to 70%
Buffer Strips (vegetated filter strips)	Can reduce sediments, phosphorus and nitrogen about 79, 67, and 84%, respectively, on a 4% slope
URBAN BMPs	
Structural Controls	Sediment basins can reduce sediment about 70%
Nonvegetated Soil Stabilization	Reduce sediments 75 to 95%
Runoff Detention Retention	50 to 90% of sediments retained
SILVICULTURE BMPs	
Proper Design of Haul Roads	45% sediment reduction with grass 92% sediment reduction with 15 in. of rock
Debris Removal	Keep debris out of streams that may deflect or constrict water resulting in bank and channel erosion
Limiting Disturbed Areas	Control over potential causes of nonpoint source runoff

detected. Under either nutrient load reduction expected nutrient concentration changes in the lower part of the reservoir will be minimal. The majority of the nutrients entering Beaver Reservoir are assimilated in the upper reach of the reservoir, a typical situation in reservoirs such as Beaver.

The reduction of nutrients expected from the implementation of urban and silviculture BMPs is not adequately known. The identification of specific areas to implement the BMPs and the exact types of BMPs that should be implemented ws beyond the scope of this project. However, some additional reduction in nutrients could be expected.

Regulatory considerations to reduce nutrients to Beaver Reservoir are not quantifiable. However, as the population of northwest Arkansas increases, the implementation of zoning and development would be beneficial in maintaining and protecting the lake. A viable lake association aware of the demands of increasing population and development would be invaluable in protecting the reservoir.

b.1.5 Estimated Cost of Feasible Alternatives

Table b.1.3 summarizes the agricultural BMPs recommended by the SCS (1986) to be implemented in the Beaver Lake watershed. In addition, Table b.1.10 summarizes the total BMP needs identified during the SCS inventory based on random sampling, the estimated total BMPs needed, the unit cost, the proportion of the practices expected to be applied, and the projected costs. The total cost of implementing the BMPs listed in Table b.1.10 is about $5 millions dollars.

Costs associated with urban and silviculture vary considerably depending on complexity of structures and maintenance requirements. Estimated costs for selected BMPs (EPA 1987) are:

- Runoff detention/retention basins - $100 to $1,500 per acre and maintenance costs of $10 to $75 per acre.
- Debris removal - $160 to $800 per 100 ft.

Table b.1.10. Beaver Lake recommended BMP implementation.

Practices	Unit	Total Identified	Total Needed	Unit Cost $	Participation Rate	Projected Total $
Liquid Manure Tank (Concrete)	cu yd	30	1,020	140.0	0.8	114,240
Dry Stack Structure	cu yd	1,410	47,930	1.7	0.25	20,370
Fencing	ft	58,500	263,525	1.5	0.8	316,230
Dead Animal Disposal Pits	each	22	748	500.0	0.8	299,200
Pond	cu yd	68,200	1,229,000	1.0	0.8	983,200
Pasture and Hayland Planting	acre	800	27,200	25.5	0.9	624,240
Critical Area Planting	acre	50	1,700	540.0	0.8	734,400
Deferred Grazing - No Fencing	acre	210	7,140	32.0	0.6	137,088
Grasses and Legumes in Rotation	acre	405	13,770	32.0	0.5	220,320
Planned Grazing Systems	acre	160	5,440	32.0	0.8	139,264
Proper Grazing Use	acre	55	1,870	15.5	0.8	23,188
Range Seeding	acre	50	1,700	22.0	0.25	9,350
Waste Utilization, Dry	acre	1,921	65,314	5.0	0.9	293,910
Cost of Practices						3,915,000
Cost of Technical Assistance						1,047,000
Total Installation Costs						4,962,000

- Proper design of Haul Roads and Trails - Grass plus fertilizer $5.00/30 m of roadbed; 15 cm or rock $79.00/30 m of roadbed; 20 cm of rock $266/30 m.

b.1.6 Activities to be Undertaken

Although the implementation of BMPs, is currently is progress, a lake management body needs to be established. The primary purpose of the lake management body would be to serve as a focal point of management activities. The functions of the lake management body could include:

- Communicating the concerns and interests of the local interest groups to the lead federal agency responsible for the operation of Beaver Reservoir (U.S. Army Corps of Engineers) and the lead state agency for protecting water quality in Arkansas (the Arkansas Department of Pollution Control and Ecology).
- Communicating the activities of participating states and federal agencies to local interest groups.
- Ensuring that the public is informed as restoration activities are initiated and when restoration/protection activities are needed.

The U.S. Army Corps of Engineers - Little Rock District would have oversight of all activities that affect the operation of Beaver Reservoir and the project purposes. The Arkansas Department of Pollution Control and Ecology would have oversight of water quality issues that pertain to designated and existing uses in Beaver Reservoir. The Arkansas Department of Pollution Control and Ecology, would communicate activities of various state and federal agencies to the lake management body. Figure b.1.1 illustrates the networking that will have to take place for a Beaver Reservoir restoration/maintenance project to work.

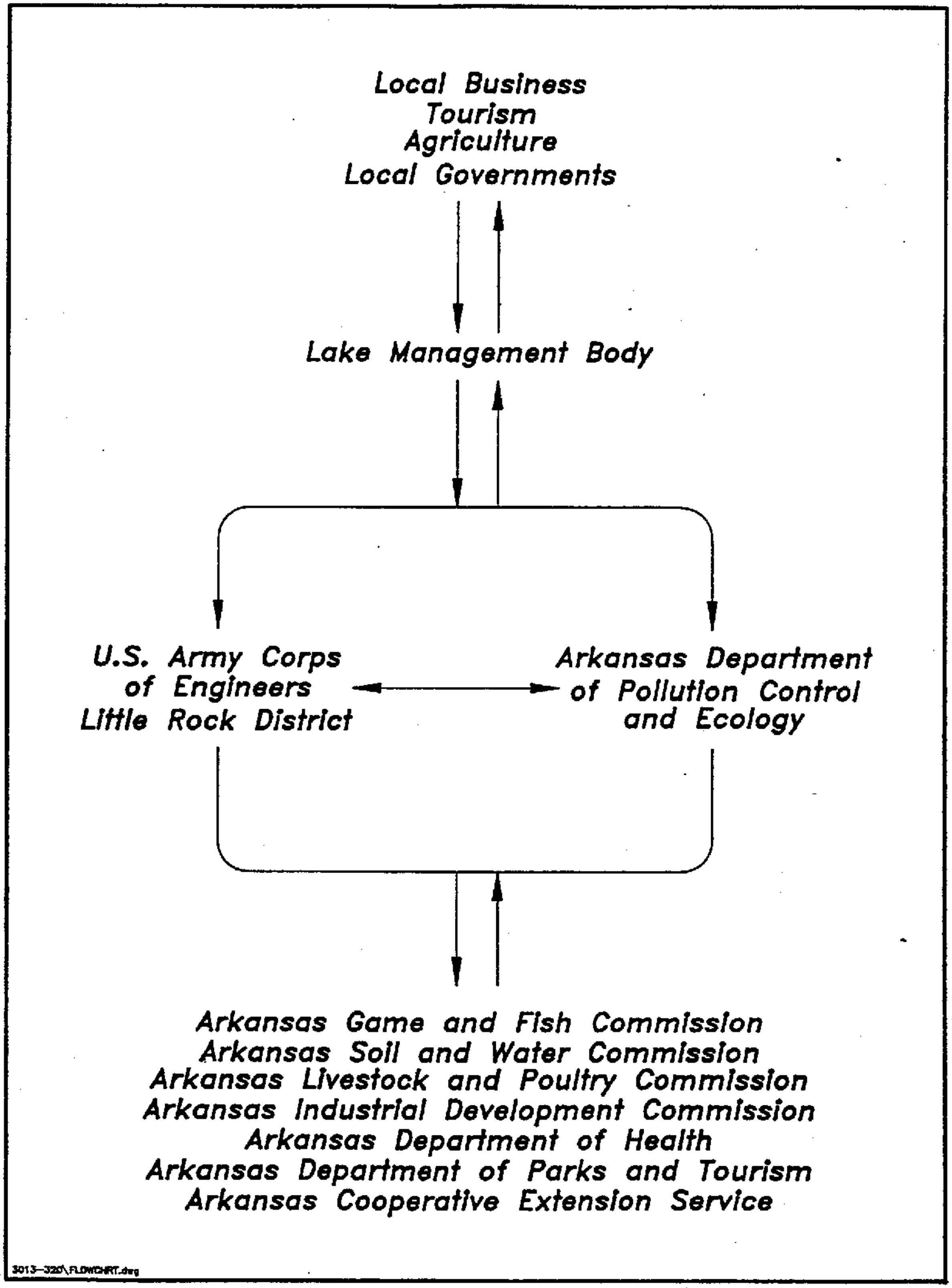

Figure b.1.1. Beaver Lake networking system.

b.2.0 BENEFITS EXPECTED FROM RESTORATION

b.2.1 Project Objectives in Terms of Benefits

The major existing uses of Beaver Reservoir are hydroelectric power, water supply, recreation, and flood control. In 1990, between January and June, 178,078,300 kwh of electricity were generated. Carroll and Boone Counties withdrew 2,124,702 m^3 of water and the BWD withdrew 18,302,000 m^3 for domestic water supply purposes. Approximately, $20.9 million of flood damage was prevented by the presence of the reservoir as of September 1988 (Section a.5.0).

For the last decade Beaver Reservoir has averaged 4.8 million visitors per year. There has been no consistent decease in visitations (Section a.5.0). The Reservoir is noted for its clear water although turbid conditions occasionally occur in the headwaters. Contacts with marina operators noted an increase in the numbers of fishermen, boaters, scuba divers and tourists each year.

Based on the results of this study and on the continued recreational demands place on the lake, Beaver Reservoir is not a severely degraded lake. Beaver Reservoir has maintain its aesthetic appeal because of its natural setting. Although Beaver Reservoir is not degraded to the degree that has been perceived by segments of the general public, it is important that the lake be protected and maintained since the potential exists for lake degradation. The project restoration objective is to improve existing uses by reducing nutrient and sediment inputs to Beaver Reservoir via state-of-the-art management in the watershed.

b.2.2 Proposed Water Quality Changes and Anticipated Water Quality Changes

As stated in Section b.1.3, the feasible alternatives for Beaver Reservoir are:

- BMPs;
- Regulatory considerations; and
- Lake associations.

Anticipated water quality changes associated with the implementation of BMPs include:

- About a 44% reduction in nutrient loads;
- A concomitant reduction in phosphorus and nitrogen concentrations between 30 and 40% in the upper end of Beaver Reservoir; and
- A concomitant decease in chlorophyll a concentrations between 30 and 40% in the upper end of Beaver Reservoir.

Anticipated water quality changes associated with regulatory considerations are difficult to quantify because the type of regulations imposed will largely be dependent on local governments. Development regulations could have substantial effects in protecting the lake from future degradation by ensuring that as development progresses runoff water quality is considered in development plans. In addition, local regulations could be effective in reducing existing local problems in individual coves or embayment on Beaver

Likewise water quality changes associated with a lake association are difficult to estimate. The ability of a lake association to affect water quality changes will depend on the cohesiveness of the members and their willingness to be active. An active informed lake association can identify major and minor sources of pollution and take appropriate action to eliminate or reduce the source.

b.2.3 Relation of Benefits to Water Quality Changes

Major increases in recreational use of Beaver Reservoir are not expected with the implementation of a lake restoration alternatives. However, existing levels of uses will be maintained.

With a reduction in nutrients and sediment loads with the implementation of BMPs, the BWD may experience a reduction in problems with turbidity, and potential trihalomethane precursors. A reduction in turbidity and trihalomethane precursors will potentially reduce treatment costs.

b.2.4 Quantitative Estimation of Benefits

Recreational benefits are not expected to increase significantly with the implementation of BMPs since visitations to the lake remain high. However, it is important to implement the BMPs to protect existing uses. Based on data provided by the U.S Fish and Wildlife Service (USFWS), there were approximately 166,400 resident fishermen and about 59,600 non-residents that fished in Northwest Arkansas (UFWS 1989). On an average the resident fishermen spent a total of $520 per year and the non-resident fishermen spent a total of $595 per year. These monies were spent on food and lodging, transportation, boat fuel, bait, fishing equipment, licenses, etc. The revenues generated were worth approximately $86.5 million from resident and $35.4 million from non-resident fishermen. Although these estimates are for Northwest Arkansas and not just for Beaver Reservoir, a significant portion of these revenues can be assumed to result from the good fishery in Beaver Reservoir.

Fourt (1988) reported striped bass catch records from the Lost Bridge Marina. Using a value estimate of $5.35 per pound for a striped bass, the striped bass catch recorded at the Lost Bridge Marina was worth $115,532. The $5.35 per pound estimate was based on an estimate by the American Fisheries Society - Southern Division. Assuming the value of the striped bass fishery is similar at the 12 public access areas the potential value of the striped bass fishery alone is about $1.4 million annually.

Although the estimates of benefits of the Beaver Reservoir fishery to the economy of Northwest Arkansas is significant, these estimates do not include the revenues generated by average 4.7 million average annual recreational users of Beaver Reservoir. The USFWS estimated that approximately 42% of the nonconsumptive recreational users (e.g. birdwatchers, swimmers, picnickers, etc) in the State of Arkansas are "spenders" and spend an average of $128 per year in pursuit of their recreation. Assuming that 42% of the 4.7 million annual visitors to Beaver Reservoir are nonconsumptive recreation "spenders", then the approximate revenues generated are approximately $253 million.

Based on these estimates, Beaver Reservoir is a significant source of revenues in the Northwest Arkansas area. As a significant source of revenues, expenditures to reduce or maintain present nutrient loads are worthwhile. It is cost effective to spend time and money to protect and maintain a lake rather than wait until problems are blatantly obvious.

b.2.5 Water Quality Changes From Increased Loadings

To provide a perspective on potential water quality improvements with reduced nutrient loadings, increases in nutrient loads also were investigated using the BATHTUB model. Table b.2.1 summarizes the results of a 25, 50 and 100% increases in nutrient loads to Beaver Lake. In the upper end of the reservoir, total phosphorus concentrations increases ranged from 16 to 40%, total nitrogen concentrations increases ranged from 18 to 45% and chlorophyll a concentrations increases ranged from 6 to 19%. Secchi disc transparency would not decrease at 25 and 50% load increases, but would decrease about 17% at an increase of 100%. In the vicinity of the BWD, total phosphorus, total nitrogen, and chlorophyll a concentrations were estimated to increase by 20, 29 and 25% at a 100% nutrient load increase. Secchi disc transparency would decrease by 7%.

Table b.2.1. Estimated increases in concentrations of total phosphorus (TP), total nitrogen (TN) and chlorophyll a (Chla), and estimated decreases in Secchi disc transparency (SD) based on BATHTUB model results with a 25%, 50% and 100% increase in nutrient loads.

Segment	25% Increase				50% Increase				100% Increase			
	TP (mg/m^3)	TN (mg/m^3)	Chla (mg/m^3)	SD (m)	TP (mg/m^3)	TN (mg/m^3)	Chla (mg/m^3)	SD (m)	TP (mg/m^3)	TN (mg/m^3)	Chla (mg/m^3)	SD (m)
1 (Upper White)	172	1,627	18	0.6	197	1,905	20	0.6	242	2,428	21	0.5
2	99	1,203	14	0.7	110	1,374	15	0.7	128	1,681	16	0.7
3	61	1,074	12	0.8	67	1,228	13	0.8	78	1,507	14	0.8
4	49	910	10	0.9	53	1,025	10	0.9	60	1,227	12	0.9
5	38	763	8	1.1	41	846	9	1.1	45	986	10	1.1
6 (BWD)	30	634	7	1.3	32	693	7	1.3	35	792	8	1.3
7	25	545	6	1.7	26	589	7	1.6	28	662	7	1.6
8	21	470	5	2.1	22	504	6	2.1	23	559	6	2.0
9	17	399	4	2.4	18	425	5	2.4	19	465	5	2.3
10	13	326	3	2.9	14	345	4	2.9	15	373	4	2.8
11	11	280	3	3.7	11	294	3	3.6	12	316	3	3.5
12 (DAM)	10	255	2	4.5	10	266	2	4.4	11	283	3	4.3

b.3.0 PHASE 2 MONITORING PROGRAM

b.3.1. Introduction

The primary purposes of the Phase 2 Monitoring Program are:

- To monitor changes in nutrient and sediment loads to Beaver Reservoir;
- To evaluate the effectiveness of the BMP implementation in the watershed;
- To monitor changes in in-lake concentrations of total phosphorus, the nitrogen fractions nitrate, ammonia, and total Kjeldahl nitrogen; chlorophyll a and Secchi disc transparency.

The sampling and analysis program utilized by the National Eutrophication Survey and this study provide a good comparable data base for tracking water quality trends in Beaver Reservoir. Water quality monitoring should continue indefinitely in order to provide a continuing understanding of the water quality of Beaver Reservoir; to assess the effectiveness of BMPs; and to detect warning signs of potential problems such as increases in nonpoint source nutrient loads versus point source nutrient loads or vice versa.

The United States Army Corps of Engineers-Little Rock District has a monitoring program that was initiated in February 1992. "The overall goals of the plan are to perform point and non-point source nutrient load accounting for Beaver Lake, water quality trend analysis, and to provide guidance in establishing the effectiveness of implementing best land management practices (BMP's) within the Beaver Lake Basin." Twelve stream sites and five in-lake sites will be monitored. The monitoring program is scheduled for one year with the options to extend the project through April 1996. The major drawback to the proposed monitoring program is the monitoring activities are restricted to the area of the Lake south of the Arkansas Highway 12 bridge.

b.3.2 Recommended Program

As noted in the review of historical information there are a number of organizations that collect water quality data in Beaver Reservoir such as the USGS, ADPCE, Corps of Engineers - Little Rock District and the BWD. There currently is no common goal, nor a consistent Quality Assurance and Quality Control Program among these monitoring programs. Because the resources to monitor water quality in Beaver Reservoir already exist, it is recommended that these groups develop a common monitoring program that addresses the concerns of each institution and, concomitant with the monitoring program, develop a QA/QC program that is consistent among groups. Because the Army Corps of Engineers -Little Rock District has oversight for the Beaver Lake Project, it is suggested that the Army Corps of Engineers have oversight responsibilities for networking these different institutions. Two levels of networking are envisioned. At one level, where the Corps of Engineers - Little Rock District would be actively involved at the policy level where the goals of the different institutions would be developed. The second level would be technical where technical representatives from agencies monitoring Beaver Reservoir would develop the monitoring and QA/QC program to meet the goals and objectives set at the policy level. The ADPCE has the responsibility for water quality in lakes and streams in Arkansas, so it is suggested that the ADPCE serve as the lead agency in developing the monitoring program for Beaver Reservoir. At both levels of the network, representatives of any lake association formed in the watershed should be included.

The coverage of the lake by existing water quality monitoring programs is adequate to track changes in the lake on an annual basis. However, the existing program is not adequate to track decreases in loads through the implementation of BMPs. Therefore it is suggested that every five years a comprehensive study of Beaver Reservoir be conducted by the U.S. Army Corps of Engineers-Little Rock District or by the ADPCE. This comprehensive study could be conducted by ADPCE personnel or contracted. The proposed comprehensive study would use a protocol similar to the one used during this study and by the National Eutrophication Survey in conjunction with the protocols developed during U.S. Army Corps of Engineers-Little Rock District monitoring program discussed in b.3.1.

It is also suggested that the level of effort currently employed to assess the fish community by the Arkansas Game and Fish Commission be continued. A closer relationship needs to be developed between the fisheries community and the community of institutions primarily concerned about water quality.

At the local level, it is recommended that a base program be developed that can be conducted by members of a lake association. The base parameters to be monitored would include:

- Secchi disc transparency; and
- Temperature

At a minimum these parameters should be monitored at least 4 times a year at the upper end of the lake, near the middle of the lake, and near the dam (e.g. April, July, October and January). Additional sites could be established in selected coves such a Prairie Creek, Rocky Branch, Indian Creek, War Eagle and Monte Ne. Cove information is limited and it may be that additional nonpoints source impacts are evident in coves but not the main body of the lake.

A preferred program would include a monitoring frequency of 12 times during the growing season (May through October) and 6 times from November through April. This base program could be continued indefinitely with minimal costs to a lake association and would provide a continuous record of conditions throughout the lake.

b.3.3 Responsible Agency

For Beaver Reservoir, it is recommended that the Army Corps of Engineers - Little Rock District have responsibility for to coordinating the monitoring program. By working closely with a lake association, misperceptions about the water quality of the reservoir can be alleviated and many potential problems that could affect water quality could be resolved before water quality problems occurs.

b.3.4 Funding

It's suggested that the Army Corps of Engineers - Little Rock District assume responsibilities for coordinating details for joint funding of a monitoring program on Beaver Reservoir.

b.4.0 SCHEDULE AND BUDGET

Because the activities typically associated with a Clean Lake Study Phase II - Implementation Project are already being implemented (BMP Implementation and a monitoring program), an extensive milestone schedule and budget would be redundant. The major issue that needs to be addressed at this time is the implementation of a Lake Association. The implementation of a Lake Association should be initiated as soon as possible. The cost associated with implementing a Lake Association should be minimal and primarily consist of contributions of individual time to lay the foundation for the Association. However, because of the size of Beaver Reservoir and the number of urban and rural areas involved, a workshop to assist in the establishment of Lake Association would be appropriate. The cost of conducting a Lake Association workshop might cost from $5000 to $10,000. Furthermore, it is recommended that such a workshop be coordinated through the North American Lake Management Society (NALMS). NALMS has the resources and the experience to conduct the proposed workshop.

b.5.0 SOURCES OF MATCHING FUNDS

Sources of matching funds for a workshop could be obtained through cost share and in-kind match. Sources could include:

- Municipalities (e.g. Fayetteville, Springdale and Rogers);
- County governments (e.g. Washington, Benton, Carroll, and Boone);
- Industries; and
- Volunteer contributions.

With the ongoing activities in the watershed under the SCS BMP implementation program the farmers implementing the BMPs are already providing the in-kind or cash match. The existing monitoring program being initiated by the U.S. Army Corps of Engineers comes from designated Federal funds. Therefore, matching funds might not be required at this time.

b.6.0 RELATIONSHIP TO OTHER POLLUTION CONTROL PROGRAMS

Through the provisions of the Clean Water Act as amended and other State and Federal initiatives, there exist a number of interrelated pollution control implementation and technical assistance programs related to this project. Some of these programs have already been discussed in previous sections of this report. These interrelated and pollution control programs are listed below:

1. Section 843 of the Water Resources Development Act of 1986, as amended

- Description - Section 843 of the Water Resources Development Act of 1986 authorized the Beaver Lake Water Quality Demonstration Project. Furthermore, Section 903(a) of the Act modified the multipurpose project at Beaver Lake "to authorize and direct the Secretary of the Army, in cooperation with the Administrator of the Environmental Protection Agency and the Chief of the Soil Conservation Service and in consultation with appropriate State and local agencies, to conduct a one year comprehensive study of the Beaver Lake Reservoir to identify measures which will optimize achievement of the project's purposes while preserving and enhancing the quality of the reservoir's water." The first phase of the study has been completed and is summarized in the report entitled "Feasibility Report and Environmental Assessment and Finding of No Significant Impact" The next phase of the project is ongoing and consists of the implementation of BMPs in the watershed and the monitoring program previously discussed (Section b.3.0).
- Managing Agency - U.S. Army Corps of Engineers

2. Section 314 of the Clean Water Act, as amended

- Description - Under Section 315 (b)"(d)"(1) and "(2) of the Water Quality Act of 1987, Beaver Lake is designated as a Demonstration Project. Selected objectives of the program applicable to Beaver Lake are:

  a) "develop cost effective technologies for the control of pollutants to preserve and enhance lake water quality while optimizing multiple lake uses;"

  b) "control nonpoint sources of pollution which are contributing to the degradation of water quality in lakes;" and

  c) "evaluate the feasibility of implementing regional consolidated pollution control strategies".

- Managing Agency - Arkansas Department of Pollution Control and Ecology.

3. Section 319 of the Clean Water Act as amended

- Description - This program provides grants to fund implementation activities. Through the 319 program, the Arkansas Soil and Water Conservation Commission has three water quality technicians that are developing waste management plans for poultry, hog and cattle producers.
- Managing Agency - Arkansas Soil and Water Commission
- Eligible activities related to Clean Lake Projects - Implementation of watershed specific activities including: best management practices, hydrologic modifications and construction of water quality improvement structures. Funding is provided on a 60% Federal, 40% local basis.

4. State of Arkansas Revolving Loan Program

- Description - This program provides loans to eligible public entities to: construct wastewater treatment and transportation facilities.
- Managing Agency - Arkansas Department of Pollution Control and Ecology
- Eligible activity related to the Clean Lake Projects - Wastewater treatment and transportation facilities construction.

5. Agriculture Conservation Program

- Description - Funds activities to control erosion and sedimentation to surface waters to improve water quality, conserve energy and ensure continuous food supply.
- Managing Agency - Agricultural Stabilization and Conservation Service - United States Department of Agriculture (USDA)
- Eligible activities related to Clean Lakes Project - Implementation of Agricultural Best Management Practices and/or construction of water quality improvement structures on a site specific basis. Cost share generally 75% Federal and 25% local with a $3500/year/individual limitation for 5 years. Through long term agreements approximately $1.0 millon has been committed in the Beaver Watershed.

6. Conservation Reserve Program

- Description - To protect the Nation's long term ability to produce food/fiber, reduce soil erosion and sedimentation, improve water quality, improve habitat for fish and wildlife, curb production of surplus commodities and provide income supports.
- Managing Agency - Agricultural Stabilization and Conservation Service - USDA.

- Eligible activities related to Clean Lakes Project - Set aside of croplands to meet State's individual objectives related to the Clean Lakes Project. Although this program is available it is not presently used in the Beaver Lake Watershed.

7. River Basin Surveys and Investigation

- Description - This program provides technical assistance to local or State water resources agencies to coordinate water and land resources programs.
- Managing Agency - Soil Conservation Service and Agricultural Extension Service- USDA
- Eligible activities related to the Clean Lakes Project - Technical assistance in coordination of erosion and sedimentation control, flooding, floodplain and agricultural water management. This program has already been implemented in the Beaver Watershed as part of the Arkansas Critical Erosion Cooperative River Basin Study authorized in January 1983, in accordance with Section 6 of Public Law 83-566. The report from this study was completed by the Soil Conservation Service and the Forest Service in cooperation with the Arkansas Soil and Water Conservation Commission in March 1986 (SCS 1986).

8. Resource Conservation and Development

- Description - This program assists resource managers at the local level in the initiation and implementation of long range resource conservation and development programs.
- Managing Agency - Soil Conservation Service - USDA
- Eligible activities related to the Clean Lakes Project - Sedimentation and erosion control, public recreation, fish and wildlife habitat enhancement,

management of agricultural water resources and pollution activities. This program became available in the Beaver Watershed as of 2 March 1992.

9. Water Quality Incentive Program

- Description - This program assists local landowners to manage land in specific ways with the intent to protect water quality.
- Managing Agencies - Agricultural Stabilization and Conservation Service, Soil Conservation Service and the Cooperative Extension Service.
- Eligible activities related to the Clean Lakes Project - Individual landowners enter into cooperative agreements to manage grasslands and nutrient applications on grasslands in a specified manner to reduce nutrient runoff to streams.

10. Water and Waste Disposal Systems for Rural Communities

- Descriptions - Provides funding to alleviate health hazards and promote orderly growth in rural area by funding water treatment and waste disposal facilities.
- Managing Agency - Farmer's Home Administration (USDA)
- Eligible activities related to Clean Lakes Projects - Construction of water treatment and wastewater collection and treatment facilities. Entities must have legal status under State authorities to receive funding. The USDA recently provided funds in conjunction with the Arkansas Industrial Development Commission to upgrade wastewater treatment facilities in Huntsville, Arkansas. The USDA is presently funding numerous water systems that will use water from Beaver Reservoir such as the Huntsville/Madison County and south White River Projects.

11. Watershed Protection and Flood Prevention Loans

- Description - This program provides funds to local sponsors for cost share of water resources improvements.
- Managing Agency - Farmer's Home Administration - USDA
- Eligible activities related to the Clean Lakes Project - Construction of water quality improvement structures to address: sedimentation control, fish and wildlife development public recreation, flood prevention and irrigation needs. Because of the relatively high interest rates associated with this program there is no activity ongoing in the Beaver Watershed.

b.7.0 PUBLIC PARTICIPATION SUMMARY

A public participation meeting was held in Springdale, Arkansas at the Springdale Public Library on 22 September 1992. The public notification of the meeting was published in the Arkansas Democrat Gazette and the Springdale Morning News on 8 August 1992 and in the Eureka Springs Times Echo on 12 August 1992. Copies of the Beaver Lake Clean Lake Report were deposited for review in the Northwest Arkansas Regional Library Headquarters in Fayetteville, Arkansas and at the Carroll-Boone Water District Office in Eureka Springs. For individuals or groups unable to attend the public hearing, written comments were accepted by the ADPCE until 2 October 1992.

A tape recording of the public participation meeting is available at the ADPCE office in Little Rock, Arkansas. Of the participants attending the meeting, only four individuals presented comments about the report. Two of the participants wanted the Army Corps of Engineers to prohibit the cutting of grass to the water edge. By maintaining a buffer strip of uncut grass around the lake, nutrients and sediments would be filtered out of runoff water. A third participant considered the report to be "illegitimate" because the impacts of landfills where not considered in the report. The fourth participant was concerned about the motives behind the report rather than the content of the report. These concerns ranged from highly technical jargon not understood by the lay person, to the conclusions of the report being politically motivated because the Governor of Arkansas is running for the Office of President of the United States. Newspaper articles about the public participation meeting are presented in Appendix D. In addition, the prepared statement of the only participant to submit written comments is also included in Appendix D.

Two parties submitted written comments outside of the public participation meeting: The National Water Center in Eureka Springs, Arkansas and the Arkansas Soil and Water Commission (Appendix D). The opinion of the National Water Center is that Beaver Reservoir is becoming more eutrophic due to nonpoint source pollutants from the poultry and swine industries, and septic tanks around the lakeshore. Their restoration recommendations included the following:

- The elimination of septic tank systems and installation of low-flush toilets/holding tank systems, or utilizing biological/dry compost toilets;
- Allow only wind or human powered recreational boats on the reservoir to limit petro-chemical fuels because the reservoir is a drinking water source.
- Eliminate all poultry/swine land application practices and ship waste to a central collection facility where it can be composted as a fertilizer/feed commodity or mixed with wood carbon and pelletized into a combustible fuel for heating.

The Soil and Water Commission had no objections to the report's findings but felt the conclusions were hard to extract without specific attention given to individual parameters.

In general, few public comments or written statements were submitted on the content of the report and restoration alternatives.

b.8.0 OPERATION AND MAINTENANCE PLAN

b.8.1 Introduction

The proposed alternative in this study does not involve an operation and maintenance plan per se. The major recommended alternative to maintaining and protecting Beaver Reservoir is the formation of a lake association.

b.8.2 Function of the Lake Management Body

The primary purpose of the lake management body would be to serve as a focal point of management activities within the watershed including:

- Public monitoring of existing and future point and nonpoint sources of pollution;
- Utilization of appropriate on-site waste management systems in developments (i.e. residential, commercial or industrial) outside the service area of a sewer improvement district;
- Voluntary implementation of BMPs to control nonpoint source pollution;
- Coordinate an ongoing monitoring program;
- Conduct public involvement programs, mass media campaigns, and community workshops to solicit support for the lake management effort; and
- Solicit funds for financing of lake management body activities.

b.9.0 COPIES OF PERMITS AND PENDING APPLICATIONS

The restoration alternative proposed in this feasibility study do not necessitate the need for any permits.

c.1.0 ENVIRONMENTAL ASSESSMENT

c.1.1. Alternatives

The recommended restoration or protection alternatives for Beaver Lake include:

- Implementation of best management practices (BMPs) to minimize runoff entering the lake (e.g., vegetated filter strips, no-till or minimum-till planting, resistant crops, alternative pesticides, etc.).
- Regulatory
- Lake association

This section evaluates the environmental consequences of these proposed management alternatives:

(c)(1) Displacement of People

None of these procedures will displace any individuals.

(c)(2) Defacement of Residential Areas

These procedures will not deface any property.

(c)(3) Changes in Land Use Patterns

No changes in land use patterns are proposed. However, the implementation of a lake association or regulatory considerations could result in controlled development.

(c)(4) Impacts on Prime Agricultural Land

Agricultural BMPs will be designed individually for each farm and implemented with the voluntary cooperation of the landowners. Negative impacts should be minimal. Positive impacts should include more efficient use of animal waste.

(c)(5) Impacts on Parkland, Other Public Land, and Science Resources

There will be no affect on parkland or other public lands. Improvement in water quality should have a positive impact on the scenic beauty of the lake and the areas surrounding it.

(c)(6) Impacts on Historic, Architectural, Archaeological, or Cultural Resources

Proposed restoration alternative will not impact historic architectural, archaeological or cultural resources.

(c)(7) Long Range Increases in Energy Demand

There will be no long range increases in energy demand associated with any of the proposed management alternatives.

(c)(8) Changes in Ambient Air Quality or Noise Levels

No significant changes in ambient air quality or noise levels are anticipated.

(c)(9) Adverse Impacts of Chemical Treatment

No chemical treatment is proposed.

(c)(10) Compliance with Executive Order 11988 on Floodplain Management

No activities are proposed in the floodplain.

(c)(11) Dredging and Other Channel, Bed, or Shoreline Modifications

Dredging is not proposed.

(c)(12) Adverse Effects on Wetlands and Related Resources

There will be no negative effects on existing wetlands or related resources from the proposed alternatives.

(c)(13) Feasible Alternatives to Proposed Project

Viable alternatives to the proposed plan are already being implemented in the watershed. The alternative proposed in this report provides a mechanism to ensure watershed management activities are maintained as ongoing projects as completed.

(c)(14) Other Necessary Mitigative Measures Requirements

No mitigative measures are required.

(c)(15) Summary

The proposed restoration or protection alternatives represent the most cost-effective, environmentally satisfactory approaches for restoring and maintaining the Beaver Lake ecosystem. The proposed alternatives offer no significant negative environmental impacts.

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