TMDLS FOR DISSOLVED OXYGEN FOR WHITE RIVER BELOW BULL SHOALS DAM AND NORTH FORK RIVER BELOW NORFORK DAM

(REACHES 11010003-002U AND 11010006-001)

MAY 1, 2009

TMDLS FOR DISSOLVED OXYGEN FOR WHITE RIVER BELOW BULL SHOALS DAM AND NORTH FORK RIVER BELOW NORFORK DAM

(REACHES 11010003-002U AND 11010006-001)

Prepared for

Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118

Prepared by

FTN Associates, Ltd.
3 Innwood Circle, Suite 220
Little Rock, AR 72211

FTN No. 3013-201

MAY 1, 2009

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ADEQ	Arkansas Department of Environmental Quality
AGFC	Arkansas Game and Fish Commission
ANRC	Arkansas Natural Resources Commission
APCEC	Arkansas Pollution Control and Ecology Commission
ADYN	Hydrodynamic component of RMS model used to calculate TMDLs
BOD_5	5-day biochemical oxygen demand
CAST	Center for Advanced Spatial Technology
CBODu	ultimate carbonaceous biochemical oxygen demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
Corps	US Army Corps of Engineers
CPN	Civic Practices Network
DO	dissolved oxygen
EPA	US Environmental Protection Agency
LA	load allocation
MORAP	Missouri Resource Assessment Partnership
MOS	margin of safety
NBODu	ultimate nitrogenous biochemical oxygen demand
NH_3-N	ammonia nitrogen
NPDES	National Pollutant Discharge Elimination System
RMS	River Modeling System
RQUAL	temperature and water quality component of RMS model used to calculate TMDLs
SWPA	Southwestern Power Administration
TMDL	total maximum daily load
TVA	Tennessee Valley Authority
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WES	Waterway Experiment Station
WLA	wasteload allocation
WWTP	wastewater treatment plant

1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for dissolved oxygen (DO) for the White River below Bull Shoals Dam (Reach 11010003-002U) and the North Fork River below Norfork Dam (Reach 11010006-001). Both stream reaches were cited as not supporting the designated use of aquatic life (trout fishery) according to the 2008 Arkansas 303(d) list (Arkansas Department of Environmental Quality (ADEQ) 2008; US Environmental Protection Agency (EPA) 2008). The sources of contamination and causes of impairment from the 2008 303(d) list are shown in Table 1.1. The TMDLs in this report were developed in accordance with Section 303(d) of the Federal Clean Water Act and EPA's regulations at Title 40 Code of Federal Regulations (CFR) Part 130.7.

Table 1.1. 303(d) listing for the stream reaches in this report.

Stream Name and Reach No.	Impaired Use	Sources [a]	Causes	Category [b]	Priority
White River 11010003-002U	Aquatic life	Hydropower	Low DO	5A	High
North Fork River 11010006-001	Aquatic life	Hydropower	Low DO	5A	High

Notes: (a) See text for explanation of source of impairment.
(b) Category 5A means the waterbody is definitely impaired and a TMDL is needed.

ADEQ labeled the source of impairment as "hydropower" in the 303(d) list because most of the flow in these tailwater reaches comes from hydropower releases, which are low in DO. However, the low DO is not caused by water flowing through hydropower turbines. Causes of the low DO are discussed in Section 2.1 (General Information) and Section 3.0 (Existing Water Quality Conditions).

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standard for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources, including natural background. The MOS is a percentage of the

TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

2.0 BACKGROUND INFORMATION

2.1 General Information

The White River below Bull Shoals Dam (Reach 11010003-002U) and the North Fork River below Norfork Dam (Reach 11010006-001) are located in northern Arkansas near Mountain Home (see Figure 2.1). General information for these stream reaches is listed in Table 2.1.

Table 2.1. General information for the stream reaches in this report.

Stream Name	Reach Number	Length (miles)	ADEQ Planning Segment	Ecoregion
White River	11010003-002U	3.0	4I	Ozark Highlands
North Fork River	11010006-001	4.8*	4F	Ozark Highlands

* The length specified in the 303(d) list is 4.2 miles, but the length as measured on aerial photos is 4.8 miles.

These two stream reaches are referred to as tailwaters because each one is located immediately downstream of a large dam that controls nearly all of the flow in each reach. Table 2.2 provides general information for these two dams.

Table 2.2. General information for Bull Shoals Dam and Norfork Dam.

	Bull Shoals	Norfork
River that was impounded	White River	North Fork River
Surface area of lake at top of conservation pool	45,440 acres [a]	21,990 acres [a]
Total drainage area upstream of dam	6,051 square miles [a]	1,808 square miles [a]
Year that dam was completed	1951 [b]	1943 [b]
Elevation at top of flood pool	695 ft [a]	580 ft [a]
Elevation at top of conservation pool	654 ft [a]	552 ft [a]
Elevation at bottom of conservation pool	628.5 ft [a]	510 ft [a]
Elevation of hydropower intakes (centerline)	535 ft [a]	447.4 ft [a]
Elevation of streambed at dam	450 ft [a]	374 ft [a]
Number of hydropower turbines	8 [a]	2 [a]
Total flow capacity of hydropower turbines	26,400 cfs [c]	7,200 cfs [c]

Notes:
a. From Tables 4-09 and 4-10 of United States Army Corps of Engineers (Corps) (1993)
b. From Table 3-03 of Corps (1993)
c. From Southwestern Power Administration (SWPA) (2008a)

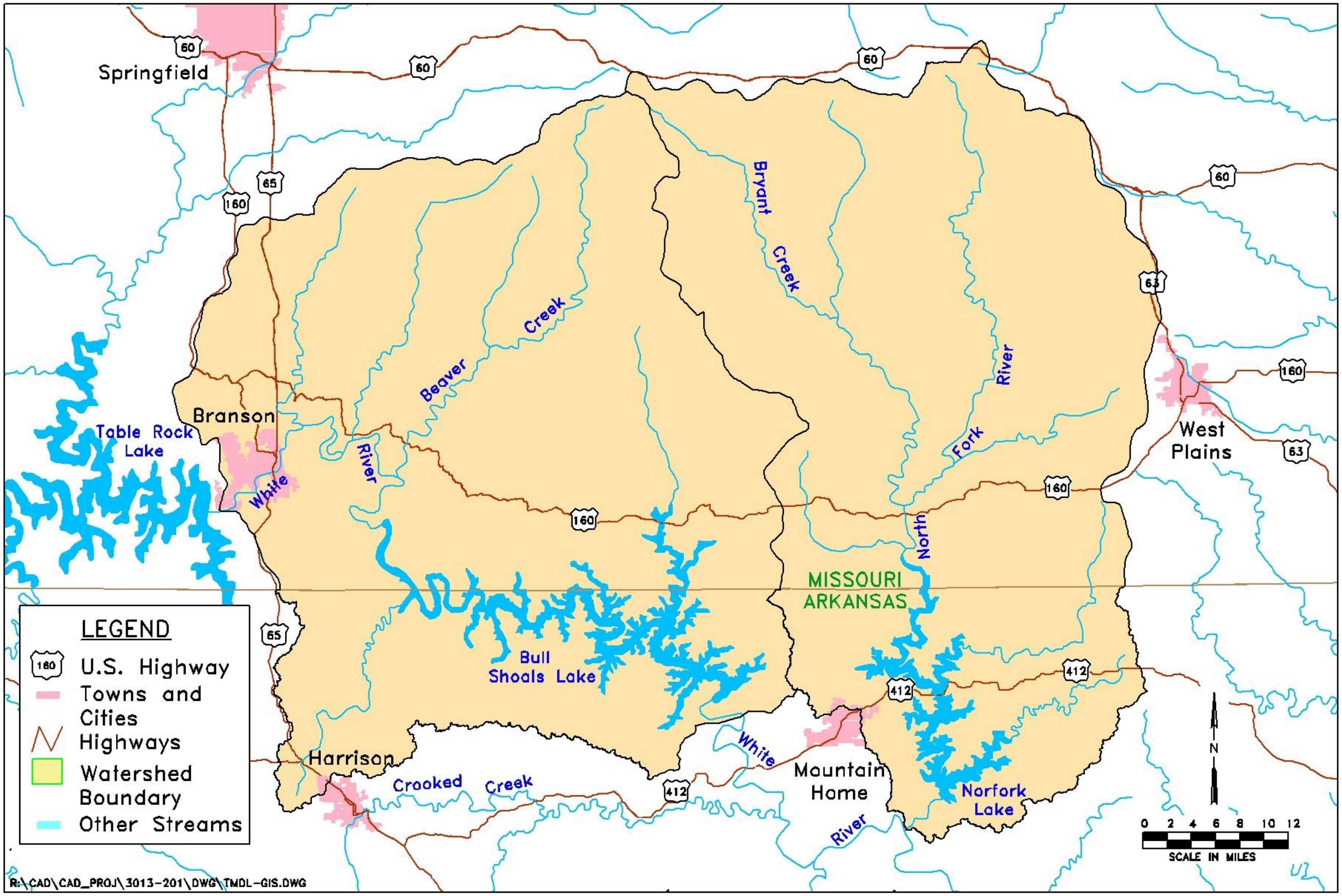


Figure 2.1. Watershed map.

In addition to the number of hydroelectric turbines listed in Table 2.2, these dams have "house units" (sometimes called station service units), which are small hydroelectric turbines that produce electricity on a continuous basis for use by the Corps' facilities at the dams. Bull Shoals Dam has two house units with a combined continuous flow of 50 cubic feet per second (cfs). Norfork Dam has one house unit with a continuous flow of 20 cfs.

The water quality in these two stream reaches is heavily influenced by the quality of the water in each lake. During the late summer and fall, all water released from each lake is normally through the hydropower turbines. The hydropower releases consist of water from the lower part of the lake (the hypolimnion) because the hydropower intakes are located more than 100 ft below the normal water surface elevation for each lake (the top of conservation pool). The water in the hypolimnion of each lake stays cool all year long due to vertical stratification in the lakes. During the spring and summer, water at the surface of the lakes (the epilimnion) is heated by solar radiation, and this temperature increase causes the surface water to become less dense than water near the bottom of the lake. This inhibits vertical mixing of water between the surface and the bottom of the lakes because the cooler, denser water on the bottom tends to stay on the bottom and the warmer, lighter water tends to stay on top. The lack of vertical mixing means that oxygen from the atmosphere that keeps the surface water aerated does not get mixed into the bottom of the lake. DO in the hypolimnion gradually decreases during the summer and fall due to the consumption of oxygen by decay of dissolved or particulate organic matter in the water and in the sediment. This pattern of hypolimnetic DO decline continues until late fall when "turnover" occurs. Turnover occurs when the surface water cools off enough to become more dense than the hypolimnetic water, at which point the aerated surface water sinks and mixes with the hypolimnetic water.

2.2 Trout Fishing

After the Bull Shoals and Norfork dams were built and hydropower releases were initiated, most of the native warmwater fish were no longer able to survive due to the cool temperatures of the hydropower releases throughout the year. Trout were experimentally stocked below Norfork Dam as early as 1948 and below Bull Shoals Dam in 1952 (Arkansas Game and

Fish Commission (AGFC) 1991). The Norfork National Fish Hatchery was built below Norfork Dam in 1957. This hatchery is operated by the US Fish and Wildlife Service (USFWS) and produces nearly 1.8 million trout each year for stocking in the White River basin and other river basins (USFWS 2006). Continual stocking of trout is necessary in the Norfork and Bull Shoals tailwaters because their reproduction in these streams is not sufficient for maintaining their population. For this reason, these tailwaters are referred to as “put and take” trout fisheries. In 2004, AGFC projected that the numbers of trout that would be stocked that year were approximately 1.22 million in the Bull Shoals tailwater and 139,000 in the Norfork tailwater. The projected stockings for these two tailwaters together represented about 60% of the statewide total trout stocking (2.24 million). Most of the stocked trout were rainbow trout; the others were brown trout, cutthroat trout, and brook trout (AGFC 2004a).

Trout fishing in the Bull Shoals and Norfork tailwaters is very important from an economic standpoint. The trout fishing in these tailwaters attracts people from other states as well as Arkansas. A report by USFWS estimates that the number of people fishing for trout in Arkansas multiplied by the number of days per year that each person fished (“angler days”) is over 1.5 million, which represents 39% of the total estimate for trout fishing in all US waterbodies stocked with trout from national fish hatcheries (USFWS 2005). In 1988, the economic benefits due to trout fishing were estimated to be $87,412,000 downstream of Bull Shoals Dam and $17,329,000 downstream of Norfork Dam (AGFC 1991). Current estimates of economic benefits would likely be higher. Results of a 1994 trout angler survey indicated that all trout fishing in Arkansas generated over $133,000,000 in economic value at that time (AGFC 2004a). Trout permit sales have generally continued to increase over time since the early 1990s. During the fiscal year 2001-2002, the number of trout permits sold was 159,665 (AGFC 2004a).

USFWS estimated statewide economic benefits from trout fishing in Arkansas during 2004 to be approximately $62.9 million in retail sales, $112.7 million in industrial output, and $28.3 million in job income. This study also estimated that trout fishing in Arkansas generated approximately $3.8 million in sales and motor fuel taxes, $1.4 million in state income tax, and $2.9 million in federal income tax during 2004 (USFWS 2005). If it is assumed that these statewide economic benefits for trout fishing can be divided among different waterbodies in proportion to the number of trout stocked in each waterbody, then about 60% of the statewide economic benefits can be attributed to the Bull Shoals and Norfork tailwaters.

2.3 DO Committee

A multi-agency committee was formed in November 1990 by then-Governor Bill Clinton to develop short-term and long-term solutions to the DO issue in the White River basin (Civic Practices Network (CPN) 2003). The White River DO Committee still meets semiannually and consists of representatives from ADEQ, AGFC, the Corps, SWPA, the Arkansas Natural Resources Commission (ANRC), the Missouri Department of Conservation, and the Missouri Department of Natural Resources.

2.4 Hydropower Operations

The Corps owns the dams and the hydropower facilities at each dam, but SWPA sets the daily generation schedules at each dam. SWPA is a federal agency operating within the US Department of Energy. SWPA markets the electricity generated at Bull Shoals and Norfork dams and delivers it primarily to public bodies such as rural electric cooperatives and municipal utilities. According to SWPA, generating electricity at Bull Shoals and Norfork dams instead of at a fossil fuel generating facility prevents the burning of either 463,000 tons of coal, 1.6 million barrels of oil, or 9.8 billion cubic feet of natural gas each year and prevents the emission of 808,000 tons of greenhouse gases.

Hydropower facilities such as those at Bull Shoals and Norfork dams will often operate in “peaking” mode, where electricity is generated during the parts of the day with the highest electric demand and no electricity is generated during the remainder of the day. This is normal for hydropower facilities because they provide the capability of starting and stopping generation much more quickly than an electric generating facility that burns fossil fuels. However, peaking operations result in periods of time with no hydropower releases where the only flow in the tailwater reaches is from leakage of low-DO water through and around the dam.

Under normal hydropower operations with turbines running at full capacity, very little air is entrained in the water as it flows through the hydropower turbines; this causes the DO in the hydropower releases to be similar to the DO in the hypolimnion of the lake. When the hydropower turbines are run at reduced capacity, though, more air can be entrained in the water, which improves the DO in the hydropower releases. In accordance with operational plans developed by the White River DO Committee, SWPA has been voluntarily reducing generation at both Bull Shoals and Norfork when DO concentrations in the tailwaters are low. These operational modifications are described in the following excerpt from SWPA's public comments on the draft version of this report:

> "Beginning in 1991, both projects operated in accordance with the White River DO Operation Action Plan. Under that plan, when the DO levels of the upstream water become so low that it causes the downstream DO concentrations during generation to recede to 6 mg/L, all available turbine air-venting options are utilized as well as spreading load over all available units to maintain 6 mg/L as long as possible. If the lake DO concentrations continue to deteriorate and the downstream DO concentrations recede to 4 mg/L during generation, recommended maximum generation rates are computed and Southwestern has voluntarily reduced generation to further improve the DO concentration of the water received from upstream to assure a minimum of 4 mg/L during generation. Beginning in 2000, further enhancement was made to the plan to include pulsing of generation during non-generation periods to improve downstream DO concentrations during the brown trout spawning season."

SWPA estimates that these efforts have caused them to forego approximately $22 million (calculated with 2007 rates) in hydropower benefits from 1991 through 2007.

The operational modifications have improved DO in the hydropower releases to a certain extent, but not up to the state water quality standard of 6.0 mg/L during critical periods. Physical modifications were also made at the Bull Shoals and Norfork hydropower facilities to further minimize the occurrence of low DO in the tailwaters. These physical modifications consisted of improvements in turbine venting, which is essentially the practice of aspirating air into the water as it flows through the turbine so that the water is aerated as much as possible. The physical modifications to the Bull Shoals and Norfork hydropower facilities are described in the following excerpt from SWPA's public comments on the draft version of this report:

"a. In 1993, the Corps Waterway Experiment Station (WES) installed turbine hub deflectors on both units at Norfork and units 1-4 at Bull Shoals.

b. Also in 1993, WES installed modified air vents on units 5-8 at Bull Shoals.

c. In 1997, the Tennessee Valley Authority (TVA) installed improved design hub deflectors on both Norfork units and all eight Bull Shoals units.

d. Also in 1997, TVA improved the turbine air venting system at all units at both projects, including cutting additional air vent holes into the turbine head covers."

2.5 Water Quality Standards

Water quality standards that apply to the Bull Shoals and Norfork tailwaters are given in Arkansas Pollution Control and Ecology Commission (APCEC) Regulation No. 2 (APCEC 2007). The designated uses for these two stream reaches are primary and secondary contact recreation; domestic, industrial, and agricultural water supply; and trout fishery. The numeric criteria that apply to these two stream reaches that are relevant to this report are the year-round temperature criterion of 20°C (68°F) and the year-round DO criterion of 6.0 mg/L. It should be noted that Arkansas water quality standards do not allow a diurnal DO fluctuation below 6.0 mg/L for trout waters.

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Sections 2.201 through 2.204 of Regulation No. 2. These sections impose the following requirements:

1. Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
2. Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.
3. For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.
4. For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

2.6 Land Use

Land use data were compiled for the watersheds draining into the impaired reaches listed in Table 2.1. The watershed used for the White River excluded the area upstream of Table Rock Dam because that area was not considered relevant to the White River below Bull Shoals Dam. The Arkansas portion of the watersheds was characterized with summer 2004 land use data obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas in Fayetteville (CAST 2005). The Missouri portion of the watersheds was characterized with land use data based on imagery from 2000 to 2004. These land use data were published by the Missouri Resource Assessment Partnership (MORAP 2005). After aggregating the data from each state into a small number of land use categories, the data from both states were combined. The predominant land uses in these watersheds are forest and pasture. The spatial distribution of these land uses is shown on Figure 2.2 and land use percentages for each watershed are shown in Table 2.3.

Table 2.3. Land use percentages.

Land Use Category	Watershed for Bull Shoals Tailwater	Watershed for Norfork Tailwater
Urban	2.0%	1.1%
Barren	2.3%	0.7%
Water	3.8%	2.2%
Forest	65.3%	60.8%
Pasture	26.4%	34.7%
Cropland	0.2%	0.5%
TOTAL	100.0%	100.0%

2.7 Nonpoint Sources

As shown in Table 1.1, the final 2004 Arkansas 303(d) list did not identify specific nonpoint sources causing DO impairments in the tailwaters below Bull Shoals and Norfork Dams. Nonpoint source inflows that directly enter these tailwaters do not appear to be having any detrimental effects on DO. The reason for low DO in these tailwaters is low hypolimnetic DO in Bull Shoals Lake and Norfork Lake. As discussed in Section 2.1, low hypolimnetic DO is caused by decay of organic matter during extended periods of vertical stratification.

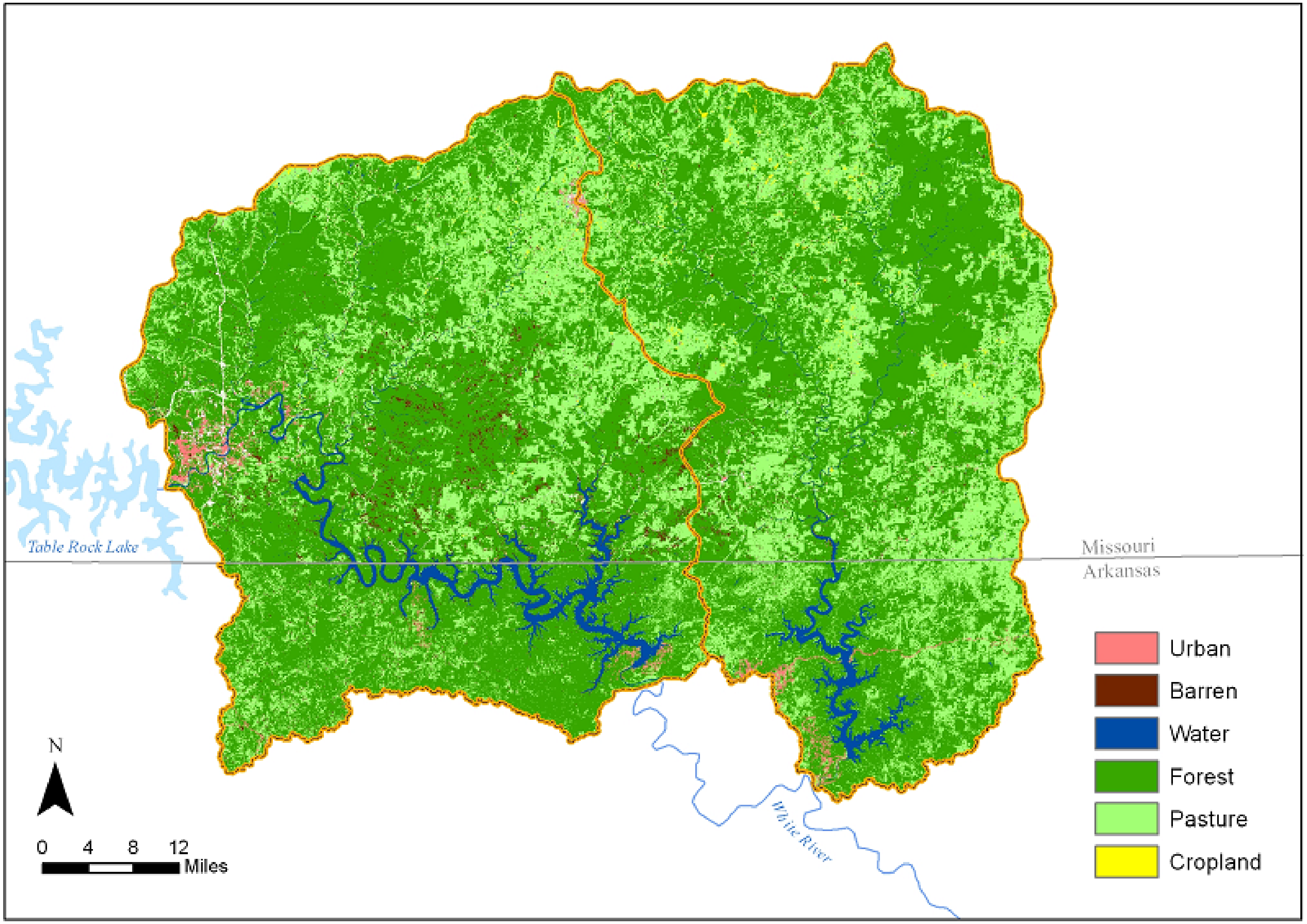


Figure 2.2. Land use map.

Various activities such as agriculture and urbanization in the watersheds may be contributing some organic matter to the hypolimnion of these lakes. However, deep reservoirs tend to have low hypolimnetic DO even if their watersheds are relatively undeveloped. For example, Lake DeGray, Lake Ouachita, and Lake Greeson (all located in central to southwest Arkansas) have relatively undeveloped watersheds and were used to represent reference conditions in a recent study for Beaver Lake. Low hypolimnetic DO values have been measured near the dam in all three of these reservoirs (ADEQ 2000, 2006).

The US Geological Survey (USGS) investigated eutrophication trends based on hypolimnetic DO dynamics in several reservoirs including Bull Shoals Lake and Norfork Lake. Their study showed that a significant factor in the year-to-year variation in hypolimnetic oxygen deficit for each reservoir was the total volume of water discharged through the dam during the stratification period. The regression analyses indicated that this accounted for 57% of the year-to-year variation for hypolimnetic oxygen deficit in Bull Shoals Lake and 68% of the year-to-year variation for hypolimnetic oxygen deficit in Norfork Lake. The summary of the report stated that “It is possible that the aging and evolutionary processes in Beaver, Table Rock, Bull Shoals, and Norfork Lakes are more dominant in controlling biological production and eutrophication in each reservoir immediately above the dam than loading phenomena from the respective basins” (USGS 1996).

2.8 Point Sources

There are two point source discharges with National Pollutant Discharge Elimination System (NDPES) permits to discharge into the impaired stream reaches listed in Table 2.1. Table 2.4 lists design flows and permit limits for each discharge for 5-day biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), and DO. The location of each discharge is shown on Figure 2.3.

Table 2.4. Design flow and permit limits for point source discharges.

Facility Name	Permit Number	Design Flow	BOD_5 Limit (average)	NH_3-N Limit (average)	DO Limit (minimum)
City of Bull Shoals Wastewater Treatment Plant (WWTP)	AR0037028	0.573 MGD	10 mg/L (year-round)	no limit	2 mg/L (year-round)
Norfork National Fish Hatchery	AR0002437	36.9 MGD*	20 mg/L (year-round)	3 mg/L (year-round)	5 mg/L (May-Oct) 6 mg/L (Nov-Apr)

* Highest monthly average flow reported by the hatchery during 2003-2005.

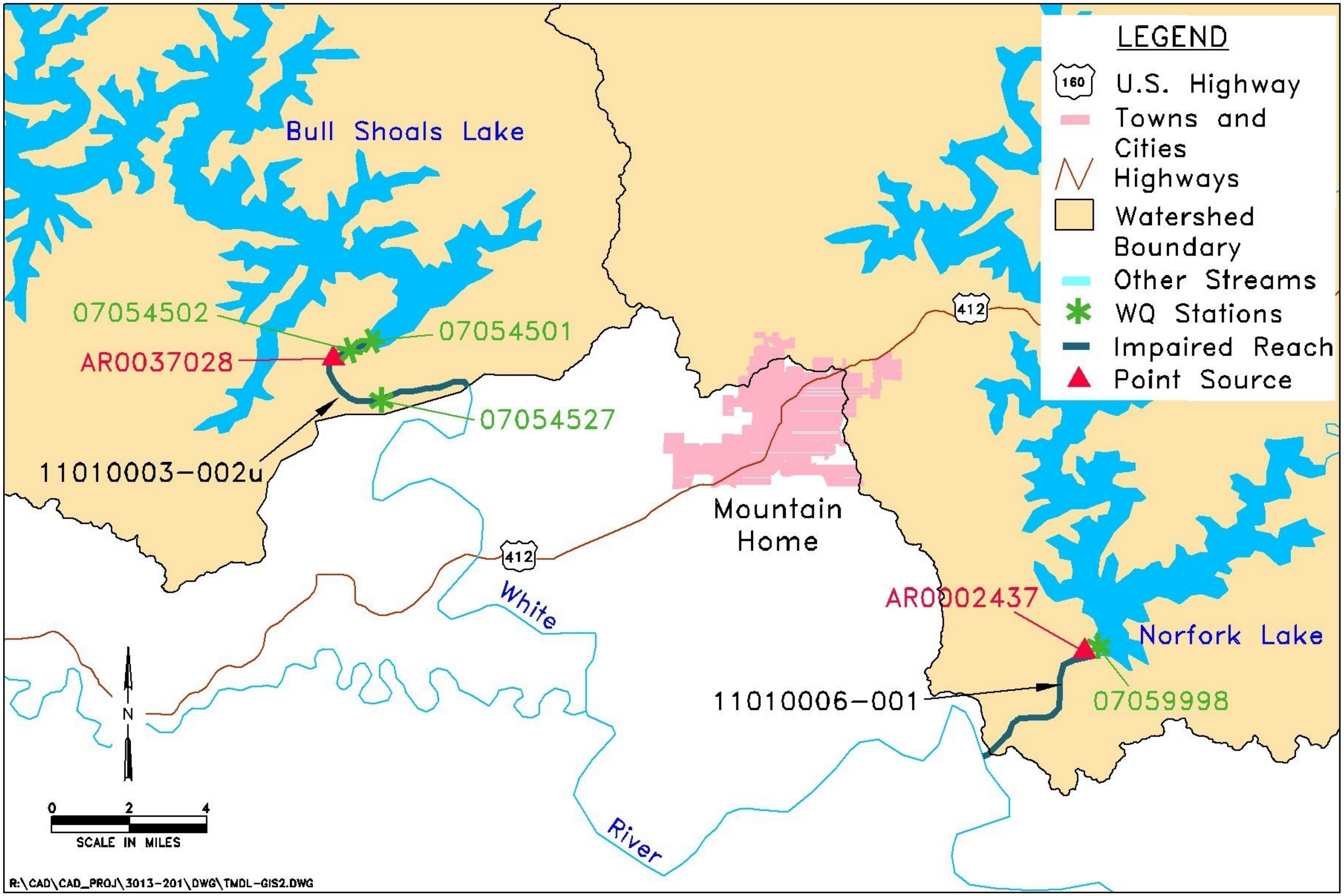


Figure 2.3. Map of point sources and water quality stations.

3.0 EXISTING WATER QUALITY CONDITIONS

3.1 Inventory of Water Quality Data

Hourly monitoring of DO and water temperature below Bull Shoals and Norfork dams has been conducted by USGS since the 1990s. This monitoring began as a result of an interagency agreement for dealing with low-DO conditions in these tailwaters. In addition, ADEQ and USGS have conducted a limited amount of water quality sampling in the Bull Shoals and Norfork tailwaters during certain historical periods. Another small set of data is the DO readings taken by AGFC personnel at various locations when trout are being stocked (to ensure the trout are released into waters with adequate DO). The discussion in the following sections of this report focuses mostly on the hourly DO data because those data provide a more complete characterization of DO conditions in these tailwaters than the other data sets.

3.2 Bull Shoals Data

3.2.1 Overview of Data

Collection of temperature, DO, and water quality data occurs at Stations 07054501, 07054502, and 07054527 in the Bull Shoals tailwater (see Figure 2.3 for locations). DO measured at these three sites generally increases with distance downstream from the dam. The site just downstream of the dam (Station 07054501) experiences the lowest DO levels. Analyses were performed on data from this site because it represents the critical location for DO. The spatial trend of DO increasing as you go farther downstream of the dam is confirmed by the AGFC DO readings from their trout-stocking runs (Table 3.1).

Table 3.1. AGFC DO readings during trout-stocking runs downstream of Bull Shoals Dam.

Date	DO Measured at Each Location (mg/L)*							
	Bull Shoals Dam	Rivercliff	State Park Trout Dock	Gunga La	Gastons	Stetsons	Whitehole	Wildcat
8/06/92	5.1	5.1	5.5		6.1			
8/13/92	4.6	4.6	4.6		6.0	6.9		7.4
8/28/92	4.4	4.6	5.3		6.0			
9/08/92	3.9	3.9	4.1		5.6	6.1		
10/10/92	3.5	3.5	3.5		4.9	4.9	5.0	6.5
10/19/92	3.7	3.7	3.8		4.5	4.9	5.2	6.1
10/22/92	4.1	4.1	4.8		6.1			
8/12/93	5.5		6.4					
8/18/93	5.4		5.5	5.8	7.1			
8/26/93	4.3		4.6		5.7	7.2		
10/15/93	4.8		6.3					
10/21/93	5.7		6.0					
8/27/97	5.7	5.8	6.2					
9/12/97	5.3	5.8	6.3					
9/16/97	4.2		4.8		5.6	6.3		
10/01/97	4.9		4.9	5.1	7.3			
10/30/97	4.6		4.6	4.9	5.6	5.9	6.3	
7/29/98	5.1		6.2					
8/25/98	5.1		6.9					
9/10/98	5.6		7.0					
9/17/98			4.5	4.7	4.9	5.5	6.0	
9/25/98	4.8		4.4	4.8	5.3	6.0		
9/29/98	5.2		6.5					
8/09/99	4.7		6.0					
8/16/99	5.4		6.3					
8/26/99	5.9		6.8					
8/30/99	5.0		5.7	6.1				
10/12/99	5.2		3.6		4.4	5.2	5.5	
8/02/00	5.1		5.7		6.3			
8/14/00	5.5		6.1					
9/05/00	5.4		6.9					
9/18/00	3.7		4.9	4.9	12.8			
10/02/00	3.7		4.4	6.2				

* Locations are shown in order of increasing distance from dam from left to right in the table.

Figures 3.1 through 3.5 show plots of the hourly DO data from Station 07054501 for the months of June through December from 1995 through 2008. In general, these plots show DO concentrations below Bull Shoals Dam steadily decreasing between June and November and then increasing in December, after the reservoir de-stratifies, although there is variation from year to year in the timing of the fall increase in DO concentrations. The critical season minimum DO concentrations most commonly range between 3 mg/L and 2 mg/L. In 1998 and 1999, DO concentrations actually dropped below 2 mg/L. In 2006, the lowest DO concentration was much higher (5.7 mg/L).

In several places in Figures 3.1 through 3.5, there are sharp increases in the DO data. Examples of when this occurred are July 24, 1996; July 29, 1998; September 7, 2000; and July 11, 2006. SWPA personnel recently researched DO operations, hourly generation patterns, venting operations, etc. for each of these dates. Their findings indicate that these shifts were due to re-calibration of the DO monitors on these dates rather than operational changes at the dam.

3.2.2 DO in Wet Years Versus Dry Years

In their public comments on the draft version of this report (Appendix E), SWPA stated that the higher tailwater DO concentrations in 2006 were due to the fact that most of 2006 was drier than normal, which presumably resulted in smaller loads of nutrients and organic matter entering the reservoir and less hypolimnetic oxygen demand. In other words, SWPA's comments suggest that there is a pattern of higher tailwater DO values in dry years and lower tailwater DO values in wet years. In order to examine this pattern, statistics for tailwater DO and reservoir inflow were computed. Table 3.2 shows percentages of hourly DO data that are below certain levels each year and Table 3.3 shows which months were wetter or drier than normal. The flow statistics in Table 3.3 represent inflow to Norfork Lake instead of Bull Shoals Lake because the USGS flow gage that would be the most representative of inflow to Bull Shoals Lake (White River near Branson) was discontinued from October 2002 through September 2006.

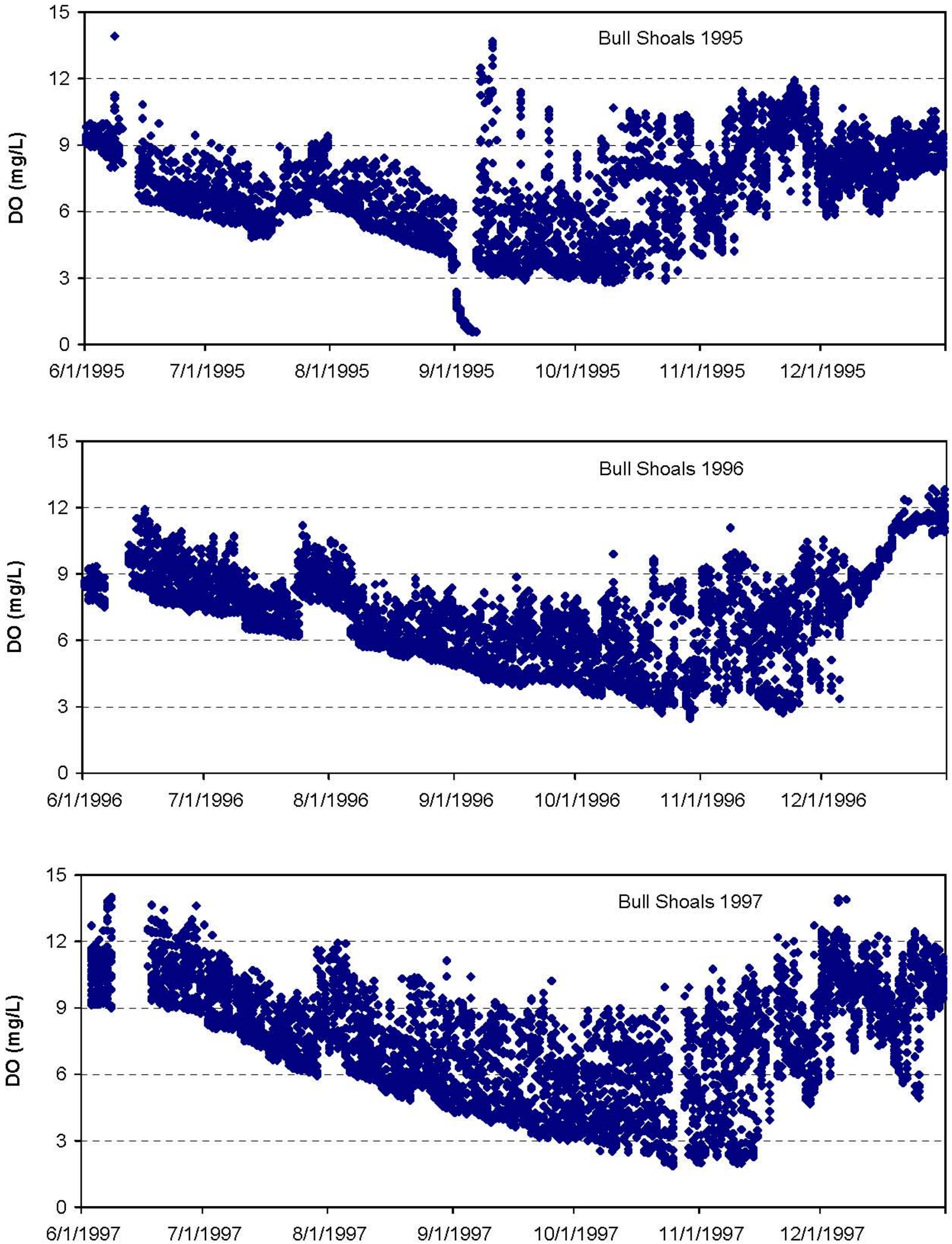


Figure 3.1. Hourly DO data at Station 07054501 in Bull Shoals tailwater from 1995 to 1997.

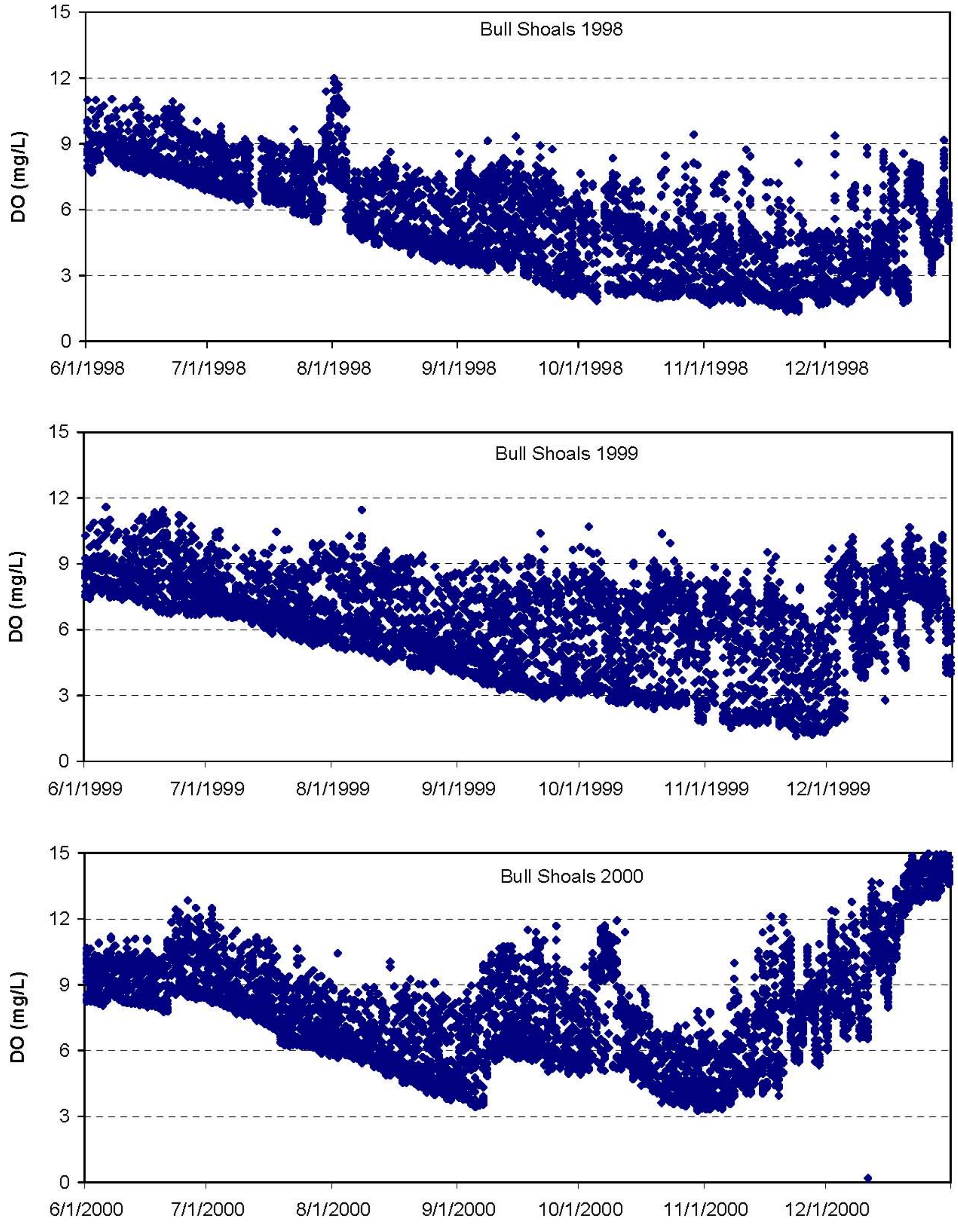


Figure 3.2. Hourly DO data at Station 07054501 in Bull Shoals tailwater from 1998 to 2000.

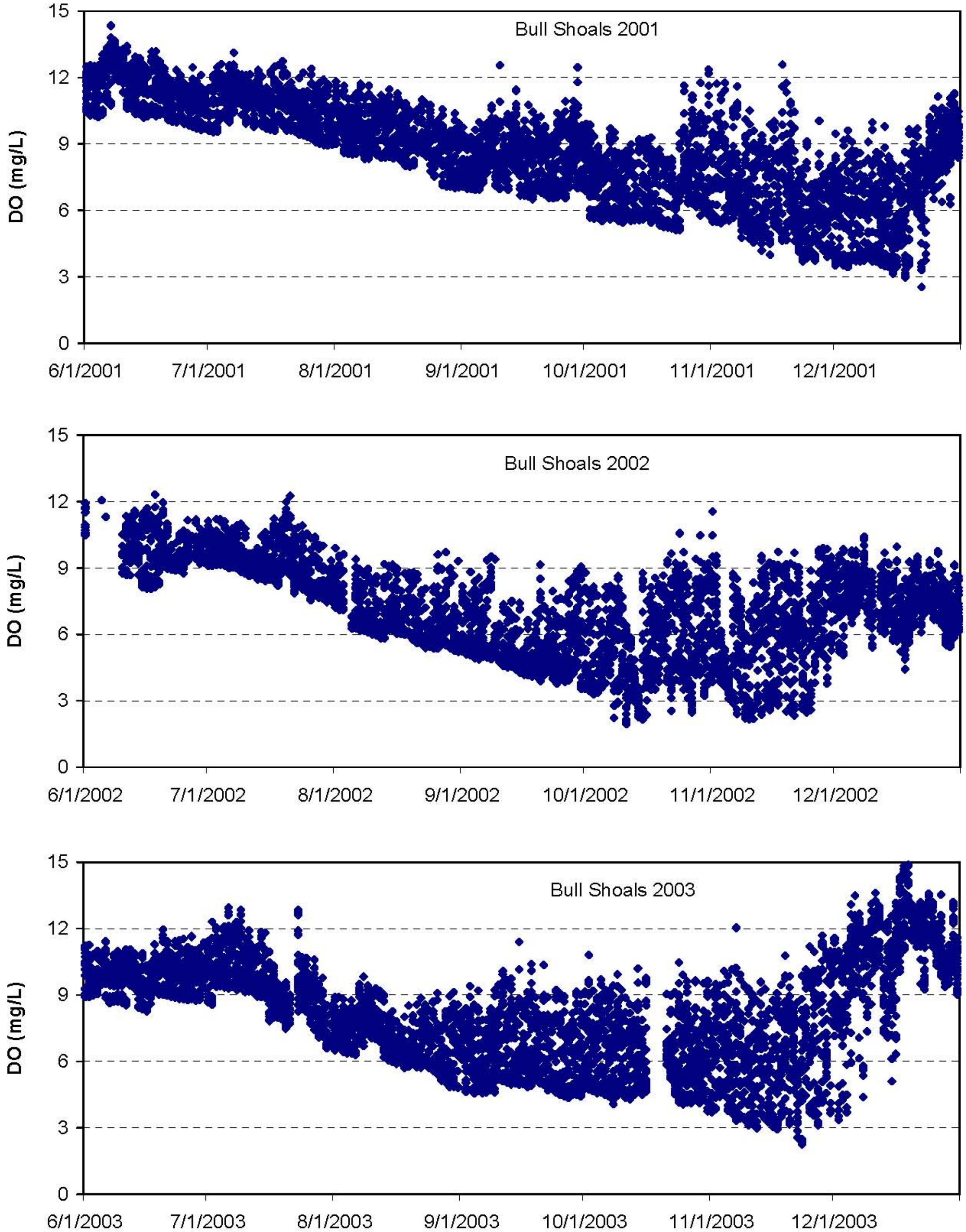


Figure 3.3. Hourly DO data at Station 07054501 in Bull Shoals tailwater from 2001 to 2003.

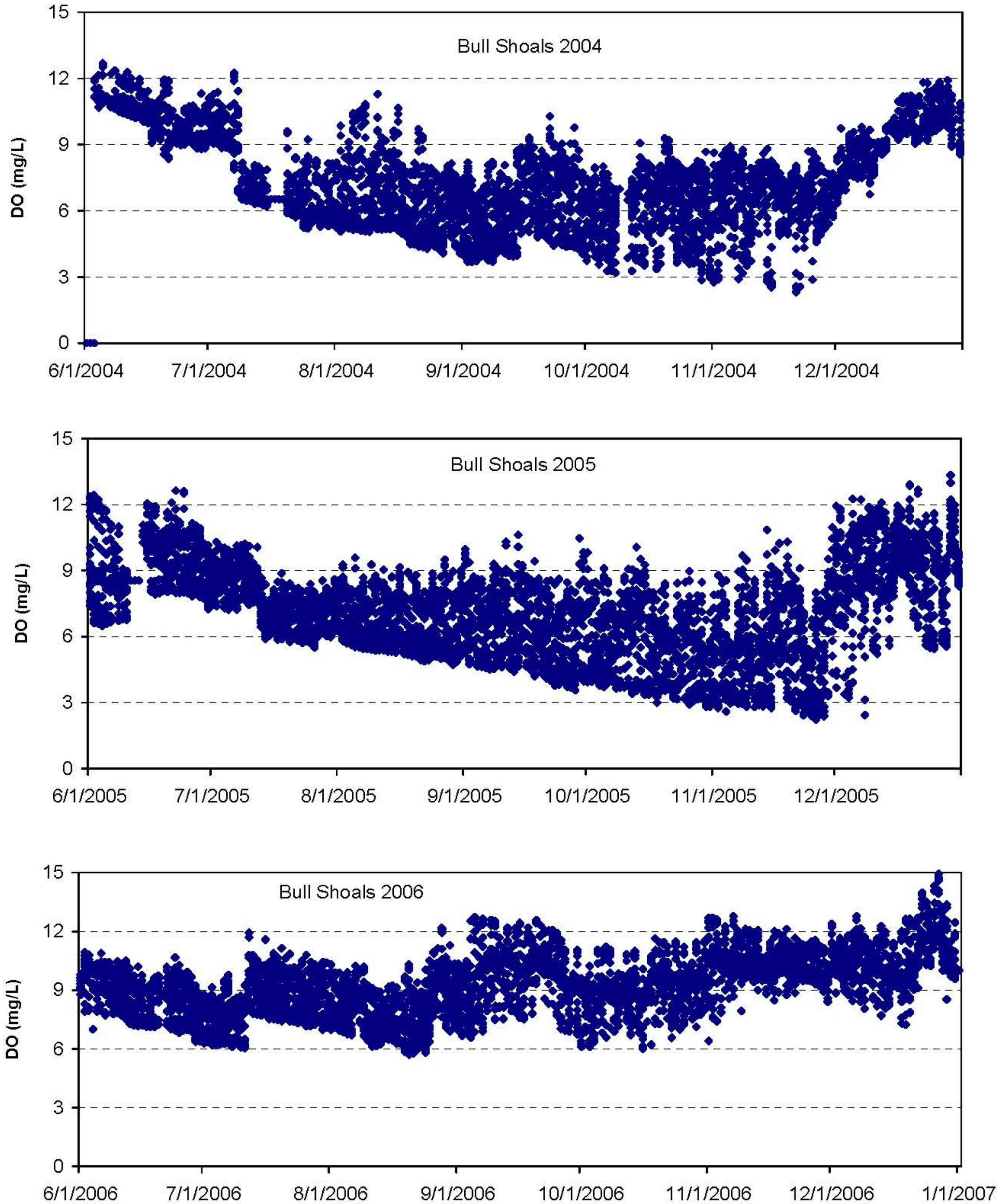


Figure 3.4. Hourly DO data at Station 07054501 in Bull Shoals tailwater from 2004 to 2006.

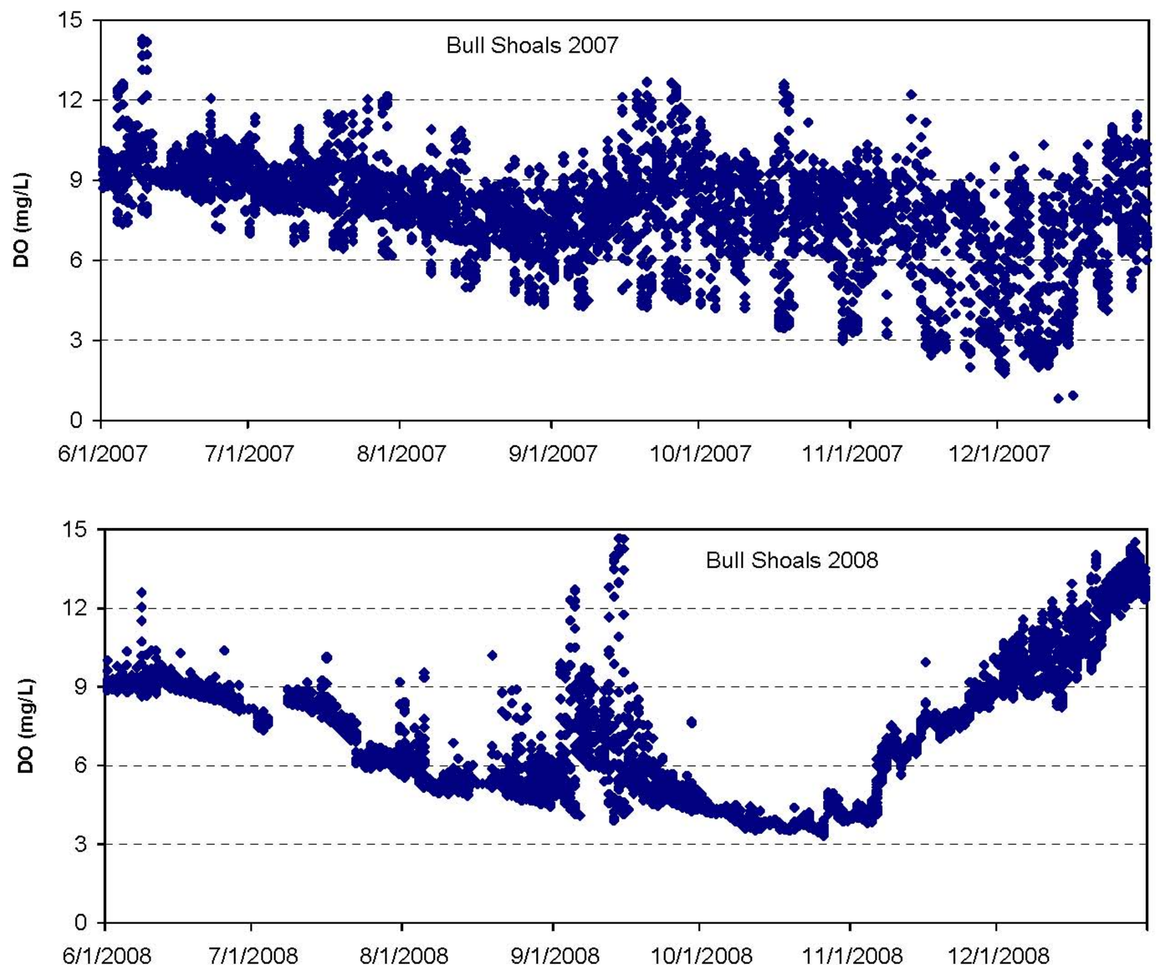


Figure 3.5. Hourly DO data at Station 07054501 in Bull Shoals tailwater from 2007 to 2008.

Table 3.2. DO statistics by year for Bull Shoals tailwater (07054501).

Year	Percentage of DO values during June – December that are below:			
	6 mg/L	5 mg/L	4 mg/L	3 mg/L
1995	33%	20%	11%	3%
1996	31%	17%	7%	1%
1997	30%	19%	10%	3%
1998	56%	45%	30%	20%
1999	38%	24%	15%	8%
2000	26%	13%	4%	0%
2001	15%	6%	2%	0%
2002	33%	19%	8%	3%
2003	22%	11%	3%	0%
2004	29%	13%	5%	2%
2005	31%	16%	9%	2%
2006	0.4%	0%	0%	0%
2007	15%	10%	6%	2%
2008	39%	23%	10%	0%

Table 3.3. Percent of normal flow for North Fork River near Tecumseh, MO (07057500).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	156%	96%	98%	102%	150%	154%	115%	133%	94%	95%	56%	63%
1996	70%	47%	47%	103%	139%	86%	76%	84%	175%	132%	205%	159%
1997	99%	182%	162%	111%	76%	99%	84%	98%	82%	80%	52%	49%
1998	100%	93%	178%	102%	85%	87%	106%	111%	84%	138%	61%	68%
1999	93%	158%	104%	100%	91%	70%	77%	81%	75%	85%	50%	50%
2000	46%	53%	42%	29%	38%	58%	64%	69%	65%	64%	46%	43%
2001	52%	111%	53%	34%	30%	46%	57%	70%	66%	68%	42%	89%
2002	54%	92%	141%	147%	267%	104%	101%	139%	91%	84%	52%	52%
2003	63%	63%	55%	54%	61%	56%	58%	77%	107%	83%	117%	113%
2004	92%	72%	89%	141%	120%	70%	86%	87%	71%	84%	96%	112%
2005	200%	107%	67%	76%	47%	56%	67%	75%	78%	73%	102%	52%
2006	47%	44%	65%	45%	139%	66%	75%	73%	70%	112%	120%	187%
2007	189%	129%	56%	57%	57%	66%	110%	87%	77%	66%	37%	43%
2008	37%	108%	351%	248%	101%	98%	104%	96%	165%	n.a.	n.a.	n.a.

Notes: Calculated from monthly flow data that were downloaded from USGS web site.

very dry (less than 40% of normal flow)

dry (40% to 70% of normal flow)

near normal (70% to 130% of normal flow)

wet (130% to 160% of normal flow)

very wet (more than 160% of normal flow)

DO data for some of the years tend to follow this pattern. The five years with the most DO values below 4 mg/L were 1998, 1999, 1995, 1997, and 2008. Each of these five years included one or two months between February and June when the flow was more than 30% above normal. The four years with the fewest DO values below 4 mg/L were 2006, 2001, 2003, and 2000. For each of these four years, the flow was more than 30% below normal for every month between March and June (except for May 2006).

The pattern of higher tailwater DO values in dry years and lower tailwater DO values in wet years is only a general pattern and is not always true when comparing two individual years. For example, the flow for the months of March through June was generally higher in 2002 than in 1998, but the percentages of low DO values were higher in 1998 than in 2002. This shows that the tailwater DO during critical conditions is affected by other factors besides the amount of inflow during the spring.

In the USGS public comments on the draft version of this report (Appendix E), they pointed out that tailwater DO tends to be lower in wet years because wet years result in more water being discharged through the dam, which can result in depletion of the cold, oxygenated water in the hypolimnion towards the end of the stratification period in the fall. If the hypolimnetic water begins to be depleted due to large hypolimnetic releases through the hydropower turbines, it is replaced by water from the upper layers of the lake that is warmer and has a greater oxygen demand. If this is actually occurring during wet years, then the tailwater temperatures should tend to be slightly warmer towards the end of the stratification period during wet years. Statistics were compiled for the observed hourly tailwater temperatures for October and November, which is towards the end of the stratification period (Table 3.4). The three years with the highest tailwater temperatures (2008, 1995, and 1999) were all years with wetter than normal months during the spring, and the three years with the lowest tailwater temperatures (2001, 2006, 2003) were all drier than normal throughout the spring (except for May 2006). However, this pattern is not consistent among other years, which is probably due in part to variations from year to year in meteorological conditions.

Table 3.4. Temperature statistics by year for Bull Shoals tailwater (07054501).

Year	Temperatures (°F) during October – November for selected percentiles:				
	90th percentile	70th percentile	50th percentile	30th percentile	10th percentile
1995	61.1	60.3	59.8	58.9	57.4
1996	55.7	54.5	53.7	52.9	51.2
1997	58.0	57.0	56.1	55.1	54.3
1998	58.7	57.5	56.4	55.8	55.1
1999	60.8	60.2	59.5	58.3	57.2
2000	57.3	55.7	54.8	54.2	53.3
2001	50.6	49.7	48.8	47.3	46.1
2002	58.4	57.9	57.6	56.8	55.3
2003	54.3	53.4	52.2	51.1	48.6
2004	57.8	57.4	57.0	56.6	55.7
2005	54.8	54.0	53.3	52.0	51.0
2006	52.5	51.6	51.1	50.6	49.9
2007	54.4	53.7	53.1	52.5	50.4
2008	62.2	61.7	60.5	59.6	58.8

3.2.3 DO During Periods With and Without Generation

Analyses of the hourly release flows and tailwater DO concentrations from 2002 through 2006 during October and November indicate differences in tailwater DO levels when power generation for the main turbines was and was not occurring. During periods without generation from the main turbines (i.e., generation only from the house units), DO concentrations exhibited a typical diurnal pattern of fluctuation between high DO levels during the day and low levels during the night and early morning (Figure 3.6). During generation periods, this diurnal pattern was disrupted, most often increasing DO levels in the tailwater. A duration plot comparing the distribution of DO concentrations associated with generation and non-generation flow (Figure 3.7) indicates that DO concentrations below 4 mg/L and 6 mg/L occur more often during periods of non-generation. During periods with generation from the main turbines, only about 8% of DO concentrations are less than 4 mg/L, and 30% are less than 6 mg/L. During periods without generation from the main turbines, around 25% of DO concentrations are less than 4 mg/L, and 50% are less than 6 mg/L.

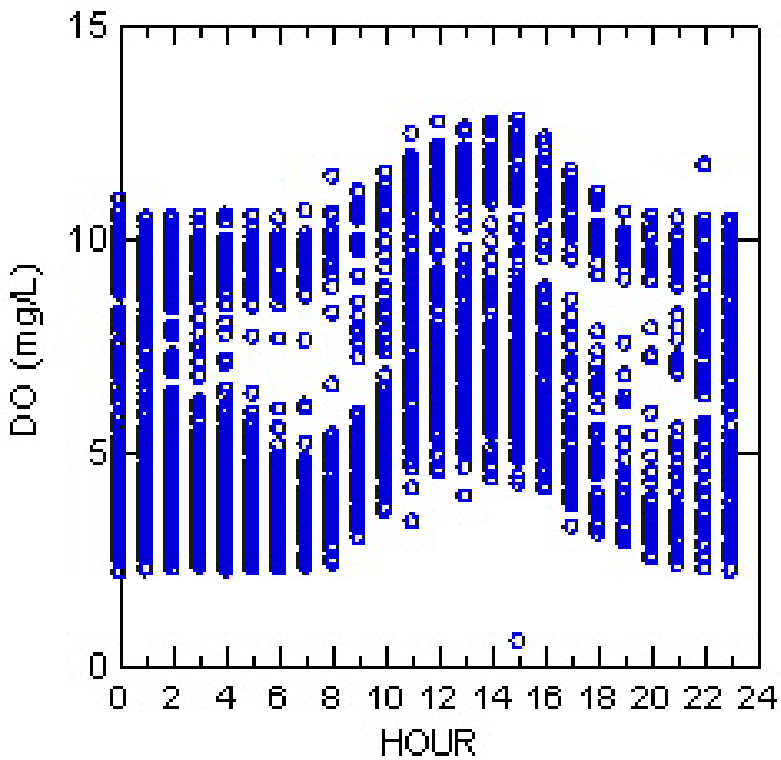


Figure 3.6. Diurnal DO variation for Bull Shoals tailwater.

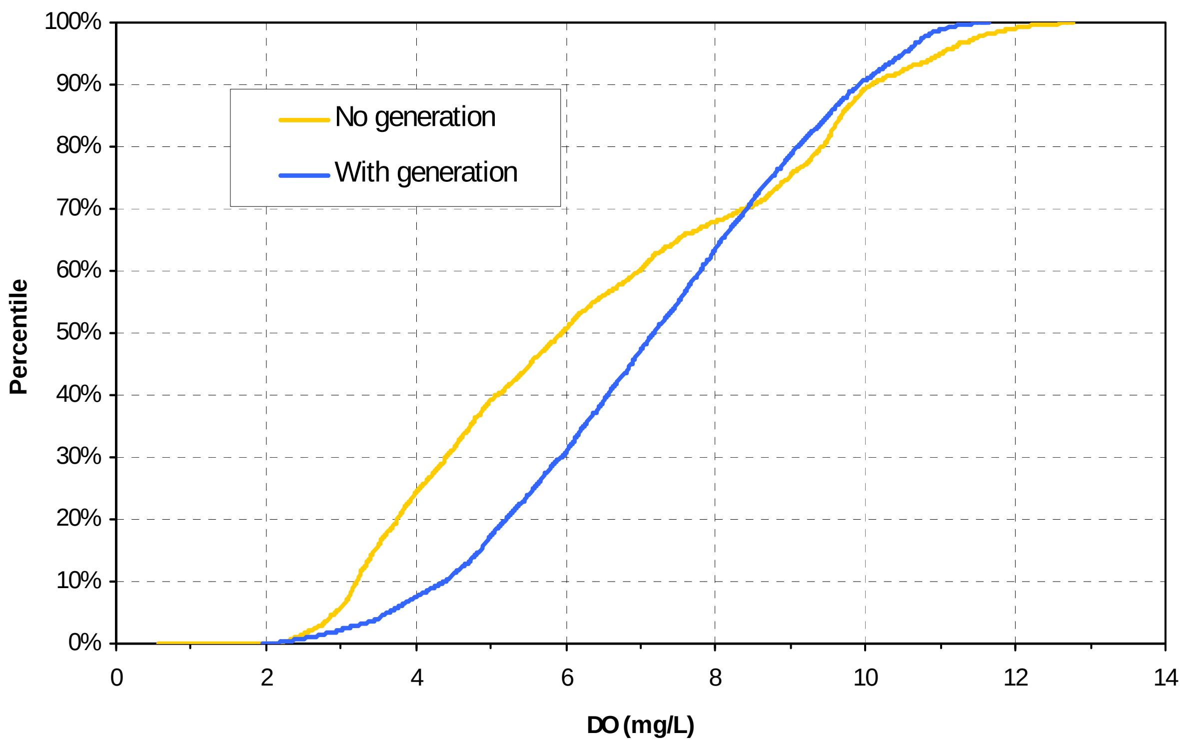


Figure 3.7. Duration plot for DO in Bull Shoals tailwater (Station 07054501).

3.3 Norfork Data

3.3.1 Overview of Data

Collection of temperature, DO, and water quality data occurs at Station 07059998 in the Norfork tailwater (see Figure 2.3 for location). DO data collected during trout-stocking runs indicate that DO concentrations increase with distance from the dam (see Table 3.5) in a similar manner as below Bull Shoals Dam. Therefore, the lowest tailwater DO concentrations would be expected to occur just downstream of the dam, and analysis of the data from Station 07059998 should reflect the most critical DO conditions in this tailwater reach.

Plots of the hourly DO data from this monitoring site are shown on Figures 3.8 through 3.12. In general, these plots show DO concentrations below Norfork Dam steadily decreasing between June and October and then increasing in December after the reservoir de-stratifies. The timing of the occurrence of the lowest DO concentrations and the increase in DO after de-stratification does vary from year to year. The annual minimum DO levels in the tailwater are commonly less than 1 mg/L. However, in 1995 and 1996, DO concentrations were always greater than 1 mg/L, staying predominantly above 3 mg/L. A review of hydropower operation records for Norfork Dam indicated high water levels in the reservoir during 1995, which made it possible to continuously run one turbine unit at 10 mW during the entire summer (SWPA 2008b).

3.3.2 DO During Wet Years Versus Dry Years

In Section 3.2.2, the suggested pattern of higher tailwater DO values in dry years and lower tailwater DO values in wet years was examined for the Bull Shoals data. The Norfork data were also examined to see if they followed this pattern. Percentages of hourly DO data that are below certain levels each year are shown in Table 3.6.

Table 3.5. AGFC DO readings during trout-stocking runs downstream of Norfork Dam.

Date	DO Measured at Each Location (mg/L)*						
	Norfork Dam	Quarry Park	Rainbow Trout Dock	Gene's Trout Dock	McClellan's Trout Dock	Cook's	River Ridge
8/06/92	5.0	5.0	5.9	6.0	6.2		
8/13/92	4.9	5.2	5.8	5.8	6.1		
8/28/92	4.0	5.0	6.0	6.1	6.6		
9/08/92	4.0	4.4	5.6	5.8	6.0		
10/10/92	3.7	5.0	5.9	6.0			
10/19/92	3.8	5.0	6.0	6.0			
10/22/92	3.8	5.0	6.0	6.0			
8/18/93	5.5	5.7		5.8	6.7		
10/15/93	1.3	1.7		2.2	4.4	6.1	
10/21/93		4.6		4.9	5.7	6.2	
8/12/97	4.8	7.5					
9/10/97		5.6		5.8	6.4		
9/27/97		4.0			6.0		
11/06/97	5.3	5.8		6.0			
11/12/97	5.3	6.0					
7/30/98	5.2			5.2	6.1		
8/17/98	5.9			7.0			
9/09/98	5.8			6.7			
9/29/98	4.4			4.9	5.5	6.5	
10/27/98	4.9			5.1	5.4		6.8
11/25/98	5.9			5.9	6.2		
8/16/99	5.3			5.1	6.0		
8/27/99	4.0			4.6	6.2		
9/17/99	5.4			6.0			
8/02/99	5.4			5.6	6.6		
8/14/00	5.3		5.7		6.2		
9/02/00	4.8			6.8			
9/11/00		4.8		5.7	6.3		

* Locations are shown in order of increasing distance from dam from left to right in the table

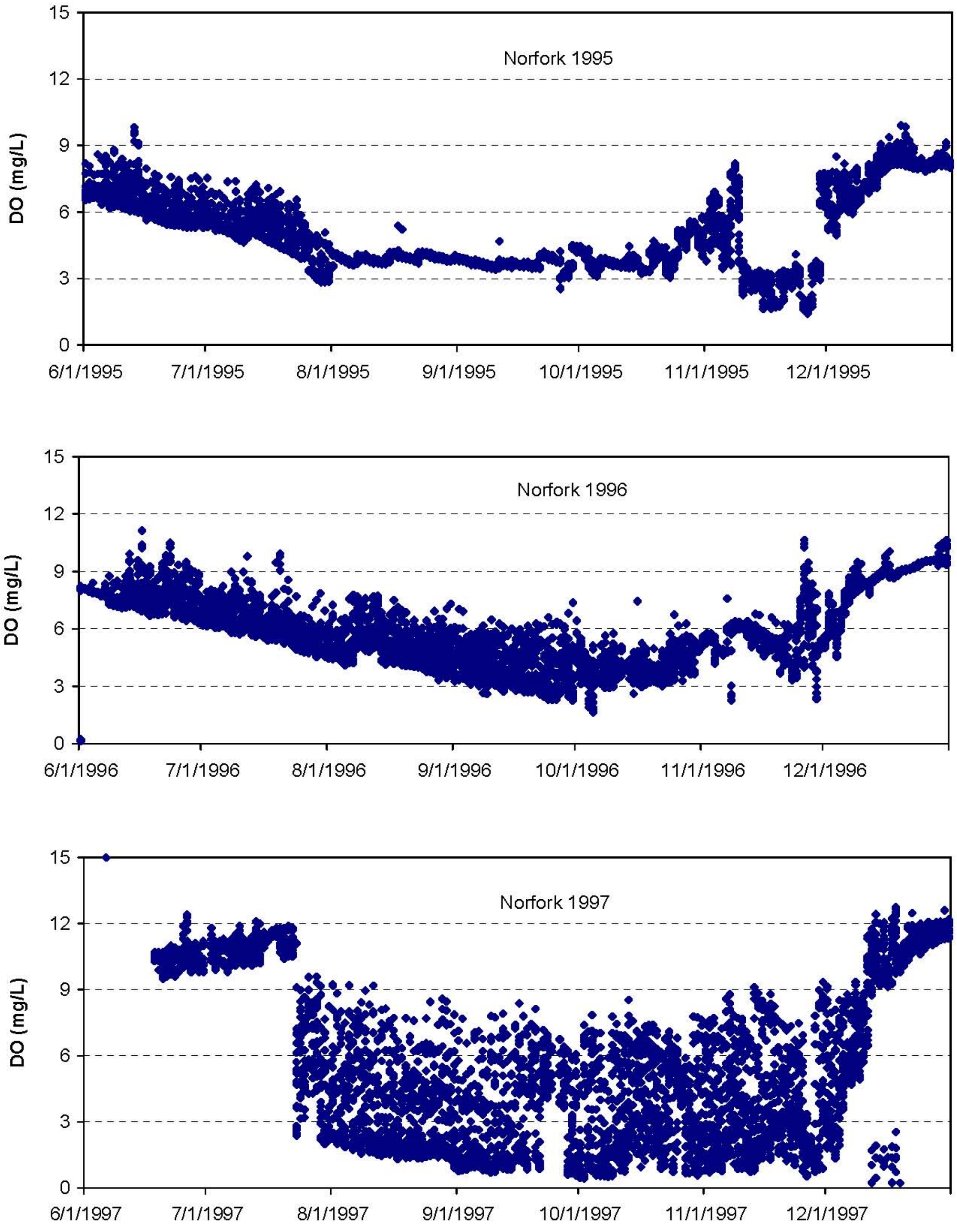


Figure 3.8. Hourly DO data at Station 07059998 in Norfork tailwater from 1995 to 1997.

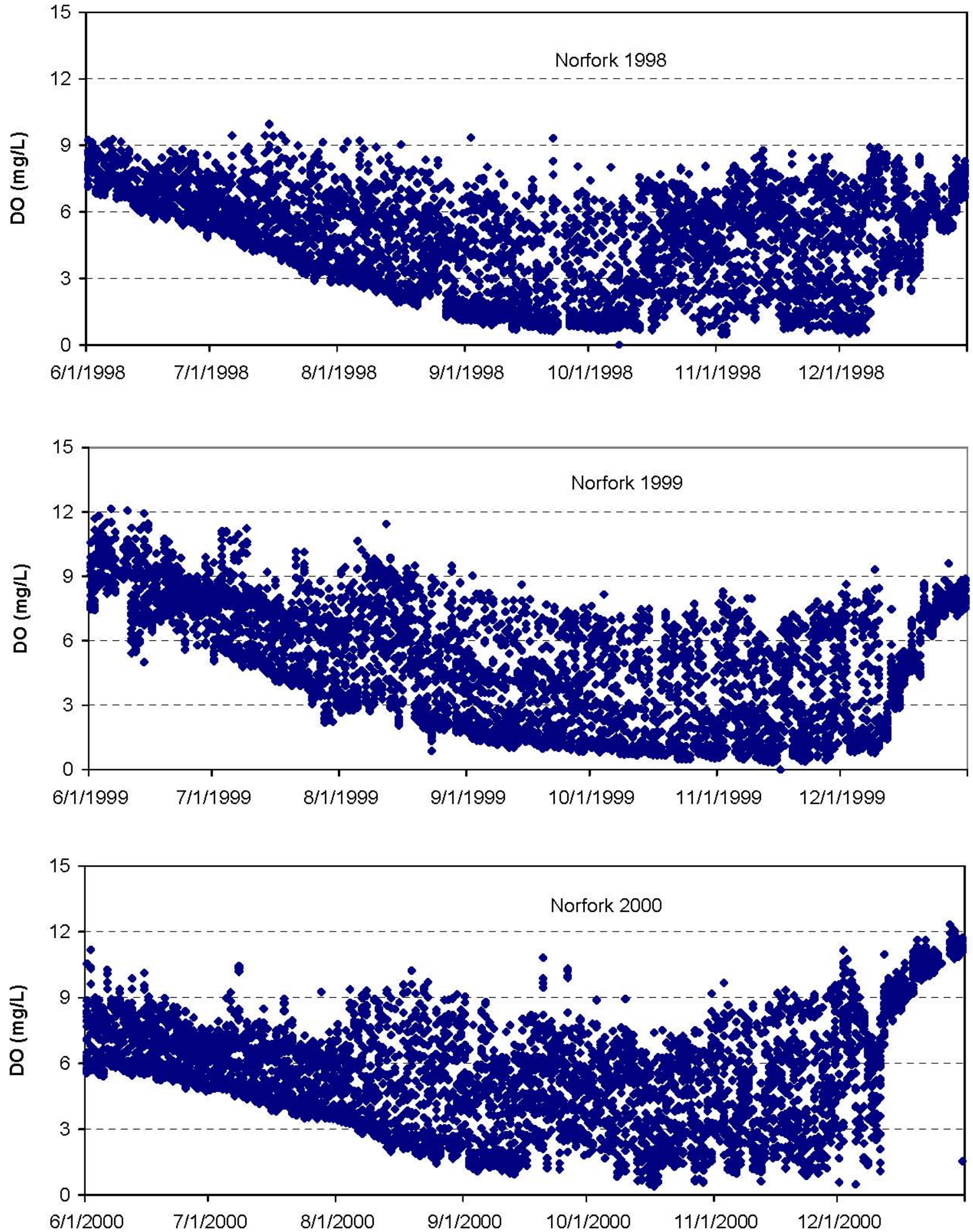


Figure 3.9. Hourly DO data at Station 07059998 in Norfork tailwater from 1998 to 2000.

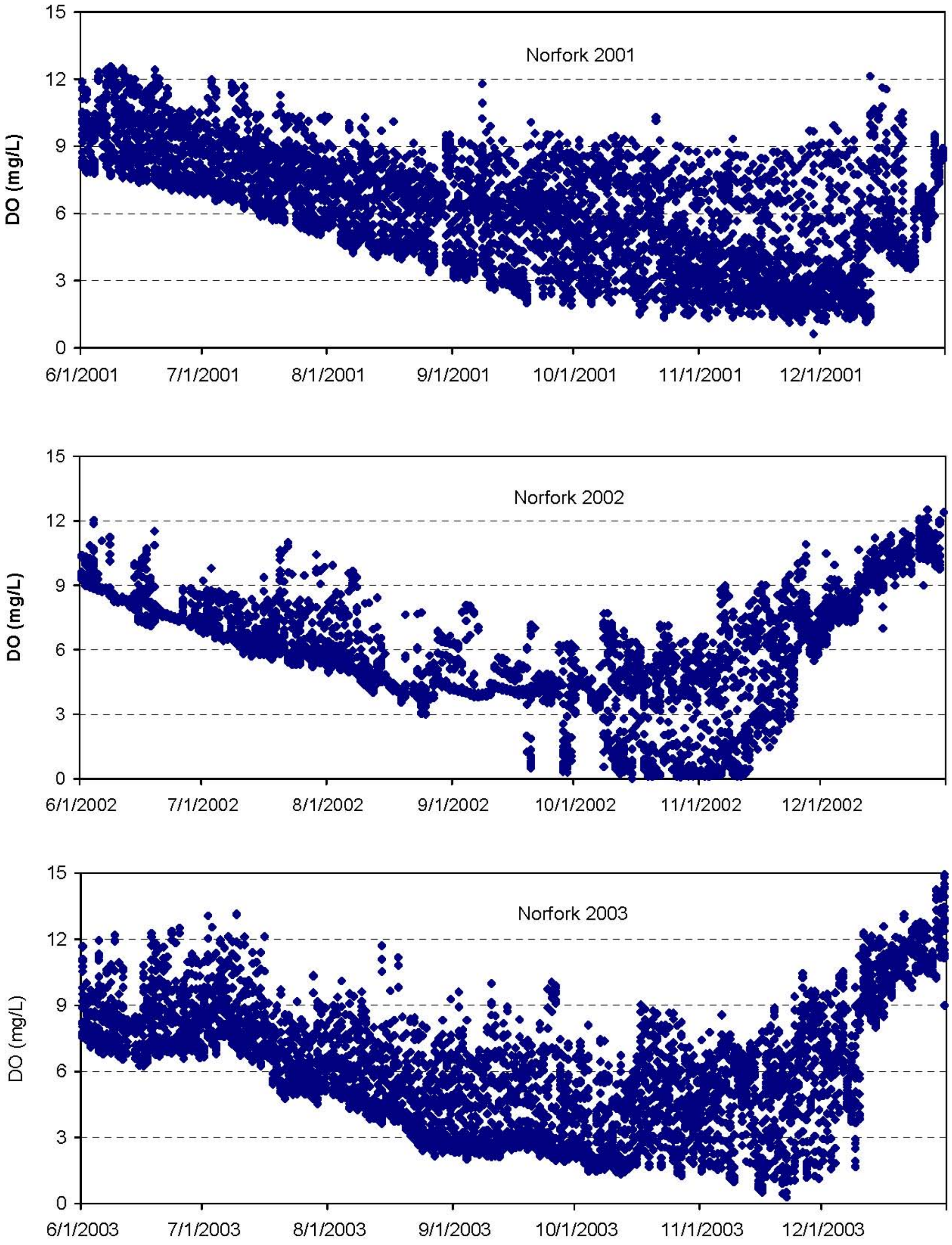


Figure 3.10. Hourly DO data at Station 07059998 in Norfork tailwater from 2001 to 2003.

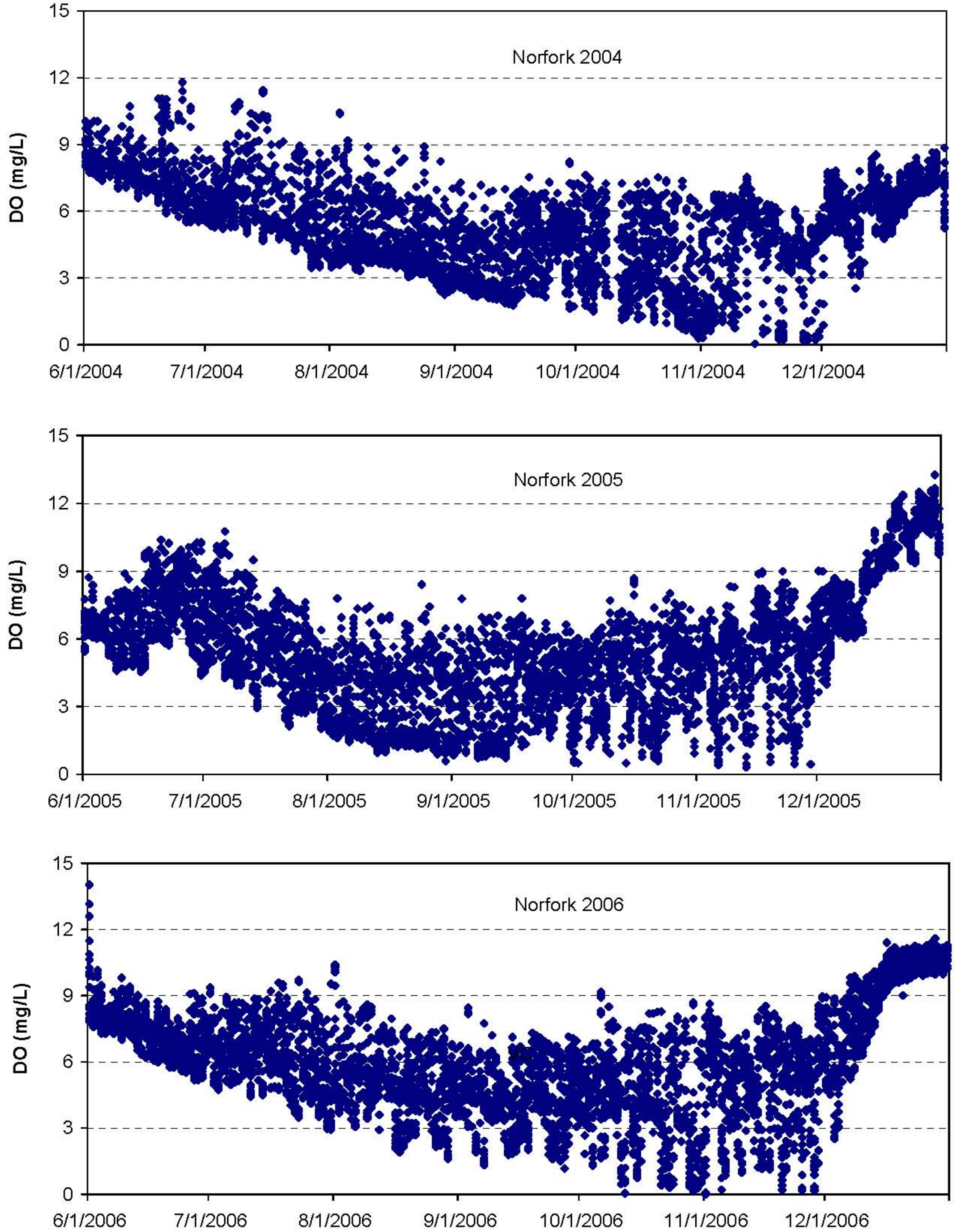


Figure 3.11. Hourly DO data at Station 07059998 in Norfork tailwater from 2004 to 2006.

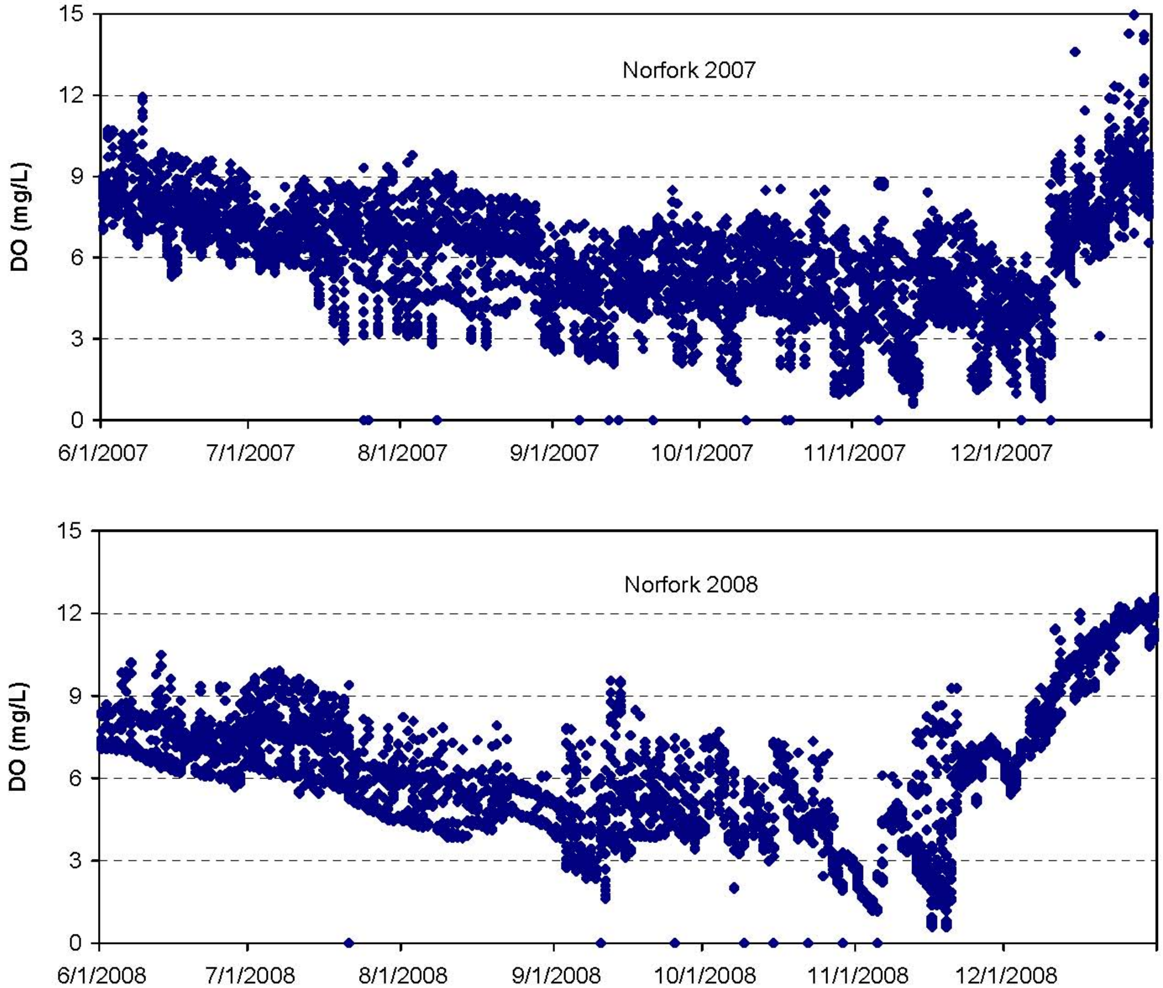


Figure 3.12 Hourly DO data at Station 07059998 in Norfork tailwater from 2007 to 2008.

Table 3.6. DO statistics by year for Norfork tailwater (07059998).

Year	Percentage of DO values during June – December that are below:			
	6 mg/L	5 mg/L	4 mg/L	3 mg/L
1995	73%	58%	43%	6%
1996	58%	37%	17%	3%
1997	56%	47%	36%	28%
1998	65%	47%	34%	24%
1999	60%	49%	38%	31%
2000	58%	41%	28%	17%
2001	44%	32%	21%	12%
2002	53%	40%	19%	10%
2003	46%	34%	23%	15%
2004	60%	42%	25%	14%
2005	62%	44%	27%	18%
2006	52%	35%	20%	9%
2007	48%	34%	17%	8%
2008	52%	36%	16%	7%

The DO data for the Norfork tailwater did not consistently follow this pattern. The four years with the most DO values below 4 mg/L were 1995, 1999, 1997, and 1998. Each of these four years included one or more months between February and June when the flow was more than 30% above normal. However, each of these four years also included months when the flow was slightly below normal. The four years with the fewest DO values below 4 mg/L were 2008, 1996, 2007, and 2002. Two of these years (1996 and 2007) were generally drier than normal during the spring, but the other two years (2002 and 2008) were considerably wetter than normal during the spring. In fact, the spring of 2008 was wetter than any other year during 1995 through 2008, but that year had the fewest DO values below 4 mg/L. As with the Bull Shoals data, this analysis shows that the tailwater DO during critical conditions is affected by other factors besides the amount of inflow.

As discussed in Section 3.2.2, USGS pointed out that tailwater DO can be lower in wet years because wet years result in more water being discharged through the dam, which can result in depletion of the cold, oxygenated water in the hypolimnion towards the end of the stratification period in the fall. For the Bull Shoals tailwater, this situation was investigated by examining tailwater temperatures to see if they were slightly warmer during wet years than during dry years (see Section 3.2.2). This analysis was not conducted for the Norfork tailwater because the relationship between tailwater DO and amount if inflow during the spring is poor.

3.3.3 DO During Periods With and Without Generation

Analyses of the hourly release flows and tailwater DO concentrations from 2002 through 2006 during October and November indicate differences in tailwater DO levels when power generation for the main turbines was and was not occurring. A duration plot comparing the distribution of DO concentrations associated with generation and non-generation flow (Figure 3.13) indicates that DO concentrations below 4 mg/L and 6 mg/L occur more often during periods of non-generation. During periods of generation from the main turbines, only around 12% of DO concentrations are less than 4 mg/L and 65% are less than 6 mg/L. During periods without generation from the main turbines, around 65% of DO concentrations are less than 4 mg/L, and 90% are less than 6 mg/L.

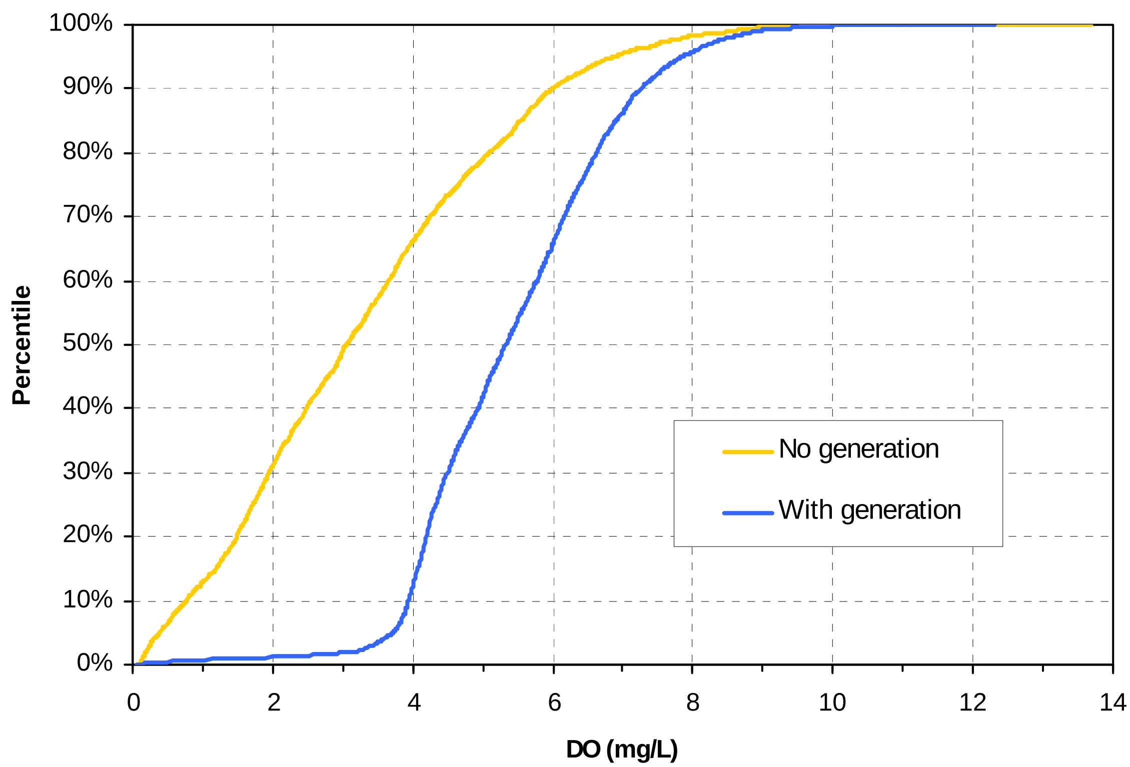


Figure 3.13. Duration plot for DO in Norfork tailwater (Station 07059998).

3.4 Trout Kills

Trout kills have occurred at various times due to high water temperatures and/or low DO downstream of Bull Shoals and Norfork dams. For trout waters, the Arkansas water quality standards (APCEC 2007) specify a single value (6.0 mg/L) for the minimum DO and a single value (20°C) for the maximum water temperature. The effects of different DO levels on trout have been studied by EPA and have been summarized in Table 3.7 (EPA 1986 as cited in AGFC 2003).

Table 3.7. Effects of different DO concentrations on trout.

	Embryo and Larval Stages		**Other Life Stages**
	DO in the Water Column	**DO in the Intergravel Space**	**DO in the Water Column**
No Production Impairment	11 mg/L	8 mg/L	8 mg/L
Slight Production Impairment	9 mg/L	6 mg/L	6 mg/L
Moderate Production Impairment	8 mg/L	5 mg/L	5 mg/L
Severe Production Impairment	7 mg/L	4 mg/L	4 mg/L
Limit to Avoid Acute Mortality	6 mg/L	3 mg/L	3 mg/L

As shown on the DO plots on Figures 3.1 through 3.5 and 3.8 through 3.12, tailwater DO concentrations below 3 mg/L have occurred on many occasions during the fall. Some of these low-DO readings have resulted in trout kills. The trout kills that have been documented since 1990 are listed in Table 3.8. Some of the trout kills in Table 3.8 were caused by high temperatures rather than low DO. In addition to the trout kills in Table 3.8, there were 12 confirmed trout kills between 1963 and 1981 as a result of high water temperatures that equaled or exceeded 26.7°C (80.0°F). The lethally high water temperatures between 1963 and 1981 were presumed to be due to long periods of non-generation at Bull Shoals Dam (AGFC 1991).

Table 3.8 provides a list of documented occurrences where trout actually died, but it does not provide any information concerning the times when low DO causes trout to experience sub-lethal stress, which decreases the activity and growth of the trout and increases their susceptibility to disease (AGFC 2003).

Table 3.8. List of documented trout kills since 1990.

Date	Which Tailwater	DO (mg/L)	Temperature (°C)	Species [a]	Abundance
10/10-12/90	Bull Shoals	1.1 – 1.7	-	RB, BN, CT	1,200 – 1,500 [b]
10/25/92	Norfork	0.4 – 1.6	-	RB, BN	35 [c]
09/17/93	Norfork	-	-	-	24 – 26 [b]
10/18/02	Bull Shoals	-	-	-	26 [c]
11/01/04	Norfork	1.0 – 1.5	-	RB, BN, CT	162 [c]
10/31/06	Norfork	-	-	RB, BN, CT, BK	80 [c]

Notes:
a. Species: RB = rainbow trout, BN = brown trout, BK = brook trout, CT = cutthroat trout
b. Number visually estimated
c. Number recovered

4.0 WATER QUALITY MODELING AND TMDLS

4.1 Overview of Model

In order to evaluate the linkage between pollutant sources and water quality, a computer simulation model was used. The model used for the TMDLs in this report was the River Modeling System (RMS), which was developed by the Tennessee Valley Authority (TVA). The components of the RMS modeling system are a hydrodynamic model (ADYN), a temperature and water quality model (RQUAL), a physical habitat model (RHAB), and a bioenergetics (FISH) model. Only the ADYN and RQUAL components were used for these TMDLs.

TVA initially applied all of the RMS models to the Bull Shoals and Norfork tailwaters in the late 1990s and early 2000s (TVA 2002). These models were calibrated using flow records, stream velocity, meteorology records, and other data from 1996. Later, the two models were merged and extended downstream along the White River to Batesville (TVA 2005). The updated model simulates the White River from the Bull Shoals Dam to Batesville (River Miles 418.4 to 299.7) and the North Fork River from the Norfork Dam to its confluence with the White River (River Miles 4.8 to 0.0). The updated model was calibrated using several data sets collected in 2001 through 2004.

TVA's updated version of the model was used for these TMDLs with only minor changes to the calibration coefficients because the model was already calibrated and tested.

4.2 Hydraulic Model (ADYN)

The ADYN model simulates one-dimensional, longitudinal, unsteady flow. The ADYN model requires one input file (*.aii). This model simulates time-varying flow and water surface elevations along the simulated river reach. The file contains cross-sectional geometry, boundary and initial conditions, and lateral inflows. Most of the data contained in the TVA input file were not changed for this modeling effort. The simulation control, reach geometry, channel roughness, node interpolation, and boundary conditions were not changed from TVA's model.

The only data changed in the model were the simulation period and flows from the Bull Shoals Dam and Norfork Dam and other lateral inflows. Two versions of the input file were created to simulate two critical, low-flow periods of 30 days each:

- October 26, 1998 00:00 – November 24, 1998 24:00
- October 12, 2004 00:00 – November 10, 2004 24:00

The TMDL scenarios presented in this report represent these periods. FTN modified the flows in the ADYN input files to simulate flow during these periods. Hourly tailwater flows (1998) and hydropower releases (2004) from the Bull Shoals and Norfork dams were obtained from the Corps Little Rock District. These data were formatted and copied into the ADYN input files into files representing each of the model periods. The flow released from Bull Shoals Dam varies from 50 cfs during low-flow periods to up to 16,500 cfs during generation from the main turbines. The minimum hydropower release at the Bull Shoals Dam is created by two house units with a combined constant release of 50 cfs. The 1998 tailwater flow data for Bull Shoals Dam were adjusted to show a minimum flow of 50 cfs. The flow released from Norfork Dam varies from 20 cfs to a maximum of 3,500 cfs during hydropower releases. The minimum hydropower release of 20 cfs is due to releases from a house unit.

During the 1998 simulation period, SWPA voluntarily restricted the generation rate from 391 MW to 260 MW at Bull Shoals and from 87 MW to 48 MW at Norfork. During the 2004 simulation period, SWPA voluntarily restricted the generation rate from 87 MW to 45 MW at Norfork. The purpose of reducing generation rates is to entrain more air in the hydropower releases and increase their DO concentrations.

Data representing flows from lateral inflows were also edited to reflect the model periods. Flows representing lateral inflows were either set at constant value or estimated by calculating daily flows using a drainage area ratio (area at mouth/area at gage). In most cases, the estimated flows were consistent with flows used in the model calibration scenarios. Table A.1 (in Appendix A) shows the estimated lateral inflows.

The City of Bull Shoals WWTP was also added to the model at River Mile 417.5 on the White River (about one mile downstream of Bull Shoals Dam). Flows from Piney Creek, Sylamore Creek, Polk Bayou, and downstream distributed local flows were set to a constant value because they are downstream of the area of concern for the TMDL.

An additional adjustment was made to the lateral flow on the North Fork River due to leakage from karst and the wicket gate. The ADYN model requires that all lateral flows enter the model as distributed flows between two nodes in the model. The original version of the calibrated model distributed the flow from this source between nodes at River Mile 4.8 and River Mile 2.71. In reality, this flow enters the river near the Norfork Dam, and should not be distributed over a distance of several miles. The model was changed so that the flow from leakage entered the model between the upstream boundary (River Mile 4.8) and the next downstream node (River Mile 4.68). With this adjustment, the flows, depths, and velocities more accurately predicted the actual conditions in the North Fork River.

The ADYN model calculates flow, velocity, depth, and channel width for each model node at time steps of 1 hour. Model output for the two time periods was reviewed to be sure that the model was generating reasonable results for velocity, depths, and flows. The data appeared to be reasonably close to expected values.

4.3 Water Quality Model (RQUAL)

The RQUAL model simulates time-varying temperature, DO, ultimate carbonaceous biochemical oxygen demand (CBODu), and ultimate nitrogenous biochemical oxygen demand (NBODu) along the White River and North Fork River. The model uses the hydrodynamic data generated by ADYN as well as data contained in three input files for the simulation. These files are the boundary conditions file, the meteorological file, and the coefficients and initial conditions file.

The RQUAL boundary condition file (*.rib) specifies the temperature, DO, CBODu, and NBODu concentrations at each boundary in the model. The boundary condition file for the White River/North Fork model contains input for 19 boundaries. These include the two upstream boundaries of Bull Shoals Dam and Norfork Dam. There are also 12 lateral inflows on the White River and five lateral inflows on North Fork. The lateral inflows represent flow added to the system through, tributaries, point sources, leakage from the dams, and other sources.

The concentrations of the input parameters (temperature, DO, CBODu, and NBODu) are specified on an hourly basis during the model period. For this modeling project, two sets of boundary conditions files were created for the two model periods. The data for temperature and DO concentrations at the Bull Shoals and Norfork Dams was available on an hourly basis. The hourly DO data were taken from the same data that were plotted in Section 3 of this report. Concentrations of CBODu and NBODu were set to be consistent with the values used in TVA's calibrated model. Temperature, DO, CBODu, and NBODu values used for the remaining lateral inflows were also consistent with the values used in TVA's calibrated model.

There are two NPDES-permitted facilities that are included in the model; these are the City of Bull Shoals WWTP (Permit No. AR0037028) and the Norfork National Fish Hatchery (Permit No. AR0002437). The Bull Shoals WWTP was not included in the original model, and was added to the White River at River Mile 417.5. The Norfork Fish Hatchery was included in the calibrated model at North Fork River Mile 4.68. Concentrations for the inflow representing the Bull Shoals WWTP was set based on the permit limits for this facility. A ratio of 2.3 was used to convert BOD_5 permit limits to CBODu. A factor of 4.57 was used to estimate NBODu concentrations from ammonia nitrogen permit limits. Table A.2 (located in Appendix A) shows the boundary conditions used for each inflow.

The RQUAL meteorology file contains hourly data for several parameters. The parameters specified in this file include cloud cover, dry bulb temperature, dew point temperature, barometric pressure, wind speed, and short-wave solar radiation. The data were collected near Flippin, Arkansas, at Station 723447. Data were downloaded from the National Climatic Data Center website and formatted to provide hourly updates for the model.

The RQUAL coefficients and initial conditions file contains rates and coefficients that define the water quality processes simulated by the model. These processes include reaeration, CBODu decay, nitrification, photosynthesis and respiration of algae and aquatic macrophytes, and sediment oxygen demand. The coefficients file developed for the calibrated model was used for these TMDLs with only one change. The rates for photosynthesis and aquatic weed respiration in the North Fork River were the only values changed in this file for the TMDL model. In TVA's model, a respiration rate of 1.0 g O_2/m^2/day and a photosynthesis rate of

4.5 g O_2/m^2/day were used for the North Fork River to reproduce diurnal DO variations in the measured data. These rates are approximately three times higher than the photosynthesis and respiration rates in the White River. Documentation with the model (TVA 2002) states that the high rates are probably not fully representative of the main channel flow. Thus, based on professional judgment, the rates were adjusted in order to obtain more reasonable model results. The photosynthesis rate was changed to 2.25 g O_2/m^2/day (half of its original value). The respiration rate was changed to 0.3 g O_2/m^2/day, which is consistent with the respiration rate used by TVA in the Bull Shoals tailwater.

4.4 Projection Simulations

The projection scenarios were developed so that water quality standards were met consistently in the White River and North Fork River during the critical periods. The applicable water quality standard for trout waters in Arkansas is a minimum DO of 6 mg/L. The model output showed that the lowest DO values in the White River occurred just downstream of the Bull Shoals dam, at the upper end of the modeled segment. Similarly, the lowest DO values in the North Fork River occurred downstream of the Norfork Dam, at the upper end of the modeled segment of the North Fork River. Because the model showed that the lowest DO levels occur near the dams, the scenarios analyzed in this TMDL focused on increasing the DO in the water released from the dams.

During times of hydropower generation, the majority of flow at these locations comes from the releases from the dams. Because they have hypolimnetic releases, both dams release water that is lower than the water quality standard at times. The DO of water released from the dams contains a significant amount of variation. DO in water released from Bull Shoals varied from 1.4 mg/L to 9.5 mg/L. DO in water released from Norfork varied from 0.3 mg/L to 7.5 mg/L. Due to the large volume of water released from the dams and the low DO levels in the water, the model showed that the DO needed to be increased in the dam releases in order to meet water quality standards in the receiving waters during periods of high-flow periods.

The critical modeling period for the Bull Shoals tailwater was October 26, 1998, through November 24, 1998. The model was initially set up to simulate existing conditions, with DO values at the Bull Shoals Dam unchanged from measured data. The DO values for other inflows (springs and tributaries) were assumed to be the same as values used in the calibrated model. The model predicted DO values near 2.0 mg/L during the simulation period, with the lowest DO levels occurring just downstream of the dam. Model output is shown in Appendix A.

The two sources of flow into the White River at the Bull Shoals Dam are the hydropower releases from the dam and the leakage from the karst geology and wicket gate. FTN first adjusted the DO in the hydropower releases from the Bull Shoals Dam so that any observed values below 6 mg/L were increased to 6 mg/L. This increased the predicted DO in the river during generation periods. However, during low-flow periods, when the flow immediately downstream of the dam is dominated by karst and wicket gate leakage, the DO remained lower than water quality standards. In order to meet water quality standards in the river, the DO in the leakage was also increased from 2 mg/L to 6 mg/L.

In summary, the following changes were made to the inputs for existing conditions in order for the predicted DO in the White River to meet the water quality standard of 6 mg/L. Model output showing the predicted DO levels after these changes is shown in Appendix A.

1. For hydropower releases from Bull Shoals Dam, all observed values below 6 mg/L were increased to 6 mg/L.
2. For karst and wicket gate leakage, the DO was adjusted to a constant value of 6 mg/L.

The critical modeling period in the North Fork River was October 12, 2004, to November 10, 2004. The model was initially set up to simulate existing conditions in the North Fork River, with flows and DO values at the Norfork Dam consistent with measured data. The DO values for other inflows were assumed to be the same as values used in TVA's calibrated model. The model predicted DO values as low as 1 mg/L occurring just downstream of the Norfork Dam during the critical period. Model output is shown in Appendix A.

The flow immediately downstream of Norfork Dam consists of hydropower releases as well as leakage from karst geology and the wicket gate. FTN first adjusted the DO in the hydropower releases from Norfork Dam so that any observed values below 6 mg/L were increased to 6 mg/L. This increased the predicted DO during generation periods. However, during low-flow periods, when the flow immediately downstream of the dam is dominated by karst and wicket gate leakage, the predicted DO remained lower than the water quality standard. For this reason, DO in the leakage was also increased from 1.5 mg/L to 6 mg/L.

In summary, the following changes were made to the inputs for existing conditions in order for the predicted DO in the North Fork River to meet the water quality standard of 6 mg/L. Model output showing the predicted DO levels after these changes is shown in Appendix A.

1. For hydropower releases from Norfork Dam, all observed values below 6 mg/L were increased to 6 mg/L.
2. For karst and wicket gate leakage, the DO was adjusted to a constant value of 6 mg/L.

4.5 TMDL Calculations

The TMDLs for the White River and the North Fork River were calculated as minimum allowable loads of DO rather than maximum allowable loads of CBODu and NBODu. This approach was used because implementation of the TMDL will likely be focused on adding DO to the water rather than reducing CBODu or NBODu for inflows to the tailwaters.

The required DO loads were calculated as averages during the critical modeling periods. The boundary loads from the dams, as well as flows from tributaries and distributed loads, were included in the nonpoint source LA. The WLA includes the NPDES-permitted point sources. An implicit MOS was used based on conservative assumptions in the modeling. The loads are shown in Table 4.1.

Table 4.1. TMDLs for Bull Shoals and Norfork tailwaters.

	Minimum allowable loads of DO (lbs/day) for:	
	White River (11010003-002U)	**North Fork River (11010006-001)**
WLA for point sources	10	1,847
LA for nonpoint sources	16,343	23,784
MOS	implicit	implicit
TMDL	16,353	25,631

These TMDLs require that hydropower releases from Bull Shoals Dam and Norfork Dam contain a DO of at least 6.0 mg/L. The 6.0 mg/L minimum DO level also applies to water entering the tailwater areas from karst and wicket gate leakage. In addition to this, it is recommended that water discharged from the Norfork National Fish Hatchery maintain a minimum DO of 6 mg/L year round. The permit currently requires a minimum DO of 6 mg/L during the months of November through April, but allows a DO of 5 mg/L during the months of May through October. Because the limiting factor for maintaining DO standards appears to be the DO concentrations of water entering the rivers immediately downstream of the dams, future increases in point source loads of CBODu or NBODu may be allowable, but only if the modeling shows that the increases will not cause or contribute to a violation of the DO standard.

5.0 IMPLEMENTATION ALTERNATIVES

Considerable work has been completed, and is underway, identifying and evaluating alternatives for improving tailwater DO concentrations at both Bull Shoals and Norfork dams. A number of these alternatives are described below.

5.1 Role of ADEQ in Improvement of Tailwater DO

Public comments from many individuals (in Appendix E) showed considerable confusion about ADEQ's authority and potential roles with regard to improving DO in the Bull Shoals and Norfork tailwaters. ADEQ has the authority to protect the quality of waters of the state by permitting and regulating point source discharges and certain aspects of some industrial activities and construction activities. However, ADEQ does not have authority to regulate most nonpoint source runoff to waterbodies, nor do they have authority to regulate the operation of dams or hydropower facilities. Therefore, ADEQ has no authority to require anyone to implement measures that will bring the DO in these tailwaters up to 6.0 mg/L at all times. ADEQ's role will be to continue facilitating a group of stakeholders to take action in implementing measures that will improve DO in these tailwaters.

5.2 Watershed Management

As discussed in Section 2.4, the leakage of low-DO water from the hypolimnion of each lake is believed to contribute significantly to low-DO conditions in the tailwaters. As discussed in Section 2.7, all deep lakes and reservoirs lose DO in deep waters during temperature stratification (i.e., summer), when mixing is primarily limited to the warmer surface layers. Therefore, it is normal that this should occur in Bull Shoals Lake and Norfork Lake, and is not necessarily an indication that these lakes are being heavily impacted by nutrient and/or organic matter inputs from their watersheds. Neither Bull Shoals Lake nor Norfork Lake has been classified as impaired by ADEQ during their routine statewide water quality assessments, as of 2008 (ADEQ 2008).

The rate of DO loss in the hypolimnion during stratified conditions is a function of a number of factors, including the weather. Wind, stormwater inflows, and air temperatures determine when stratification occurs, how strongly temperature layers are separated, and how long stratification lasts. It is also known that anthropogenic nutrient inputs to reservoirs can increase the rate of DO loss in deep waters during temperature stratification, which affects how low the DO levels become in these deep waters (Wetzel 2001,Gliwicz and Kowalczewski 2006). Therefore, implementation of practices to reduce inputs of nutrients and organic matter to Bull Shoals Lake and Norfork Lake has the potential for some improvement in DO in these reservoirs. Water quality models of these reservoirs have already been developed (USGS 2002, USGS 2003) and could be used to estimate the potential benefits of reducing nutrient and organic matter inputs on reservoir DO. However, given the nature of deep reservoirs, that low-DO conditions occur in the deep waters of even reservoirs with little anthropogenic inputs of nutrients and organic matter, it is unlikely that watershed management practices to reduce these inputs to Bull Shoals Lake and Norfork Lake would alone result in tailwater DO levels that would meet state water quality standards.

ADEQ has always supported the implementation of best management practices (BMPs) that will minimize anthropogenic loads of nutrients and organic matter into these lakes and other waterbodies. ADEQ will continue to support the implementation of watershed BMPs, but raising tailwater DO levels up to state water quality standards will require implementation of other measures that provide more direct benefits to tailwater DO.

5.3 Minimum Flow

Increased minimum flows (i.e., minimum continuous releases) have been authorized for Bull Shoals and Norfork dams through the 2006 Energy and Water Development Appropriations Act (Corps 2009). Modeling studies indicate that increased minimum flows are not expected to cause significant changes in tailwater DO levels (USGS 2002; USGS 2003; Corps 2006), but the issue of minimum flow is discussed here because of its potential benefit to the trout fisheries in these tailwaters. The primary objective of increased minimum flow is to improve tailwater habitat for trout by increasing the amount of time that portions of the streambed are inundated.

The increase in wetted area provides additional habitat for trout, and for aquatic invertebrates, which serve as food for trout and other aquatic organisms. With these improvements in trout habitat and food sources, trout growth and reproduction rates are expected to increase. The potential economic benefits of improved trout fisheries due to increased minimum flows were estimated to be $3,458,678 per year for the Bull Shoals tailwater and $1,519,722 per year for the Norfork tailwater. These benefits would be mostly attributable to freshwater sportsmen (Corps 2009).

At Bull Shoals, 5.0 feet of reservoir storage from the flood control allocation has been reallocated for the purpose of maintaining a target minimum release of 800 cfs on a continuous basis. The existing minimum release has been estimated to be 210 cfs, consisting of 160 cfs of karst and wicket gate leakage and 50 cfs from the house units. The additional 590 cfs of minimum release at Bull Shoals will be discharged through the main turbine, so no new release facilities are required. However some modifications to the Corps operational facilities are required, including modifying the computer language used to remotely operate the turbines.

At Norfork, 3.5 feet of reservoir storage has been reallocated, half from the flood control allocation, and half from the conservation pool allocation. This reallocation is intended to provide a target minimum release of 300 cfs on a continuous basis. The existing minimum release has been estimated to be 115 cfs, consisting of 55 cfs of karst and wicket gate leakage, 20 cfs from the house unit, and 40 cfs from the Norfork National Fish Hatchery. The additional 185 cfs of minimum release will be discharged through a siphon that will be constructed and will be independent of the hydropower operations. Other modifications that will be necessary will include modifying the computer language used to remotely operate the turbines.

5.4 Alternatives Evaluated by TVA

In 1997, TVA published documents detailing their evaluation of alternatives for improving tailwater DO while minimizing the impact on power generation (TVA 1997a; TVA 1997b). The executive summaries of these documents are included as Appendices B and C. TVA evaluated ways to aerate the water upstream of the dam (forebay oxygen diffuser), as it going through the dam (turbine venting and forced air), and downstream of the dam (aerating weir).

A forebay diffuser system takes oxygen from either a liquid oxygen tank or onsite pressure swing adsorption (PSA) plant and injects it into the hypolimnion of the lake through long diffuser lines near the dam. As the bubbles rise through the water column, the oxygen is dissolved into the water. One advantage of this alternative is that all water flowing from the hypolimnion to the tailwater (including leakage) would be aerated. The primary disadvantage of this alternative is the high ongoing costs to either purchase liquid oxygen to the system or to operate a PSA plant that will concentrate atmospheric oxygen.

Some of the public comments from individuals indicated that a forebay diffuser system would negatively affect the fishery in the lake. This perception seems to result from an occurrence of a no-fishing zone in a reservoir in another state where a forebay diffuser was installed. Apparently fish were attracted to the area where the diffuser was installed (due to improved DO conditions) and that resulted in fishermen being concentrated in that area and overfishing the area, which is why the no-fishing zone was set up for part of the year. Therefore, the forebay diffuser was not harming the fishery; the no-fishing zone was caused by overfishing, not the forebay diffuser.

Turbine venting is a passive method for aspirating air into the water as it flows through the hydropower turbines. Both Bulls Shoals and Norfork dams have utilized turbine venting since the mid-1990s. This is a relatively low-cost alternative but it does not have the capability to raise DO levels up to the state water quality standard of 6.0 mg/L. Turbine venting does not add any oxygen to the water when generation is not occurring. As discussed in Section 3, the tailwater DO levels tend to be lower during non-generation periods than during generation periods.

The forced air alternative is similar to turbine venting except that it uses blowers to force air into the water passageways in the turbines. The forced air alternative would be capable of raising the DO levels up to the state water quality standard of 6.0 mg/L during periods of generation.

An aerating weir (either an infuser weir or a hybrid infuser-labyrinth weir) would be built downstream of the dam (locations were evaluated ranging from 0.2 to 2.5 miles downstream of the dams). Aeration of the water would be achieved by water flowing over the weir through specially designed grates. A weir would be expensive to install but would have very low maintenance costs. An advantage of a weir is that it aerates all water flowing through the tailwater (not just hydropower releases). A major disadvantage is that the weir would back water up at the base of the dam, which would slightly reduce the head on the hydropower turbines. Another disadvantage is that the length of stream between the dam and the weir would have low aeration (and probably low DO) due to backwater from the weir; DO benefits are provided only downstream of the weir.

Estimates of DO improvement and costs for installation, operation, and maintenance for these alternatives are shown in Table 5.1 for Bull Shoals and Table 5.2 for Norfork.

Table 5.1. Estimated DO levels and costs for alternatives at Bull Shoals Dam (TVA 1997a).

Alternative	DO (mg/L)	Capital Cost (in 1997 dollars)	Operation & Maintenance Cost (in 1997 dollars)
Turbine Venting (existing units)	2.5	$152,000	$12,000
Turbine Venting (modernized units)	4.0	$8,270,000	$12,000
Forced Air	4.0	$4,227,000	$134,000 - $150,000
Forebay Diffuser (liquid oxygen)	4.0	$1,860,000	$565,000 - $890,000
Forebay Diffuser (PSA)	4.0	$6,125,000	$250,000 - $412,000
Forced Air	6.0	$4,687,000	$179,000 - $198,000
Forebay Diffuser (liquid oxygen)	6.0	$1,860,000	$1,254,000 - $1,735,000
Forebay Diffuser (PSA)	6.0	$6,125,000	$511,000 - $792,000
Infuser Weir	6.0+	$11,125,000	$26,000
Labyrinth-Infuser Hybrid Weir	6.0	$14,955,000	$28,000

Table 5.2. Estimated DO levels and costs for alternatives at Norfork Dam (TVA 1997b).

Alternative	DO (mg/L)	Capital Cost (in 1997 dollars)	Operation & Maintenance Cost (in 1997 dollars)
Turbine Venting (existing units)	2.5	$100,000	$10,000
Forced Air	4.0	$1,275,000	$56,000 - $61,000
Forebay Diffuser (liquid oxygen)	4.0	$1,281,000	$276,000 - $386,000
Forebay Diffuser (PSA)	4.0	$3,745,000	$176,000 - $236,000
Forced Air	6.0	$1,432,000	$68,000 - $74,000
Forebay Diffuser (liquid oxygen)	6.0	$1,459,000	$512,000 - $659,000
Forebay Diffuser (PSA)	6.0	$4,986,000	$283,000 - $360,000
Infuser Weir	6.0	$4,200,000	$28,000
Hybrid Labyrinth-Infuser Weir	6.0	$5,000,000	$28,000

5.5 Other Alternatives

5.5.1 House Unit Air

In 2000, a forced air aeration system was tested on the Norfork Dam house generator to determine the potential for DO improvements to the station service flows. Because this system would only affect a small portion of the total discharge at Norfork dam, it was not evaluated as a system to be implemented instead of other alternatives, but rather in addition to other alternatives. The best oxygen transfer rates resulted in a 2-mg/L increase in DO in the house unit discharge, but DO in the leakage was not aerated and reduced the effectiveness of the system. Using the results of the 2000 test and a USGS estimate of leakage, TVA estimated that a forced air system for the house unit at Norfork Dam could increase DO in water releases at base flow only about 0.5 mg/L.

5.5.2 Paddlewheel Aerator

In 2003, AGFC personnel investigated the potential for a mechanical “paddlewheel” aerator to improve DO conditions in the Norfork tailwaters under base flow conditions. Initially, this appeared to be an effective low-cost alternative with an purchase and installation cost of about $6,400. However, additional evaluation of this alternative has identified a number of obstacles. The primary obstacle is the vulnerability of the aerator to damage during the high-flow conditions during power generation. A system for lifting the aerator out of the water during generation periods would have cost over $100,000. In addition, it appears that the initial estimates of DO improvement with the aerator were higher than is actually likely to occur. As a result, this alternative is no longer being considered as a likely option for increasing tailwater DO levels.

5.5.3 SDOX System

In 2008, the company BlueInGreen began working with the Norfork National Fish Hatchery and the National Science Foundation to evaluate the potential for their Supersaturated Dissolved Oxygen (SDOX™) Delivery system to address problems with low DO in the hypolimnetic water that the hatchery was withdrawing for its operations. The SDOX system works by taking water from the river, supersaturating it with oxygen, and then delivering the oxygen-saturated water back to the river. BlueInGreen reports that the SDOX system provides a number of advantages over bubble oxygen injection systems (LOX injection), including use of less oxygen, smaller capital investment, and flexibility of delivery rate (including turning the system off without damage) and delivery location. BlueInGreen reports that use of the SDOX system in the Norfork tailwater would not require any modification to the dam, could operate at all tailwater flow conditions, could provide location-targeted delivery, could provide adjustable delivery rates to respond to changing tailwater DO conditions, and could maintain any tailwater DO level desired, up to saturation. Costs for this system were not available.

5.6 Summary

Over the long course of concern about DO levels in the tailwaters of Bull Shoals Lake and Norfork Lake, numerous alternatives for increasing tailwater DO levels have been proposed and considered. The Corps has already implemented turbine venting, and is in the process of implementing increased minimum tailwater flows at Bull Shoals and Norfork dams. However, it is not expected that these actions will eliminate low-DO conditions in the tailwaters. Therefore, additional alternatives need to be implemented. Several of the alternatives outlined above have the potential to increase DO in the tailwaters to meet water quality standards.

6.0 PUBLIC PARTICIPATION

Federal regulations at 40 CFR 130.7(c)(1)(ii) specify that TMDLs shall be subject to public review as defined in the state's Continuing Planning Process (CPP). ADEQ conducted a public review of the draft version of this TMDL report (dated June 18, 2008) starting on October 27, 2008. The public review period extended through December 22, 2008. The draft version of the report was available on the ADEQ web site during the review period.

Public comments were received from 7 agencies, organizations, and companies, and 407 individuals. These comments and ADEQ’s responses are presented in Appendix E. Numerous revisions have been made to this report as a result of the public comments. This public participation process is consistent with guidelines in the Arkansas CPP and federal regulations at 40 CFR 25.

The comments from individuals and organizations expressed tremendous public support and desire to improve DO in these tailwaters. Numerous comments were from people who live outside of Arkansas but come to fish in these tailwaters. The comments from agencies were more technical in nature. Some of the agency comments expressed a desire to focus more on the effect of nonpoint source loads of nutrients and organic matter being transported from the watersheds into the lakes and causing low DO in the hypolimnion of each lake. Other agency comments provided explanations of situations that can cause differences in tailwater DO between wet and dry years.

Arkansas Governor Mike Beebe has charged ADEQ with facilitating a group of stakeholders to take action in implementing measures that will improve DO in these tailwaters. On August 18, 2008, ADEQ held a meeting of stakeholders, including concerned citizens, staff members from the Arkansas congressional delegation, and representatives from the Corps, SWPA, AGFC, and USFWS. As discussed in Section 5.1, ADEQ does not have authority to regulate these dams or their hydropower operations, but ADEQ staff will continue to work diligently to bring stakeholders together to move forward with improving DO in these tailwaters.

7.0 CONCLUSIONS

The conclusions below are based on the review of background information, the analyses of observed water quality data, the water quality modeling results, and the review of previous studies of implementation alternatives.

1. Low DO concentrations in the Bull Shoals and Norfork tailwaters are due to low DO of water coming from the hypolimnion of each lake. Oxygen demand due to CBODu or NBODu from point sources or tributaries does not appear to be the cause of the DO impairments in these tailwaters.
2. Activities such as urbanization and agriculture in the watersheds upstream of each lake will contribute some nonpoint source loads of organic matter and nutrients to each lake. These loads are likely having a small effect on hypolimnetic DO. However, low hypolimnetic DO occurs in deep reservoirs even when watersheds are relatively undeveloped. Therefore, reducing nonpoint source pollution in the watersheds may indirectly improve tailwater DO slightly, but by itself it is not expected to raise the tailwater DO enough to meet the water quality standard of 6.0 mg/L at all times.
3. ADEQ supports the implementation of BMPs that will minimize anthropogenic loads of nutrients and organic matter into these lakes. At the same time, ADEQ is encouraging the implementation of one or more other measures near the dam that will raise the tailwater DO enough to meet the standard of 6.0 mg/L at all times.
4. Increased minimum flows from each dam will benefit the trout fisheries in these tailwaters due to improved habitat for invertebrates that are trout food sources, decreased likelihood for water temperatures that are too high for trout, and potentially higher DO concentrations in the tailwaters.
5. Funding needs to be appropriated to perform work at each dam that is necessary to implement increased minimum flows.
6. Increasing the minimum flows without any other implementation measures will not result in meeting the water quality standard of 6.0 mg/L immediately below each dam during critical periods. If DO in hydropower releases is low, then adding more low-DO water will not alleviate DO problems immediately below each dam.
7. Implementation measures are needed that will increase DO levels in both the hydropower releases and the leakage. The modeling showed that increasing the DO concentrations to 6 mg/L in hydropower releases alone (i.e., without increasing DO concentrations in the leakage) results in predicted DO values below the water quality standard during non-generation periods.

8. Various alternatives for increasing DO in these tailwaters were identified and examined as early as 1997 by TVA and more recently by BlueInGreen, Inc. Sufficient information is available to select one or more alternatives and move forward with implementation.

8.0 REFERENCES

ADEQ. 2000. Water Quality Assessment of Arkansas' Significant Publicly-Owned Lakes, Summer 1999. Report Number WQ00-06-1. Downloaded from Arkansas Department of Environmental Quality web site (www.adeq.state.ar.us/water/branch_planning/pdfs/WQ00-06-1.pdf).

ADEQ. 2006. Unpublished water quality data from 2004 sampling of significant publicly owned lakes. Obtained via e-mail on October 12, 2006 from Jim Wise, Water Division, Arkansas Department of Environment Quality.

ADEQ. 2008. 2008 List of Impaired Waterbodies (303(d) List). Published February 2008. Downloaded from Arkansas Department of Environmental Quality web site (www.adeq.state.ar.us/water/branch_planning/pdfs/303d_list_2008.pdf).

AGFC. 1991. White River Minimum Flow Study – Overview, Status and Recommendations. Draft report by Jim Spotts, State Trout Biologist, Arkansas Game and Fish Commission. August 26, 1991.

AGFC. 2003. Potential for a Mechanical Aeration System for Zero Generation Periods Below Norfork Dam. Report #TP-03-03. Prepared by Stan Todd, Assistant Trout Biologist, Arkansas Game and Fish Commission. March 13, 2003.

AGFC. 2004a. Arkansas Trout Management Plan. Prepared by Darrell Bowman and Melissa Jones, Arkansas Game and Fish Commission. January 22, 2004. Downloaded from AGFC web site (www.agfc.com/pdfs/fisheries/mgmtplans/trout_management_plan.pdf).

AGFC. 2004b. Minimum Flow Fact Sheet. February 26, 2004. Downloaded from Arkansas Game and Fish Commission web site (www.agfc.com/pdfs/fisheries/minimumflow/minimumflow_facts_2004.pdf)

ANRC. 2007. 2006 Monitoring Season, Upper White River, Dissolved Oxygen Data Collection & Analyses Project Report. Draft report prepared by the Arkansas Natural Resources Commission. April 2007.

APCEC. 2007. Regulation No. 2, As Amended. Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas. Adopted by the Arkansas Pollution Control and Ecology Commission to be effective on November 25, 2007. Downloaded from ADEQ web site (www.adeq.state.ar.us/regs/files/reg02_final_071125.pdf).

CAST. 2005. Land Use / Land Cover Summer 2004. Dataset developed by Center for Advanced Spatial Technologies, University of Arkansas, Fayetteville. Downloaded from CAST web site (www.geostor.arkansas.gov/Portal/index.jsp).

Corps. 1993. White River Basin, Arkansas and Missouri, Water Control Master Manual. United States Army Corps of Engineers, Little Rock District. March 1993.

Corps. 2004. White River Minimum Flows Reallocation Study Report. United States Army Corps of Engineers, Little Rock District. July 2004.

Corps. 2009. Final Environmental Impact Statement White River Basin, Arkansas, Minimum Flows. United States Army Corps of Engineers, Little Rock District. Revised January 2009.

CPN. 2003. "Army Corps Districts Use Alternative Dispute Resolution - Case Study #2: The Experience of the White River Dissolved Oxygen Committee." Accessed from Civic Practices Network web site (www.cpn.org/topics/environment/army3.html#two).

EPA. 1986. Quality Criteria for Water. EPA-600/3-77-001. Office of Water Regulations and Standards. United States Environmental Protection Agency.

EPA. 2008. Approved Arkansas 2008 Section 303(d) List. Approved October 2008 by U.S. Environmental Protection Agency, Region 6. Downloaded from EPA web site (www.epa.gov/Region6/water/npdes/tmdl/303d/ar/2008-epa-final-approved-list.pdf).

Loginetics, Inc. 2005. White River Tailwater Model - Phase 1 Model Extension and Preliminary Calibration. Prepared for AGFC by G. Hauser, Loginetics, Inc.

MORAP. 2005. "Missouri Landcover". Missouri Resource Assessment Partnership. August 22, 2005. Data downloaded from Missouri Spatial Data Information Service web site (www.msdis.missouri.edu/data/lulc/lulc05.htm).

SWPA. 2008a. "Project Table" listed below each daily generation schedule on Southwestern Power Administration web site (www.swpa.gov/generationschedules.aspx).

SWPA. 2008b. Phone conversation with George Robbins, Southwestern Power Administration.

TVA. 1997a. Bull Shoals Project Aeration Options. Report No. WR97-1-760-102. Prepared by J.S. Adams, J.C. Carter, B. Hadjerioua, E.D. Harshbarger, G.E. Hauser, J.H. Hoover, P.N. Hopping, P.A. March, and M.H. Mobley. Tennessee Valley Authority, Norris, TN.

TVA. 1997b. Norfork Project Aeration Options. Report No. WR97-2-760-106. Prepared by J.H. Hoover, E.D Harshbarger, B. Hadjerioua, W.D. Proctor, G.E. Hauser, M.H. Mobley, J.C. Carter Jr., and J.S. Adams. Tennessee Valley Authority. Norris, TN.

TVA. 2001. Norfork Dam House Unit Forced Air Evaluation. Report No. WR2001-2-760-135. Prepared by J.C. Carter, Jr. Tennessee Valley Authority. Norris, TN.

TVA. 2002. Model Exploration of Hydrodynamics, Water Quality, and Bioenergetic Fish Growth in Bull Shoals and Norfork Tailwaters. Report No. WR98-1-590-174. Prepared by G. Hauser, B. Hadjerioua, and M. Shiao. Tennessee Valley Authority. Norris, TN.

USFWS. 2005. The Economic Effects of Rainbow Trout Stocking by Fish and Wildlife Service Hatcheries in FY 2004. Prepared by James Caudill, Division of Economics, U.S. Fish and Wildlife Service. December 5, 2005. Downloaded from USFWS web site (www.fws.gov/species/rainbowtrout/DrJimCaudill-report.pdf).

USFWS. 2006. Norfork National Fish Hatchery - Economic Effects of Rainbow Trout Production 2004. Brochure downloaded from U.S. Fish and Wildlife Service web site (www.fws.gov/norfork/Norfork-EconomicImpact.pdf).

USGS. 1996. Eutrophication trends inferred from hypolimnetic dissolved-oxygen dynamics within selected White River reservoirs, northern Arkansas-southern Missouri, 1974-94. Water Resources Investigations Report 96-4096. Report prepared by W.R. Green, United States Geological Survey, Little Rock, Arkansas. Downloaded from USGS web site (http://pubs.er.usgs.gov/usgspubs/wri/wri964096).

USGS. 2002. Simulation of Hydrodynamics, Temperature, and Dissolved Oxygen in Norfork Lake, Arkansas, 1994-1995. Water Resources Investigation Report 02-4250. Prepared by J.M. Galloway and W.R. Green. Downloaded from US Geological Survey web site (http://ar.water.usgs.gov/LOCAL_REPORTS/WRIR02-4250.pdf).

USGS. 2003. Simulation of Hydrodynamics, Temperature, and Dissolved Oxygen in Bull Shoals Lake, Arkansas, 1994-1995. Water Resources Investigation Report 03-4077. Prepared by J.M. Galloway and W.R. Green. Downloaded from the US Geological Survey web site (http://water.usgs.gov/pubs/wri/wri034077/WRIR03-4077.pdf).

APPENDIX A

Selected Input and Output from Water Quality Model

Table A.1. Flow inputs for ADYN model.

Model input	River Mile	Value	Comments
White River			
BS boundary	418.41	Hourly Flow	Bull Shoals Releases, minimum flow of 50 cfs
Leakage	418.41	160 cfs	Estimated Karst and Wicket Gate Leakage
Dew Spring	416.7	50 cfs	Estimated (consistent with calibrated model)
Bull Shoals POTW	417.5	0.9 cfs	NPDES Permit limit
Cotter Spring	404.13	10	Estimated (consistent with calibrated model)
3 unnamed springs	398	18	Estimated (consistent with calibrated model)
Crooked Creek	395	Daily Flow	Based on Buffalo River at St. Joe
Buffalo River	388	Daily Flow	Based on Buffalo River at St. Joe
Upstream distributed local	417.96	Daily Flow	Based on Buffalo River at St. Joe
Piney Creek	352	10	Estimated (downstream of area of concern)
Sylamore Creek	341.93	20	Estimated (downstream of area of concern)
Polk Bayou	301.8	10	Estimated (downstream of area of concern)
downstream distributed local	370.9	30	Estimated (downstream of area of concern)
North Fork River			
NF boundary	4.8	Hourly Flow	Norfork Release, includes house unit flow
Leakage	4.8	55	Estimated Karst and Wicket Gate Leakage
house unit	4.8	0 cfs	Flow set to 0 because flow is already included in NF boundary, NF boundary minimum flow is 20 cfs
Hatchery	4.68	57.1 cfs	Average of recent flow reported in Discharge Monitoring Reports
Otter Ck	2.83	Daily Flow	Based on N. Sylamore Creek near St. Joe
dist local	4.8	Daily Flow	Based on N. Sylamore Creek near St. Joe

Table A.2. Boundary Conditions for RQUAL model.

Model input	River Mile	Temp (deg C)	DO (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Comments
White River						
BS boundary	418.41	from file/varies hourly	from file/varies hourly	2.4	0.6	
Leakage	418.41	same as dam release	2	3	0.1	
Dew Spring	416.7	14	8	3	0.1	
Bull Shoals POTW	417.5	25	2	23	9.14	Based on NPDES permit limits
Cotter Spring	404.13	14	8	3	0.1	
3 unnamed springs	398	14	8	3	0.1	
Crooked Creek	395	30	6.74	1.5	0.06	
Buffalo River	388	30	11.33	2.8	0.1	
Upstream distributed local	417.96	25	8.2	1.5	0.4	
Piney Creek	352	25	8.2	1.5	0.4	
Sylamore Creek	341.93	25	8.2	1.5	0.4	
Polk Bayou	301.8	25	8.2	1.5	0.4	
downstream distributed local	370.9	25	8.2	1.5	0.4	
North Fork River						
NF boundary	4.8	from file/varies hourly	from file/varies hourly	2.4	0.6	
Leakage	4.8	same as dam release	1.5	3	0.1	
house unit	4.8	-	-	-	-	Flow set to 0 because flow is already included in NF boundary
Hatchery	4.68	same as dam release	5 (May – October) 6 (Nov – April)	46	13.71	Based on NPDES permit limits
Otter Ck	2.83	25	8.21	1.5	0.04	
dist local	4.8	25	8.21	1.5	0.04	

White River predicted DO profiles for existing conditions:
(right hand side of plots is upstream end)

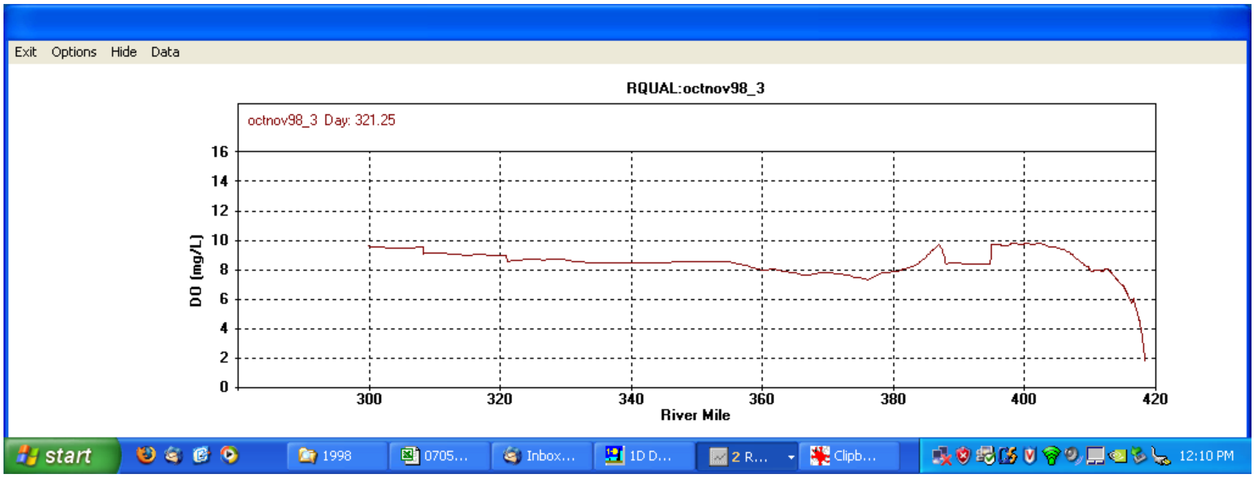


Figure A.1. Low Flows from Bull Shoals Dam (11/15/98 06:00)

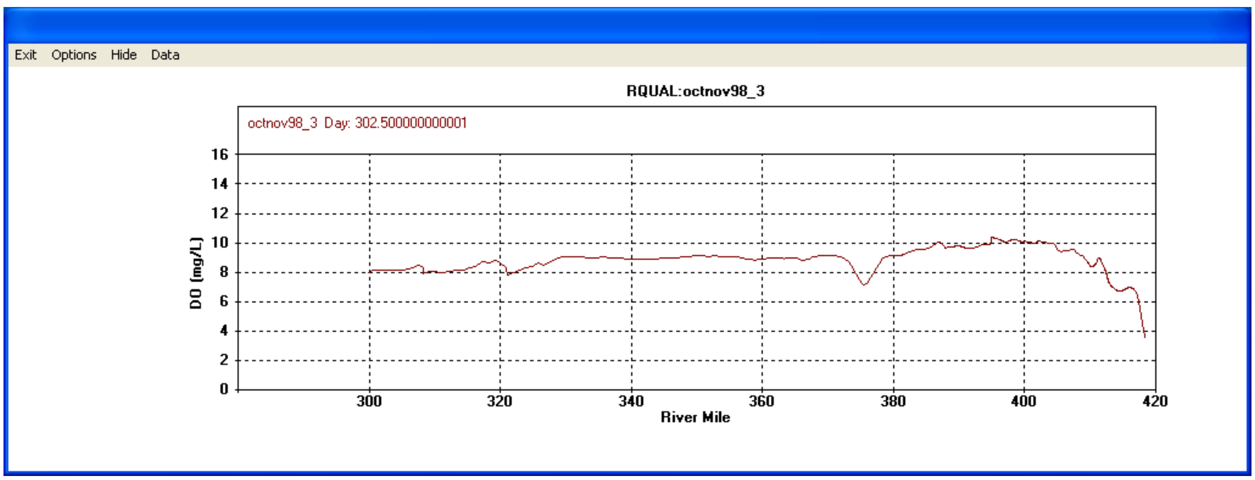


Figure A.2. High Flows from Bull Shoals Dam (10/28/98 12:00)

White River predicted DO profiles for TMDL conditions
(right hand side of plots is upstream end)

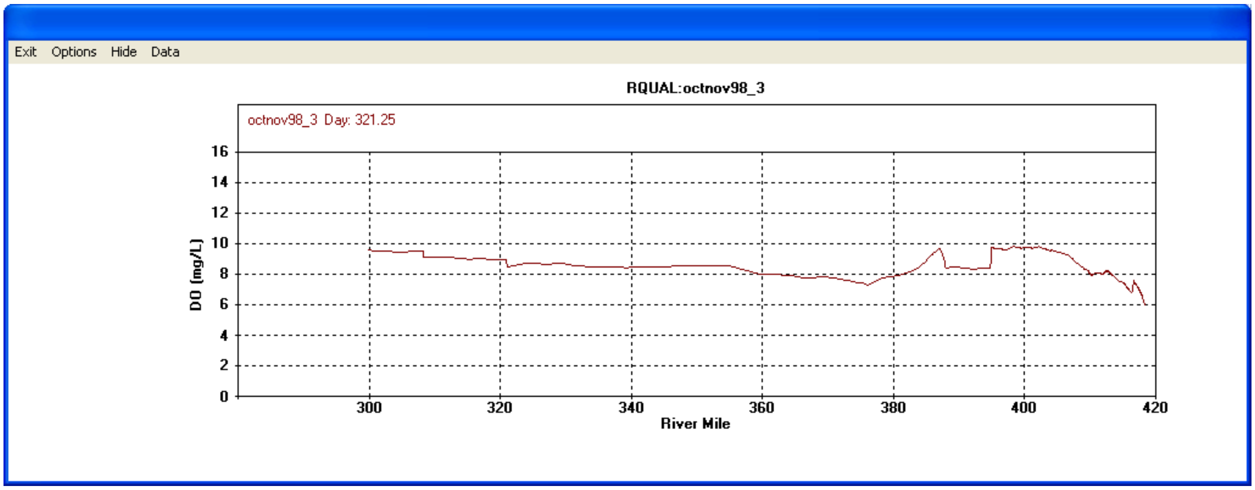


Figure A.3. Low Flows from Bull Shoals Dam (11/15/98 06:00)

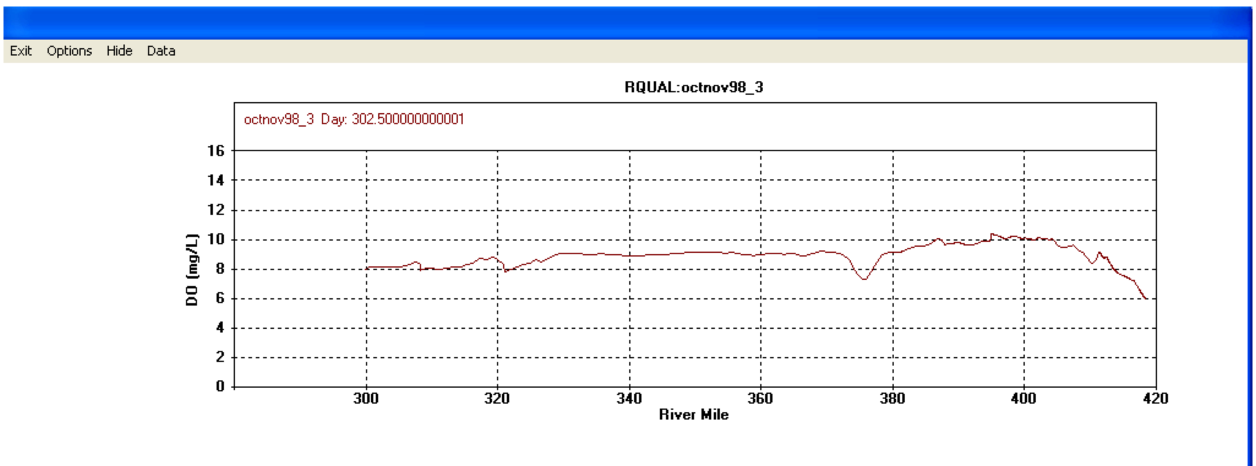


Figure A.4. High Flows from Bull Shoals Dam (10/28/98 12:00)

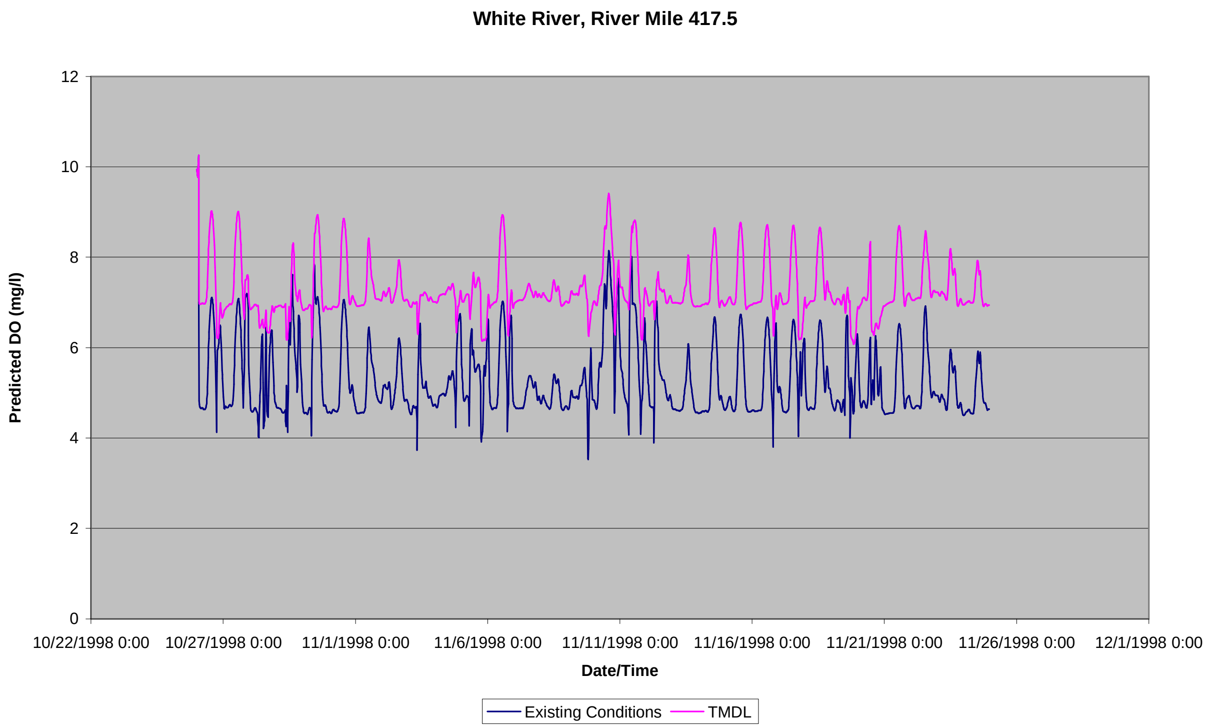


Figure A.5. Predicted DO Time Series for White River at RM 417.5 (about 1 mile downstream of Bull Shoals Dam) for Existing Conditions and TMDL Conditions

North Fork River predicted DO profiles for existing conditions:
(right hand side of plots is upstream end)

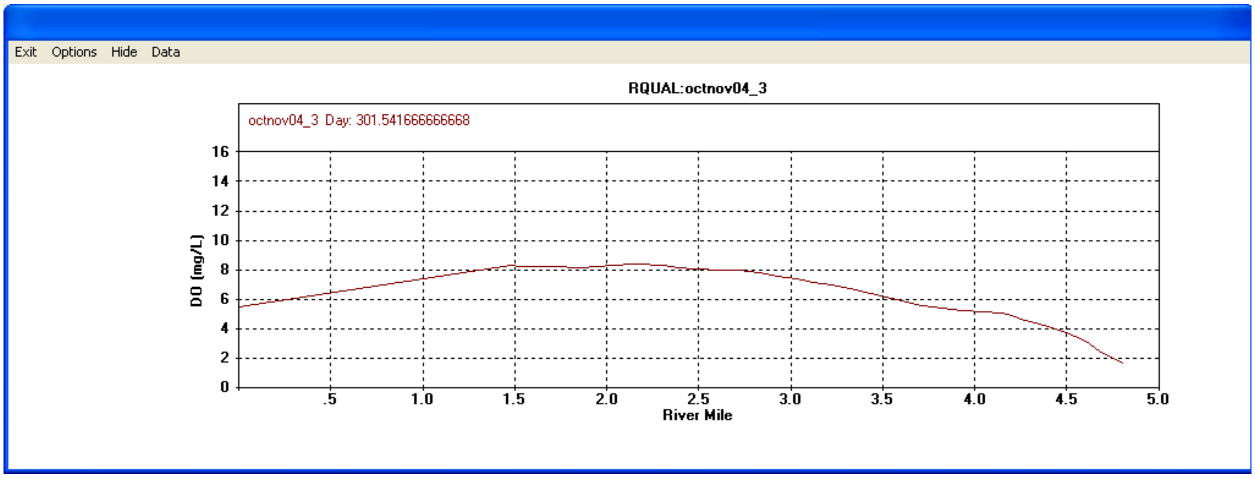


Figure A.6. Low Flows from Norfork Dam (10/26/2004 13:00)

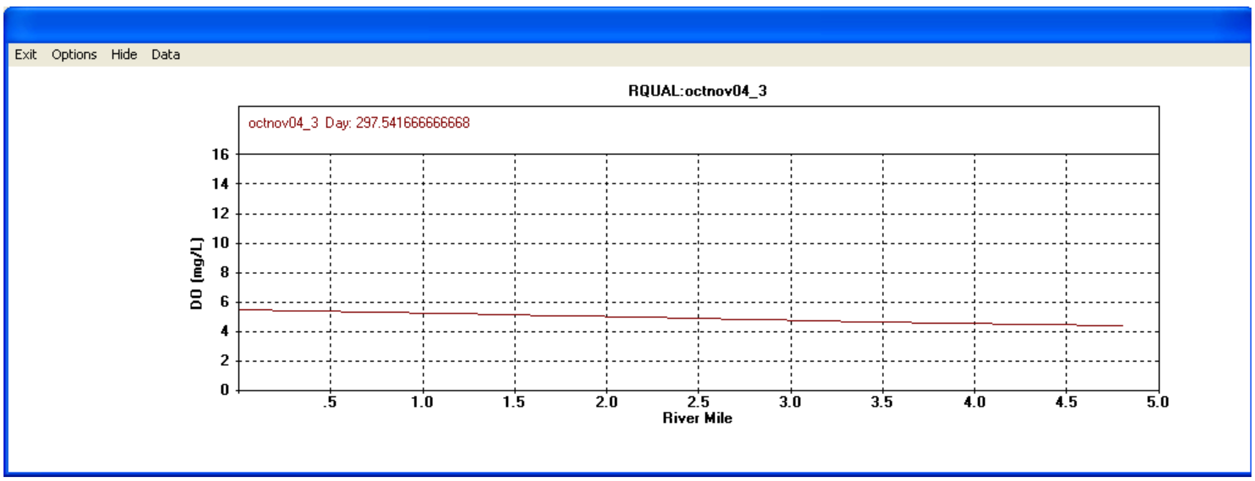


Figure A.7. High Flows from Norfork Dam (10/22/04 13:00)

North Fork River predicted DO profiles for TMDL conditions:
(right hand side of plots is upstream end)

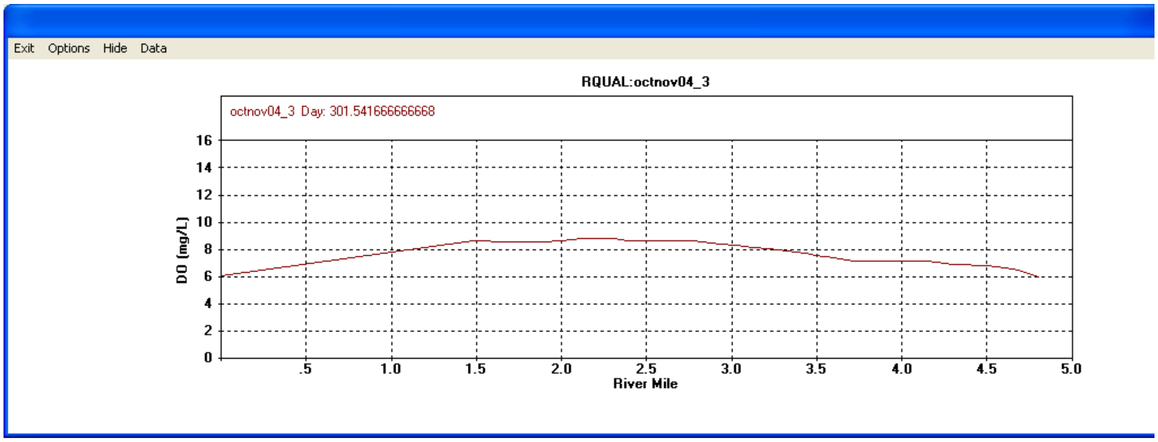


Figure A.8. Low Flows from Norfork Dam (10/26/2004 13:00)

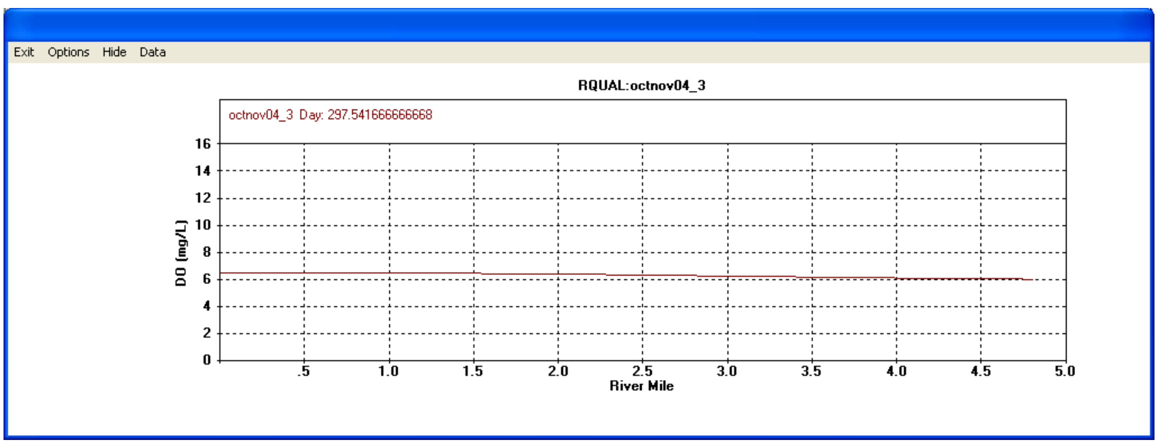


Figure A.9. High Flows from Norfork Dam (10/22/04 13:00)

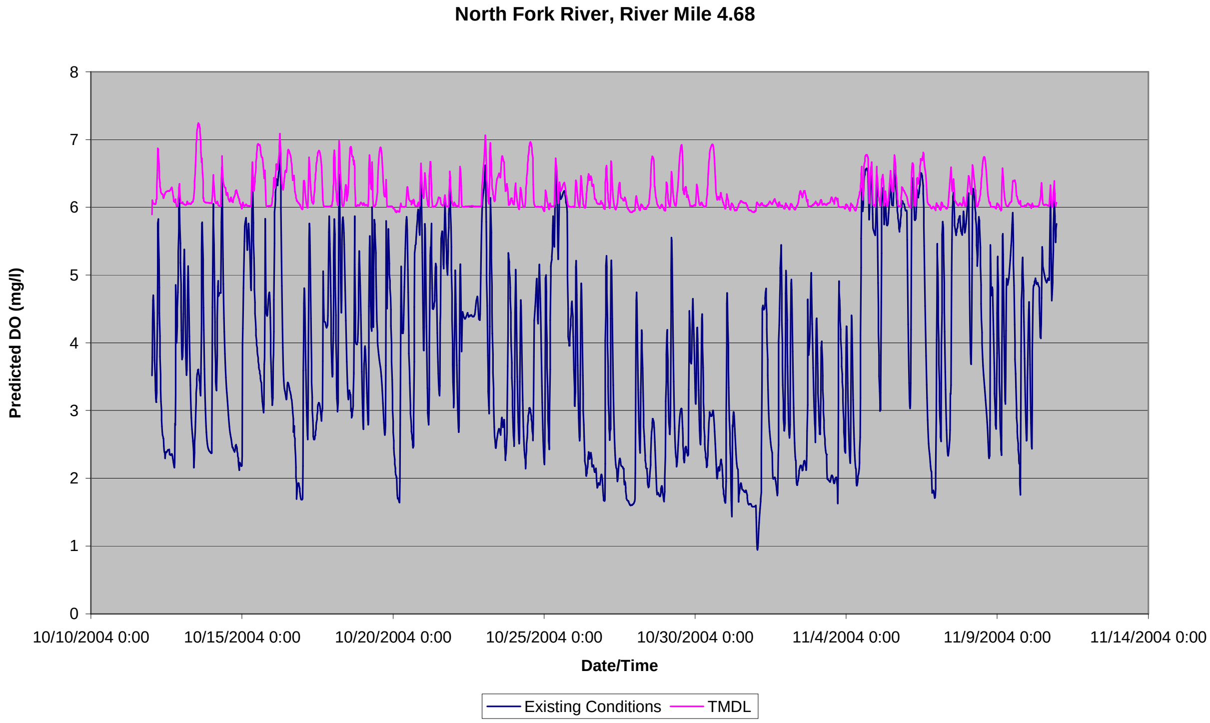


Figure A.10. Predicted DO Time Series for North Fork River at RM 4.68 (about 0.12 miles downstream of Norfork Dam) for Existing Conditions and TMDL Conditions

APPENDIX B

Excerpt from TVA Study of Bull Shoals Aeration Options

File copy

TENNESSEE VALLEY AUTHORITY
RESOURCE GROUP, ENGINEERING SERVICES
ENGINEERING LABORATORY

Darrell Bowman

DRAFT

BULL SHOALS PROJECT AERATION OPTIONS

WR97-1-760-102

Prepared by

J. Stephens Adams
James C. Carter
Boualem Hadjerioua
E. Dean Harshbarger
Gary E. Hauser
John H. Hoover
Paul N. Hopping
Patrick A. March
Mark H. Mobley

Norris, Tennessee
February 1997

EXECUTIVE SUMMARY

The Little Rock District of the Army Corps of Engineers is conducting a major rehabilitation study for the Bull Shoals powerhouse. As requested by the Little Rock District, the Tennessee Valley Authority (TVA) Engineering Laboratory is supporting the project by providing preliminary estimates of dissolved oxygen (DO) improvement and cost for various options to aerate releases from Bull Shoals Dam. The options included in this feasibility investigation were:

- Turbine venting (existing and modernized units)
- Forced air
- Forebay oxygen diffuser
- Aerating weir

In addition, three other options identified by the Army Corps of Engineers, Hydraulic Design Center (HDC) were briefly examined in a screening assessment to evaluate their potential. The HDC options included a submerged weir, regulating sleeve valve, and tailrace channel modifications.

Cost Comparison

The estimated capital cost and annual operation and maintenance (O&M) cost of the viable alternatives are summarized in Table 1. These are feasibility level cost estimates derived from TVA experience in installing similar systems at TVA projects. The estimated costs shown in Table 1 include direct costs, overheads, contractor profits, and contingencies. Capital costs were based on preliminary designs of systems that aerate hydroplant discharges (see relevant discharges in Table 1) from an incoming DO level of 0 mg/L to the DO value shown in Table 1. O&M costs evaluated for each technology reflect their unique operating characteristics. For the "throttled options" (forced air and forebay oxygen diffusers), historical intake DO patterns were used to determine the air or oxygen supply required. Table 1 shows a range in O&M cost for these options that include the mean annual O&M and the worst case year O&M. Power loss costs were not part of the TVA scope in this investigation, so they were not included in Table 1.

Comparison of Important Characteristics

Each aeration system has unique features and characteristics other than cost that may make one system more desirable for installation at Bull Shoals than another. Table 2 is provided to assist in that evaluation by listing important issues that should be considered. For example, an aerating weir has the capability to provide a substantial minimum flow in the riverbed downstream of the project. Also, the options produce different seasonal DO patterns and therefore will elicit different biological responses in the tailwater. These biological responses are beyond the scope of this report, but they should be estimated as part of other investigations where TVA's bioenergetic model for tailwaters is being applied.

Power impacts (reduced capacity, efficiency loss, shifted energy) vary from one aeration option to the next. Qualitative comments on power impacts are provided in Table 2. Power impacts should be factored into aeration decisions as part of the broader rehabilitation investigation.

Table 1. Summary of Expected DO and Cost Estimates for Primary Aeration Options

Aeration Options	DO (mg/L)	Capital Cost	O&M Cost	Relevant Discharge (cfs)	Comments
Turbine Venting (existing units)	2.5	$152,000	$12,000	26,000 (instant.)	O&M is inspection, operation
Turbine Venting (modernized units)	4.0	$8,270,000	$12,000	26,000 (instant.)	O&M is inspection, operation
Forced Air	4.0	$4,227,000	$134,000 - $150,000	26,000 (instant.)	O&M range is mean - worst case
Forebay Diffuser (liquid O_2)	4.0	$1,860,000	$565,000 - $890,000	6,600 (24-hr avg.)	O&M range is mean - worst case
Forebay Diffuser (PSA)	4.0	$6,125,000	$250,000 - $412,000	6,600 (24-hr avg.)	O&M range is mean - worst case
Forced Air	6.0	$4,687,000	$179,000 - $198,000	26,000 (instant.)	O&M range is mean - worst case
Forebay Diffuser (liquid O_2)	6.0	$1,860,000	$1,254,000 - $1,735,000	6,600 (24-hr avg.)	O&M range is mean - worst case
Forebay Diffuser (PSA)	6.0	$6,125,000	$511,000 - $792,000	6,600 (24-hr avg.)	O&M range is mean - worst case
Infuser Weir	6+	$11,125,000	$26,000	28,000 (instant.)	O&M is inspection, cleaning
Labyrinth-Infuser Hybrid Weir	6.0	$14,955,000	$28,000	28,000 (instant.)	O&M is inspection, cleaning

Table 2. Important Characteristics of Primary Aeration Options

Characteristic	Turbine Venting	Forced Air Injection	Oxygen Injection (LO_x)	Oxygen Injection (PSA)	Aerating Weir
Reliability	High	O&M dependent.	O&M and LO_x vendor dependent.	O&M dependent.	High
Power Impacts	Efficiency and capacity loss during system operation.	Efficiency and capacity loss during system operation.	None	None	Increased tailwater level reduces plant capacity and energy generation.
O&M	Minimal	Standard compressor maintenance.	Requires constant attention.	We have no experience.	Passive; some clearing of debris from weir crest.
Safety Concerns	None	Minimal	Oxygen handling. Cryogenic temperatures.	Oxygen handling.	Attractive nuisance.
Flexibility for Varying DO Level	Low	Medium	High	High	Low
Minimum Flow Augmentation	No	No	No	No	Yes
Nitrogen Saturation Concern	Yes	Yes	No	No	No
Comments	Limited DO uptake. Higher DO at lower flows.	Requires space for blower and piping.	Increased DO in reservoir.	Increased DO in reservoir.	Aesthetically pleasing. Low DO in weir pool. DO benefit above target at low flows; year round benefit at no added cost. Location may impact existing spawning beds or sport fishing businesses.

Turbine Venting - Existing Units

Turbine venting is a low capital cost, low O&M cost option because of its passive aeration, ease of installation, and little maintenance other than routine inspection. Turbine venting success depends highly on plant operating conditions. Turbine venting offers an economical means for obtaining a significant increase in tailrace DO, but it cannot achieve either of the desired DO levels under discussion (4 mg/L, 6 mg/L). Turbine venting with existing units can achieve up to 2.5 mg/L at full gate (26,000 cfs).

The success of turbine venting depends on low pressures developed on the turbine hub and draft tube. This study focused on a venting option that reflects available aspiration potential at the relevant discharge, rather than producing a design for a target DO like 4 mg/L or 6 mg/L. Capital costs assume installation of hub baffles and air supply modifications at all eight units. O&M costs reflect valve and piping inspection and operation for the installed systems. To make these cost estimates consistent with all the other options, contractor profit was included, even though it is likely that the work would be performed in-house by the Corps.

Turbine Venting - Modernized Units

The turbines at Bull Shoals are good candidates for implementing auto-venting turbine (AVT) technologies in modernized units. Analyses show that new units should be capable of providing a DO in the powerhouse discharge of at least 4 mg/L. This is based on a flow of about 26,000 cfs and assumes three AVT technologies are furnished in each unit. For lower discharges (e.g., for single-unit operation), DO levels approaching 5 mg/L are achievable. In supplying AVT technologies for new units, a wide range of design factors and, consequently, potential air supply arrangements exist. If the air supply piping is properly sized, DO levels approaching 4 mg/L should be achievable with only two AVT technologies per unit. If the flow during the low DO season is held to less than 26,000 cfs, it may be desirable to provide AVT technology for only a few of the units. The large number of design factors, including the historical variation of reservoir DO and the expected operating conditions of the powerhouse, underscore the importance of performing detailed hydraulic and economic evaluations to obtain an optimal solution for the type and number of AVT technologies to be provided in new, modernized units.

Forced Air

The forced air option utilizes blowers to force air into the water passageways in the turbine. The system can be designed to provide air supply to meet almost any desired DO level. A degree of redundancy for equipment failure exists with this option because multiple blowers are required to meet maximum capacity, but they are not all in simultaneous use at lower flows. Special concerns for the forced air option include powerhouse space, maintenance of mechanical equipment, significant station service power requirements, noise, and potential for nitrogen supersaturation.

Capital costs in Table 1 reflect design of a blower system with capacity to aerate the full instantaneous turbine capacity (26,000 cfs) to the desired DO levels. O&M costs depend primarily on the power usage for the blowers, which in turn depends on the incoming DO. Mean and worst case power usage were derived from actual 1991-1995 DO conditions assuming average turbine usage of 6.6 hours per day at full capacity during the low DO season. The O&M costs in Table 1 reflect this range from mean year to worst case year. To minimize power usage and gas supersaturation, blower systems are normally operated precisely to meet a flat target DO in response to variable incoming DO. O&M costs in Table 1 do not include downstream monitoring, which would be desirable to provide feedback on the system to minimize energy costs.

Forebay Oxygen Diffuser

Forebay diffuser systems can be sized to provide almost any aeration requirement with a high oxygen transfer efficiency. Oxygen costs, however, escalate dramatically with each additional increment of aeration required from the system. Diffusers can be supplied with oxygen from either a bulk liquid oxygen (LO_X) storage tank or an onsite pressure swing adsorption (PSA) plant. Results of this study indicate that LO_X would be preferred for an aeration increment of +2 mg/L, while PSA would be more economical for an aeration increment of +4 mg/L. For +6 mg/L, use of both supply systems would be preferred.

Capital costs in Table 1 reflect design of a line diffuser with capacity to aerate a reservoir volume roughly equal to the average daily discharge at the project, rather than a design to aerate the instantaneous flow. O&M costs depend primarily on the oxygen usage, which in turn depends on the incoming DO. Mean and worst case oxygen usage were derived from historical DO conditions, and the O&M costs in Table 1 reflect this range. To minimize oxygen usage, forebay diffuser systems are normally operated precisely to meet a flat target DO in response to variable incoming DO. O&M costs in Table 1 do not include downstream monitoring, which would be desirable to provide feedback on the system to minimize oxygen usage.

Aerating Weir

Aerating weirs are capital intensive structures that are passive, reliable, and require low O&M. Weirs can achieve essentially any aeration level desired by varying the weir height. Weirs can achieve aeration and minimum flow objectives simultaneously. Deep tailwater depths for full turbine flow at Bull Shoals led to preliminary designs for structures that are essentially low dams (18 ft high) rather than weirs.

An infuser and a hybrid labyrinth-infuser were identified as feasible alternatives for the Bull Shoals tailwater. The infuser has a lower capital cost than the hybrid but will have a higher power loss due to its higher tailwater depth at the dam. Costs shown in Table 1 are for the weir structure and its design, and they do not include site exploration, physical modeling, roads, property acquisition, or additional earth embankments that may be needed.

Both the infuser and labyrinth-infuser hybrid weir alternatives can safely achieve DO targets of 4 mg/L or 6 mg/L. Costs are reported for a weir that achieves 6 mg/L. No significant cost savings would accrue from designing for a 4 mg/L DO level, because the weirs require clearance under the infuser decks sufficient to aerate full turbine capacity. This clearance is determined by tailwater elevation and not by desired DO level.

There are significant contrasts between weirs and the other aeration options. Weirs create a low DO weir pool upstream, so the length of enhanced tailwater is shorter than the other options. Weirs tend to be more permanent than the other options (except AVT). Thus, they induce a year-round power loss due to tailwater increase (if flashboards are not used), but they provide a year-round aeration benefit in excess of DO targets. In contrast, the "throttled" options, such as forced air and oxygen, are normally operated precisely to meet a flat target DO in response to variable incoming DO in order to minimize blower or oxygen usage. Also, weirs achieve significantly more aeration at the lower flows than at higher flows because lower weir tailwater increases the drop heights. Because they are designed to aerate to desired levels at full turbine capacity, they will provide aeration in excess of the DO target at all lower flows.

HDC Options

A submerged weir in the immediate tailrace, designed to produce aeration in a hydraulic jump, appeared to be technically feasible. The hydraulic jump from a submerged weir could produce an aeration increment of +1 mg/L to +2 mg/L DO. Although this is only a fraction of that produced by an aerating weir, the submerged weir was about a third as high and less than half as long as the least expensive aerating weir (infuser).

The regulating sleeve valve option could produce good aeration levels, but posed problems because of the number of valves required and because bypass piping and connections to the draft tube would be difficult. Also, significant releases would be required to bypass the turbines, and mixing of the aerated releases with unaerated turbine discharge would be a concern.

No reasonable draft tube alteration or other tailrace modifications were conceivable that could provide an attractive aeration option.

Combinations

The forced air, forebay oxygen diffuser, and aerating weir were the only options that could individually provide adequate aeration to meet 6 mg/L at full gate for eight-unit operation. All options except turbine venting for existing units could individually meet the 4 mg/L DO level. Combinations of options to meet either of these levels may prove attractive in the broader investigation.

DO levels obtainable with turbine venting are limited, so additional options would have to be applied to meet the desired DO levels. One attractive combination would be to use venting to supply a portion of the DO and a reservoir diffuser system to provide the rest as a "topping off" system to be used as needed in worst case years. Venting with existing units would provide 2 mg/L, and an additional 4 mg/L could be provided by a forebay diffuser with a PSA system.

To provide a DO level in the powerhouse discharge of 6 mg/L under all operating conditions, AVT in new units would need to be supplemented with other methods of aeration. Possible "topping off" options include forced air or a forebay oxygen diffuser system. To consider combining AVT with the forced air or aerating weir options, the effect of the latter on performance of the auto venting turbine would have to be evaluated. AVT with modernized units would perhaps be best combined with a 2 mg/L capacity forebay diffuser (LO_X) to provide a 6 mg/L desired level.

Forced air systems could be used in combination with forebay diffuser systems or tailrace weirs to meet desired tailrace DO levels. The difference in cost of a blower system designed for 4 mg/L is not much lower than one designed for 6 mg/L, due to the cost of piping, buildings, and other facilities required in addition to the blowers. The incremental cost savings of a reduced blower system to work in combination with another aeration option are therefore not likely to justify a combination system over a blower system adequate to do the aeration alone.

Oxygen systems for large flow projects like Bull Shoals are often most economical when used in combination with other aeration alternatives, due to the large oxygen supply required by an individual oxygen system to aerate large turbine discharges. Forebay diffuser systems are best used as "topping off" options in combination with another aeration technique used as a "base" aeration. Forebay diffusers in combination with tailrace weirs or with forced air systems are likely to be more expensive than systems sized to meet the DO requirements alone, because the incremental savings for weirs or forced air systems designed for use in combinations are not significant.

The expense of mobilization, cofferdam, and foundation development for a weir varies little with the weir height (i.e., ability to aerate). Accordingly, there is often no real cost incentive to build a lower weir for the reduced level of aeration that may be appropriate in combination with another aeration option. Thus, weirs are usually preferred as individual, stand-alone aeration systems, unless some system is desired to aerate the weir pool. The only use of a weir in a combination that may have merit for the Bull Shoals case is a submerged weir in the tailrace that provides 1 to 2 mg/L DO with turbine venting (existing units) for another 2.5 mg/L with perhaps a small forebay oxygen system for topping off in worst case years.

APPENDIX C

Excerpt from TVA Study of Norfork Aeration Options

File Copy

WR97-2-760-106

Darrell Bowman

NORFORK PROJECT AERATION OPTIONS

DRAFT

TVA

ENGINEERING LABORATORY
NORRIS, TENNESSEE 37828

EXECUTIVE SUMMARY

The Southwestern Power Administration (SWPA) is conducting an investigation of options to restore full power generation at Norfork Dam during the low dissolved oxygen (DO) season. Current operating policy requires that turbine output be limited in order to maintain a minimum of 4 mg/L DO in the turbine releases. As requested by SWPA, the Tennessee Valley Authority (TVA) is providing preliminary estimates of DO improvement and cost for various options to aerate turbine releases from Norfork Dam. The options included in this feasibility investigation were:

- Turbine venting (existing units)
- Forced air
- Forebay oxygen diffuser
- Aerating weir

Cost Comparison

The estimated capital cost and annual operation and maintenance (O&M) cost of the aeration options are summarized in Table 1. These are feasibility level cost estimates based on TVA experience in installing similar systems at TVA projects. The estimated costs shown in Table 1 and Figure 1 include direct costs, overheads, contractor profits, and contingencies. O&M costs evaluated for each technology reflect their unique operating characteristics. For the "throttled options" (forced air and forebay oxygen diffusers), historical intake DO patterns were used to determine the air or oxygen supply required. Table 1 and Figure 2 show the range in O&M costs for these options that include the mean annual O&M and the worst case year O&M. Power loss costs were not part of the TVA scope in this investigation, so they were not included in Table 1.

Comparison of Important Characteristics

Each aeration system has unique features and characteristics other than cost that may make one system more desirable than another for installation at Norfork. Table 2 is provided to assist in that evaluation by listing important issues that should be considered. For example, an aerating weir has the capability to provide a substantial minimum flow in the riverbed downstream of the project. Also, the options produce different seasonal DO patterns and therefore will elicit different biological responses in the tailwater. These biological responses are beyond the scope of this report, but they should be estimated as part of other investigations where TVA's bioenergetic model for tailwaters is being applied.

Power impacts (reduced capacity, efficiency loss, shifted energy) vary from one aeration option to the next. Qualitative comments on power impacts are provided in Table 2. Power impacts should be factored into aeration decisions as part of the broader rehabilitation investigation.

TABLE 1

Summary of Expected DO and Cost Estimates for Primary Aeration Options

Aeration Options	Minimum Expected DO[a] (mg/L)	Capital Cost	Annual O&M Cost[b]	Discharge (cfs)
Turbine Venting (existing units)	2.5	$100,000[a]	$10,000	6,200 (instant.)
Forced Air	4.0	$1,275,000	$56,000-$61,000	6,200 (instant.)
Forebay Diffuser (liquid O_2)	4.0	$1,281,000	$276,000-$386,000	2,000 (24-hr avg.)
Forebay Diffuser (PSA)	4.0	$3,745,000	$176,000-$236,000	2,000 (24-hr avg.)
Forced Air	6.0	$1,432,000	$68,000-$74,000	6,200 (instant.)
Forebay Diffuser (liquid O_2)	6.0	$1,459,000	$512,000-$659,000	2,000 (24-hr avg.)
Forebay Diffuser (PSA)	6.0	$4,986,000	$283,000-$360,000	2,000 (24-hr avg.)
Infuser Weir	6.0	$4,200,000	$28,000	6,200 (instant.)
Hybrid Labyrinth-Infuser Weir	6.0	$5,000,000	$28,000	6,200 (instant.)

[a]Modifications recommended by TVA have already been installed by USCOE. $100,000 is TVA's estimate of actual USCOE expenditures.
[b]Cost ranges denote mean case to worst case estimates, based on historical intake DO patterns.

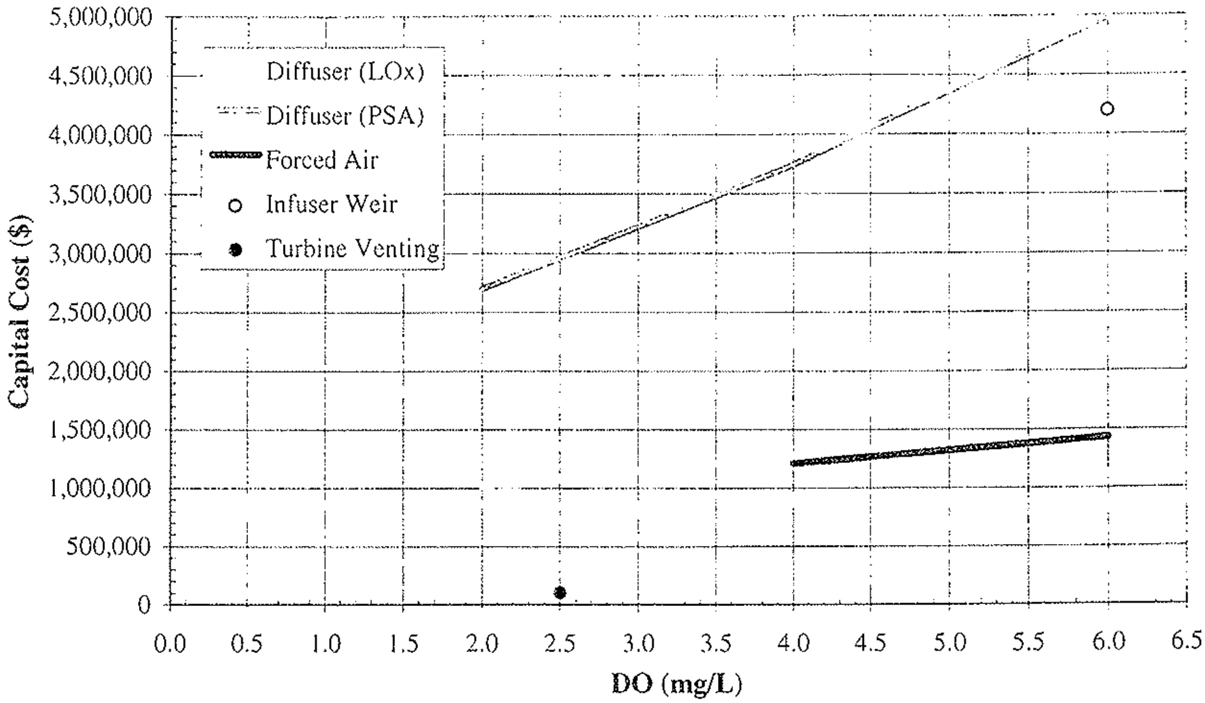


Figure 1. Summary of Capital Costs for Primary Aeration Options

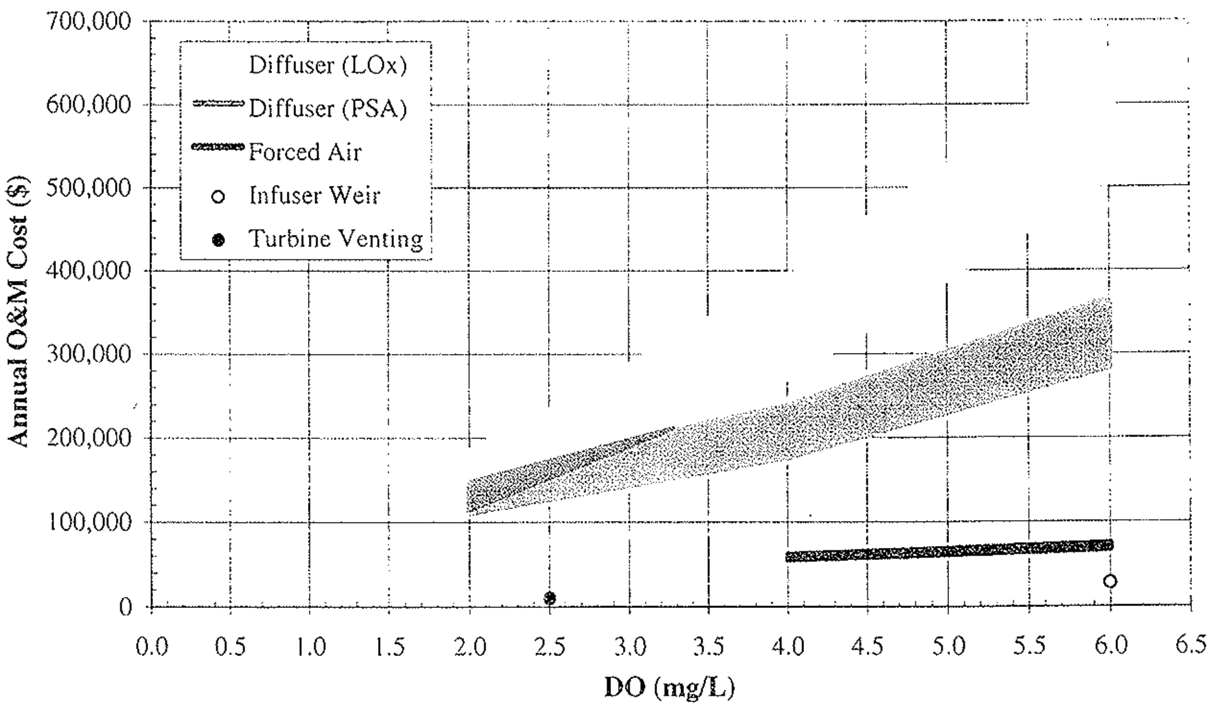


Figure 2. Summary of O&M Costs for Primary Aeration Options

TABLE 2

Important Characteristics of Primary Aeration Options

Characteristic	Turbine Venting	Forced Air Injection	Oxygen Injection (LO_x and PSA)		Aerating Weir
Reliability	High	O&M dependent	O&M and LO_x are vendor dependent	Complicated by large number of moving components	High
Power impacts	Efficiency and capacity loss during system operation	Efficiency and capacity loss during system operation	None	Cost of operating compressors	Increased tailwater level reduces plant capacity and energy generation
O&M	Minimal	Standard compressor maintenance	Requires constant attention during low DO season	Both	Passive; some clearing of debris from weir crest
Safety Concerns	Noise level, Strong Suction	Noise level, Rotating Machinery	Oxygen handling, and cryogenic temperatures	Moderate	Attractive nuisance
Flexibility for Varying DO Level	Low	Medium	High	High	Low
Minimum Flow Augmentation	No	No	No	No	Yes
Nitrogen Saturation Concern	Yes	Yes	No	No	No
Comments	Limited DO uptake. Higher DO at lower water flows.	Requires space for blower and piping. Station power required for operation.	Increased DO in reservoir. Could reduce anoxic products in releases.	Both	Aesthetically pleasing. Low DO in weir pool. DO benefit above target at low flows; year-round benefit at no added cost. Location may impact existing spawning beds or sport fishing businesses.

Turbine Venting - Existing Units

Turbine venting is a low capital cost, low O&M cost option because of its passive aeration, ease of installation, and low maintenance other than routine inspection. Turbine venting success depends highly on plant operating conditions. Turbine venting offers an economical means for obtaining a significant increase in tailrace DO, but it cannot achieve either of the desired DO levels under discussion (4 mg/L or 6 mg/L). Turbine venting with existing units is estimated to achieve a minimum DO in the discharge of 2.5 mg/L at full wicket gate opening (6,200 cfs).

The success of turbine venting depends on low pressures developed on the turbine hub and draft tube. This study focused on a venting option that utilizes available aspiration potential at the relevant discharge, rather than producing a design for a target DO of 4 mg/L or 6 mg/L. Capital costs assume installation of hub baffles and air supply modifications for both units. O&M costs reflect valve and piping inspection and operation for the installed systems. To make these cost estimates consistent with all the other options, contractor profit was included, even though the work has already been performed by the USCOE.

Special concerns for turbine venting applications are the obtainable DO limit, noise, and effect on turbine power generation efficiency.

Forced Air

The forced air option utilizes blowers to force air into the water passageways in the turbine. The system can be designed to provide an air supply to meet almost any desired DO level. A degree of redundancy for equipment failure exists with this option because multiple blowers are required to meet maximum discharge capacity, but they are not all in simultaneous use at lower flows. Special concerns for the forced air option include space availability in or near the powerhouse, maintenance of mechanical equipment, significant station service power requirements, noise, potential for nitrogen supersaturation, and effect on turbine power generation efficiency.

Capital costs in Table 1 reflect the design of a blower system with the capacity to aerate the full instantaneous turbine flow (6,200 cfs) to the desired DO levels. O&M costs depend primarily on the power usage for the blowers, which in turn depends on the incoming DO. Mean and worst case power usage were derived from actual 1991 to 1996 DO conditions, assuming average weekday turbine usage of 7.5 hours per day at 6,200 cfs during the low DO season. The O&M costs in Table 1 reflect this range from mean year to worst case year. To minimize power usage and gas supersaturation, blower systems are normally operated precisely to meet a flat target DO in response to variable incoming DO. O&M costs in Table 1 do not include downstream monitoring, which would be desirable to provide feedback on the system to minimize energy costs.

Forebay Oxygen Diffuser

Forebay diffuser systems can be sized to provide almost any aeration requirement with a high oxygen transfer efficiency. Oxygen costs, however, escalate dramatically with each additional increment of aeration required from the system. Diffusers can be supplied with oxygen from either a bulk liquid oxygen (LO_X) storage tank or an onsite pressure swing adsorption (PSA) plant. Results of this study indicate that LO_X would be less expensive for an aeration increment of +2 mg/L, while a PSA may be justified for greater aeration increments.

Capital costs in Table 1 reflect the design of a line diffuser with the capacity to aerate a reservoir volume roughly equal to the average daily discharge at the project, rather than a design to aerate the instantaneous flow. O&M costs depend primarily on the oxygen usage, which in turn depends on the incoming DO. Mean and worst case oxygen usage were derived from historical DO conditions, and the O&M costs in Table 1 reflect this range. To minimize oxygen usage, forebay diffuser systems are normally operated precisely to meet a flat target DO in response to variable incoming DO. O&M costs in Table 1 do not include downstream monitoring, which would be desirable to provide feedback on the system to minimize oxygen usage.

Aerating Weir

Aerating weirs are capital intensive structures that are passive, reliable, and require low O&M. Weirs can achieve essentially any desired aeration level by varying the weir height. Weirs can also achieve aeration and minimum flow objectives simultaneously.

An infuser and a hybrid labyrinth-infuser were identified as feasible alternatives for the Norfork tailwater. The infuser has a lower capital cost than the hybrid, but will have a higher power loss due to its higher tailwater depth at the dam. Costs shown in Table 1 are for the weir structure and its design, and they do not include site exploration, physical modeling, roads, property acquisition, or additional earth embankments that may be needed.

Both the infuser and hybrid labyrinth-infuser weir alternatives can safely achieve DO targets of 4 mg/L or 6 mg/L. Costs are reported for a weir that achieves 6 mg/L. No significant cost savings would accrue from designing for a 4 mg/L DO uptake, because the weir requires clearance under the infuser decks sufficient to aerate full turbine capacity. The height of the weir is determined by the tailwater depth of the weir and the aeration target.

Combinations

A combination of aeration systems may provide a more desirable solution than utilizing a single system. Combinations typically have one option providing "base" aeration and a second option considered as a "topping" system. TVA experience at several projects has shown that the combination of two or more aeration systems provides more flexibility and reliability, and often decreases operating costs compared to a single aeration system. Combinations are not necessarily more expensive to implement than a single aeration system.

Turbine venting, forced air, and forebay oxygen diffuser systems are good candidates for use in combination systems. Aerating weirs are not usually preferred as part of a combination system. This is because the installation cost does not vary significantly as the design aeration capacity of the weir changes (a 6 mg/L weir costs about the same as a 4 mg/L weir). Thus, weirs were usually preferred as individual, stand-alone aeration systems, unless a system is required to aerate the weir pool.

Turbine venting and forebay oxygen diffuser systems provide a viable combination for Norfork. Testing of the turbine venting modifications performed by TVA, at Norfork, indicate a DO uptake of about 2.5 mg/L when incoming DO is almost zero. A forebay oxygen diffuser system could be designed to provide the balance of the DO uptake requirement.

Forced air and forebay oxygen diffuser systems could not be used in combination at Norfork. This combination would not be able to utilize the full capability of the existing turbine venting system installed at Norfork, because the turbine venting and forced air systems cannot be used concurrently.

TENNESSEE VALLEY AUTHORITY
River System Operations & Environment
River Operations

Norfork Dam
House Unit Forced Air Evaluation

WR2001-2-760-135

Prepared by
James C. Carter, Jr.

Norris, Tennessee

February 2001

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

Page

LIST OF TABLES

NORFORK DAM HOUSE UNIT FORCED AIR EVALUATION

BACKGROUND

Norfork Dam is located on the North Fork of the White River in north central Arkansas and is operated by the United States Army Corps of Engineers (COE), Little Rock District. The Southwestern Power Administration (SWPA) markets power generated at Norfork Dam, and water releases are generally made for power generation. The Norfork National Fish Hatchery (NNFH), managed by the United States Fish and Wildlife Service (USFWS), is located immediately downstream of Norfork Dam. The Arkansas Game and Fish Commission (AGFC) manages the trout fishery in the Norfork River below Norfork Dam. During summer and fall when only the house unit is operating, low dissolved oxygen (DO) levels occur in both the water supplied to the NNFH and in the Norfork Dam tailrace. The low DO levels may be improved by injecting air into the house unit discharge. The Tennessee Valley Authority was requested by SWPA and AGFC to evaluate forced air injection to improve the house unit release DO during these periods.

The evaluation consisted of connecting station service air to the house unit spiral case and operating the unit at various wicket gate openings to determine oxygen transfer characteristics in order to estimate potential DO improvements. This report presents the results of the forced air study performed at Norfork Dam in September 2000.

TEST DESCRIPTION

The forced air tests performed on the Norfork house unit are similar to index tests where the unit is tested at various wicket gate openings. Compressed air was supplied to the spiral case in varying amounts to increase DO levels in the unit discharge. Measurements of environmental and mechanical performance were made using station instrumentation and a computerized data collection system with electronic sensors. During these tests, only the house unit was operating.

Mechanical performance measurements included compressed air flow, wicket gate opening, headwater and tailwater elevations, unit discharge, and power. Environmental performance measurements included spiral case DO and temperature; tailrace DO, temperature, and total dissolved gas (TDG); and forebay DO, temperature, and sample depth.

Compressed Air Flow

Prior to testing, the plant staff fabricated a flow metering/distribution chamber (Figure 1). Air hoses were used to connect the flow chamber to the air supply and existing pressure gauge connections on the unit. Air flow was metered by measuring the differential pressure across the orifice plate installed in the flow chamber.

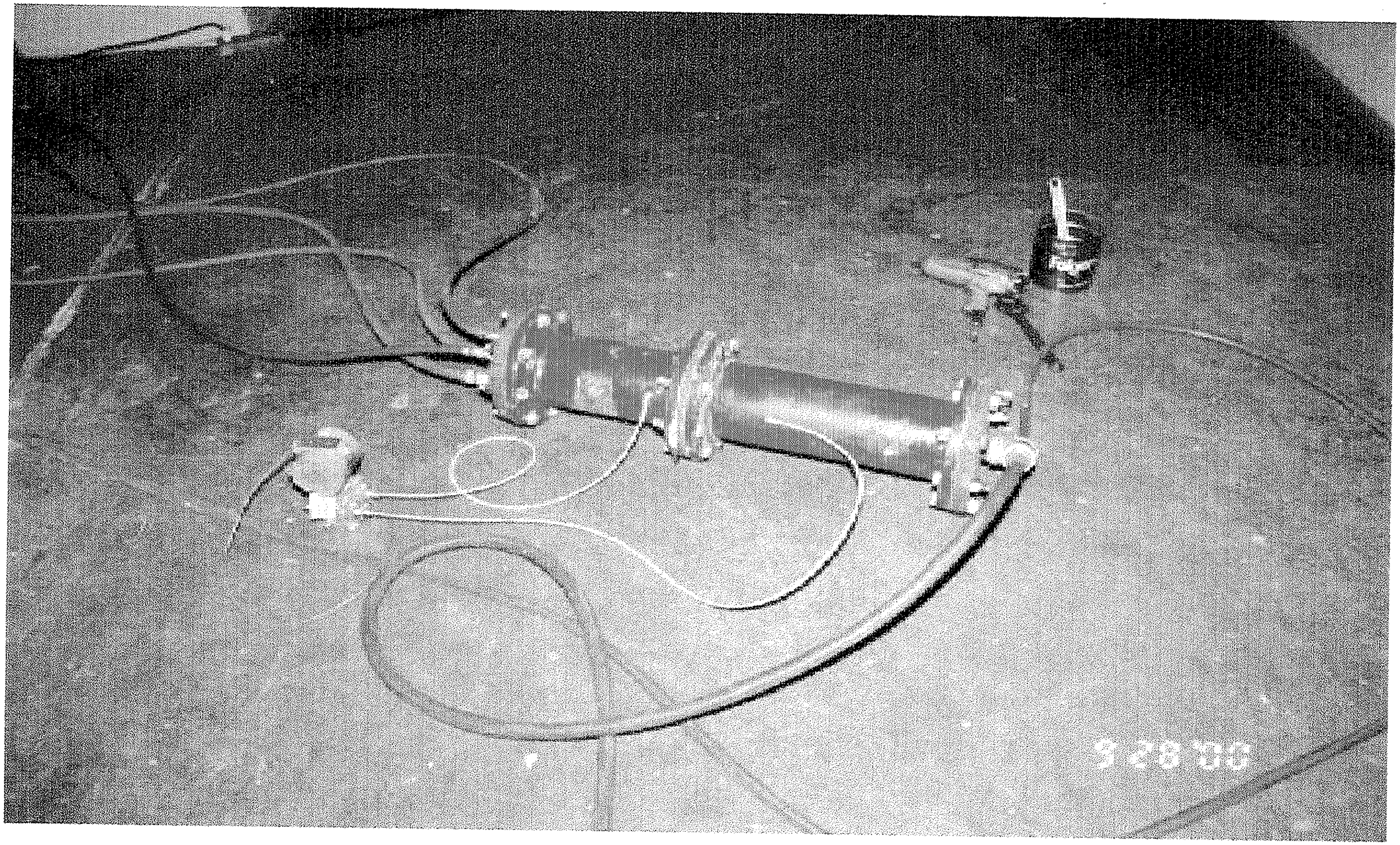


Figure 1. Air Flow Metering/Distribution Center - Norfork Dam House Unit

Wicket Gate Position

Wicket gate position was measured with a slide-wire type precision potentiometer attached to the gate servomotor linkage at the unit governor. The gate position was calibrated at zero percent and ninety percent open.

Head

Gross head is the difference between the headwater and tailwater elevations. Headwater and tailwater elevation readings were recorded from the plant control room instrumentation.

Discharge

Discharge was measured using the clamp-on ultrasonic flow meter shown in Figure 2. Also, discharge was measured using the R2 and R4 Winter-Kennedy (W-K) piezometer taps located in the spiral case. Differential pressure readings between these two taps provide a relative index measurement of the discharge.

Power

Power measurements were made using a power transducer connected to the unit potential transformer and current transformer circuits. Exciter volts, amps, and VARs were read in the control room.

Dissolved Oxygen

DO and temperature measurements were made using calibrated DO probes. The incoming DO probe was connected to the penstock just downstream of the penstock isolation valve. Forebay profiles were made by the United States Geological Services (USGS) staff using a similar DO probe. The exiting DO probe was located in the unit discharge (Figure 3) near the draft tube outlet.

Total Dissolved Gas

TDG refers to the percent saturation of nitrogen, oxygen, and argon. This parameter is important because nitrogen supersaturation can result where air is injected to improve DO levels. At Norfork, TDG was measured by the DO probe located in the unit discharge.

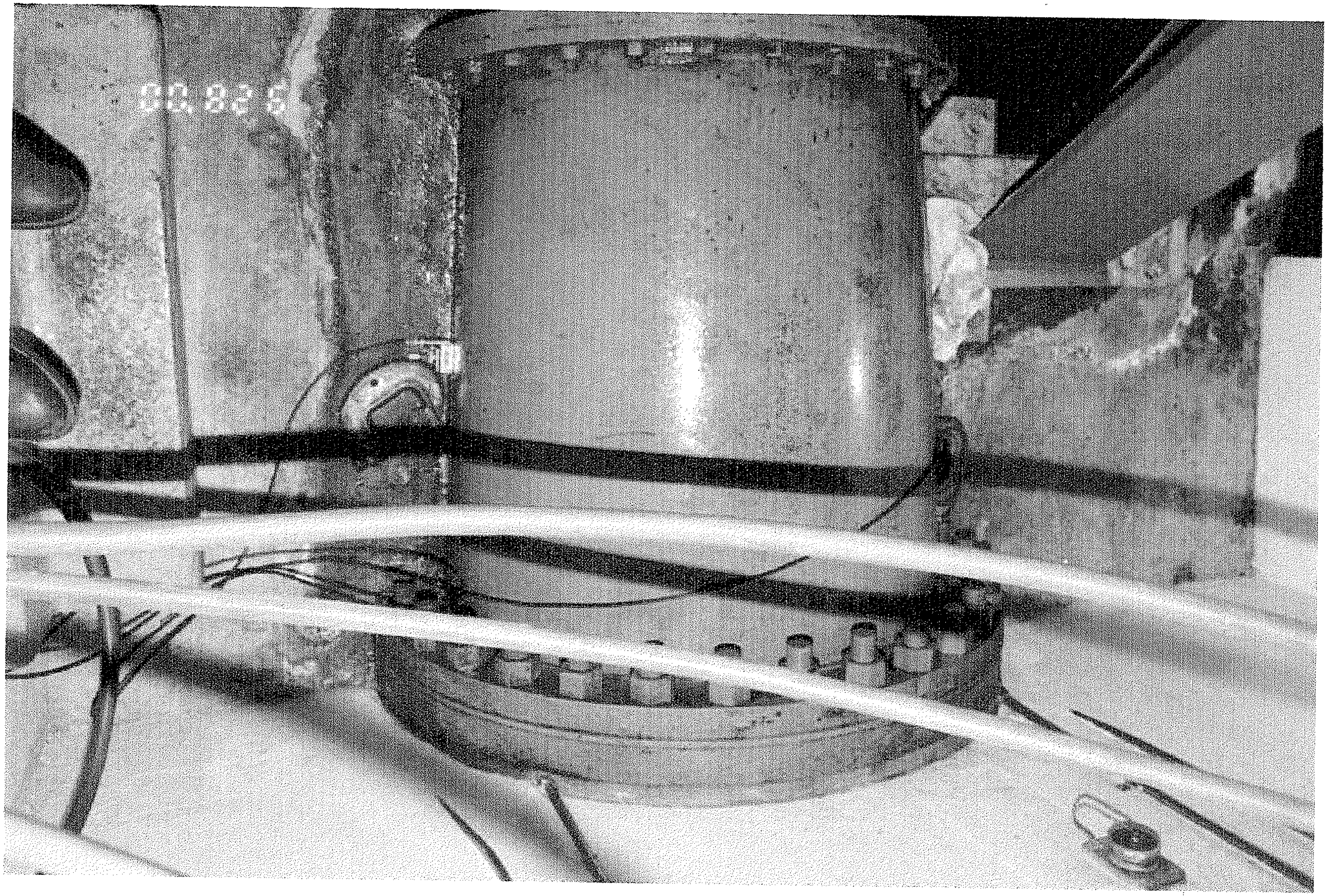


Figure 2. Ultrasonic Flow Metering of Norfork House Unit Discharge

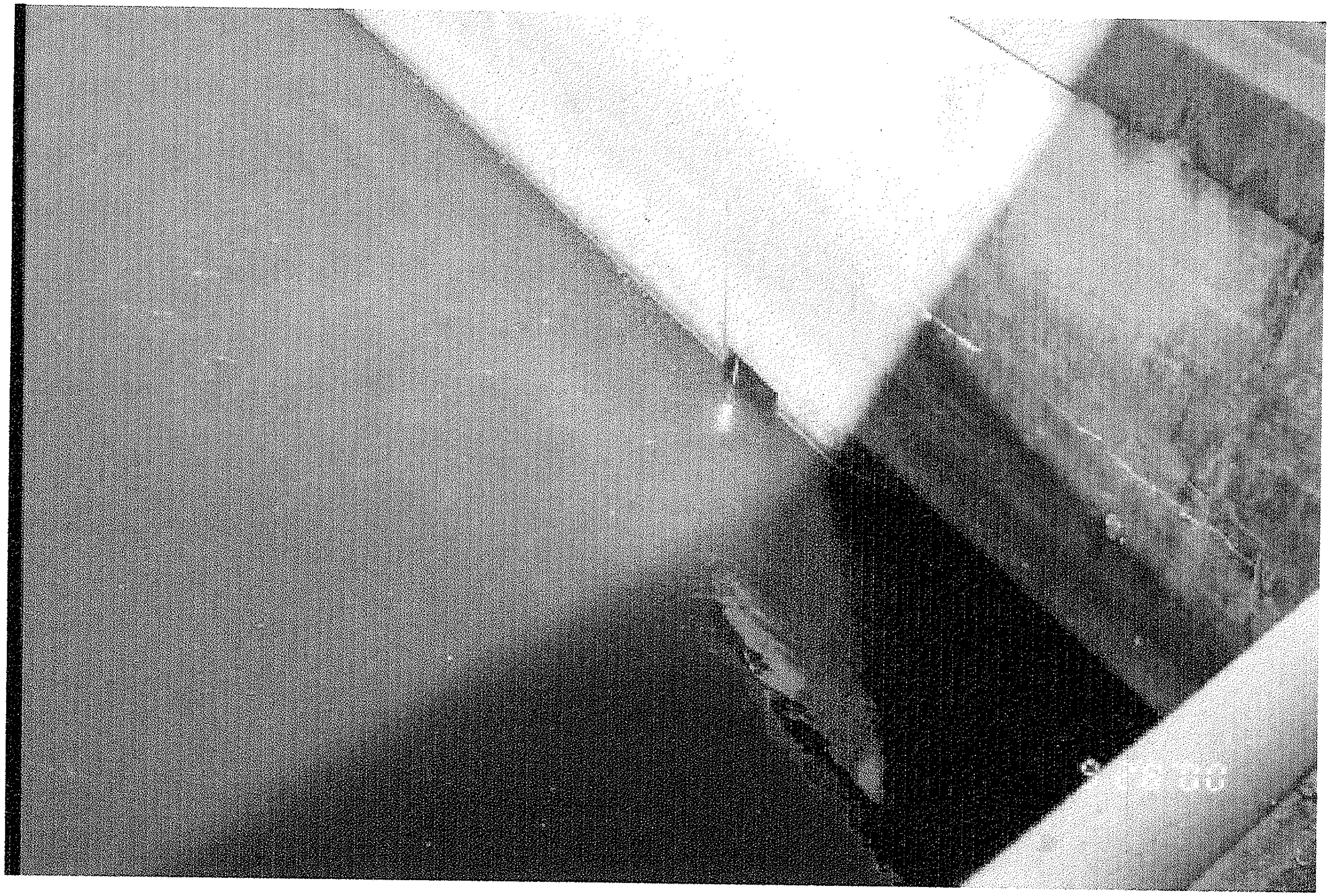


Figure 3. Tailrace Dissolved Oxygen Instrument Location - Norfork Dam House Unit

DISCUSSION OF TEST RESULTS

Summaries of the data obtained during the September 2000 tests are included in Table 1. Expected DO levels for various house unit operating conditions are presented in Table 2. Air flow, unit efficiency, and DO relationships are presented in graphical form (Figures 4, 5, and 8) and discussed below.

Mechanical Performance

Mechanical performance includes those parameters that show the effect of air flow on unit efficiency and turbine operation. At Norfork, the house unit discharge, power, and head were measured so that efficiencies with air injection could be compared to normal operating efficiencies.

Discharge

Because the W-K taps had never been calibrated, discharge was measured using a clamp-on ultrasonic-type flowmeter in addition to measuring the W-K differential pressures. Unfortunately, the only place to locate the clamp-on flowmeter was on the spiral case-to-penstock transition. Since diameters are different at each end of the transition, an average area was assumed for the flow computations. Review of the W-K data and the clamp-on flow meter data found that neither the ultrasonic flow meter nor the W-K differential method was able to provide consistent results.

Because the discharge could not be measured directly, model data obtained from the COE was used to estimate the house unit discharge for various power levels. These discharge estimates are the values used for computation of unit efficiency and oxygen transfer efficiency.

Unit Efficiency

Unit efficiencies were calculated using estimated discharge values corrected to a common gross head of 173 feet. The unit efficiencies calculated for the single-unit tests are shown in Table 1 and on Figure 4 for various power levels. Because the discharge was estimated and the power levels of the house unit are small compared to the main units, it is difficult to calculate the change in unit efficiency with an accuracy better than two to three percent.

Environmental Performance

Environmental performance consists of parameters that show the amount of DO improvement. At Norfork, forebay DO and temperature, spiral case DO and temperature, and tailrace DO and temperature were measured so that oxygen transfer efficiencies could be estimated. Tailrace

TABLE 1

Data Summary - Norfork Dam House Unit Test of September 28, 2000

Run No.	Wicket Gate (% open)	Headwater Elevation (feet)	Tailwater Elevation (feet)	Gross Head (feet)	W-K DP (in. wc)	Estimated Discharge (cfs)	Measured Power (kW)	Power Corrected to 173' (kW)	Efficiency (%)	Measured Air Flow (scfs)	DO Scroll Case (mg/L)	DO Tailrace (mg/L)	TDG Tailrace (%)	Comments
1	n.a.	546.30	373.2	173.07	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	(1)
2	89.2	546.30	373.3	173.05	52.17	55.0	698	698	86.9	0.18	0.04	1.23	91.1	(1)
3	15.0	546.30	373.3	173.02	-0.32	n.a.	(29)	(29)	n.a.	0.25	0.03	0.87	90.1	(1)
4	15.0	546.30	373.3	173.02	-0.32	n.a.	(26)	(26)	n.a.	0.86	9.48	6.48	121.4	(2)
5	15.0	546.30	373.3	173.04	-0.32	n.a.	(22)	(22)	n.a.	1.14	9.63	7.18	126.1	(3)
6	24.6	546.30	373.3	173.05	-0.32	5.5	28	28	34.8	0.00	9.71	1.02	93.7	(1)
7	24.6	546.30	373.2	173.08	-0.24	6.5	34	34	35.5	0.91	7.43	5.42	120.2	(2)
9	33.9	546.30	373.2	173.08	5.64	15.0	115	115	52.5	0.00	8.00	1.07	97.3	(1)
10	34.1	546.30	373.2	173.08	9.54	17.0	137	137	55.1	0.89	7.94	3.56	99.0	(2)
12	43.5	546.30	373.2	173.08	8.46	21.5	193	193	61.3	0.00	7.80	1.01	92.1	(1)
13	43.6	546.30	373.2	173.08	7.04	21.5	208	207	65.9	0.91	5.94	3.18	93.7	(2)
14	52.5	546.30	373.2	173.08	15.08	30.0	304	304	69.3	0.00	5.67	0.79	89.7	(1)
15	52.7	546.30	373.2	173.08	15.13	30.1	316	315	71.6	0.91	5.66	2.44	94.8	(2)
16	61.5	546.30	373.2	173.07	23.06	38.0	423	423	76.2	0.00	5.63	1.08	92.7	(1)
17	62.2	546.30	373.2	173.07	22.96	38.5	426	426	75.8	0.90	5.61	2.26	94.6	(2)
18	71.4	546.30	373.3	173.04	32.60	44.5	530	529	81.4	0.00	5.59	1.34	93.0	(1)
19	71.3	546.30	373.3	173.04	31.73	44.4	524	524	80.8	0.91	5.61	2.01	93.8	(2)
20	80.3	546.30	373.3	173.03	43.49	50.0	620	620	84.9	0.00	5.56	1.35	92.6	(1)
21	80.3	546.30	373.3	173.03	42.76	50.0	620	619	84.8	0.93	5.55	2.00	93.8	(2)
22	90.0	546.30	373.3	173.02	51.85	54.5	699	699	87.7	0.00	5.54	1.61	93.4	(1)
23	89.8	546.30	373.3	173.02	48.30	54.4	698	698	87.8	0.88	5.53	2.02	93.6	(2)
24	33.4	546.30	373.3	173.00	13.49	17.0	136	136	54.7	0.00	5.53	2.06	93.9	(1)
25	33.8	546.30	373.3	172.99	1.89	18.5	150	150	55.6	0.42	5.51	n.a.	n.a.	(2)
26	43.6	546.30	373.3	172.99	13.23	21.5	192	192	61.2	0.00	5.53	1.35	91.9	(1)
27	43.7	546.30	373.3	173.01	4.72	21.5	206	206	65.4	0.42	0.04	2.00	94.4	(2)
28	33.7	546.30	373.3	173.02	12.35	18.5	148	148	54.6	0.00	0.02	1.41	94.5	(1)
29	33.9	546.30	373.3	173.02	1.84	18.6	160	160	58.9	n.a.	0.02	n.a.	n.a.	(2)

Notes: (1) Air Valves Closed; (2) Two Air Valves Open; (3) Four Air Valves Open

TABLE 2

Expected DO Levels During Periods of Non-Power Generation - Norfork Dam

Norfork Tailrace				DO in = 0.1 mg/L	
Discharge cfs	Forced Air scfs	Qleak cfs	DOleak mg/L	DO out mg/L	
20	0.4	0	0.1	2.1	Normal discharge, 2% air, Zero leakage
20	0.4	25	0.1	1.0	Normal discharge, 2% air, 25 cfs leakage
20	0.4	50	0.1	0.7	Normal discharge, 2% air, 50 cfs leakage
20	0.4	75	0.1	0.5	Normal discharge, 2% air, 75 cfs leakage
20	0.4	100	0.1	0.4	Normal discharge, 2% air, 100 cfs leakage
20	0.8	100	0.1	0.6	Normal discharge, 4% air, 100 cfs leakage
20	1.2	100	0.1	0.7	Normal discharge, 6% air, 100 cfs leakage
20	2.0	100	0.1	0.9	Normal discharge, 10% air, 100 cfs leakage
40	0.8	100	0.1	0.7	Increased discharge, 2% air, 100 cfs leakage
40	1.6	100	0.1	0.9	Increased discharge, 4% air, 100 cfs leakage
40	2.4	100	0.1	1.1	Increased discharge, 6% air, 100 cfs leakage
40	4.0	100	0.1	1.5	Increased discharge, 10% air, 100 cfs leakage

ND 1.8

ID 3.0

61
120

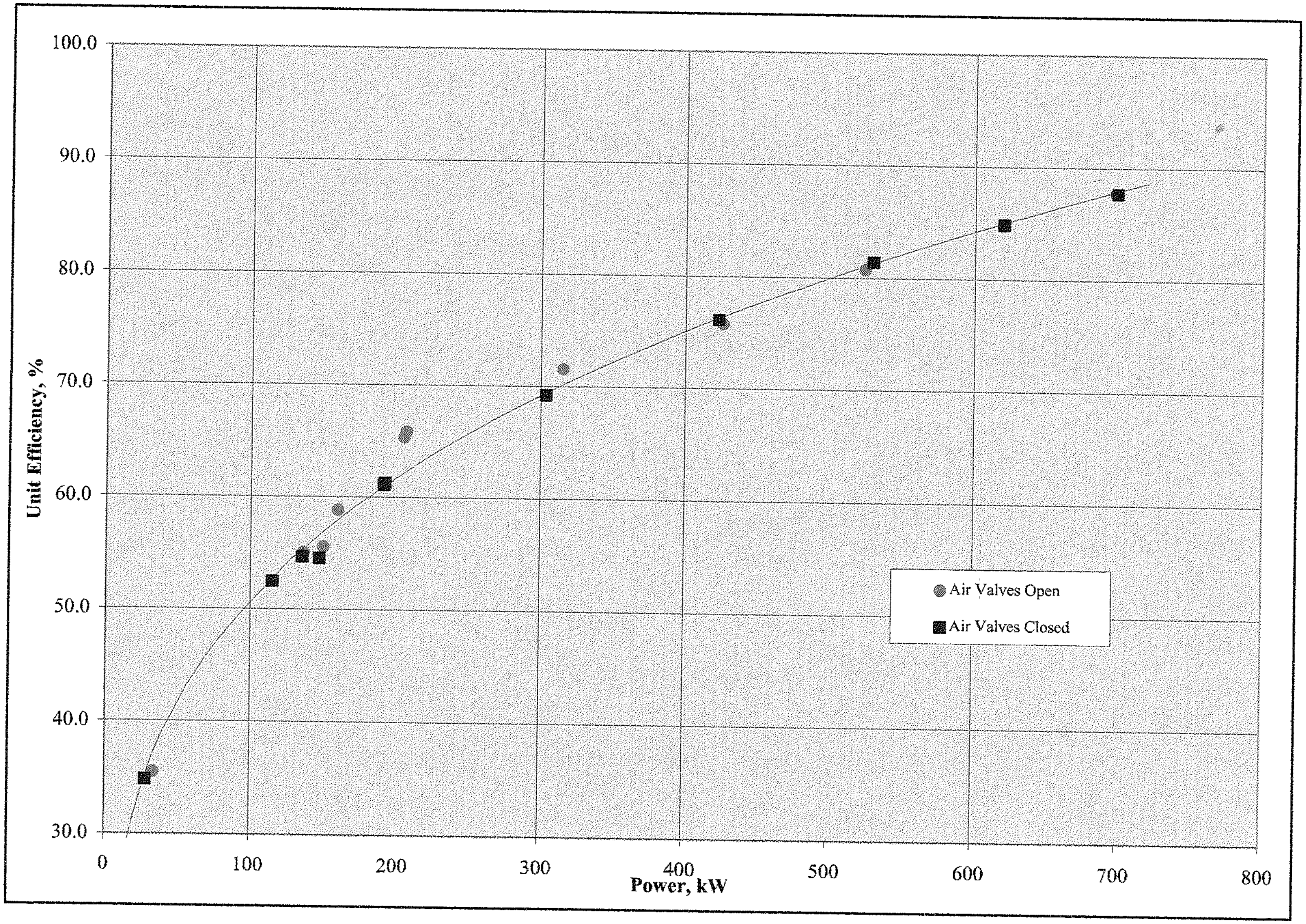


Figure 4. Unit Efficiency - Norfork Dam House Unit

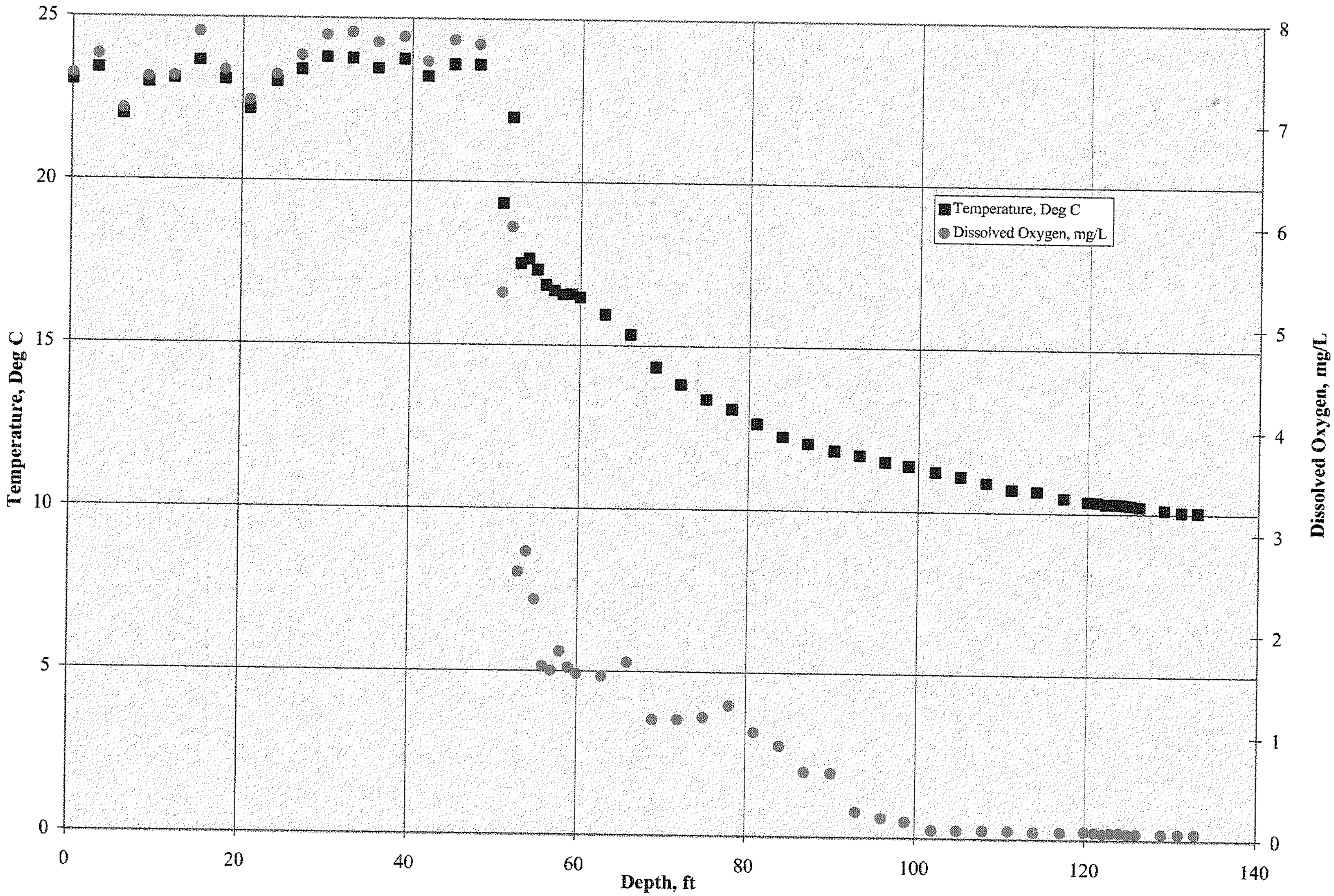


Figure 5. Norfork Dam Forebay Profile, September 28, 2000

TDG levels and the amount of air flow injected were also measured to determine the DO improvement limits for forced air injection.

Forebay DO and Temperature

Profiles of the forebay DO and temperature were made by the United States Geological Services (USGS) staff and are shown on Figure 5. At the house unit intake depth of 123 feet, the DO was about 0.07 mg/L. The forebay profiles were used to calculate oxygen transfer efficiency and DO improvement.

Spiral Case DO and Temperature

Spiral case DO and temperature were measured just upstream of the penstock isolation valve. The data is listed in Table 1, but does not appear to be representative of the incoming DO. The spiral case DO values are significantly higher than the forebay DO values due to the accumulation of air in the penstock. Air could be heard in the penstock at the isolation valve location during these tests.

Tailrace DO and Temperature

Tailrace DO and temperature were measured at the house unit draft tube exit. The DO instrument was suspended by rope from the wing wall to a depth of about 3 feet. Some of the disparity in the tailrace DO data shown in Table 1 is due to the instrument being relocated further away from the draft tube exit between test runs 17 and 18. During test run 2, the amount of air injected was so great that the house unit discharge appeared "milky" looking, as shown in Figure 6. This was due to the large quantity of air and the subsequently small bubble size. As the amount of discharge increased and the amount of air injected decreased, the house unit discharge looked typical of turbine venting aeration methods (Figure 7).

Tailrace TDG

Tailrace TDG data, listed in Table 1, was measured by the same instrument used to measure tailrace DO and temperature. As with the tailrace DO and temperature, there are some discrepancies due to relocating the instrument during the test. The highest TDG levels occurred during test runs 4 and 5, while the unit was operating at very low discharge and maximum injection air. The injection air flow was regulated during the remaining test runs to minimize the amount of air lost up the unit penstock. During the remaining runs, TDG levels were within acceptable limits.

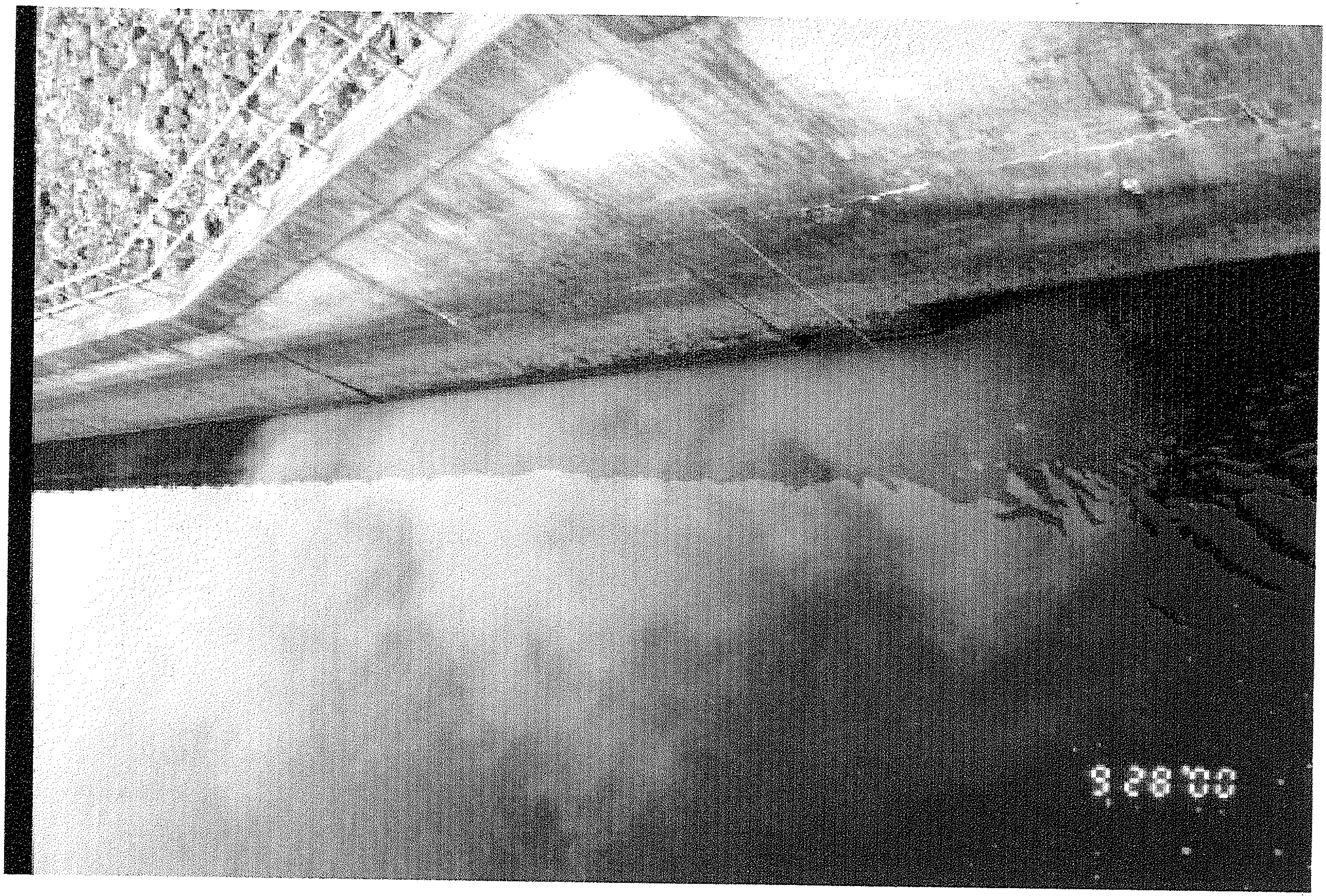


Figure 6. Norfork Dam House Unit Tailrace with Air Injection at Low Discharge Conditions

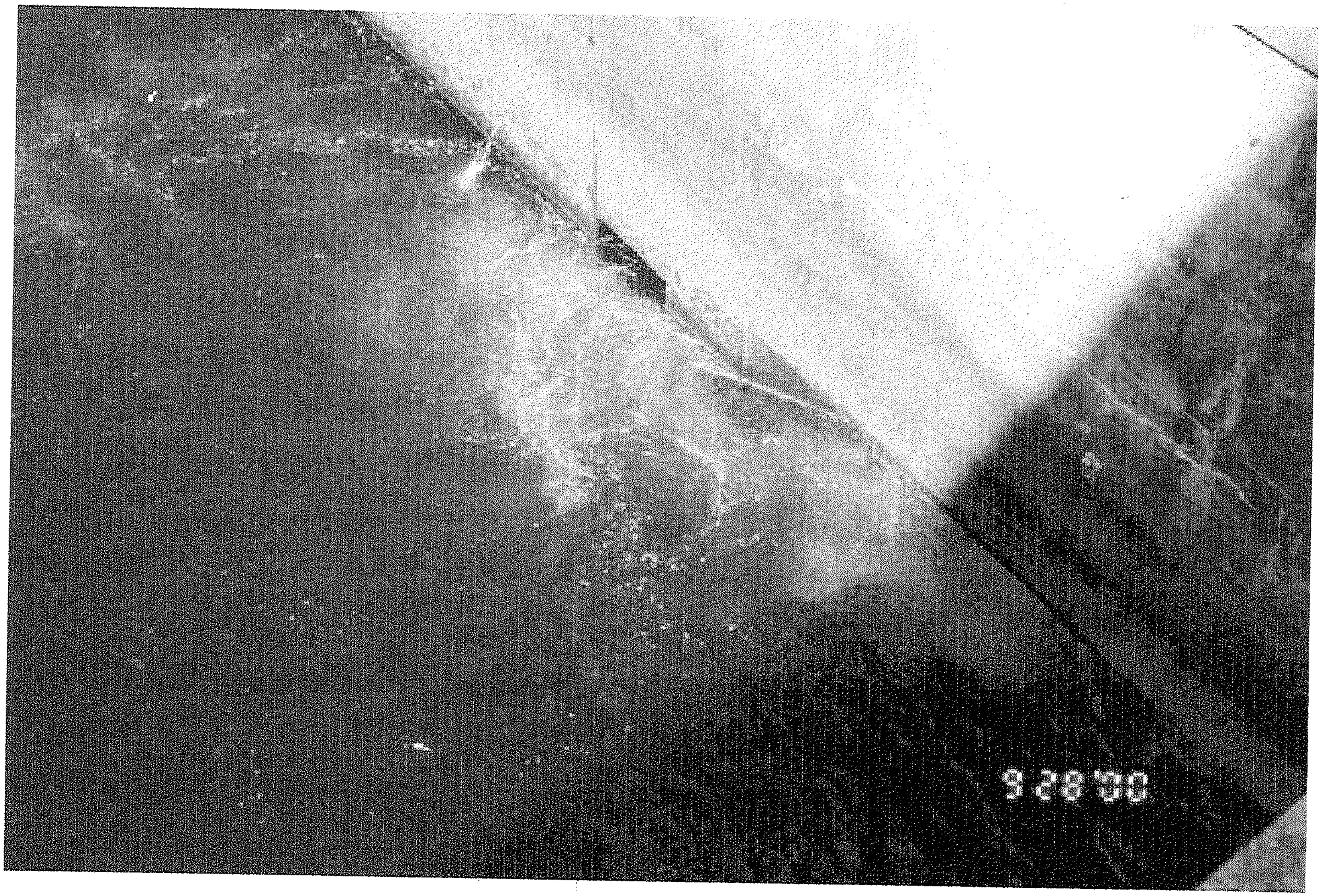


Figure 7. Norfork Dam House Unit Tailrace with Air Injection at Normal Discharge Conditions

Air Flow

Air flow was supplied by the station air compressors using rubber hoses and a distribution header. Hoses were routed from the distribution header to each of the four spiral case pressure taps where the air was injected. The amount of air injected was measured using a square-edged orifice plate installed in the distribution header shown in Figure 1.

Oxygen Transfer Efficiency and DO Improvement

Oxygen transfer efficiency describes the ability of the oxygen in the air injected to improve the amount of oxygen in the discharge. Transfer efficiency is directly proportional to the air/water flow ratio, Qa/Qw, and the residence time for the discharge in the draft tube and tailwater. The oxygen transfer efficiencies shown on Figure 8 were calculated using the data listed in Table 1 and the forebay DO and temperatures.

CONCLUSIONS

The data obtained indicate that air injected into the house unit spiral case does improve DO levels in the unit discharge. The amount of DO improvement depends on the amount of discharge and the quantity of air injected. By improving the house unit DO discharge levels, the DO in the total flow from Norfork Dam can also be improved to some degree.

Total flow from Norfork Dam consists of the house unit discharge, main unit wicket gate leakage, and structure leakage from various locations in the dam. Based on wicket gate clearance measurements, the main unit wicket gate leakage was calculated to be about 20 cfs for both units. The DO level is estimated to be about 0.1 mg/L. Structure leakage is estimated to be about 80 cfs total, with a DO level of about 0.1 mg/L. Structure leakage could be lower, or higher, but without a direct measurement, it is difficult to refine the estimated 80 cfs. Using the test discharge, 100 cfs of leakage and the corresponding DO levels, the expected DO levels shown in Table 2 were computed. The total flow of 100 cfs is the tailrace pool flow, prior to mixing with the fish hatchery outflow. To illustrate the significance of the total leakage on expected DO level, flows of 25, 50, and 75 cfs are included in Table 2 for comparison to the 100 cfs values.

Assuming no leakage at the main unit or structure, and the normal house unit discharge of 20 cfs, with 0.4 scfs (2 percent) of air injected, the discharge DO level could be expected to be 2 mg/L. However, normal leakage is 100 cfs (main units 20 cfs and structure 80 cfs), so if the 20 cfs from the house unit were injected with 0.4 scfs (2 percent) of air, the discharge DO level would be expected to be no greater than 0.4 mg/L.

Various amounts of injection air for various discharge levels along with the expected DO levels are shown in Table 2. The best DO improvement expected for normal house unit discharge conditions is about 1 mg/L. Increasing the house unit discharge to 40 cfs could result in DO levels of 1.5 mg/L.

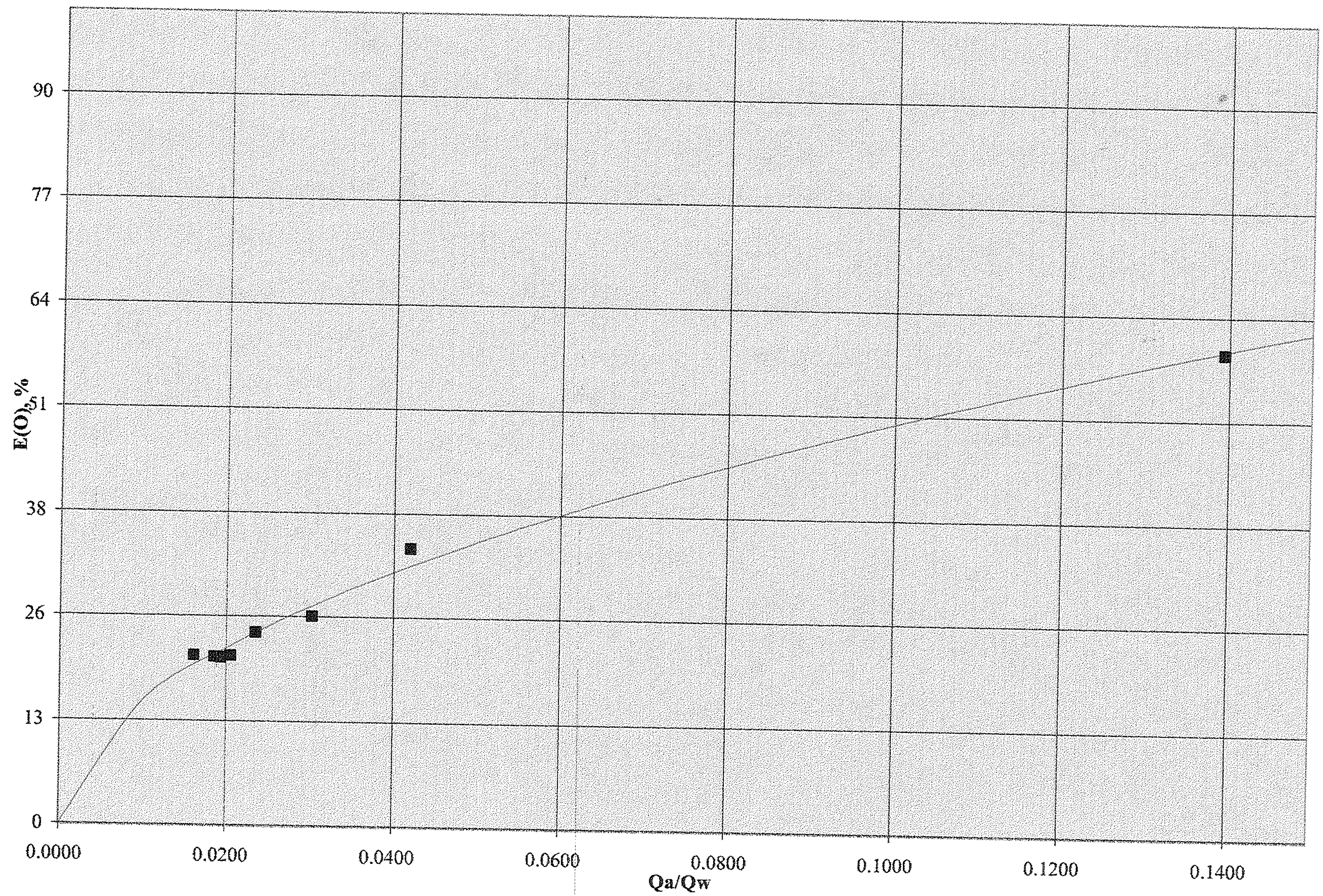


Figure 8. Norfork Dam House Unit Oxygen Transfer Efficiency

It is recommended that the structure leakage be verified by downstream measurement of the tailrace flow.

APPENDIX D

AGFC Report Describing Implementation of Paddlewheel Aerator

Potential for a Mechanical Aeration System for Zero Generation Periods Below Norfork Dam

Stan Todd
Assistant Trout Biologist
Arkansas Game & Fish Commission

March 13, 2003

AGFC Trout Management Program
Report# TP-03-03

Water discharged from Bull Shoals and Norfork Dams from June through December is often low in dissolved oxygen (DO). The U.S. Corps of Engineers (COE) and Southwestern Power Administration (SWPA) have modified flood control and hydropower operations to increase DO in hydropower water releases. The COE and SWPA attempt to reduce impacts to the fishery by placing loading restrictions on the generators during low DO periods in an effort to increase the efficiency of aeration systems and keep DO levels above 4 ppm. During the brown trout spawn and periods of zero generation, the main units are pulsed to provide some DO above that from base flows. These efforts have been somewhat successful and have raised DO from as low as 0.2 ppm previously to around 3.5 ppm. No attempts have been made to increase DO in leakage or in releases from house generators and DO in water releases at base flows remain low and are often below 1 ppm.

Trout behavior changes in response to low DO (Stark and Bowman 1995). Trout are less active, locate themselves in areas with the highest DO content, and feed less (Weithman and Hass 1984) and generally will avoid areas with DO levels less than 5 ppm (May, 1973). Digestion is slowed, reducing food conversion efficiencies and growth (Mekhanic 1957, Yeager 1987, Young 1987) and continued exposure to stressors like low DO increases susceptibility to disease (Snicsko 1974). Doudoroff and Shumway (1970) showed that swimming speed and growth declined with declining DO and that large fluctuations in DO result in slowed feeding and impaired growth. Although trout may survive DO levels only slightly above lethal levels, they must make various physiological changes that affect other aspects of health (Randal and Smith 1967). Trout require significantly higher DO levels during spawning periods (Beamish 1964, Liao 1971). The lowest DO conditions below Norfork Dam typically coincide with the brown trout spawning period (Pender 1998) and could reduce spawning success. Summer low DO periods could also reduce the success of other species attempting to incubate eggs or rear fry.

Between 1996 and 1998, a study was performed on the Norfork Tailwater to determine if seasonal low DO conditions below Norfork Dam impacted the health of brown and brook trout (Todd and Bly 2000). The study showed that seasonal low DO levels in water discharges from Norfork Dam reduced health (normality) and feeding of brown and brook trout. A health assessment performed during the low DO period below Bull Shoals and Norfork dams in 2002 showed that health of rainbow, brown, and brook trout below both dams was similar to that found during the low DO period in the 1996-98 study (Todd, et al. 2003). The condition of trout below Bull Shoals and Norfork dams is in part a function of the water quality that they are exposed to both during hydropower releases and base flows.

The Clean Water Act requires the U.S. Environmental Protection Agency (EPA) to develop and publish criteria for water quality accurately reflecting the latest scientific knowledge (U.S. EPA 1986, 2002). The EPA recommends a 30-day average daily mean DO of 6.5 ppm and a 7-day average daily minimum of 5.0 ppm to prevent chronic effects and a 1-day minimum of 4.0 ppm to prevent acute effects to juvenile and adult trout (Table 1). The EPA currently recommends a 7-day average daily mean DO of 9.5 ppm and a 1-day minimum of 8.0 ppm to protect embryonic and larval trout to 30 days post emergence

(Table 1). The U.S. EPA also lists a quantitative level of effect for salmonids and invertebrates that they feed upon (U.S. EPA 1986). The EPA recognizes impairments to trout at DO concentrations below 9 ppm for embryonic and larval trout and 6 ppm for other life stages and severe impairments to embryonic and larval trout below 7 ppm DO and 4 ppm for other life stages (Table 2). The limits to avoid acute mortality are listed as 6 ppm DO for embryonic and larval trout and 3 ppm for other life stages (Table 2). Invertebrates that trout feed upon are recognized as being detrimentally effected below 5 ppm DO (Table 2). Based on these recommendations the State has set water quality standards for coldwater at 6.0 ppm.

Dissolved oxygen in Norfork Dam discharges declined steadily from June through September and then improved from November through December (Figure 1). Daily variation in DO was a high as 8 ppm and primarily dependant on discharge (Figure 1). Minimum DO levels recommended by the U.S EPA to prevent impacts to the aquatic environment were violated frequently (Figures 2-5). The 30-day average daily mean DO (previous 30 days) dropped below the recommended value (6.5 ppm) on 125 days between August 1 and November 31 (Figure 2). The 7-day average daily mean DO (previous 7 days) dropped below the recommended minimum (9.5 ppm) on 63 days between October 15 and December 31 (Figure 3). The 7-day minimum daily mean DO (previous 7 days) dropped below the recommended value (5.0 ppm) on 101 days between August 1 and November 31 (Figure 4). The daily minimum DO dropped below the recommended value for juvenile and adult trout (4.0 ppm) on 81 days between August 1 and November 31 and below the recommended value for embryonic and larval trout (8.0 ppm) on 58 days between October 15 and December 31 (Figure 5). Additionally, DO dropped below State water quality standards (6.0 ppm) on 139 days between July 1 and November 31 (Figure 5).

Based on the EPA's estimates of the level of effect, adult trout were slightly impaired on 30 days, moderately impaired on 28 days, severely impaired on 30 days and subject to possible acute mortality on 51 days from July through December 2002. Embryonic and larval trout were slightly impaired on 3 days, moderately impaired on 9 days, severely impaired on 4 days, and subject to possible acute mortality on 45 days between the estimated beginning of spawning on October 15 through December 31. Aquatic invertebrates that trout utilize as food were impaired on 28 days and subject to acute mortality on 81 days during the 2002 low DO season.

Although DO in hydropower releases have been improved, DO remains below what is required to support trout health and sometimes is below potentially lethal levels. Further improvements are needed, especially to un-aerated leakage and house unit releases.

In September 2000, a forced air aeration system was tested on the Norfork Dam house generator to determine the potential for DO improvements to the 20 cfs station service flows (Carter 2001). The best oxygen transfer rates were obtained at normal flows (20 cfs) and resulted in a 2 ppm increase in DO in the house unit discharge; however, DO in leakage was not aerated and reduced the effectiveness of the system. On June 8, 2001, the U.S Geological Survey (USGS) measured leakage and station service flows at 61.6 cfs. Using the results of the 2000 test and the USGS estimate, a forced air system for the house unit at Norfork Dam could increase DO in water releases at base flow only about 0.5 ppm.

A mechanical aerator placed in the tailrace and operated at base flows would treat both house unit flow and leakage and has the potential to improve DO levels for trout. A mechanical aerator in the tailrace could possibly reduce levels of some highly reactive substances such as hydrogen sulfide or reduce nitrogen super saturation but would probably not reduce concentrations of manganese in discharges from Norfork Dam that require a long contact time to oxidize. A mechanical aerator may be unable to operate under hydropower flows due to wave action and uneven loading. However a relay system could be constructed to only operate an aerator at base flows. Using the USGS estimate of base flows (61.6 cfs), 13.8 lbs/hour of oxygen is needed to provide an increase of 1 ppm DO. Paddlewheel aerators produced by House Manufacturing can transfer 3.2 lbs of oxygen/hour/HP and a 15 HP unit could transfer 48 lbs per hour and potentially boost Norfork base flows (61.6 cfs) 3.4 ppm DO. A second unit could potentially boost base flows at Norfork Dam to the current State standard (6 ppm). Aeration at base flows could reduce the need for pulsing of main units during off-peak hours during the summer low DO season.

We are recommending that the COE investigate the potential for mechanical aeration to further improve water quality (dissolved oxygen) below Norfork Dam. If this is not feasible, we recommend investigating any alternatives to improve water quality in station service and leakage flows to State standards.

Mike,
Stan is proposing a low cost, possible solution to low dissolved oxygen (D.O.) in the Norfork tailwater during periods of one generation. The cost of the paddlewheel plus installation is approximately $6,4000 and could potentially increase the D.O. by as much as 3 ppm and 2 units could possibly raise D.O.'s to 6 ppm (state standards).

This proposal was presented to the COE and SWPA for their comment and input in 2003. It has set in draft form awaiting comments from both parties. The COE reported at the November 2004 Dissolved Oxygen Committee meeting, they have made no movement on the paddlewheel aeration system that we proposed to improve D.O. at non-generation in Norfork tailwater. However, SWPA wants to work with AGFC to get the paddlewheel(s) installed before next low D.O. season.

In light of this cooperative gesture by SWPA, we would like to pursue the paddlewheel aeration system. I request approval for the trout program personnel to work with the local COE folks and SWPA and see if we can get one paddlewheel installed before next fall.

Melissa Jones

References

Beamish, F.W.H. 1964. Seasonal changes in the standard rate of oxygen consumption of fishes, Can. J. Zool. 42:189-194.

Carter, J.C. 2001. Norfork Dam house unit forced air evaluation. Tennessee Valley Authority, River System Operations & Environment, River Operations. WR2001-2-760-135, 16pp.

Doudoroff, P., and D. L. Shumway. 1970. Dissolved oxygen requirements of freshwater fishes. FAO Fish. Tech. Pap. 86. 291 pp.

Laio, P.R. 1971. Water requirements of salmonids. Prog. Fish Cult. 33:210-215.

Mekhanic, F.Y. 1956. The effect of oxygen concentration in water on the growth and nitrogen exchange in rainbow trout. Rybnow Khozyajstvo 33:74-75.

May, B. E. 1973. Seasonal depth distribution of rainbow trout (Salmo gairdneri) in Lake Powell. Proc. Utah Acad. Sci. Arts and Letters 50:64-72.

Pender, D.R. 1998. Factors influencing brown trout reproductive success in Ozark tailwater rivers. M.S. thesis, Univ. Ark., Fayetteville. 146pp.

Randall, D. J., and J. C. Smith. 1967. The regulation of cardiac activity in fish in a hypoxic environment. Physiol. Zool. 40:104-113.

Snicsko, S.F. 1974. The effects of environmental stress on outbreaks of infectious diseases of fishes. J. Fish Biol. 6:197-208.

Stark, J. and D. Bowman. 1995. Movement of resident trout in the Bull Shoals Tailwater in response to differing levels of dissolved oxygen and spawning. Proj. Rep., Ark. Game and Fish Comm. 21pp.

Todd, C.S. and T.R. Bly. 2000. Health and condition of trout in the Norfork Tailwater, Arkansas, following hypoxic periods. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 54:157-166.

Todd, C.S., J. Stein and D. Bowman. 2003. 2002 Bull Shoals and Norfork Tailwaters Trout Health Assessment. Arkansas Game and Fish Commission, Trout Program Report #TP-02-03. 13pp.

Weithman, A.S. and M.A Hass. 1980. Effects of varying levels of dissolved oxygen on the trout fishery in Lake Taneycomo, Missouri. Mo. Dep. Conserv., Fish and Wildl. Res.Ctr., U.S. Army Corps of Engineers, Little Rock Dist., Contract No. DACW03-78-C-007. 148pp.

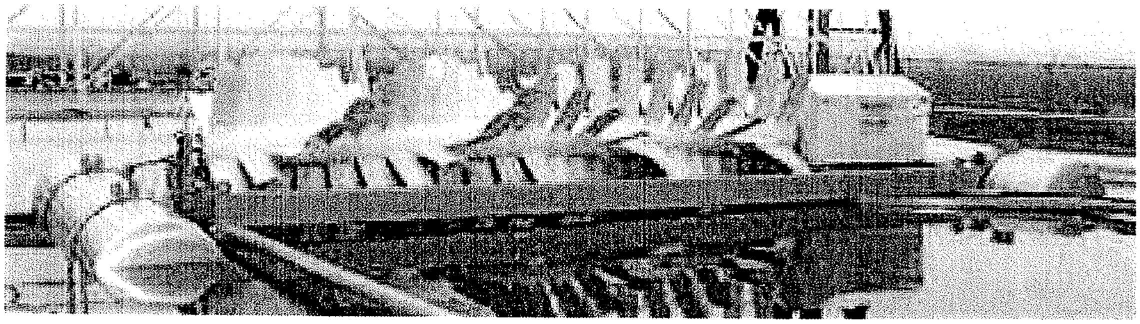
Yeager, B.L., W.M. Seawell, C.M. Alexander, D.M. Hill, and R. Wallus. 1987. Effects of aeration and minimum flow enhancement on the biota of Norris Tailwater. Tech. Rep., Tenn. Valley Authority, Off. Nat. Resour. And Econ. Devel. TVA/ONRED/AWR 87/41 90pp.

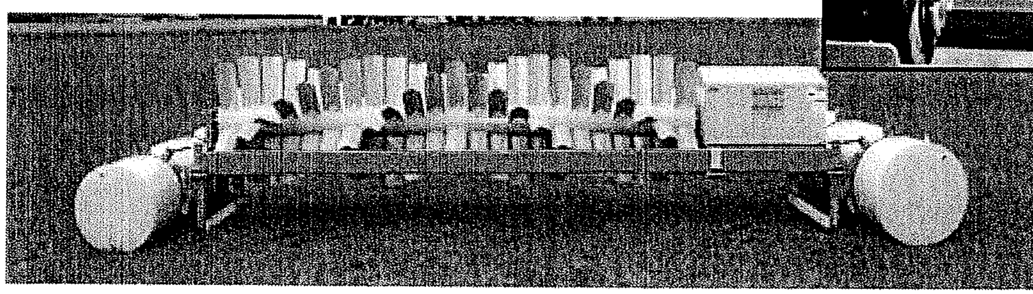
Young, R.C. 1987 Response of rainbow trout to variable dissolved oxygen regimes. Tenn. Valley Authority, Off. Nat. Resour. And Econ. Devel. TVA/ONRED/AWR 87/40 39pp.

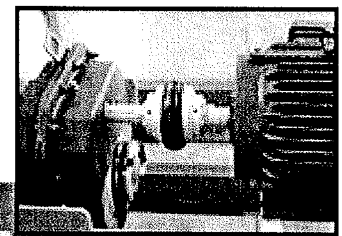
Raleigh, R. F., L. D. Zuckerman, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.124). 65 pp. (First printed as: FWS/OBS-82/10.71, September 1984-J.)

U.S. EPA. 1986. Quality criteria for water. U.S. Environmental Protection Agency Office of Water Regulations Standards. EPA-600/3-77-001. 477p.

U.S. EPA. 2002. National Recommended Water Quality Criteria: 2002. U.S. Environmental Protection Agency Office of Science and Technology. EPA-822-R-02-047. 33 pp.







House Manufacturing Company, Inc.
Chad House, Sales
Barry House, Mechanical Engineer
1-800-327-8299
www.housemfg.com

15HP 3-phase 460/480V 16.5A	$5250.00
15" rotor length approximately 4' diameter	
can use 220V	
starter required	
single phase protection recommended	
maintenance – annual oil change	
estimated oxygen transfer rate 48 lbs/hour (3.2 lbs/hr/HP)	
freight	$150.00
estimated installation cost	$1000.00
Estimated total cost	$6400.00

Table 1. Water quality criteria for ambient dissolved oxygen concentration (US EPA, 1986).

	Coldwater Criteria		Warmwater Criteria	
	Early Life Stages [1,2]	Other Life Stages	Early Life Stages [2]	Other Life Stages
30 Day Mean	NA [3]	6.5	NA	5.5
7 Day Mean	9.5 (6.5)	NA	6.0	NA
7 Day Mean Minimum	NA	5.0	NA	4.0
1 Day Minimum [4,5]	8.0 (5.0)	4.0	5.0	3.0

1 These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. The 3 mg/L differential is discussed in the criteria document. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

2 Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching.

3 NA (not applicable).

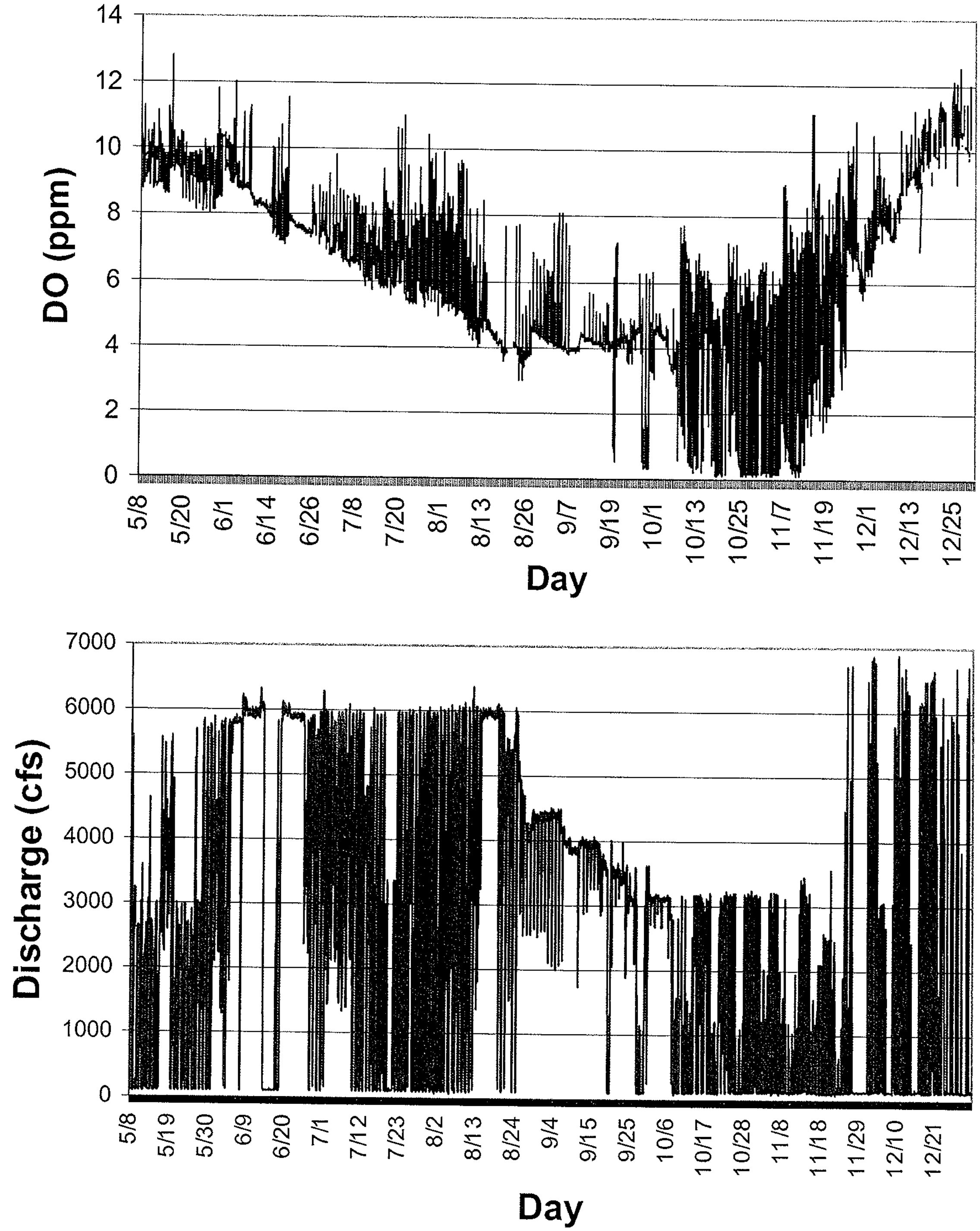
4 For highly manipulatable discharges, further restrictions apply.

5 All minima should be considered as instantaneous concentrations to be achieved at all times.

Table 2. Dissolved Oxygen Concentrations (mg/L) Versus Quantitative Level of Effect (US EPA, 1986).

1. Salmonid Waters		
a. Embryo and Larval Stages		
No Production Impairment	11*	(8)
Slight Production Impairment	9 *	(6)
Moderate Production Impairment	8 *	(5)
Severe Production Impairment	7 *	(4)
Limit to Avoid Acute Mortality	6 *	(3)
(* Note: These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. The 3 mg/L difference is discussed in the criteria document.)		
b. Other Life Stages		
No Production Impairment	8	
Light Production Impairment	6	
Moderate Production Impairment	5	
Severe Production Impairment	4	
Limit to Avoid Acute Mortality	3	
2. Nonsalmonid Waters		
a. Early Life Stages		
No Production Impairment	6.5	
Slight Production Impairment	5.5	
Moderate Production Impairment	5	
Severe Production Impairment	4.5	
Limit to Avoid Acute Mortality	4	
b. Other Life Stages		
No Production Impairment	6	
Slight Production Impairment	5	
Moderate Production Impairment	4	
Severe Production Impairment	3.5	
Limit to Avoid Acute Mortality	3	
3. Invertebrates		
No Production Impairment	8	
Some Production Impairment	5	
Acute Mortality Limit	4	

Figure 1. DO gauge readings and discharge from Norfork Dam between May 8, 2002 and December 31, 2002.



Draft

Figure 2. 30-day average daily mean DO (previous 30 days) in discharge from Norfork Dam from June 6, 2002 to December 31, 2002 and the U.S. EPA recommended minimum level (US EPA, 1986, 2002).

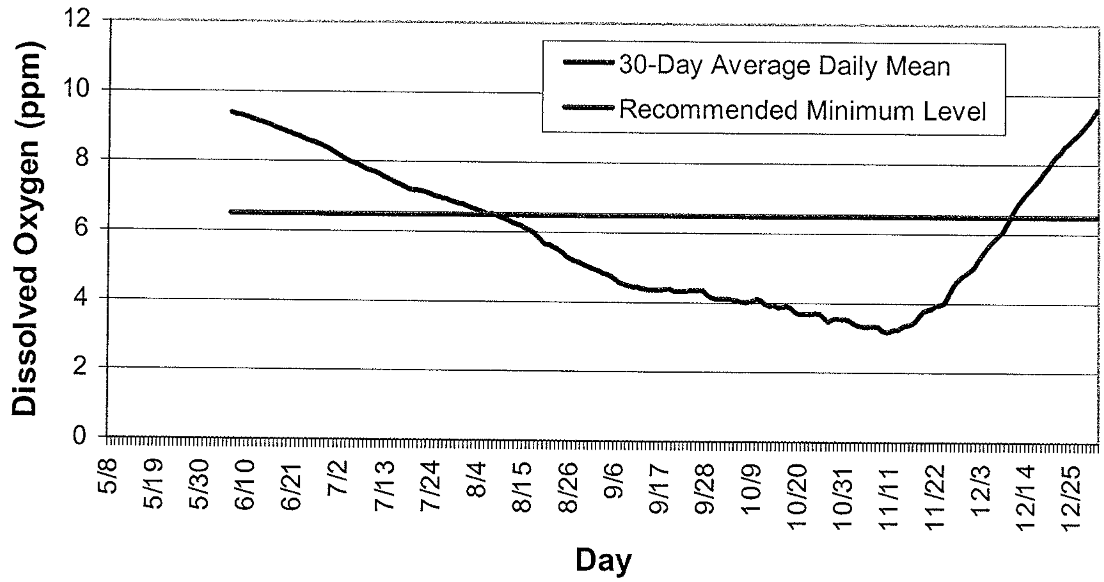


Figure 3. 7-day average daily mean DO (previous 7 days) in discharge from Norfork Dam from May 14, 2002 to December 31, 2002 and the U.S. EPA recommended minimum level (US EPA, 1986, 2002).

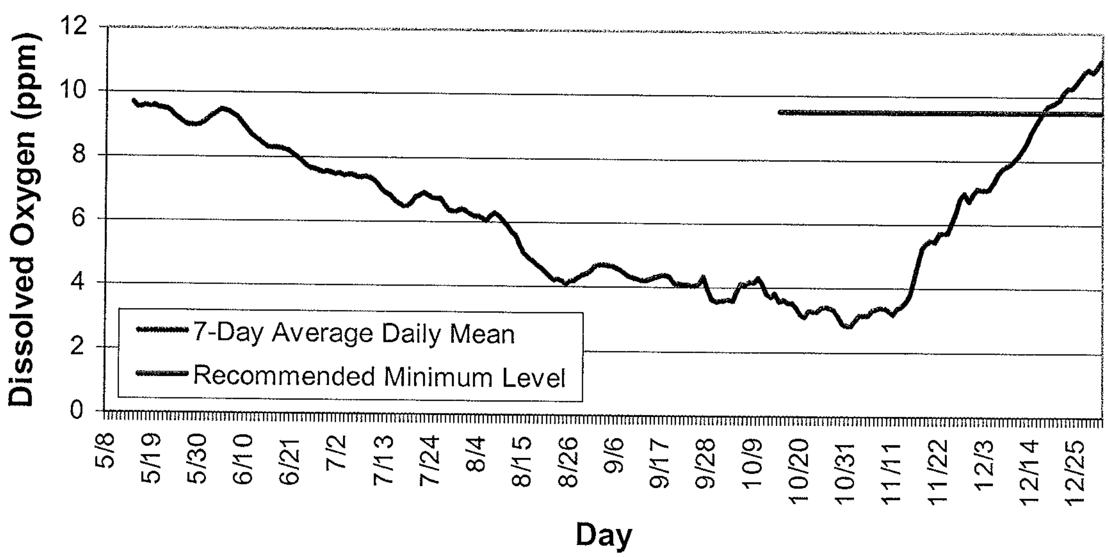


Figure 4. 7-day minimum daily mean DO (previous 7 days) in discharge from Norfork Dam from May 14, 2002 to December 31, 2002 and the U.S. EPA recommended minimum level (US EPA, 1986, 2002).

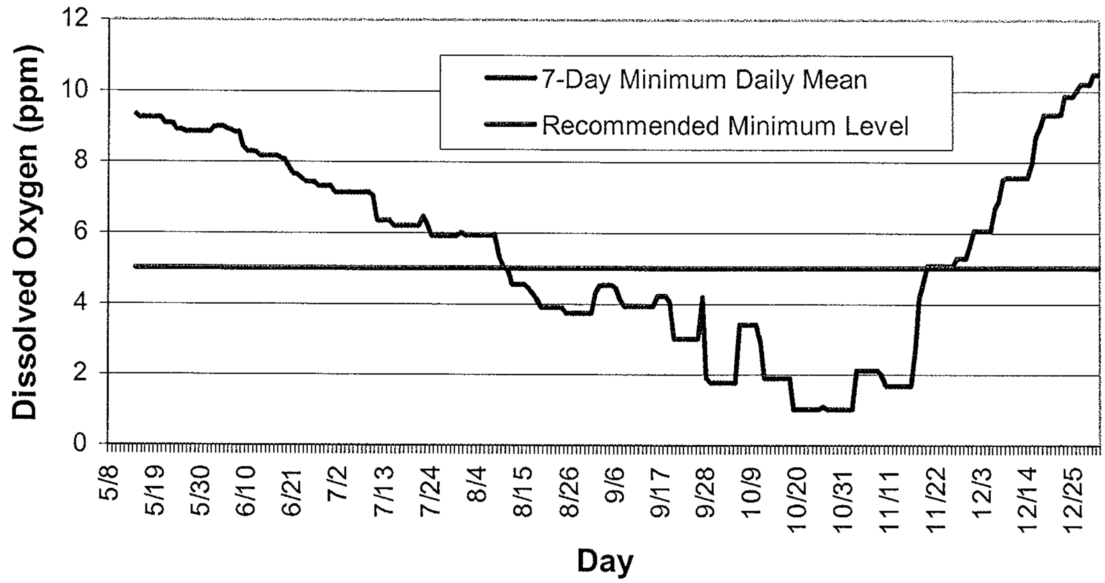
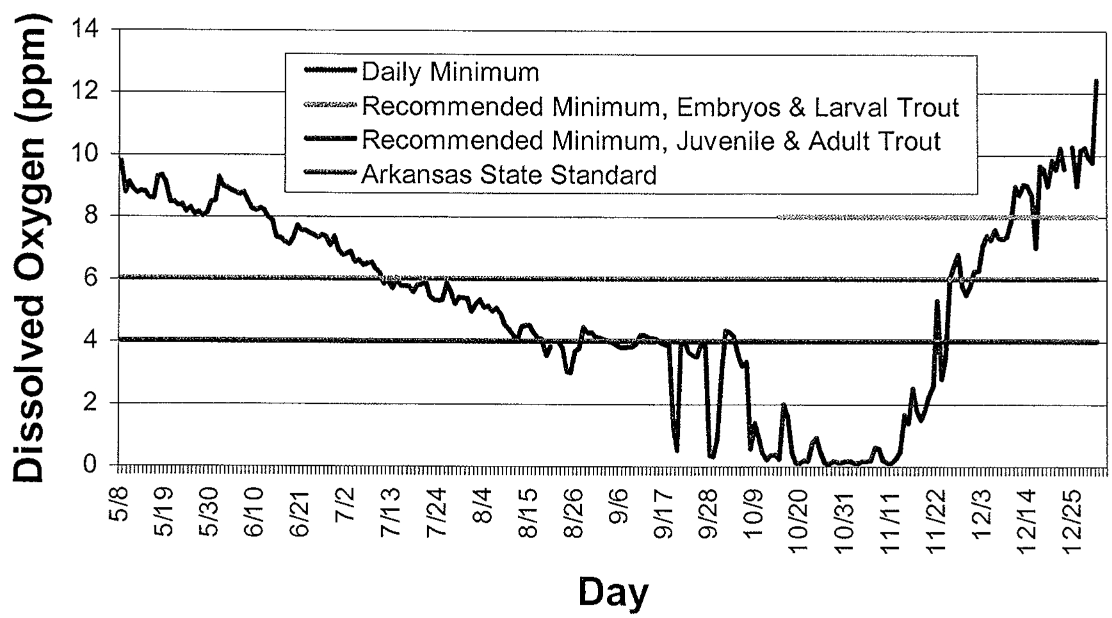


Figure 5. Daily minimum DO in discharge from Norfork Dam from May 8, 2002 to December 31, 2002, U.S. EPA recommended minimum levels (US EPA, 1986, 2002), and Arkansas State water quality standard (ADEQ Reg. 2).



APPENDIX E

Public Comments Received by ADEQ on Draft TMDL

PUBLIC COMMENTS AND RESPONSES

DO TMDLs FOR WHITE RIVER BELOW BULL SHOALS DAM
AND NORTH FORK RIVER BELOW NORFORK DAM

Draft report: June 18, 2008
Public comment period: October 29, 2008 – December 22, 2008
Revised report: April 30, 2009

Comments that were received by ADEQ during the public comment period are shown on the following pages with ADEQ responses inserted in a different font.

TABLE OF CONTENTS FOR PUBLIC COMMENTS AND RESPONSES

E.1 COMMENTS FROM AGENCIES, ORGANIZATIONS, AND COMPANIES

E.1.1 Comments From U.S. Geological Survey

Saw where the public comment period was extended for the Bull Shoals and Norfork tailwater DO TMDL. Didn't realize it had been released for public comment until I saw the news of its extension. Oh well.

I tend to agree with FTN about their conclusions (#2) concerning nonpoint source loading of organic matter and nutrients resulting from growing sources of urbanization and agriculture in each watershed and how these loads are likely to have a small affect on hypolimnetic DO, but only slightly if any.

When the wet year - dry year issue is raised, people generally assume that in wet years more runoff occurs, more organic matter, more nutrients, therefore greater oxygen consumption. In dry years, this phenomenon is reduced in magnitude. That may be true, but like FTN concludes, "reducing nonpoint source pollution in the watersheds may indirectly improve tailwater DO slightly, but certainly not enough to meet the water quality standard of 6.0 mg/L."

The issue related to low tailwater DO levels in wet years vs. better DO levels in dry years and quite simple. Think of it this way, once the lake becomes thermally stratified, the cold-water hypolimnion becomes isolated from the surface mixing layer or epilimnion. The density difference (thermocline) between the epilimnion and hypolimnion is so strong, the wind energy cannot keep the two layers mixed together. Once stratification sets up, there is only a finite volume of cold, oxygenated water in the hypolimnion to support the trout fishery below. As this cold, oxygenated water is mined out of the hypolimnion, it is replaced by warmer, lower DO water, water with greater DO demand. Therefore, the tailwater becomes warmer and less oxygenated sooner than later. If this finite volume of water is completely mined out of the reservoir before winter mixing occurs, the tailwater will become too warm and have little or no DO to support the trout fishery.

In wet years, when spring flood water is stored in the flood pool (above conservation pool) and the reservoir becomes thermally stratified while water remains in the flood pool, the only way to bring the pool elevation back to the conservation level is to release water from the hypolimnion. In doing so, the equivalent volume of flood storage has to be removed from the cold, oxygenated hypolimnion. This cold, oxygenated water is therefore removed from the system and not available to sustain the tailwater trout fishery any further for the remainder of the summer and fall season. An example this year for Bull Shoals, was when the pool was near full flood stage, we went out and measured a temperature and DO profile at the buoy line. I can't remember the exact stage that the pool was in, but it was within a foot or so from the maximum, like 43 feet into the flood pool. From the elevation and capacity table (storage curve) for Bull Shoals, the volume of that 43 feet was the same as the bottom 181 feet. Therefore, the bottom 181 feet had to be evacuated to bring the pool down 43 feet to conservation pool level. Removing 181 feet of cold, oxygenated water is a lot of trout water. What was left after that, I don't know. But we do know, the DO levels towards the end of the DO season were not very good in the Bull Shoals tailwater. Look at Beaver Lake on the other hand. Beaver Lake is the first to fill, last to empty. The USACE didn't start evacuating the flood pool until a couple of weeks ago. The Beaver tailwater did not get bad at all this year because the flood water remained in the flood pool the entire DO season.

One management alternative might be to evacuate the winter and spring flood storage before the thermocline sets up. That way, the water evacuated to bring down the pool to conservation level is mixed water, not isolated in the bottom. This is probably not a feasible alternative however. I suspect a lot if not most of the flood storage occurs after the thermocline is established. That being the case, the only way to remove flood storage is off the bottom. Unless the surface water in the flood pool in early spring or so is cool enough to sustain a trout fishery. Then the flood storage could be removed from the surface, given the mechanism to do so.

Anyway, just wanted to forward you some of my thoughts about the situation. Holler back, if needed.

W. Reed Green, Ph.D.
Assistant Director, USGS Arkansas Water Science Center
U.S. Geological Survey
401 Hardin Road
Little Rock, Arkansas 72211
501.228.3607
wrgreen@usgs.gov
http://ar.water.usgs.gov

Response: ADEQ appreciates this information, some of which has been incorporated into Sections 3.2.2 and 3.3.2 of the revised report. ADEQ still believes that implementation of best management practices (BMPs) to minimize anthropogenic loads of nutrients and sediment to each lake will not be sufficient by itself to raise hypolimnetic DO concentrations enough to meet the DO criteria in the tailwaters.

E.1.2 Comments From U.S. Army Corps of Engineers

This letter and enclosed comments are in response to the Arkansas Department of Environmental Quality's recent public review period of the Proposed Total Maximum Daily Load for Dissolved Oxygen for White River below Bull Shoals Dam and North Fork River below Norfork Dam report (Proposed TMDL). The Little Rock District Corps of Engineers appreciates this opportunity for comment and the previous cooperative efforts our agencies have undertaken in regard to this low dissolved oxygen issue.

The Little Rock District, U.S. Army Corps of Engineers (USACE) is responsible for the operation and maintenance of Bull Shoals and Norfork Lakes. These multi-purpose reservoirs were constructed in the upper White River Basin for flood control and hydropower generation and were completed in 1951 and 1944, respectively. The power generated at these projects is marketed by the Southwestern Power Administration, as provided by the Flood Control Act of 1941. In addition to the flood control and hydropower benefits of the lakes, they also have contributed largely to the economic and recreation benefits of the region. The Little Rock District contends it is relevant to acknowledge that while observing the original purpose of the reservoirs, each tailwater currently supports a high quality trout fishery under current operations.

The affected waters of this proposed TMDL are portions of the tailwaters of the lakes and include a 3 mile reach (l1010003-002U) of the White River and 4.2 miles reach (11010006-001) of the North Fork River. The Proposed TMDL identifies an impaired aquatic life use below these projects with the cause as low levels of Dissolved Oxygen (DO) and the source as hydropower (HP).

Response: ADEQ labeled the source of impairment as “hydropower” in the 303(d) list because most of the flow in these tailwater reaches comes from hydropower releases which are low in DO. However, ADEQ recognizes that the low DO is not caused by water flowing through hydropower turbines.

Construction of the dams at Bull Shoals and Norfork resulted in the creation of an artificial trout fishery due to the cold water hypolimnetic releases from the dams. Without this cold water discharge, the critical temperature necessary for trout species survival could not be met on a "year round" basis. Unfortunately while the lakes are in a stratified condition the crucial water temperature is present only in the hypolimnion layer of the stratified water column which also can be extremely low in the also crucial dissolved oxygen.

The Proposed TMDL also notes deep reservoirs tend to have low DO even if their water sheds are relatively undeveloped and that various activities associated with agriculture and urbanization may contribute organic matter to the hypolimnion. It seems this is an accurate description of both Bull Shoals and Norfork watersheds. During the vertically stratified period the surface water is aerated by the atmosphere and primary production thus maintaining adequate DO levels. The oxygen in the isolated hypolimnion is being reduced due to the DO consumption during the decay of organic matter in the water and sediment. Lake stratification is a natural occurrence in various water body types including some farm ponds and large reservoirs such as Bull Shoal and Norfork. The vertical stratification isolates the stratified layers from each other and water mixing between layers is inhibited during this condition.

We recognize that evaluation of downstream waters on the above mentioned reservoirs may verify DO levels below the state standard for the designated use of "trout waters"; however a full listing of the sources contributing to the low DO has not been identified.

Response: ADEQ acknowledges that the TMDL report does not specifically identify every individual source of material that creates oxygen demand in the hypolimnion of each lake. Such an effort was beyond the scope of this study and was not considered crucial because ADEQ believes that low hypolimnetic DO will still occur even without large anthropogenic loads of nutrients and sediment (as discussed in Section 2.7 of the TMDL report).

Water quality problems at reservoirs are a watershed issue and must be evaluated and addressed in that manner or success will not be achieved. Dissolved Oxygen issues are associated with the hydropower releases from high head projects such as these due to naturally occurring stratification phenomena not from hydropower generation in and of itself. During the stratification period, typically mid-August through mid-December, DO concentrations in the tailwater immediately below each project fall below state standards during both periods of generation and non-generation. Nutrient enriched runoff into the reservoir, particularly during period of above normal precipitation also contributes to decreased levels of DO in the reservoir. In this case, the state standard authorizes a lower DO level, 5 mg/l, in the reservoir, than in the trout waters below, 6 mg/l. The action of water conveyance from the reservoir to tailwater whether during periods of power generation or not, does not in and of itself result in the decrease in DO levels. This decrease in DO levels is a function of the low DO levels found in the hypolimnion of the reservoir.

Response: The watershed approach for this water quality problem includes ADEQ's support and encouragement for implementing best management practices (BMPs) throughout each watershed, but the primary focus of implementation needs to be adding DO to the water either before or after it flows from the hypolimnion of each lake to the tailwater. The numeric criterion for DO in each tailwater is based on what is needed to maintain the designated use, not what the upstream criterion is.

The USACE is committed to the highest water quality in the reservoir and tail waters of all of its projects and recognizes the economical and ecological benefits of the trout fisheries to the State of Arkansas. Numerous project modifications, the development of an Operational Action Plan for Low Dissolved Oxygen Season, the near completion of the White River Minimum Flow Environmental Impact Statement are some of measures that the Little Rock

District has taken to maintain and improve the high quality of water and fisheries associated with our projects. The District has been working with numerous partners to minimize the DO problem since the early 1990s through various structural and operation modifications. In 1991, at the request of then Governor Bill Clinton, the Ad Hoc Committee on Project Operations-White River was established and eventually grew to the White River Dissolved Oxygen Committee in 1993 in an effort to cooperatively address the DO issue in the White River. While a long-term permanent solution has not been adopted, incremental progress has been achieved in an effort to protect the trout fishery downstream from Bull Shoals and Norfork Dams. For the past 14 years, the modified operations resulted in minimization of low DO impacts to the extent reasonably possible while preserving the flood control and hydropower benefits of the projects.

Response: ADEQ appreciates the Corps of Engineers being involved in the White River DO Committee and for working with other agencies concerning minimum flow and other issues that affect water quality in these tailwaters. Cooperation among numerous entities will be necessary to develop and implement measures that will allow the DO criterion to be met in these tailwaters.

Considering the natural process of stratification in the large reservoirs, the influence of watershed runoff, and the nature of the largely non-regulated compliance with non point pollution programs, the District also wants to acknowledge that the consideration of revision of state water quality standard or designated use may be necessary to reflect the reasonable and prudent dissolved oxygen conditions in the tailwater reaches.

Response: ADEQ believes that the current designated use of trout fishery and its corresponding DO criterion of 6 mg/L are appropriate for these two stream reaches.

We look forward to actively working with your organization to preserve the high quality water sources and fisheries we currently maintain in the State. If you have any questions regarding this letter, the point of contact for this action is Mr. Mike Rodgers, at 501-324-5030.

Sincerely

Ronald Carman, P.E.
Acting Chief,
Planning and Environmental Office

Response: ADEQ appreciates the comments above.

COMMENTS IN ENCLOSURE FROM U.S. ARMY CORPS OF ENGINEERS:

November 26, 2008 Review Comments on Proposed Total Maximum Daily Load for Dissolved Oxygen for White River below Bull Shoals Dam and North Fork River below Norfork Dam

1. Section 2.3: The Norfork National Fish Hatchery is not a member of the White River Dissolved Oxygen Committee. Please remove their name from the list.

Response: The requested change has been made to the report.

2. Section 3.1: The second sentence "This monitoring began as a result of an interagency agreement for dealing with low DO conditions in these tailwaters." should be changed to "This monitoring began as a result of an interagency agreement for dealing with low DO conditions in these tailwaters during periods of hydropower generation." This better reflects the initial task of the White River Dissolved Oxygen Committee.

Response: The requested change has been made to the report.

3. Section 4.2, third paragraph: It is stated "The TMDL scenarios presented in this report represent these periods." Are these periods the worst case periods?

Response: The TMDLs were calculated using the model results for the time periods listed immediately above the sentence referenced in the comment.

4. Table 4.1: Minimum allowable loads of dissolved oxygen for the two tailwaters are expressed in pounds per day. How does this translate into parts per million?

Response: The loads in pounds per day were calculated as the parts per million for each inflow multiplied by the flow rate for that inflow.

5. Hydropower is listed as the cause of low dissolved oxygen in the lakes. As mentioned in the TMDL other non-hydropower lakes also experience low dissolved oxygen levels. The cause is lake stratification, a naturally occurring phenomena in all deep lakes located in temperate zones.

Response: See the response to the first comment from the Corps of Engineers (page E-3).

6. A full listing of the sources contributing to the low dissolved oxygen has not been identified in the Draft TMDL; water quality problems at reservoirs are a watershed issue and must be evaluated and addressed in that manner. From experience, years with high inflows to these reservoirs result in lower than average dissolved oxygen levels. Nutrients are added to these lakes during all inflow events, higher loading in higher inflow years.

Response: ADEQ acknowledges that the TMDL report does not specifically identify every individual source of material that creates oxygen demand in the hypolimnion of each lake.

Such an effort was beyond the scope of this study and was not considered crucial because ADEQ believes that low hypolimnetic DO will still occur even without large anthropogenic loads of nutrients and sediment (as discussed in Section 2.7 of the TMDL report). DO levels in wet years versus dry years have been analyzed in Sections 3.2.2 and 3.3.2 of the revised report. The suggested pattern of lower DO in wetter years and higher DO in drier years was maintained in some years but not all years. Also please see the USGS public comments (starting on page E-1) concerning the effect of wet and dry flow regimes on DO.

7. In the Draft TMDL, the computations were simply a mass balance at the outlet, the tailwater. Solutions only identified selected options, omitting the option to change the designated use of the tailwaters and/or state water quality standard. Consideration of changing the designated use and/or state water standard may be necessary to reflect the reasonable and prudent DO conditions in the tailwaters.

Response: ADEQ believes that the current designated use of trout fishery and its corresponding DO criterion of 6 mg/L are appropriate for these two stream reaches.

E.1.3 Comments From Southwestern Power Administration

This letter and enclosed comments are in response to the Arkansas Department of Environmental Quality (ADEQ) "Notice of Availability of the Proposed Total Maximum Daily Load for Dissolved Oxygen for White River Below Bull Shoals Dam and North Fork River Below Norfork Dam Located Within the State of Arkansas" (PROPOSED TMDL) published on October 29, 2008. The notice requested comments regarding the PROPOSED TMDL be provided to ADEQ prior to 4:30 p.m. on November 27, 2008 (Thanksgiving Day). Southwestern Power Administration (Southwestern) appreciates the opportunity to review and provide comments on the PROPOSED TMDL during the public comment period. Please find Southwestern's specific comments regarding the PROPOSED TMDL detailed in the enclosure. In addition, Southwestern has the following major concerns.

The PROPOSED TMDL lists hydropower as the source of the impairment in the tailwaters of Bull Shoals and Norfork. After reviewing the PROPOSED TMDL, Southwestern could not identify any quantitative or qualitative analysis that can specifically be used to cite hydropower as the source of the low dissolved oxygen (DO) levels below Bull Shoals and Norfork. In fact, as documented in the PROPOSED TMDL, the DO levels in the tailwaters of Bull Shoals and Norfork are greater during periods of hydropower generation than periods of non-generation. It is apparent to Southwestern, and acknowledged in Section 2.1 of the PROPOSED TMDL, that the low DO levels in the tailwaters of both projects are due, in part, to the natural phenomenon of lake stratification. As previously stated in comments regarding the draft total maximum daily load for the Bull Shoals and Norfork tailwaters and letters regarding the 303(d) listing of the tailwaters to ADEQ, Southwestern also believes that non-point source nutrient and organic matter contained in the inflow to the reservoirs from watersheds of Bull Shoals and Norfork contribute significantly to the severity of the low DO conditions occurring in the hypolimnions of the reservoirs. The PROPOSED TMDL briefly discusses and inappropriately dismisses the severe impact that the nutrient and organic matter loading has on the hypolimnetic DO in the Bull Shoals and Norfork reservoirs. Southwestern believes that the watershed discussion in the PROPOSED TMDL should be expanded and thoroughly documented prior to dismissing the influence the watersheds have on the tailwater DO levels. Furthermore, Southwestern requests that the source of the impairment of the tailwaters below Bull Shoals and Norfork be changed to lake stratification and non-point source loading.

Response: ADEQ labeled the source of impairment as "hydropower" in the 303(d) list because most of the flow in these tailwater reaches comes from hydropower releases which are low in DO. However, ADEQ recognizes that the low DO is not caused by water flowing through hydropower turbines.

Southwestern also reviewed the "Arkansas Pollution Control and Ecology Commission, Regulation No. 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas." Regulation No. 2 states that "...Water Quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development…" The value of hydropower and the human activity in the upstream watershed are undeniably important to economic and social development. Realizing the extreme economic and possible social impacts (reduction in hydropower benefits and reduced human development in the watershed areas of Bull Shoals and Norfork), Southwestern suggests that the river segments immediately below Bull Shoals and Norfork have been incorrectly segmented. Southwestern believes that the river segments immediately downstream of Bull Shoals and Norfork are transition zones that are needed for mixing and water aeration. Under the existing and prior conditions, the downstream trout fishery, as described by the Arkansas Game and Fish Commission and the Arkansas Department of Parks and Tourism, has become a "world class" and "exceptional" fishery. Southwestern concedes that while the current operation generally provides sustainability during the seasonal critical period, it does not provide conditions that are optimal for the growth of the trout. Since the ultimate solution to the problem probably will require a major investment in the upstream watershed that could have an enormous negative economic impact to the region, and since the "world class" and "exceptional" trout fishery was developed under existing conditions, it appears that re-segmentation of the river reaches immediately below both dams as transition zones with separate water quality standards would be both justifiable and reasonable. As such, it would not be necessary to list the tailwaters of Bull Shoals and Norfork as impaired.

Response: ADEQ believes that the current designated use of trout fishery and its corresponding DO criterion of 6 mg/L are appropriate for these two stream reaches. Changing the designated use so that the DO criterion will be less stringent is not appropriate. ADEQ is working to bring stakeholders together to identify and implement a solution whose cost will not be detrimental to economic or social development. Actually, a solution that would keep DO in these tailwaters at or above 6 mg/L during critical times would likely bring economic benefit due to the improved fishery during those times.

At recent meetings held by ADEQ among affected agencies and concerned groups where the PROPOSED TMDL was discussed and possible solutions to the low DO problem were explored for the Bull Shoals and Norfork tailwaters, most of the solutions focused on securing funding to install and operate forebay oxygen diffuser systems. As discussed at the meetings, a diffuser system has extremely high installation costs and prohibitive, recurring operation and maintenance costs. If any of those additional costs were assigned to the hydropower purpose, they would ultimately be passed on to Federal hydropower consumers. It should be noted that Southwestern has voluntarily modified the hydropower equipment and operations at Bull Shoals and Norfork to improve the DO concentrations in the tailwaters during generation and non-generation periods, and Southwestern has directly spent nearly $2 million on those efforts. As a result of those modifications, Southwestern has foregone approximately $22 million (2007 rates) in hydropower benefits from 1991 through 2007 to maintain a minimum DO concentration of 4 mg/L in the tailwaters during periods of generation. Therefore, Southwestern does not believe it would be appropriate to pass on the additional costs of a forebay oxygen diffuser system that would further enhance the existing "world class" fishery.

Response: ADEQ has not selected or endorsed a specific implementation strategy such as installing and operating a forebay oxygen diffuser system. ADEQ does not intend to unilaterally select an implementation strategy; instead, ADEQ is working to facilitate a group of stakeholders that will select and implement actions to improve DO concentrations in these tailwaters.

ADEQ appreciates the quantitative information concerning the financial impacts that SWPA has already incurred due to efforts to improve DO concentrations in these two tailwaters. This information has been incorporated into Section 2.4 of the report.

The hydropower production at the Bull Shoals and Norfork projects reduces the need for burning 463,000 tons of coal, 1,600,000 barrels of oil, or 9,831,000,000 cubic feet of natural gas each year. In addition, the electricity produced at these projects annually prevents the emission of 808,000 tons of greenhouse gases. Southwestern has worked with the Corps of Engineers, the White River Dissolved Oxygen Committee and other interests to improve recreation at trout fisheries that already enjoy an "exceptional" reputation in a cost effective manner which protects eight million electric consumers in Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas. We appreciate the opportunity to provide comments on the PROPOSED TMDL. Please contact Mr. Marshall Boyken at 918-595-6646 or marshall.boyken@swpa.gov if you have any questions.

Sincerely,

George Robbins

George Robbins
Director, Division of Resources and Rates

Response: ADEQ appreciates the information concerning the amounts of fossil fuel consumption and greenhouse gas emission that is reduced by hydropower at these two dams. This information has been incorporated into Section 2.4 of the report.

COMMENTS IN ENCLOSURE FROM SOUTHWEST POWER ADMINISTRATION:

November 24, 2008

Southwestern Power Administration Comments for the PROPOSED Total Maximum Daily Loads (TMDL) for Dissolved Oxygen for the White River below Bull Shoals Dam and the North Fork River below Norfork Dam
June 18, 2008

PROPOSED TMDL for Dissolved Oxygen for the White River below Bull Shoals Dam and North Fork River below Norfork Dam (Reaches 11010003-002U and 11010006-001), June 18, 2008:

(Note: Paragraphs are numbered from the beginning of the referenced section or sub-section)

1. PROPOSED TMDL, Section 1.0, Paragraph 1, Sentence 3, Page 1-1. The sentence refers to Table 1.1 on page 1-1 that lists hydropower as the source of the impairment of the water. Hydropower is not the source of the low dissolved oxygen (DO) in the tailwaters at Bull Shoals and Norfork. Hydropower is a discharge from a dam. According to longstanding Environmental Protection Agency (EPA) rules, a discharge from a dam does not constitute an addition of a pollutant even though some physical and chemical properties of the water may have changed as water moved through the dam. Rather, the cause of the impairment should be listed in Table 1.1 as non-point source loading and lake stratification. Please correct.

Response: Please see response to first comment from SWPA (page E-8).

2. PROPOSED TMDL, Section 1.0, Table 1.1, Page 1-1. Table 1.1 lists hydropower as the source of the impairment. Again, hydropower is not the source of the low DO in the tailwaters at Bull Shoals and Norfork. Hydropower is a discharge from a dam. According to longstanding EPA rules, a discharge from a dam does not constitute an addition of a pollutant even though some physical and chemical properties of the water may have changed as the water moved through the dam. Rather, the cause of the impairment should be listed in Table 1.1 as non-point source loading and lake stratification. Please correct.

Response: Please see the response to comment #1.

3. PROPOSED TMDL, Section 2.1, Table 2.2, Page 2-1. Respectively, Footnote A. and Footnote B. state "…Tables 4-09 and 4-10 of the United States Army Corps…" and "…Table 3-03 of Corps…" Footnote A. should state "...Tables 4-09 and *4-11* of the United States Army Corps of Engineers, White River Basin Water Control Master Manual, 1993…" and Footnote B. should state "...Table 3-03 of the United States Army Corps of Engineers, White River Basin Water Control Master Manual, 1993…" Please correct.

Response: The requested change has been made to the report.

4. PROPOSED TMDL, Section 2.1 and Section 2.2, Page 2-1. This is the second page "2-1" in the TMDL. Please correct.

Response: The requested change has been made to the report.

5. PROPOSED TMDL, Section 2.1, Paragraph 3, Sentence 1, Page 2-1. The sentence states that Bull Shoals has "a" house unit. Bull Shoals has two house units. Please correct.

Response: The requested change has been made to the report.

6. PROPOSED TMDL, Section 2.1, Paragraph 4, Sentence 8, Page 2-1. The sentence states that the DO in the hypolimnion is consumed by the decay of organic matter in the water and the sediment. Please identify the source of the organic loading in the water and sediment.

Response: Organic matter in the hypolimnion comes from both internal and external sources. The primary internal source is likely algae that use nutrients and carbon dioxide to grow in the upper layer of the lake and then they eventually die and sink into the hypolimnion. External sources of organic material consist of dissolved or particulate organic matter that enters the lake through large or small streams flowing into the lake or direct runoff along the shoreline. Identifying specific locations in the watershed where external sources originate was beyond the scope of this project. Organic loading in the sediment will consist of particulate organic matter (either from internal or external sources) that has settled to the bottom. Due to the age of these lakes, there is virtually no oxygen demand remaining from organic matter that existed along the bottom of each lake when it was impounded.

7. PROPOSED TMDL, Section 2.3, Paragraph 1, Sentence 2, Page 2-2. The sentence states that the United States Geological Survey (USGS) and the Norfork National Fish Hatchery (USFWS) are members of the DO Committee. The USGS and USFWS are not members of the DO Committee. Please correct.

Response: The requested change has been made to the report.

8. PROPOSED TMDL, Section 2.4, Paragraph 2, Sentence 3, Number 2, Page 2-3. The Number 2 requirement states "…Water Quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important *economic* or social development…"

   a. Hydropower is undeniably an important economic and social development, and the clean, renewable energy that hydropower provides must be maintained. Arkansas Regulation 2.202 allows for water quality standards to accommodate the value of the hydropower resource.

   b. Southwestern believes that agriculture practices and human development in the watersheds of Bull Shoals and Norfork contribute significantly to the severity of the low DO problems in the water discharges from the projects. A comprehensive watershed management plan to address those problems would impose a significant economic hardship on those entities engaged in activities in the watersheds that contribute to the nutrient loading into the reservoirs. Additionally, the plan could have significant social impacts to the region by restricting development in the watersheds. Those economic and social impacts *must* be considered when categorizing the use of these river segments. Southwestern also believes that it is proper to interpret Regulation 2.202 to allow for a lower water quality standard in the dam discharges due to the economic and social impacts that may occur if watershed practices were changed to improve the low DO in the dam discharges.

Response: ADEQ agrees that hydropower is an important economic and social development, but less stringent water quality standards are not needed to accommodate hydropower. On the contrary, ADEQ believes that improving DO to meet the current DO criterion would likely bring economic benefits due to the improved fishery.

c. Southwestern suggests that the tailwaters of Bull Shoals and Norfork are not impaired, but rather, they have been segmented incorrectly. Southwestern believes that the segments directly downstream of Bull Shoals and Norfork for approximately 2,000 feet are transition zones that are needed for mixing and water aeration. Southwestern requests that a Use Attainability Analysis be conducted on the river segments immediately downstream of the Bull Shoals and Norfork projects that considers the economic importance of hydropower generation to the region and the economic importance of the current land practices in the upstream watersheds to accurately categorize the use of the river segments.

Response: ADEQ is not interested in conducting a Use Attainability Analysis on these tailwaters because the current designated uses and numeric criteria are considered appropriate.

9. PROPOSED TMDL, Section 2.6, Paragraph 2, Sentence 2, Page 2-4. The sentence states "…deep reservoirs tend to have low hypolimnetic DO even if their watersheds are relatively undeveloped." Southwestern would like to review the studies that have been completed that quantify the low DO in deep reservoirs with relatively undeveloped watersheds to ascertain to what level of low DO in the hypolimnion is due to lake stratification. It is Southwestern's belief, based on other studies, that the low DO levels in the hypolimnion are significantly influenced by the land use practices in the watershed.

Response: FTN will provide a copy of the data upon which this statement was based.

10. PROPOSED TMDL, Section 2.6, Paragraph 2, Sentence 3, Page 2-4. These sentences reference a study at Beaver Lake that used the reservoirs in southwest Arkansas to represent undeveloped watersheds. Southwestern requests a copy of the study to review.

Response: FTN will provide a copy of the data upon which this statement was based.

11. PROPOSED TMDL, Section 2.6, Paragraph 2, Sentence 4, Page 2-4. The sentence states that low hypolimnetic DO has been measured near the dams of the three reservoirs in southwest Arkansas. Southwestern would like to review the data collected at these projects for comparison to the Bull Shoals and Norfork DO data.

Response: FTN will provide a copy of the data upon which this statement was based.

12. PROPOSED TMDL, Section 2.6 and Section 2.7, Page 2-1. This is the third page "2-1" in the TMDL. Please correct.

Response: The requested change has been made to the report.

13. PROPOSED TMDL, Section 2.6, Paragraph 3, Sentences 2, 3 and 4, Page 2-1. The sentence states that the variation in year to year hypolimnetic DO levels at Bull Shoals is a function of the volume of water being discharged. Since the release volume is a function of reservoir inflow, Southwestern continues to believe that the variance in hypolimnetic DO levels at Bull Shoals and Norfork is due to the quantity of volume that flows *into* the reservoirs and the amount of nutrients and organic material that the inflows contain. Sentence 4 in paragraph 3 contains a quote from a 1996 USGS report that supports the statement made in sentences 2 and 3; however, the 1996 USGS report also contains statements that support the influential role that nutrient and organic loading play on the DO levels of the reservoirs. The same 1996 USGS report also states:

a. "Ecosystem succession rates (aging and evolution) in reservoirs are similar to natural lakes, but greatly accelerated because of stresses created by human activities within the drainage basin."

b. "The mass flux of nutrients and organic matter increases with increased flow into the system because greater quantities of constituents generally are delivered with greater streamflow."

c. "The human stresses on the landscape within the drainage area upstream of a reservoir can increase the amount of nutrients and organic compounds available for transport, and, therefore, can accelerate the eutrophication processes within the reservoir."

d. "The water quality in Bull Shoals and Norfork Lakes would probably remain stable, however, increased nutrient and organic loading into these reservoirs, such as from increased anthropogenic activities within the basin, would counteract these trends, accelerating the eutrophication rates."

Southwestern contends that the information contained in the 1996 USGS report supports the fact that increased nutrient and organic loading in the Bull Shoals and Norfork reservoirs increases the severity of the low DO in the hypolimnion of the two projects. Therefore, to improve the low DO problem in the Bull Shoals and Norfork tailwaters, watershed management must be considered as an option. Southwestern requests that a paragraph be included in Section 2.6 regarding the effect that the upstream nutrient and organic loading has on the hypolimnions of Bull Shoals and Norfork.

Response: The first three statements above are simply generic statements about reservoirs that were found in the introductory sections of the USGS report without being applied directly to Bull Shoals and Norfork Lakes. The fourth statement was obviously applied to these lakes, but it is still a general, qualitative statement. The fourth statement is referring to hypothetical future increases in nutrient and organic loading, and does not imply that current loadings are causing significant eutrophication in either of these two lakes. Also, the greatest impacts from watershed loading and eutrophication are normally observed in the upper part of a reservoir, not in the vicinity of the dam where releases are being made.

14. PROPOSED TMDL, Section 2.7, Table 2.4, Page 2-1. The table shows that there are two point source discharges that are allowed to enter in the North Fork and White Rivers. The table displays that the DO limits on those point source discharges are less than the state standard of 6 mg/L. The Norfork National Fish Hatchery discharge is directly below Norfork and, evidently, is allowed to discharge water with a DO limit of 5 mg/L, even during low DO periods. Why are point source discharges allowed to emit waste streams that are less than the state standard into a stream segment classified as trout waters? Please explain.

Response: The DO permit limit for the Norfork National Fish Hatchery discharge will be re-evaluated when that permit comes up for renewal. Because this is a continuous discharge that is immediately below the dam (i.e., at the critical location for DO), the DO permit limit will likely be increased to the instream criterion in the standards (6 mg/L).

15. PROPOSED TMDL, Section 3.1, Paragraph 1, Page 3-1. The water quality data mentioned in the paragraph provides information regarding conditions in the Bull Shoals and Norfork tailwaters over a number of years. Southwestern believes it would be beneficial to better inform the reader by denoting in the paragraph certain operational and physical changes that occurred at the projects. Beginning in 1991, both projects operated in accordance with the White River DO Operation Action Plan. Under that plan, when the DO levels of the upstream water become so low that it causes the downstream DO concentrations during generation to recede to 6 mg/L, all available turbine air-venting options are utilized as well as spreading load over all available units to maintain 6 mg/L as long as possible. If the lake DO concentrations continue to deteriorate and the downstream DO concentrations recede to 4 mg/L during generation, recommended maximum generation rates are computed and Southwestern has voluntarily reduced generation to further improve the DO concentration of the water received from upstream to assure a minimum of 4 mg/L during generation. Beginning in 2000, further enhancement was made to the plan to include pulsing of generation during non-generation periods to improve downstream DO concentrations during the brown trout spawning season. Physical modifications that have occurred at the projects include:

   a. In 1993, the Corps' Waterway Experiment Station (WES) installed turbine hub deflectors on both units at Norfork and units 1-4 at Bull Shoals.

   b. Also in 1993, WES installed modified air vents on units 5-8 at Bull Shoals.

   c. In 1997, the Tennessee Valley Authority (TVA) installed improved design hub deflectors on both Norfork units and all eight Bull Shoals units.

   d. Also in 1997, TVA improved the turbine air-venting system at all units at both projects, including cutting additional air vent holes into the turbine head covers.

   Please provide such clarification in the paragraph.

Response: ADEQ appreciates this information and considers it important. A new section (2.4 Hydropower Operations) has been inserted into the report to present this information.

16. PROPOSED TMDL, Section 3.2, Paragraph 2, Sentence 5, Page 3-1. The sentence states that the lowest DO recorded at Bull Shoals in 2006 was 5.7 mg/L. It should be noted that the inflows (and subsequent nutrient and organic loading of the reservoir) to Bull Shoals were extremely low in 2006. Southwestern believes that this data supports the fact that the nutrient and organic loading of the watershed significantly impacts the severity of the low DO in the hypolimnion of the Bull Shoals and Norfork projects. Please add a statement in paragraph 2 that states the negative effect that the nutrient and organic loading of the watersheds has on the low DO levels at Bull Shoals and Norfork.

Response: DO levels in wet years versus dry years have been analyzed in Sections 3.2.2 and 3.3.2 of the revised report. The suggested pattern of lower DO in wetter years and higher DO in drier years was maintained in some years but not all years. Also please see the USGS public comments (starting on page E-1) concerning the effect of wet and dry flow regimes on DO.

17. PROPOSED TMDL, Section 3.2, Paragraph 2, Sentence 8, Page 3-7. The sentence infers that DO concentrations were much worse at Bull Shoals in 2006 even though it was a drought year, trying to negate the impact that the watersheds have on the lake DO concentrations. A close examination of the intake DO concentrations computed by the Corps from the USGS lake profiles easily shows that 2006 was among the highest years for lake DO concentrations for the available period of 1991 through 2007. The low DO levels mentioned in the sentence were taken from the penstocks at Bull Shoals for a couple of weeks in late November. During about a week of that time, there was no generation at the project. Normally, and according to the PROPOSED TMDL report, non-generation times result in much lower DO concentrations downstream. Water for the station service penstocks and leakage originates more exclusively from the lower depths of the lake which the report shows to have dropped below 1 mg/L. However, the downstream DO monitors on the left and right bank both consistently provided readings of DO concentrations ranging from 8 mg/L to 12 mg/L during these worst condition. Such additional data, the lake profiles, and both downstream gages indicate the possibility that the penstock monitors were incorrect or some other undefined processes were occurring. Either way, it still appears that the dry 2006 season certainly provided above normal DO levels in the lake hypolimnion. Southwestern suggests either providing additional information or removing the misleading sentence.

Response: The sentence has been removed.

18. PROPOSED TMDL, Section 3.2, Paragraph 3, Sentence 4, Page 3-7. The sentence states, "…indicates that DO concentrations below 4 mg/L and 6 mg/L occur more often during periods of non-generation." Southwestern concurs with this statement. However, if the DO levels in the tailwaters of Bull Shoals are better during periods of generation than non-generation, why is hydropower cited as the source of the impairment? Please explain.

Response: Please see the response to comment #1.

19. PROPOSED TMDL, Section 3.3, Paragraph 3, Sentence 2, Page 3-9. The sentence states, "…indicates that DO concentrations below 4 mg/L and 6 mg/L occur more often during periods of non-generation." Southwestern concurs with this statement. However, if the DO levels in the tailwaters of Norfork are better during periods of generation than non-generation, why is hydropower cited as the source of the impairment? Please explain.

Response: Please see the response to comment #1.

20. PROPOSED TMDL, Section 3.4, Paragraph 2, Sentence 1, Page 3-16. The sentence states, "…Figures 3.1 and 3.4…" The sentence should state "…Figures 3.1 through 3.4 and Figures 3.7 through 3.10…" Please correct.

Response: The sentence has been revised.

21. PROPOSED TMDL, Section 3.4, Paragraph 2, Sentence 1, Page 3-16. Please change the sentence to read, "…tailwater DO concentrations *at Bull Shoals and Norfork* below…"

Response: The sentence has been revised.

22. PROPOSED TMDL, Section 3.4, Table 3.4, Page 3-16. Based on various information sources, it appears that the majority of the reported fish killed on October 08, 1990, at Bull Shoals were those stocked immediately below the dam by Arkansas Game and Fish Commission (AGFC) personnel although they were aware of potentially lethal DO concentrations. The Corps reported that they received no fish kill reports from the public and their personnel were unable to verify that a fish kill had occurred. Please provide additional information or remove the October 08, 1990, fish kill from Table 3.4.

Response: Some of the mortalities were fish that died soon after being introduced into the river, but other fish were also killed by the low DO water according to an internal AGFC memo written by Jim Spotts dated October 28, 1990. Approximately 25 percent of the mortalities were sexually mature brown trout, some of which weighed more than 10 pounds. Also, about 50 dead sculpins were observed by AGFC on October 16, 1990. Regardless of which fish constituted most of the mortalities, the bottom line is that the DO was too low for trout to survive immediately below Bull Shoals Dam at that time.

Please note that the date for this fish kill has been corrected in the report to October 11-12, 1990.

23. PROPOSED TMDL, Section 3.4, Table 3.4, Page 3-16. Please remove the fish kills dated June 16, 2002, and May 27, 2005, from Table 3.5.4. No specific quantities of fish or species have been identified for those dates.

Response: These two fish kills have been removed from the table due to lack of documentation.

24. PROPOSED TMDL, Section 3.4, Table 3.4, Page 3-16. Please remove the fish kills dated November 24, 2004, May 04, 2007, and June 05, 2007, from Table 3.4. One or two dead trout could probably be noted at any time for various reasons other than low DO.

Response: After reviewing available documentation, the fish kill dated November 24, 2004 has been removed from the list because evidence that was observed at the time is insufficient to prove that a fish kill occurred. However, an internal AGFC memo written by Jeff Williams dated November 24, 2004, points out that a fish kill could have occurred in the Norfork tailwater several days earlier based on low DO readings. Hourly DO data below Norfork Dam were below 1.0 mg/L for 16 consecutive hours on November 20, 2004, and 13 consecutive hours on November 21, 2004. Carcasses of any fish that died on those two days would have been washed downstream by the time that AGFC conducted their investigation on November 24, 2004 (in response to a report received that day).

The fish kills dated May 4, 2007, and June 5, 2007, were also removed from the table after reviewing AGFC internal memos concerning field investigations that they conducted on these dates.

25. PROPOSED TMDL, Section 4.2, Paragraph 2, Page 4-2. Both 1998 and 2004 were high inflow years that resulted in very low DO levels in the hypolimnions of Bull Shoals and Norfork. Please add language to this paragraph that elaborates on the detrimental effect that high inflows have on the low DO levels at Bull Shoals and Norfork due to the increased amount of nutrients and organics carried into the reservoirs from the watersheds.

Response: Please see response to comment #16.

26. PROPOSED TMDL, Section 4.2, Paragraph 2, Page 4-2. It also should be noted that Southwestern voluntarily restricted generation at Bull Shoals and Norfork during the low DO season in 1998 and 2004 to entrain air and subsequently raise the DO level in the hydropower releases. During the 1998 modeling period, Southwestern voluntarily restricted the generation rate at Bull Shoals and Norfork from 391 MW to 260 MW and from 87 MW to 48 MW, respectively. During the 2004 modeling period, Southwestern voluntarily restricted the generation rate at Norfork from 87 MW to 45 MW. Please note the significant operational change that Southwestern has voluntarily implemented to improve the DO levels in the tailwaters in the TMDL report.

Response: ADEQ appreciates this information; it has been incorporated into Section 4.2 of the report.

27. PROPOSED TMDL, Section 4.2, Paragraph 5, Page 4-2. The paragraph states that the City of Bull Shoals waste water treatment plant (WWTP) is included in the modeling. In Table 2.4 on page 2-1, it shows the City of Bull Shoals WWTP having a DO level release limit of 2 mg/L, which is less than the state standard of 6 mg/L for trout waters. The City of Bull Shoals WWTP outfall is only one mile downstream from the dam and is allowed to discharge a waste stream with a DO limit of 2 mg/L year round. Why are point source discharges allowed to emit waste streams that are less than the state standard into a stream segment classified as trout waters? Please explain.

Response: Please see the response to comment #14.

28. PROPOSED TMDL, Section 4.5, Paragraph 1, Page 4-7. This paragraph states how the TMDL were calculated using an unconventional approach of adding DO into a water body rather than by determining the limits of an oxygen-demanding pollutant load. Southwestern would like to learn why this irregular TMDL calculation approach was taken. Please expand the discussion regarding the reasons why the additive DO approach was taken.

Response: These TMDLs were expressed as minimum allowable loads of oxygen instead of maximum allowable loads of oxygen-demanding material because the focus for implementation needs to be on adding oxygen to the water either before or after it flows from the hypolimnion into the tailwater.

29. PROPOSED TMDL, Section 4.5, Paragraph 3, Sentence 5, Page 4-7. The sentence states, "…dams, future increases in point source loads of CBODu or NBODu may be allowable…" It is counterproductive to possibly allow for point source loading of the Bull Shoals and Norfork tailwaters to be increased in the future if the DO levels in the discharges from the dams are improved. This statement leads Southwestern to believe that if the DO levels in the Bull Shoals and Norfork tailwaters are improved, other entities will be able to take advantage of the larger assimilative capacity of the tailwaters and be allowed to discharge point source effluent in the tailwaters that is significantly under state water quality standards. Please explain the rationale of improving the DO levels in the dam discharges to allow for increased point source loading in the future.

Response: The critical location for DO is immediately below the dam. If DO standards are met at that location, then the small flow from the City of Bull Shoals WWTP (design flow is 0.573 MGD) would not be expected to cause a DO violation where it enters the White River approximately 1.1 miles downstream of the dam. In other words, if DO standards are met immediately below the dam, then the aeration of the water as it travels 1.1 miles downstream from the dam should increase the DO in the river enough to create assimilative capacity for the WWTP discharge.

30. PROPOSED TMDL, Section 4.5, Table 4.1, Page 4-8. As discussed in Comment 15, a number of operational and physical modifications have been voluntarily implemented by Southwestern at Bull Shoals and Norfork to improve the DO levels in the dam discharges. Do the "Minimum allowable loads of DO" displayed in Table 4.1 include the DO entrainment that the recommended maximum generation rate and the turbine modifications provide for the Bull Shoals and Norfork tailwaters? Please clarify.

Response: The total oxygen loads in Table 4.1 represent the amount of oxygen needed to meet the DO criterion for the flow scenarios in the simulations. These calculations do not differentiate between oxygen that enters the water through entrainment in the turbines, reaeration in the stream, or other pathways.

31. PROPOSED TMDL, Section 5.0, Paragraph 2, Sentence 4, Page 5-2. The sentence states, "…so that sufficient water will be available to maintain increased minimum flows." That statement is not in the Federal legislation. The Federal legislation reallocated water storage at Bull Shoals and Norfork for minimum flows; however, the storage provided for minimum flows may or may not maintain the AGFC-requested minimum flows in a given year depending on inflows to the reservoirs and therefore, may not be considered "sufficient" for them. Please correct.

Response: ADEQ appreciates this information. The report has been revised to reflect this information.

32. PROPOSED TMDL, Section 5.0, Paragraph 2, Sentence 5, Page 5-2. The sentence does not state correctly what equipment modifications / additions must occur at Bull Shoals and Norfork to implement minimum flows. The Supervisory Control and Data Acquisition system at Bull Shoals will be modified for minimum flows implementation. At Norfork, a siphon (not part of the hydropower facilities) will be designed and constructed to take water from the forebay of the reservoir and release it into the tailwater of the dam for minimum flows implementation. Please correct.

Response: ADEQ appreciates this information. The report has been revised to include this information.

33. PROPOSED TMDL, Section 5.0, Paragraph 3, Sentence 2, Page 5-2. The sentence states, "Modeling studies…do not indicate that increased minimum releases will result in significant changes in tailwater temperature or DO Levels…" The hydropower modifications at Bull Shoals and the siphon at Norfork for minimum flows have yet to be designed and implemented. If designed and implemented correctly, minimum flow releases through the Bull Shoals turbine and the Norfork siphon should meet the state standard of 6 mg/L during the non-generation periods in both tailwaters. The estimated cost to hydropower (both Federal and non-Federal) due to the implementation of the White River Minimum Flows Project exceeds $100 million. A project of this magnitude needs to be assessed after implementation to determine the beneficial impact that it will have on the DO levels below the Bull Shoals and Norfork. Please add a statement in Section 5.0 relating the potential significant benefits that minimum flow will have on the DO in the tailwaters.

Response: The modeling in the draft report assumed that releases for minimum flows would be from hypolimnetic waters, which are low in DO. A continuous flow of more low-DO water simply perpetuates the existing low-DO conditions immediately below each dam. The comment above states that minimum flow releases should meet the state standard of 6 mg/L during non-generation periods. If the water for minimum flow releases comes from the hypolimnion (otherwise the tailwater temperature would get too high for trout), then the releases need to be aerated by some means in order to meet the 6 mg/L criterion (which is consistent with the model results).

34. PROPOSED TMDL, Section 5.0, Page 5-1. Many alternatives are briefly described in Section 5.0 of the TMDL. However, no description or mention of watershed management is included. Southwestern believes and data supports that nutrient and organic loading in the watersheds of reservoirs significantly impacts the severity of the low DO levels found in reservoir hypolimnions. Therefore, Southwestern requests that watershed management be included as a possible implementation alternative that could be used to lessen the severity of the low DO levels in the Bull Shoals and Norfork tailwaters.

Response: Section 5 of the report has been revised to clarify the fact that ADEQ supports and encourages the use of best management practices (BMPs) that minimize anthropogenic loads of sediment and nutrients to these lakes.

35. PROPOSED TMDL, Section 6.0, Paragraph 1, Number 2, Page 6-1. As described in Comment 11 and 33, Southwestern would like to review the data that deduces that the watershed nutrient and organic loading has a small effect on the hypolimnetic DO. Southwestern agrees that watershed management alone will not improve the tailwater enough to meet the 6 mg/L state standard; however, by reducing the nutrient and organic loading from the Bull Shoals and Norfork watershed, the severity of the low DO problem in the tailwaters will be reduced. Therefore, please include watershed management as a possible implementation alternative.

Response: The magnitude of the effect of watershed loading on hypolimnetic DO was based on data from Bull Shoals, Norfork, and several other deep stratified lakes with relatively undisturbed watersheds (DeGray, Ouachita, and Greeson). These are the same data referenced in the responses to comments #10 and #11. Also, USGS stated in their public comments that watershed loads "are likely to have a small affect on hypolimnetic DO, but only slightly if any."

36. PROPOSED TMDL, Section 6.0, Paragraph 1, Number 4, Page 6-1. As stated in Comment 31, the sentence does not state correctly what equipment modifications / additions must occur at Bull Shoals and Norfork to implement minimum flows. The Supervisory Control and Data Acquisition system at Bull Shoals will be modified for minimum flows implementation. At Norfork, a siphon (not a part of the hydropower facilities) will be designed and constructed to take water from the forebay of the reservoir and release it into the tailwater of the dam for minimum flows implementation. Please correct.

Response: ADEQ appreciates this information. The report has been revised to include this information.

37. PROPOSED TMDL, Section 6.0, Paragraph 1, Number 5, Page 6-1. Please see Comment 32. The White River Minimum Flows will have a significant impact on the low DO in the tailwaters of Bull Shoals and Norfork. Please correct.

Response: ADEQ assumes that the commenter is referring to comment #33 rather than comment #32. Please see the response to comment #33.

38. PROPOSED TMDL, Section 6.0, Paragraph 1, Number 6, Sentence 2, Page 6-1. Again, if designed and implemented correctly, Southwestern believes that minimum flows at Bull Shoals and Norfork should improve the DO levels in the tailwaters significantly enough to meet the state water quality standard during non-generation periods. Please correct.

Response: Please see the response to comment #33.

39. PROPOSED TMDL, Section 6.0, Paragraph 1, Number 7, Page 6-1. The cost listed for the paddlewheel aerator is incorrect. The cost for one paddlewheel aerator is approximately $7,500. The paddlewheel aerator plan calls for the purchase of two aerators at $7,500 each. Also, the Corps' Little Rock District has spent approximately $50,000 on the design for the installation of the two paddlewheel aerators below Norfork. Finally, the Corps' Little Rock District has estimated that the cost of installing the paddlewheel aerators to be approximately $100,000. A remaining undefined cost associated with the paddlewheel aerator project is the cost of the electricity that will be needed to operate the paddlewheel aerators. In total, the project installation cost will probably exceed $165,000 (design cost plus equipment and installation cost). The operation and maintenance costs have not been defined for the project. Please correct the cost cited in Number 7 to be $165,000.

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information includes informal comments from AGFC, the public comment above from SWPA, and public comments from BlueInGreen.

40. PROPOSED TMDL, Appendix B, Table 1, Page iii. It should be noted that the costs shown in the "Capital Cost" column are 1997 costs. Please correct.

Response: These costs have now been summarized in Table 5.1 and are identified as 1997 dollars.

41. PROPOSED TMDL, Appendix C, Table 1, Page iii. It should be noted that the costs shown in the "Capital Cost" column are 1997 costs. Please correct.

Response: These costs have now been summarized in Table 5.2 and are identified as 1997 dollars.

E.1.4 Comments From Southwestern Power Resources Association

Southwestern Power Resources Association (SPRA) represents the rural electric cooperatives, municipally owned electric utilities and state power authorities that purchase hydroelectric energy and capacity generated at 24 Corps of Engineers dams in this region of the country, including the Bull Shoals and Norfork projects. The energy and capacity is marketed to our members by Southwestern Power Administration (SWPA), an agency of the U.S. Department of Energy. SPRA offers the following comments on the draft TMDLs for Dissolved Oxygen for White River Below Bull Shoals Dam and North Fork River Below Norfork Dam (draft TMDLs).

SPRA finds the draft TMDLs to be fatally flawed because they are based on incorrect premises, findings and conclusions that led to the original inclusion of the two stream segments in Arkansas' 303(d) list, as set forth below.

Dissolved Oxygen (DO) is not a pollutant. The Arkansas Department of Environmental Quality (ADEQ) defines pollutant on its web site as "any type of industrial, municipal, and agricultural waste discharged into water. Some examples include dredged soil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste."[1] DO is not a waste, nor is it discharged into water. As SWPA notes in its comments on the draft TMDLs, longstanding EPA rules find that a discharge from a dam does not constitute an addition of a pollutant.

[1] http://www.adeq.state.ar.us/water/branch_permits/individual_permits/faqs.htm

Response: By issuing a TMDL for DO, ADEQ in no way intends to imply that DO is a pollutant. Developing TMDLs for DO is the normal, legally upheld method for addressing impairments due to low DO. The method of expressing these TMDLs (minimum allowable loads of oxygen instead of maximum allowable loads of oxygen-demanding material) does not imply that DO is being considered as a pollutant.

Hydropower is not the source of the DO. The draft TDMLs in at least six instances acknowledge that, during the late summer and early fall (the "low DO season") DO in these two stream segments is lower when there is no generation.[2] How can hydropower be the source of the low DO if, during the low DO season, DO improves in these stream segments when generation occurs compared to when there is no generation? The draft TMDLs note:

> Review of hydropower records at Norfork Dam suggest that the higher tailwater DO concentrations during 1995 may be the result of high water levels in the reservoir, which made it possible to *continuously run one turbine unit at 10 mW during the entire summer* (emphasis added).[3]

It is interesting that the "source" of low DO actually improved the DO levels in the stream segments when it operated during the entire summer. In fact, the conclusions of the draft TMDLs specifically note that "increasing the DO concentrations to 6 mg/L in hydropower releases alone (i.e., without increase [sic] DO concentrations in the leakage) result in predicted DO levels *below the water quality standard during non-generation periods* (emphasis added)."[4] Logically, if raising the DO levels in the hydropower discharge to the state standard does not solve the low DO problems in the stream segments, hydropower cannot be the source of the low DO.

[2] Draft TMDLs, pp. 3-7, 3-9, 4-6 (two instances), 5-2 and 6-1
[3] Draft TMDLs, p. 3-9
[4] Draft TMDLs, Conclusion 6, p. 6-1

Response: ADEQ labeled the source of impairment as "hydropower" in the 303(d) list because most of the flow in these tailwater reaches comes from hydropower releases which are low in DO. However, ADEQ recognizes that the low DO is not caused by water flowing through hydropower turbines.

The draft TMDLs address the symptoms of the problem, rather than the cause of the low DO. Regardless of the depth or size of the reservoir, nutrients must be present for DO levels to decrease in the hypolimnion.[5] Although the draft TMDLs dismiss nutrient loading as a problem because the watershed is "relatively undeveloped," pasture comprises 26.4 percent of the watershed for the Bull Shoals tailwater and 34.7 percent of the watershed for the Norfork tailwater.[6] Fertilized pasture can be a significant source of nutrients. Even on unfertilized pasture or in forested lands, livestock grazing can contribute significantly to nutrient loading. Focusing on hydropower but not addressing nutrient loading is like ignoring the elephant in the room. To solve a problem, you must address the cause of the problem, not the symptom.

[5] Draft TMDLs, p. 2-1
[6] Draft TMDLs, p. 2-4

Response: The TMDL report did not state that nutrients must be present for DO levels to decrease in the hypolimnion. Rather, it states that DO is consumed by the decay of dissolved or particulate organic matter in the water column and in the sediment. The primary mechanism by which nutrients can affect hypolimnetic DO is by causing algae to grow in the upper layers of the lake and eventually the algae die and settle into the hypolimnion, where DO is consumed as they decay.

Language has been added to the TMDL report to clarify the fact that ADEQ supports and encourages the use of best management practices (BMPs) that minimize anthropogenic loads of sediment and nutrients to these lakes. However, the revised text in this report explains why ADEQ believes that efforts to minimize nutrient inputs to these lakes will not result in sufficient improvements to tailwater DO.

TMDLs focused on hydropower are ultimately doomed to failure. As noted above, although hydropower is the alleged source of low DO, the draft report concludes that for the TMDLs to succeed, DO must be increased for all water releases though the dams, including leakage that has no relationship to hydropower. Even so, if TMDLs are not established for nutrients within the watersheds, DO will continue to decay in the reservoirs to the point that, sometime in the future, all of the proposed "hydropower" solutions in the draft TMDLs will be insufficient to achieve and maintain water quality standards for both the stream segments cited and the reservoirs impounded by the dams. This result is guaranteed because the draft TMDLs do not address the cause of the problem (see above).

Response: These TMDLs are not focused explicitly on hydropower. The report does not adopt or recommend any specific implementation alternative that targets hydropower operations. The primary focus of implementation needs to be adding DO to the water either before or after it flows from the hypolimnion of each lake to the tailwater. ADEQ hopes that an implementation strategy can be developed with as few as possible impacts to hydropower operations.

The draft report does not comply with guidelines for TMDLs. ADEQ defines a TMDL as "a determination of the *total amount* of a substance that can be present in a waterbody without adversely affecting the designated use(s) of the waterbody (emphasis added)."[7] Likewise, the draft TMDLs report itself states: "The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate *without exceeding the water quality standard* for that pollutant and to establish *the load reduction* that is necessary to meet the standard in a waterbody (emphasis added)."[8] The substance in question is DO. The draft TMDLs do *not* determine the maximum amount of DO that can be assimilated without violating water quality standard, nor does it determine the reduction of DO needed to meet the standard. The DO standard is not a maximum, it is a *minimum*. Rather than setting the maximum amount of DO that can be present in the waterbody, the state standards establish a minimum amount, and the draft TMDLs attempt to identify solutions that will achieve this minimum. These proposed solutions, rather than removing a substance (pollutant) from the waterbody, attempt to increase that substance (pollutant). Everything is backwards because ADEQ has incorrectly defined DO as a pollutant and is not addressing the cause of the problem – nutrient loading in the reservoirs due to nonpoint sources in the watershed. If, however, ADEQ were to correctly identify nutrients as the source of the low DO, proper TMDLs could be established to *limit* the amount of nutrients in the reservoirs and thus reduce the degradation of the DO before the water is discharged through the dam.

[7] "2008 List of Impaired Waterbodies (303(d) List)", February 2008, ADEQ, p. 3
[8] Draft TMDLs, p. 1-1

Response: ADEQ acknowledges that these DO TMDLs are unusual because they are expressed as minimum loads rather than maximum loads, but this approach was used based on the necessary focus for implementation. The comment suggests that the primary cause of the low hypolimnetic DO is nutrient loading from the watershed, but no data or evidence is presented to support that claim.

Conclusion. The draft TMDLs should be rejected. ADEQ should revisit the 303(d) listing of the two stream segments and identify nutrient loading of the reservoirs as the source of the low DO, and new TMDLs established to limit nonpoint sources of nutrients in the respective watersheds.

A signed copy of these comments on SPRA letterhead has been sent to you via traditional mail.

Respectfully submitted,
Ted Coombes, Executive Director
Southwestern Power Resources Association
P.O. Box 471827
Tulsa, OK 74147

Response: ADEQ believes that these TMDLs are valid and that the 303(d) listing of these two stream reaches was appropriate.

E.1.5 Comments From Blue In Green, LLC

This is a public comment on the TMDL for the North Fork River.

Disclosure:

I work for BlueInGreen, LLC that sells oxygenation equipment and is a competitor of the river aeration system recommended in conclusion 7 in the Draft TMDL.

Comment:

The paddlewheel technology recommended in conclusion 7 of the draft TMDL is sized based on a stated efficiency of 3.2 lbs of oxygen/hr-hp with an oxygen addition rate of 48 lb/hr for a House Manufacturing 15 hp floating paddlewheel aerator (appendix D). These values are incorrect. Test results from the House Manufacturing website (http://www.housemfg.com/Documents/SDD149TA4223150.pdf) show lower rates for the unit in question. An efficiency of 3.04 lb/hr-hp and a delivery rate for 15 hp unit of 40.77 lb oxygen per hour are published. This rate was determined under ideal conditions using clean tap water at 68 deg F at a DO of 0 ppm in a still pond. Field operation delivery rates for this unit will likely be less than the test results stated, resulting in higher cost than estimated for adding the required DO to the North Fork River. Proper field design values for oxygen addition rates using the paddlewheel aerator should be obtained from the manufacturer and used for properly sizing this unit for the North Fork River.

The paddlewheel unit recommended is typically used in still water applications such as ponds and lagoons, or slow moving water systems such as oxidation ditches. The use of this aerator in a relatively rapidly moving river may not be appropriate since the flowing water may not allow the paddlewheel to properly agitate water for full contact with atmospheric air potentially resulting in lower performance. Typically, paddlewheel aerators exert force on still water. In this application, the paddlewheel would either need to exert more force than typical for agitation of water flowing towards it, or operate at higher rpm than typical for water flowing away from it. These issues may affect rates of oxygen addition, design sizing, and cost.

Proper anchoring of these floating units is critical for safety, loss prevention, and performance. Use of these floating units in a flowing river is not a typical application for aquaculture and wastewater equipment, so typical installation costs may not be accurate.

In conclusion, in order to make a fair cost comparison of the floating paddlewheel aeration system to other technologies, the recommended House Manufacturing system should be engineered by the manufacturer to ensure the equipment is appropriately sized and full installation requirements are met for the North Fork River application. I do not see any documentation from House Manufacturing stating the performance of their equipment in this atypical application. Nor do I see engineered installation recommendations and associated costs. These data are needed to make sure that the use of the floating paddlewheel unit is indeed a low-cost solution for the DO problem below Norfork Dam.

Scott Osborn, Ph.D., PE,
Chief Technology Officer
BlueInGreen, LLC

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information includes informal comments from AGFC, public comment #39 from SWPA, and public comments from BlueInGreen. This new information shows that the paddlewheel aerator might not be as effective as indicated in AGFC’s original calculations and it would require an expensive mechanism (estimated cost of $100,000) to lift it out of the water to keep it from being damaged or washed away during high flows.

E.1.6 Comments From Friends of the North Fork and White Rivers

Dear Mr. Wise,

Following are Friends of the North Fork and White Rivers feedback on the TMDL Report recently released for public comment. I again want to thank you and Teresa Marks for extending the comment period as many folks did not realize the notice for public comment had begun at the beginning of November.

The TMDL report is technically excellent, assimilating the colleted data into graphs and charts which clearly show the dissolved oxygen problem is extremely serious from late summer through fall. The report also explains the mechanism that leads to low-DO levels during this period of the year below the dams. Friends of the North Fork and White Rivers (Friends) concern is that that this TMDL report, despite its technical excellence, lacks the strong recommendations we believe the study deserves. Friends believes other government agencies which might read this report and be in a position to appropriate funds for implementation of a fix are left in suspense as to what needs to be done to eliminated the problem once and for all.

Response: The revised report does not adopt or recommend any specific implementation alternative because there are issues that need to be resolved by stakeholders before moving forward with implementation. This is not a situation where the optimal solution can be determined solely with quantitative calculations. For example, if an aerating weir was built downstream of the dam, the portion of the tailwater between the dam and the weir would be backwater with reduced aeration and low DO concentrations during critical periods. Would it be acceptable to essentially lose the trout fishery between the dam and the weir, especially downstream of Norfork Dam where the tailwater is only about 4.2 miles long? That is an example of a question for which ADEQ would want stakeholder input.

ADEQ does not have legal authority to require the implementation of any actions to improve DO in these tailwaters. ADEQ is in the process of facilitating a group of stakeholders that will work together to select and implement actions to improve DO concentrations in these tailwaters. ADEQ's intention with this group is not to continue talking about the problem for years, but to take action. However, moving forward without stakeholder involvement would lead to failure.

Friends sees the report as clearly indicating that DO is an extremely serious problem, and as such, believes the report demands strong conclusions and should make recommendations as to the preferred methods which would elevate DO levels above the minimum. We believe the final conclusion should be that the low-DO problem is intolerable and as such need to be fixed immediately using one or more of the currently available mechanisms to target the DO levels to 8 mg/L. The point at which there is no impairment of trout reproduction, not just to the 6 mg/L minimum.

Response: DO concentrations of 8 mg/L would be ideal, but ADEQ believes that the current criterion of 6 mg/L is appropriate.

Friends believes following conclusions and recommendations are appropriate and recommend be added to the existing ones at the end of the report.

Additional Suggested Conclusions:

• Dissolved oxygen levels over several months of each year continue to seriously affect aquatic environment. As indicated in Section 3.4, the ability of Trout to reproduce with no production impairment requires DO levels above 8 mg/L, trout health is affected when DO levels fall below 4 mg/L, and when DO levels fall below 2 mg/L fish die as indicated in Table 3.4.! Allowing this situation to persist is deplorable.

• The Low-DO levels persist for miles below the dams harming the fishery and likely already affecting tourism during the fall months.

• Water released from these dams into the North Fork and White Rivers enters the hydro turbines from greater than100 feet below the lake surface, which during the fall lies in the dead zone of these deep lakes. Although water passing through the modified turbines increases dissolved oxygen into the water exiting these turbines, the fact that the water coming into the turbines has very low or no oxygen content during late summer and fall of each year means that the water flowing out of the turbines is still very low in DO.

• Increased minimum flow, if implemented from at dam, will mitigate the high water temperature problem for the fishery during the summer months. However, it is expected that this will do little to increase the DO levels in the water and should not be considered in the DO problem solution set.

• Various options presented in Table 5-1 have been investigated, some of which would completely eliminate the problem and although costly must be considered for implementation. Selection of the best of these options, should be made and the funding for construction be pursued immediately.

• The solution to the low DO problem should not use the established 6 gm/L minimum DO , but should target DO levels to 8 gm/L and above so that there is no trout reproduction impairment. It does not make sense to implement a solution which would only raise the DO levels to the minimum, the solution should raise DO levels so that trout reproduction in the rivers are guaranteed.

• Unless a selection is made and funding secured shortly, further studying of the problem will add nothing to the already known. The cause of the DO problem is known and although further gathering of data may be warranted for an unbroken database, it will only continue to support the already well understood problem. After implementation of a solution, the gathering of data will provide evidence that the solution is working and could be used as a trigger for a supplemental oxygenation system.

Response: ADEQ agrees with the need for implementing measures that will raise DO levels in these tailwaters.

Suggested Recommendations:

• Given the serious effect of low-DO on the aquatic environment and the fishery, the hundreds of millions of dollars of tourism business and the resulting tax revenue the rivers bring to Arkansas, one or more of the alternative systems for increasing DO to acceptable levels should be selected immediately.

• Even though the selection(s) may not have been made, the securing of funding should be pursued immediately using the cost associated with the most costly and most effective of the systems.

Response: ADEQ has been working with other agencies and with staff from Arkansas' congressional delegation to pursue funding for implementing measures that will improve DO.

The one existing recommendation of the TMDL report, introducing a low cost paddlewheel as a means of increasing DO does not appear to be a viable alternative unless it is used in conjunction with another system. We recommend this recommendation be removed.

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information includes informal comments from AGFC, public comment #39 from SWPA, and public comments from BlueInGreen. This new information shows that the paddlewheel aerator might not be as effective as indicated in AGFC's original calculations and it would require an expensive mechanism (estimated cost of $100,000) to lift it out of the water to keep it from being damaged or washed away during high flows.

Friends believes with the issuance of this report, the time for studying the problem is over. The time for action is long overdue and ADEQ should champion the solution. The DO problem is not going away and, as indicated in the TMDL report, can be expected to worsen based on the expected increased discharges of oxygen consuming waste resulting from the increasing population growth along the White River watershed. This is another reason why Friends believes it would be wise to target a combination of DO increasing alternative mechanisms which in combination can raise the DO levels well above the minimum. The White River DO Committee thus far appears unable to make a decision, therefore, we suggest the TMDL Report with ADEQ's concurrence recommend the solution.

Response: The revised report does not adopt or recommend any specific implementation alternative because there are issues that need to be resolved by stakeholders before moving forward with implementation. At the same time, though, it is ADEQ's desire to see action (not just more talking) concerning selection and implementation of one or more measures to raise DO. ADEQ does not have authority over the dam or hydropower operations, but ADEQ is fully committed to carrying out the charge from Governor Beebe to facilitate stakeholders towards action on this issue.

Jerry Weber, President
Friends of the North Fork and White Rivers
P.O. Box 61
Mountain Home, AR, 72654

E.1.7 Comments From Norfork Lake Chamber of Commerce

We support ADEQ's trial implementation of the paddlewheel aerator.

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information shows that the paddlewheel aerator might not be as effective as indicated in AGFC's original calculations and it would require an expensive mechanism (estimated cost of $100,000) to lift it out of the water to keep it from being damaged or washed away during high flows.

We are opposed to any ideas that involve spending millions of dollars to correct a long running seasonal problem when other less expensive options have yet to be tried.

Response: ADEQ is currently facilitating a stakeholder group to pursue the most cost effective solution(s). ADEQ believes that there are effective solutions that can implemented at reasonable costs.

We oppose any forebay diffuser system being put into the lakes. In-lake systems have the potential of creating sanctuary environments, forcing no fishing seasons or zones and ultimately harming lake tourism.

Response: The third paragraph in Section 5.4 of the revised report includes a description of why a no-fishing zone was apparently implemented in another lake where a forebay diffuser was installed. The no-fishing zone was not directly caused by the forebay diffuser, but instead by overfishing in that area. The forebay diffuser would not harm lake tourism.

We have been excluded from all DO discussions either by accident or design and therefore lakeside concerns and interests have not been adequately evaluated. Until that is corrected, solutions involving the lakes need to be removed from consideration.

Response: ADEQ has never intentionally excluded anyone from stakeholder participation. Individuals representing lake interests are welcome to be involved in the selection and implementation of a solution.

Sincerely,
Norfork Lake Chamber of Commerce
PO Box 177
Gamaliel AR 72537

E.2. COMMENTS FROM INDIVIDUALS

E.2.1 List of Individuals That Submitted Comments

The next 11 pages contain a listing of the 407 individuals that submitted comments and which of the ten similar comments were submitted by each person. Following the 11-page table are the ten similar comments and ADEQ's responses (Section E.2.2). Some individuals submitted unique comments in addition to or in place of the similar comments. The unique comments are listed in Section E.2.3 along with ADEQ's responses.

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
1	Ackermann, B.	Rogersville, MO	Printout		✝								
2	Adams, D.	Bull Shoals, AR	Electronic					✝	✝	✝	✝	✝	✝
3	Adams, K. & J.	Walnut Ridge, AR	Printout	✝	✝	✝	✝						
4	Adkins, C.	Omaha, NE	Printout		✝								
5	Alexander, L.	Norfork, AR	Electronic					✝	✝	✝	✝	✝	✝
6	Allard, D.	Mountain Home, AR	Printout		✝								
7	Ambrose, A.	Little Rock, AR	Electronic					✝	✝	✝	✝		✝
8	Anderson, J.	Plano, TX	Electronic										✝
9	Anderson, M.	Mountain Home, AR	Printout		✝								
10	Andrews, B.	Springfield, MO	Electronic					✝	✝	✝	✝	✝	✝
11	Arnold, J.	Fort Smith, AR	Electronic						✝				✝
12	Atchison, D.	Springdale, AR	Electronic										✝
13	Bach, F.	Mountain Home, AR	Electronic					✝	✝		✝	✝	
14	Bailey, D.	Gamaliel, AR	Electronic							✝			
15	Bailey, F.	Mountain Home, AR	Electronic									✝	
16	Bales, E.	Des Moines, IA	Electronic							✝			
17	Barclay, R.	Rogers, AR	Electronic					✝				✝	
18	Barksdale, B.	Cotter, AR	Electronic										
19	Barton, C.	Georgetown, TX	Electronic					✝	✝	✝	✝		✝
20	Barton, K.	Lakeview, AR	Electronic					✝	✝	✝	✝	✝	✝
21	Beason, J.	Mountain Home, AR	Printout	✝	✝	✝							
22	Beavers, J.	Broken Arrow, OK	Electronic					✝		✝	✝		✝
23	Beck, M.	Mission, KS	Electronic					✝	✝	✝	✝	✝	✝
24	Beeson, T.	Nixa, MO	Electronic					✝	✝	✝	✝	✝	✝
25	Behlen, K.	Mountain Home, AR	Printout			✝							
26	Bennett, C.	West Hartford, CT	Electronic					✝	✝	✝	✝	✝	✝
27	Bennett, R.	Mountain Home, AR	Electronic		✝	✝							
28	Beringer, J.	Memphis, TN	Printout	✝	✝	✝	✝						
29	Billbe, R.	Flippin, AR	Electronic								✝		✝
30	Blair, B.	Cassville, MO	Printout		✝		✝						
31	Blair, N.	Mountain Home, AR	Electronic					✝	✝	✝		✝	✝
32	Blakemore, K.	Norfork, AR	Electronic					✝	✝	✝	✝	✝	✝
33	Blanck, G.	Flippin, AR	Electronic										
34	Bloebaum, J.	Troy, IL	Printout	✝	✝								
35	Boivin, B.	Rogers, AR	Electronic										
36	Bolin, D.	Searcy, AR	Electronic										
37	Borserine, M.	Prairie Village, KS	Electronic					✝			✝		
38	Borys, J.	Clarkridge, AR	Printout		✝								

	Name	Town or City	Format provided to FTN	Specific comments mentioned: Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
39	Boskus, R.	Mountain Home, AR	Both		✞	✞	✞						
40	Bowerman, J.	Midway, AR	Electronic					✞	✞	✞	✞	✞	✞
41	Bowker, R.	Norfork, AR	Electronic					✞	✞	✞	✞	✞	
42	Boyd, H.	Winnsboro, LA	Electronic					✞	✞	✞	✞	✞	✞
43	Boyer, G.	Schererville, IN	Printout		✞								
44	Brandenburg, J.	Bella Vista, AR	Electronic					✞	✞	✞	✞	✞	✞
45	Bransky, B.	Lawrence, KS	Electronic										
46	Branyan, S.	Rogers, AR	Electronic										
47	Breckenridge, K.	Licking, MO	Printout		✞								
48	Brent, C.	Wasilla, AK	Printout		✞								
49	Britt, A.	Harrison, AR	Electronic					✞	✞	✞	✞		
50	Brooks, R.	Georgetown, TX	Electronic					✞				✞	✞
51	Brown, J.	Osceola, IA	Electronic					✞					✞
52	Brown, R.	Rogers, AR	Electronic										✞
53	Bryan, T.	Rogers, AR	Electronic					✞					
54	Bryant, J.	Elizabeth, AR	Printout	✞	✞	✞	✞						
55	Buck, S.	Tulsa, OK	Electronic										
56	Butler, J.	Mountain Home, AR	Printout	✞	✞								
57	Byram, J.	Prairie Village, KS	Electronic					✞	✞	✞	✞	✞	✞
58	Cady, P.	Cotter, AR	Electronic					✞	✞	✞	✞	✞	✞
59	Cain, C.	Overland Park, KS	Electronic					✞	✞	✞	✞	✞	✞
60	Campbell, P.	Bull Shoals, AR	Printout		✞								
61	Canfield, D.	Mountain Home, AR	Printout	✞									
62	Canfield, J.	Mountain Home, AR	Printout	✞									
63	Cannava, T.	Fort Smith, AR	Electronic					✞	✞	✞	✞	✞	✞
64	Carlson, B.	Calico Rock, AR	Electronic					✞	✞				✞
65	Carnaghi, P.	St. Charles, MO	Electronic										✞
66	Carney, S.	Lakeland, TN	Electronic					✞	✞	✞	✞	✞	✞
67	Carpenter, J.	Cordova, TN	Both		✞	✞							
68	Carriere, J.	Mountain Home, AR	Electronic					✞	✞	✞	✞	✞	✞
69	Carril, K.	Overland Park, KS	Electronic										
70	Casey, M.	Vilonia, AR	Printout		✞								
71	Chapman, L.	Mountain View, AR	Electronic					✞	✞	✞	✞	✞	
72	Christensen, N.	Darien, IL	Printout	✞									
73	Ciocco, T.	Springfield, MO	Electronic					✞	✞	✞	✞	✞	✞
74	Clark, M.	Flippin, AR	Electronic										✞
75	Clemons, J.	North Little Rock, AR	Electronic					✞	✞	✞	✞	✞	✞
76	Cole, C.	Fort Smith, AR	Electronic					✞	✞	✞	✞	✞	✞
77	Colvard, B.	Tulsa, OK	Electronic					✞	✞	✞	✞	✞	✞
78	Conrad, D.	Elk, WA	Electronic					✞	✞	✞	✞	✞	✞

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
79	Cooper, B.	Rogers, AR	Electronic					✞	✞	✞	✞	✞	✞
80	Cordrey, R.	Mountain Home, AR	Electronic					✞	✞	✞	✞	✞	✞
81	Cornue, D.	Cotter, AR	Electronic					✞	✞	✞	✞		✞
82	Costilow, F.	Gepp, AR	Printout	✞	✞	✞							
83	Costner, P.	Eureka Springs, AR	Electronic							✞			
84	Cox, G.	Gamaliel, AR	Printout	✞	✞	✞	✞						
85	Cox, R.	Gamaliel, AR	Printout	✞	✞	✞	✞						
86	Cozzens, M. & J.	Gamaliel, AR	Printout		✞	✞	✞						
87	Crayton, R.	Poplar Bluff, MO	Printout		✞	✞							
88	Crenshaw, R.	Memphis, TN	Electronic					✞	✞	✞	✞	✞	✞
89	Crise, A.	Glen Rose, TX	Electronic										✞
90	Crook, M.	Hortonville, WI	Both		✞							✞	
91	Crouse, J.	Mountain View, AR	Electronic										✞
92	Crunkleton, H.	Cotter, AR	Electronic					✞	✞	✞			
93	Cupples, D.	West Memphis, AR	Printout	✞		✞							
94	Cupples, J.	West Memphis, AR	Printout	✞									
95	Curran, D.	Ballwin, MO	Electronic					✞		✞		✞	
96	Dally, S.	Mountain Home, AR	Electronic					✞	✞	✞	✞	✞	✞
97	Darner, K.	Cherokee Village, AR	Electronic										✞
98	Darr, J.	Cotter, AR	Electronic					✞	✞	✞	✞	✞	✞
99	Dauphin, B.	Scott, LA	Electronic										✞
100	Davis, C.	Fayetteville, AR	Electronic					✞	✞	✞	✞	✞	✞
101	Davison, G.	Willis, TX	Electronic										
102	Davisson, G.	Lee's Summit, MO	Electronic									✞	
103	Dixon, R.	Topeka, KS	Electronic					✞	✞	✞	✞	✞	✞
104	Drabant, N.	Mountain Home, AR	Printout	✞	✞	✞	✞						
105	Driscoll, K.	Corinth, TN	Printout		✞								
106	Dryden, B.	Montgomery City, MO	Printout		✞								
107	Dugan, J.	Butler, MO	Electronic						✞				
108	Dupre', F	Colleyville, TX	Electronic					✞	✞	✞	✞	✞	✞
109	Dziemiela, D.	Mountain Home, AR	Printout		✞								
110	Eagan, C.	Gamaliel, AR	Electronic	✞	✞	✞	✞						
111	Edmondson, C.	Phenix City, AL	Electronic					✞	✞	✞	✞	✞	✞
112	Egan, S.	Gamaliel, AR	Electronic	✞	✞	✞	✞						
113	Eggers, R.	Manhattan, KS	Electronic					✞			✞	✞	
114	Elstner, T.	Elizabeth, AR	Both	✞	✞	✞	✞						
115	Emerick, T.	Jordan, AR	Electronic					✞					✞
116	Emerson, H.	Waco, TX	Electronic										
117	Engeler, N.	Mountain Home, AR	Electronic										
118	Euler, J.	Cabot, AR	Printout	✞									

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
119	Feagan, M.	Leawood, KS	Electronic							✝		✝	
120	Fields, A.	Springfield, MO	Printout		✝								
121	Finch, B.	Yellville, AR	Electronic					✝			✝		✝
122	Fink, B.	Oregon, MO	Printout		✝								
123	Fiorillo, N.	Calico Rock, AR	Electronic					✝	✝	✝	✝	✝	✝
124	Fish, A.	Greenwood, IN	Electronic										
125	Fitzgerald, B.	Clarksville, AR	Printout		✝								
126	Flippo, E.	Walnut Ridge, AR	Printout	✝	✝	✝	✝						
127	Flippo, R.	Walnut Ridge, AR	Printout	✝	✝	✝	✝						
128	Flippo, T.	Walnut Ridge, AR	Printout	✝	✝	✝	✝						
129	Flynn, R.	Bartlett, TN	Printout	✝	✝	✝							
130	Foley, T.	Cotter, AR	Electronic					✝	✝	✝	✝	✝	✝
131	Forster, F.	Mountain Home, AR	Printout		✝								
132	Fountain, J.	Rogers, AR	Electronic					✝	✝	✝	✝	✝	✝
133	Fowler, C.	Bentonville, AR	Electronic										
134	Frank, C.	Clarksville, AR	Electronic					✝	✝	✝	✝	✝	✝
135	Fuhrman, R.	Fort Smith, AR	Electronic										✝
136	Fuller, B.	Fayetteville, AR	Electronic					✝	✝	✝	✝	✝	✝
137	Gabric, L.	Mountain Home, AR	Electronic		✝		✝						
138	Gamble, D.	Cotter, AR	Electronic								✝	✝	
139	Gamble, R.	Cotter, AR	Electronic					✝	✝	✝	✝	✝	✝
140	Giesy, M.	Mountain Home, AR	Printout	✝									
141	Gilbertson, J.	Jordan, AR	Both	✝	✝	✝	✝						
142	Gilpin, K.	Iola, KS	Electronic					✝	✝	✝	✝	✝	✝
143	Goodwin, P.	Springfield, MO	Electronic					✝				✝	
144	Grace, K.	Mountain Home, AR	Electronic					✝	✝	✝	✝	✝	✝
145	Gragg, J.	Salesville, AR	Printout		✝	✝	✝						
146	Graves, H.	Columbia, MO	Printout		✝								
147	Gregory, W.	Little Rock, AR	Electronic						✝		✝		✝
148	Griffith, K.	Jordan, AR	Electronic	✝	✝	✝	✝						
149	Griffith, R.	Gamaliel, AR	Electronic	✝	✝	✝	✝						
150	Guth, M.	Wheaton, IL	Printout			✝							
151	Haddick, A.	McHenry, IL	Electronic		✝		✝						
152	Haddick, D.	McHenry, IL	Electronic		✝	✝	✝						
153	Haines, R.	Fort Smith, AR	Electronic					✝		✝		✝	✝
154	Hall, D.	Mountain Home, AR	Electronic					✝	✝	✝	✝	✝	✝
155	Hanson, Ch.	Mountain Home, AR	Electronic		✝	✝	✝						
156	Hanson, Ci.	Gassville, AR	Electronic					✝	✝				✝
157	Hanson, R.	Mountain Home, AR	Printout	✝	✝	✝	✝						
158	Harmeling, G.	??	Electronic										

	Name	Town or City	Format provided to FTN	Specific comments mentioned: Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
159	Harmon, B.	Cotter, AR	Electronic						✝		✝		
160	Harten, B.	Apple Valley, MN	Electronic					✝	✝	✝	✝	✝	✝
161	Hass, B.	Little Rock, AR	Electronic										
162	Hathaway, Ji.	Little Rock, AR	Electronic						✝		✝		
163	Hathaway, Jo.	Little Rock, AR	Electronic					✝					✝
164	Hawkins, H.	Battlefield, MO	Electronic										✝
165	Hayes, D.	Bartlesville, OK	Electronic					✝					✝
166	Hearn, J.	Harrison, AR	Electronic								✝		
167	Hedges, D.	Spiro, OK	Electronic					✝	✝	✝	✝	✝	✝
168	Heitzman, K.	St. Louis, MO	Printout		✝		✝						
169	Heustis, D.	Saybrook, IL	Electronic	✝	✝	✝	✝						
170	Hiler, E.	Mountain Home, AR	Printout		✝								
171	Hill, C.	Fort Smith, AR	Electronic							✝			
172	Hodges, G.	Mountain Home, AR	Electronic					✝				✝	
173	Hollan, M.	Memphis, TN	Electronic					✝		✝			
174	Holland, G.	Bartlesville, OK	Electronic					✝	✝	✝	✝	✝	✝
175	Holtz, K.	Macon, GA	Electronic		✝								
176	Hudson, A.	Conway, AR	Electronic					✝					✝
177	Hudson, D.	Calico Rock, AR	Electronic					✝		✝	✝	✝	
178	Hulett, B.	Garnett, KS	Electronic					✝	✝	✝	✝	✝	✝
179	Huston, R.	Van Buren, AR	Electronic					✝	✝	✝	✝	✝	✝
180	Iervese, M.	Paducah, KY	Electronic								✝		
181	Ives, J.	Georgetown, TX	Electronic					✝	✝	✝	✝	✝	✝
182	Jackson, C.	Norfork, AR	Electronic					✝	✝	✝	✝	✝	✝
183	Jackson, K.	Arlington, TX	Electronic					✝		✝			
184	Jackson, W.	Little Rock, AR	Electronic									✝	
185	Jacobi, R.	Mountain Home, AR	Printout	✝									
186	Jaeger, L.	Mountain Home, AR	Printout		✝	✝							
187	Jared, D.	Elba, AL	Electronic								✝		✝
188	Johns, F.	Calico Rock, AR	Electronic					✝	✝			✝	
189	Johns, R.	Mountain Home, AR	Printout		✝	✝	✝						
190	Johnson, D.	Georgetown, TX	Electronic										
191	Johnson, L.	Jonesboro, AR	Printout	✝		✝	✝						
192	Johnson, L. & S.	Gepp, AR	Printout		✝								
193	Johnson, V.	Eads, TN	Electronic										✝
194	Jones, J.	Waterloo, IA	Printout	✝									
195	Jones, K.	Mountain Home, AR	Electronic	✝	✝	✝	✝						
196	Junck, J.	Mountain Home, AR	Electronic					✝	✝	✝	✝		✝
197	Keller, D.	Dyersburg, TN	Electronic						✝		✝	✝	
198	Kerns, D.	Gamaliel, AR	Printout		✝								

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
199	Kerry	Gainesville, MO	Printout		✞		✞						
200	Knowles, J.	Santa Fe, TN	Electronic										✞
201	Kozlowski, S.	Mountain Home, AR	Printout		✞								
202	Krinsky, H.	Beverly, MA	Electronic					✞	✞	✞	✞	✞	✞
203	Kyle, R.	Murfreesboro, TN	Electronic					✞		✞			
204	Labadie, J.	Belvidere, IL	Printout		✞								
205	Lamberth, D.	Elizabeth, AR	Printout	✞	✞	✞	✞						
206	Lane, D.	Terry, MS	Electronic					✞	✞				
207	Langston, H.	Springdale, AR	Electronic										✞
208	Laughlin, F.	Lawrence, KS	Electronic										✞
209	Lavelle, M.	Shreveport, LA	Electronic					✞	✞	✞	✞	✞	✞
210	Lawrence, R.	Elizabeth, AR	Printout	✞	✞	✞	✞						
211	Lehmberg, J.	Dayton, TX	Electronic					✞	✞	✞	✞	✞	✞
212	Lenard, La.	Nixa, MO	Electronic										✞
213	Lenard, Le.	Burlington, KS	Electronic					✞					
214	Leonard, R.	Bartlesville, OK	Electronic					✞	✞	✞	✞	✞	✞
215	Leslie, W.	St. Louis, MO	Electronic					✞	✞		✞		✞
216	Lessard, L.	Burton, TX	Electronic					✞	✞	✞	✞	✞	✞
217	Lewis, J.	Anderson, TX	Electronic										✞
218	Linomaz, M.	St. Louis, MO	Printout		✞								
219	Loader, A.	Eastwood, Australia	Electronic					✞	✞	✞	✞	✞	✞
220	Logan, G.	Lovington, IL	Printout	✞									
221	Lueken, P.	Mountain Home, AR	Electronic					✞		✞			
222	Malone, B.	Birmingham, AL	Electronic					✞					
223	Mann, G.	Midwest City, OK	Electronic										✞
224	Manry, G.	Batesville, AR	Electronic					✞	✞	✞	✞	✞	✞
225	Marshall, G.	Temple Terrace, FL	Electronic										
226	Marshall, M.	Germantown, TN	Electronic					✞	✞	✞	✞	✞	✞
227	Marshall, N. & J.	Albany, MO	Printout		✞								
228	Martin, K.	Pocahontas, AR	Printout	✞	✞	✞	✞						
229	Martin, L.	Elizabeth, AR	Printout	✞	✞	✞	✞						
230	Mathews, E. & P.	Little Rock, AR	Electronic					✞					
231	Mathews, W.	Norfork, AR	Electronic							✞			
232	McBride, G.	St. Charles, MO	Printout		✞								
233	McCain, H.	Little Rock, AR	Electronic									✞	
234	McDonald, B.	Little Rock, AR	Electronic										✞
235	McNulty, E.	Pine Bluff, AR	Electronic					✞	✞	✞	✞	✞	✞
236	Melton, L.	Little Rock, AR	Electronic					✞	✞		✞	✞	
237	Meng, G.	Gamaliel, AR	Both			✞	✞						
238	Menschik, C.	Mountain Home, AR	Electronic	✞	✞	✞	✞						

				Specific comments mentioned									
	Name	Town or City	Format provided to FTN	Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
239	Merrill, C.	Griffith, IN	Printout		✝								
240	Michal, L.	Bartlesville, OK	Electronic										
241	Mikrut, R.	Flippin, AR	Printout	✝									
242	Miller, F.	Overland Park, KS	Electronic					✝					
243	Miller, T.	Bellville, TX	Electronic					✝	✝	✝	✝	✝	✝
244	Milus, G.	Fayetteville, AR	Electronic					✝	✝	✝	✝	✝	✝
245	Miquelon, K.	Ballwin, MO	Electronic					✝	✝	✝	✝	✝	✝
246	Mobley, B.	Marshalltown, IA	Printout		✝								
247	Moeller, M.	Sapulpa, OK	Electronic										
248	Mooe, T.	Bentonville, AR	Electronic					✝					
249	Moreno, G.	Mountain Home, AR	Printout		✝								
250	Moretto, R.	Cortland, IL	Printout	✝			✝						
251	Morgan, W.	Cotter, AR	Electronic					✝	✝	✝	✝	✝	✝
252	Morris, C.	Little Rock, AR	Electronic					✝					
253	Morris, C.	Mountain Home, AR	Electronic						✝		✝		
254	Morris, W.	Germantown, TN	Electronic					✝		✝			
255	Morrow, S.	Springdale, AR	Electronic										
256	Mosier, J.	Tulsa, OK	Electronic					✝	✝	✝	✝	✝	✝
257	Mulhearn, C.	Rogers, AR	Electronic					✝	✝	✝	✝	✝	✝
258	Musielak, L.	Highland, IN	Printout		✝								
259	Naegeli, E.	St. Louis, MO	Printout		✝								
260	Nease, A.	Mountain View, AR	Electronic										✝
261	Neumann, D.	Oakland, AR	Electronic										✝
262	Nicklo, J.	Houston, TX	Electronic					✝	✝	✝	✝	✝	✝
263	Normandy, E.	Mountain Home, AR	Electronic				✝						
264	North, R.	Mountain Home, AR	Printout			✝							
265	Obering, R.	Mountain Home, AR	Printout				✝						
266	Olwell, J.	Mountain Home, AR	Electronic					✝					
267	Oneal, G.	Memphis, TN	Electronic										
268	Oneal, G.	Collierville, TN	Electronic					✝	✝	✝	✝	✝	✝
269	Orvis, C.	Cotter, AR	Electronic					✝	✝	✝		✝	✝
270	Owens, R.	Mountain Home, AR	Printout	✝	✝	✝	✝						
271	Oxnam, R.	Bozeman, MT	Electronic					✝	✝	✝	✝	✝	✝
272	Pahl, B.	Mountain Home, AR	Electronic					✝	✝	✝	✝	✝	✝
273	Painter, C.	Lafayette, IN	Printout		✝								
274	Partin, T.	Gamaliel, AR	Printout		✝								
275	Parton, C.	Yellville, AR	Electronic						✝	✝	✝	✝	✝
276	Patton, W.	Bella Vista, AR	Electronic					✝	✝	✝	✝		
277	Peters, J. & K.	Monticello, IN	Printout		✝								
278	Pettit, A.	Cotter, AR	Electronic										

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
279	Pettit, B.	Corning, AR	Electronic					✞			✞	✞	
280	Pharis, H.	Norfolk, AR	Printout	✞									
281	Phillips, C.	Lenexa, KS	Electronic										
282	Piantanida, J.	St. Louis, MO	Printout		✞	✞	✞						
283	Piveral, K.	Maryville, MO	Printout		✞	✞							
284	Poole, R.	Pittsburg, KS	Electronic						✞			✞	✞
285	Poulos, M.	Cotter, AR	Electronic					✞	✞	✞	✞		✞
286	Powell, G.	Memphis, TN	Electronic					✞					
287	Prairie, T.	Tucson, AZ	Electronic					✞	✞	✞	✞	✞	✞
288	Priest, C.	Fayetteville, AR	Electronic					✞		✞			✞
289	Pruett, M.	Springfield, MO	Electronic						✞				
290	Qualls, J.	Mountain View, AR	Electronic					✞		✞	✞	✞	✞
291	Ragsdale, R.	Little Rock, AR	Electronic					✞	✞	✞	✞	✞	✞
292	Raines, J.	Cotter, AR	Electronic					✞	✞	✞	✞	✞	✞
293	Rains, R.	Fort Smith, AR	Electronic					✞	✞	✞	✞	✞	✞
294	Reed, T.	North Platte, NE	Printout		✞								
295	Reeder, R.	Mountain Home, AR	Electronic					✞					
296	Reese, J.	Ozark, MO	Electronic					✞	✞	✞	✞	✞	✞
297	Reid, R.	Springfield, MO	Electronic					✞	✞	✞	✞	✞	✞
298	Reynolds, R.	Cherokee Village, AR	Electronic										✞
299	Reynolds, S.	Indianapolis, IN	Printout		✞	✞							
300	Reynolds, S.	Mountain Home, AR	Printout		✞								
301	Reynolds, T.	Mountain Home, AR	Printout	✞	✞	✞	✞						
302	Richardson, G.	Lawrence, KS	Electronic					✞	✞	✞	✞	✞	✞
303	Riggs, J.	Little Rock, AR	Electronic									✞	
304	Riley, R.	Rogers, AR	Electronic					✞	✞	✞	✞	✞	✞
305	Rodgers, R.	Manchester, MO	Printout		✞	✞	✞						
306	Rogers, B.	Jordan, AR	Printout		✞		✞						
307	Ron	House Springs, MO	Printout	✞									
308	Ropson, M.	Jordan, AR	Electronic					✞	✞	✞	✞	✞	✞
309	Rubio, G.	Bismarck, AR	Electronic						✞	✞			✞
310	Rush, R.	Mountain Home, AR	Printout		✞								
311	Sanderson, J.	Frankfort, IL	Printout			✞							
312	Sanderson, J.	Orland Park, IL	Printout		✞								
313	Sapp, W.	Bartlesville, OK	Electronic					✞	✞	✞	✞	✞	✞
314	Sappenfield, B.	Memphis, TN	Electronic					✞	✞	✞	✞	✞	✞
315	Sarle, B.	Mountain Home, AR	Printout		✞								
316	Schaeffer, C.	Olathe, KS	Electronic					✞	✞	✞			
317	Schill, J.	Marietta, GA	Electronic										
318	Schneider, R.	Mountain Home, AR	Printout	✞									

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
319	Schulte, C.	Waterloo, IA	Printout	✞									
320	Scott, E.	Fayetteville, AR	Electronic					✞	✞	✞		✞	✞
321	Scott, J.	Bentonville, AR	Electronic					✞	✞	✞	✞	✞	✞
322	Seay, H.	Mountain Home, AR	Electronic					✞	✞		✞		✞
323	Selig, J.	Mountain Home, AR	Printout	✞		✞							
324	Selton, R.	Jonesboro, AR	Electronic					✞	✞	✞	✞	✞	✞
325	Semrau, L.	State University, AR	Electronic						✞				
326	Sewell, G.	Pocahontas, AR	Both	✞	✞	✞	✞						
327	Shaffer, J.	Mountain Home, AR	Printout		✞	✞	✞						
328	Shaffer, L.	Afton, OK	Printout		✞								
329	Shemeluk, W.	Broken Arrow, OK	Electronic					✞			✞	✞	✞
330	Shiver, J.	Little Rock, AR	Electronic					✞	✞	✞	✞	✞	✞
331	Simmons, M.	Columbia, IL	Printout	✞									
332	Sivillo, P.	Fayetteville, AR	Electronic							✞			
333	Smallman, J.	Honolulu, HI	Electronic									✞	
334	Smart, D.	Tebbetts, MO	Printout		✞								
335	Smith, B.	Mountain Home, AR	Printout		✞	✞	✞						
336	Smith, J.	Norfork, AR	Electronic						✞	✞	✞	✞	
337	Smith, M.	Fort Smith, AR	Electronic					✞				✞	
338	Smith, S.	Gamliel, AR	Printout		✞		✞						
339	Smith, W.	Mountain Home, AR	Electronic	✞	✞	✞	✞						
340	Smuz, B.	Belvidere, IL	Printout		✞	✞	✞						
341	Snider, R.	Gamaliel, AR	Printout		✞								
342	Steffek, D.	Houston, TX	Electronic								✞		✞
343	Steffens, D.	Dallas, TX	Electronic					✞		✞		✞	✞
344	Stewart, H.	DFW Airport, TX	Printout	✞	✞	✞	✞						
345	Still, A.	Irvine, CA	Electronic					✞	✞		✞	✞	✞
346	Stoker, R.	Houston, TX	Electronic						✞				
347	Stout, B.	Clinton, AR	Electronic									✞	
348	Street, S.	Mountain Home, AR	Both	✞									
349	Strowger, F.	Mountain Home, AR	Printout			✞							
350	Swanner, M.	Springdale, AR	Electronic					✞	✞	✞	✞	✞	✞
351	Swarthout, G.	Mountain Home, AR	Printout		✞								
352	Swink, P.	West Plains, MO	Printout		✞								
353	Taylor, G.	Farmerville, LA	Electronic									✞	
354	Taylor, P.	Houston, TX	Electronic					✞	✞	✞	✞	✞	✞
355	Teter, R.	Mountain Home, AR	Printout		✞								
356	Thom, K.	Maryville, MO	Printout		✞								
357	Thorne, B.	Flippin, AR	Electronic					✞	✞	✞	✞	✞	✞
358	Thorne, S.	Flippin, AR	Electronic					✞	✞	✞	✞	✞	✞

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
359	Thrash, T.	Jamestown, LA	Electronic					✟	✟		✟	✟	✟
360	Timmons, D.	Rogers, AR	Printout	✟			✟						
361	Tipton, M.	Gassville, AR	Electronic					✟	✟	✟	✟	✟	✟
362	Toler, G.	Eureka Springs, AR	Electronic										
363	Traylor, J.	Bull Shoals, AR	Printout		✟								
364	Truzinski, J.	Jordan, AR	Printout	✟	✟								
365	Tucker, M.	House Springs, MO	Electronic					✟					
366	Turbeville, J.	Little Rock, AR	Electronic										✟
367	Turner, B.	Batesville, AR	Printout	✟	✟	✟							
368	Turner, D.	Mountain Home, AR	Electronic										
369	Twesme, L.	Lakeview, AR	Printout	✟									
370	Van Donge, K.	Fayetteville, AR	Electronic					✟	✟	✟	✟	✟	✟
371	Van Scoyoc, M.	Mountain Home, AR	Both	✟	✟	✟	✟						
372	Vekovius, G.	Flippin, AR	Electronic					✟	✟	✟	✟	✟	✟
373	Wakefield, J.	Bridgeview, IL	Printout		✟								
374	Waldeck, B. & O.	Cotter, AR	Electronic										
375	Walters, B.	Memphis, TN	Printout	✟	✟								
376	Walters, S.	Little Rock, AR	Electronic					✟					
377	Walthal, W.	Memphis, TN	Printout		✟								
378	Watkins, N.	Lepanto, AR	Electronic					✟	✟	✟	✟	✟	✟
379	Wegmann, L.	Springfield, MO	Electronic					✟	✟	✟	✟	✟	✟
380	Weinmann, D.	Sycamore, IL	Both	✟	✟	✟	✟						
381	Weinmann, G.	Elizabeth, AR	Electronic	✟	✟	✟	✟						
382	Weinmann, K.	Cortland, IL	Both	✟		✟							
383	Weinmann, T.	Sycamore, IL	Printout	✟									
384	Weliver, B.	Mountain Home, AR	Electronic					✟					
385	Wenta, R.	West Bend, WI	Printout		✟								
386	Whiteaker, W.	White Hall, AR	Electronic										
387	Wilcox, T.	Leslie, AR	Electronic					✟	✟	✟	✟	✟	✟
388	Wiley, B.	Camdenton, MO	Printout		✟								
389	Williams, W.	Cordova, TN	Electronic								✟		
390	Williamson, J.	Jonesboro, AR	Both	✟		✟							
391	Wilson, J.	Mountain Home, AR	Electronic					✟	✟	✟			✟
392	Wilson, L.	Republic, MO	Electronic					✟	✟	✟	✟	✟	✟
393	Wilson, S.	Norfork, AR	Electronic					✟		✟	✟	✟	✟
394	Winburn, R.	Fayetteville, AR	Electronic					✟	✟	✟	✟	✟	✟
395	Wintle, D.	Mountain Home, AR	Electronic				✟						
396	Woodsmall, D.	Henderson, AR	Printout	✟	✟	✟							
397	Woodward, G.	Jonesboro, AR	Electronic							✟	✟		
398	Woofter, R.	Garfield, AR	Electronic					✟		✟	✟	✟	✟

	Name	Town or City	Format provided to FTN	Specific comments mentioned									
				Support trial implementation of paddlewheel aerator	Oppose forebay diffuser system. In-lake systems can create sanctuaries, forcing no-fishing seasons or zones	Opposed to spending millions of dollars before trying less expensive options	Private lake area entities have been excluded from discussions; solutions involving the lake should not be considered	It is critical to eliminate seasonal periods of low-oxygen in the North Fork and White Rivers.	ADEQ should enforce DO standards, which do not allow diurnal fluctuation below 6 mg/L for trout streams.	Low-cost paddlewheel aerator may improve DO sometimes, but it will not resolve low DO status of Norfork tailwater	TMDL does not address remediation for low DO in Bull Shoals tailwater, although TVA study identified approaches.	ADEQ's attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem.	TMDL fails to emphasize that low-DO levels in these tailwaters is an extremely serious problem known since 1963.
399	Wooten, C.	Fort Smith, AR	Electronic					✟					
400	Wright, A.	Fort Smith, AR	Electronic					✟	✟	✟	✟	✟	✟
401	Wright, E.	Mountain Home, AR	Electronic					✟	✟	✟	✟		
402	Yoker, S.	Springfield, MO	Electronic										✟
403	Younce, D.	Benton, AR	Electronic					✟					
404	Zimmermann, J.	Flippin, AR	Electronic									✟	
405	Zortman, F.	Mountain Home, AR	Both		✟								
406	Zortman, L.	Mountain Home, AR	Both	✟	✟	✟	✟						
407	Zortman, M.	Mountain Home, AR	Printout		✟								
	Total number of times each comment was mentioned =			66	120	65	57	163	133	134	134	134	155

E.2.2 Similar Comments Submitted by Numerous Individuals

I support ADEQ's trial implementation of the paddlewheel aerator.

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information includes informal comments from AGFC, public comment #39 from SWPA, and public comments from BlueInGreen. This new information shows that the paddlewheel aerator might not be as effective as indicated in AGFC's original calculations and it would require an expensive mechanism (estimated cost of $100,000) to lift it out of the water to keep it from being damaged or washed away during high flows.

I oppose any Forebay diffuser system being put into the lakes. In-lake systems have the potential of creating sanctuary environments, forcing no fishing seasons or zones and ultimately harming lake tourism.

Response: The third paragraph in Section 5.4 of the revised report includes a description of why a no-fishing zone was apparently implemented in another lake where a forebay diffuser was installed. The no-fishing zone was not directly caused by the forebay diffuser, but instead by overfishing in that area. The forebay diffuser would not harm lake tourism.

I am opposed to any ideas that involve spending millions of dollars to correct a long-running seasonal problem when other less expensive options have yet to be tried.

Response: ADEQ is currently facilitating a stakeholder group to pursue the most cost-effective solution(s). ADEQ believes that there are effective solutions that can be implemented at reasonable costs.

Private lake area organizations, associates and individuals have been excluded from all DO discussions either by accident or by design and therefore lakeside concerns and interests have not been adequately evaluated. Until that is corrected, solutions involving the lakes need to be removed from consideration.

Response: ADEQ has never intentionally excluded anyone from stakeholder participation. Individuals representing lake interests are welcome to be involved in the selection and implementation of a solution.

It is critical to eliminate the seasonal periods of low-oxygen in the North Fork and White Rivers. Currently, both rivers have periods of low DO that are sufficient to threaten or kill trout embryo and/or adult trout. Further, the levels of dissolved oxygen periodically result in impaired growth rates of trout living in these streams. Trout kills have been observed.

Response: ADEQ agrees with the need for implementing measures that will raise DO levels in these tailwaters.

ADEQ is charged with enforcing water quality standards in Arkansas. These regulatory standards do not allow a diurnal fluctuation of DO below 6 mg/L for trout streams.

Response: ADEQ does not have any authority over the operation of dams or hydropower facilities, but ADEQ will continue to strive towards every waterbody meeting water quality standards.

While your proposed low-cost paddlewheel aerator may improve water quality during no-generation periods, the AGFC study indicates that this method will not be operable during periods of generation. Because incoming lake water is inherently low in oxygen during certain periods, it appears that this proposed method will NOT resolve the current low-oxygen status of the Norfork tailwater.

Response: The paddlewheel aerator is no longer being proposed as a low-cost alternative based on information obtained after the draft report was developed. This new information includes informal comments from AGFC, public comment #39 from SWPA, and public comments from BlueInGreen. This new information shows that the paddlewheel aerator might not be as effective as indicated in AGFC's original calculations and it would require an expensive mechanism (estimated cost of $100,000) to lift it out of the water to keep it from being damaged or washed away during high flows.

The proposed TMDL does not address any remediation for the low-oxygen status of the Bull Shoals tailwater, although the study by the Tennessee Valley Authority clearly identifies approaches which would introduce sufficient oxygen to meet the 6 mg/L standard in the tailwater.

Response: The revised report does not adopt or recommend any specific implementation alternative because there are issues that need to be resolved by stakeholders before moving forward with implementation. At the same time, though, it is ADEQ's desire to see action (not just more talking) concerning selection and implementation of one or more measures to raise DO.

Although your attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem, I do not believe ADEQ really intends that. To clarify ADEQ intent, the TMDL should state which long-term solution ADEQ believes will solve the problem once and for all.

The TMDL could additionally recommend that, should complete funding for a permanent solution not be available, then the paddlewheel be installed as a temporary measure. The TMDL should then reiterate that a paddlewheel implementation will be inadequate to meet the 6 mg/L standard, and thus is not endorsed by ADEQ as the solution to the impaired status of these two trout streams.

Response: See responses to previous comments concerning the paddlewheel aerator, which is no longer being recommended, and ADEQ's pursuit of action to improve DO.

The ADEQ TMDL fails to emphasize the fact that low-DO levels in the tailwaters of both Bull Shoals and Norfork Rivers is an extremely serious problem, known since at least 1963. The low-DO situation should be intolerable – especially to the agency charged with enforcing water quality standards. Not only are DO levels far below the state minimum standard, but they have been shown in your own TMDL to be seasonally deadly to trout! ADEQ should officially include this as a finding within the TMDL. Further, the agency should state which of the proposed fixes will work for both tailwaters. The proposed installation of a paddle wheel below Norfork Dam should be eliminated as a recommended solution, since you in the TMDL indicate this will not solve the problem.

Response: See responses to previous comments concerning the paddlewheel aerator, which is no longer being recommended, and ADEQ's pursuit of action to improve DO.

E.2.3 Other Comments Submitted by Individuals

Adams, K. & J.

Fishing and boating on Lake Norfork have always been a vacation spot for us and our families. This year with the lake so high, it made launching the boats at a disadvantage because we had to put in at other places other than Hand Cove. The lake is the only vacation spot for a lot of families, why take that away from families who enjoy the lakes and make it to where we can't even fish and enjoy the lake as it once was.

Response: ADEQ has no intent to support and encourage any measures that would negatively impact fishing and boating in the lakes. ADEQ believes that there are solutions that will solve the tailwater DO problem without negatively impacting the lakes.

Adkins, C.

I am a regular visitor to Lake Norfolk and I would hate to lose a trip down to it because I can't fish for Stripers.

Response: Please see response to comment by K. & J. Adams.

Anderson, M.

From my experience fishing the Norfork Lake, any restrictions on fishing near the dam during the summer months would make striper fishing very tough. Which would discourage fisherman from coming to our lake for vacation or to make it their home. This would seem to add insult to injury for this area during this downturn in the economy. We have many resorts and guides on Lake Norfork who rely on tourists for their income who in turn spend that income at the local businesses.

Response: Please see response to comment by K. & J. Adams.

Barksdale, B.

It appears to me that the ADEQ TMDL fails to acknowledge the full impact of the low-DO levels in the Bull Shoals and Norfork river tailwaters. This is an extremely serious problem that cries out for immediate and full attention.

I view this as a long-standing problem that must be corrected if the world class trout fisheries in these rivers are to thrive.

I have fly-fished these rivers since the late 1950s, raised our two sons making trips to fly-fish these rivers, and now enjoy sharing these precious and unique resources with my grandsons, who live in Austin, TX and Minneapolis, MN.

I hope the ADEQ will take a broader view of this situation and implement measures to address the DO situation on both rivers.

Response: ADEQ agrees with the need to implement measures to improve DO in these tailwaters.

Beason, J.

I live on Lake Norfork, and launch at Robinson Point. I came to the Twin Lakes area because of the lakes and rivers and creeks as most residents did. If the lake is shut down in areas the reason to be here will not keep me here. Think what this will have on other people looking settle here in retirement. WE ARE the money in this area.

Response: Please see response to comment by K. & J. Adams.

Behlen, K.

It would take away the only good fishing I ever get.

Response: Please see response to comment by K. & J. Adams.

Blanck, G.

i think it is necessary to do whatever is needed to control the lake-- the cost is not an issue when you realize the revenue that comes from the tourists. shutting down the seans/lakes would absolutely kill the twin lakes business'..... changes can be made in moderation, so that the problems can be cleared up with minimum impacts and cost in a long range plan. this is just my opinion. i know you will decide what's best for the waterways.. thanks for your time,

Response: ADEQ is currently facilitating a stakeholder group to pursue the most cost-effective solution(s). ADEQ believes that there are effective solutions that can be implemented at reasonable costs.

Boivin, B.

Please understand how critical it is that we work to eliminate the periods of low-oxygen in the North Fork and White Rivers. Currently, both rivers have periods of low DO that are sufficient to threaten or kill trout embryo and/or adult trout. Further, the levels of dissolved oxygen periodically result in impaired growth rates of trout living in these streams. Trout kills have been observed and if sufficient measures are not put in place, I'm afraid we can expect to see more of that in the future. The White and North Fork rivers are two magnificent places to fish and enjoy the outdoors. The amount of money that is brought into the local and state economy by these rivers each year is substantial. If the quality of our streams is not upheld and consequently if the quality of the fishing experience in north-central Arkansas diminishes, so too will the revenues from tourism, recreation, and fishing that this area relies upon. Please take this responsibility seriously, and support in full the measures that are required to uphold the quality of the White and North Fork tailwaters. Thank you.

Response: ADEQ agrees with the significant economic impact of trout fishing in these tailwaters and the need to implement measures to improve DO to protect the trout fisheries.

<u>Bolin, D.</u>

I would ask that the ADEQ document and consider the long term economic value of these fisheries first and then consider the cost of remediation. The capital cost of systems that have been proven to work by the TVA should be a fraction of the annual economic value of these fisheries to the people of the state of Arkansas.

The paddle wheel proposal makes it appear that the ADEQ either does not believe that the legal minimum DO levels are necessary or that the Bull Shoals and Norfork fisheries have no economic value to the State of Arkansas. I hope that's not the case. But it would be difficult to justify a $6,400 paddle wheel to ensure the health of a multimillion dollar State resource.

Please consider a proposal that will meet legal minimum DO levels on both the Bull Shoals and Norfork reservoirs.

Response: ADEQ agrees with the significant economic impact of trout fishing in these tailwaters. Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative. ADEQ is certainly pursuing implementation of measures that will not just slightly improve DO, but bring DO up the water quality standard of 6 mg/L.

<u>Borys, J.</u>

Closing seasons is not the answer to a problem that exists only seasonally. Close the river to fishing when oxygen is low. There are other methods that can be tried. Don't punish the lake anglers.

Response: Please see response to comment by K. & J. Adams.

Boyer, G.

I currently vacation at Norfork 2-3 times a year. I have hopes of retiring to the area before long. Any plan that results with restrictions on the lake, whether fishing or general usage, to improve conditions in the river would probably result in my changing my future plans. All options should be considered that would balance water quality on the lake with water quality on the river. Rather than treat the symptoms, dissolved oxygen levels, I see no discussion about what is causing it.

Response: Please see the response to the comment by K. & J. Adams. Also, Section 3 of the report has been revised to include additional discussion and analysis about the cause of low hypolimnetic DO.

Bransky, B.

Bring the DO levels up or suffer considerable financial loss when fishing revenue dries up due to poor fishing

Response: Please see response to comment from B. Boivin.

Branyan, S.

In reference to the TMDLS FOR DISSOLVED OXYGEN FOR WHITE RIVER BELOW BULL SHOALS DAM AND NORTH FORK RIVER BELOW NORFORK DAM, the low DO situation below this tailwater is something I follow and which affects my business as a fly fishing guide. As I see it, this, along with minimum flow which addresses the below average historic flows and temperature control for the trout fisheries, is a mitigation issue which must be addressed at the federal level. I appreciate ADEQ trying to protect the state water quality minimum standards of 6.0 ppm for DO on trout waters. Turbine venting is only partially successive in addressing the issue and is an inadequate solution for non-generation periods. Forebay oxygen diffusion seems to be a potential permanent solution to the matter. The brown trout spawn occurs just at the peak of the low dissolve oxygen period in November and this has detrimental consequences to the fishery as the big fish all head to the dam where O2 is lowest. Any fish kills during this time are simply unacceptable to me. In fact, DO standards should be at 8.0 pmm through the late fall and into the winter months in order to have an effective spawn. The effect of low DO to the fishery impacts the state's economy and the recreational and tourism industry. It's not fair that SPA and USACE use the state's resource for power generation without putting back resources into the resource they draw a profit from. Sincerely, Scott Branyan

Response: ADEQ agrees with the need for a permanent solution that would protect trout during the spawning period as well as other times of the year.

Brent, C.

As a new seasonal resident to the area I object to this plan being implemented.

`Response:  No specific plan has been selected for implementation.`

Buck, S.

I have been an Arkansas licensed fisherman for several years. My family and I travel and stay spending money in AR. I find the trout fishery to be the primary reason I come to AR. I do not lake fish. The oxygen level is critical for the trout and the area below Bull Shoals is the place that we go most often. Please give priority to keeping the oxygenation of these waters high.

`Response:  Please see response to comment by B. Barksdale.`

Butler, J.

We have some of the best fishing in the USA, let us try to work together to keep it. I think we still need more FACTS…less GUESSING.

`Response:  Please see response to comment by B. Barksdale.`

Carril, K.

I am an officer of the Heart of America Flyfisher, a club in the Kansas City area. Our members believe it is critical to eliminate the seasonal periods of low-oxygen in the North Fork and White Rivers. It is our understanding that both rivers have periods of low DO that threaten or kill trout embryo and adult trout. Additionally, the levels of dissolved oxygen periodically result in impaired growth rates of trout living in these streams. Trout kills have been observed.

We understand your attempt to incur very little cost to this problem but it appears to turn a blind eye to the seriousness of this problem. You need to take serious this threat to an important resource to the people of Arkansas. Are, to put it more bluntly in business terms, Do you want to threaten this cash-cow ?

The TMDL should state which long-term solution ADEQ believes will solve the problem once and for all. The TMDL could additionally recommend that, should complete funding for a permanent solution not be available, then the paddlewheel be installed as a temporary measure. The TMDL should then reiterate that a paddlewheel implementation will be inadequate to meet the 6 mg/L standard, and thus is not endorsed by ADEQ as the solution to the impaired status of these two trout streams.

Thank you for listening to our concern and know that our members are following this issue closely.

Response: ADEQ agrees with the need to implement long-term solutions to improve DO in these tailwaters. ADEQ believes that there are effective solutions that can be implemented at reasonable costs. Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative.

Costilow, F.

Mississippi catfish farmers have been using the "paddlewheel" for years, there has got to be something to it! Anything that can have the potential to harm tourism in this area needs to be "shot down." Trying the less expensive option first is the way to go if it could save millions.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative. ADEQ believes that there are effective solutions that can be implemented at reasonable costs.

Cozzens, M. & J.

When the economy is so bad, why is money being spent in this fashion? Everyone has to tighten their belts, why not the government. It is our tax money, right? How do you explain an expense like this to people losing jobs, homes, and everything they hold dear?

Response: It is not clear exactly what the comment means. ADEQ always supports wise stewardship of public money and will continue to do so while pursuing implementation of measures to raise the DO in these tailwaters.

Crook, M. (1)

ADEQ must take a long term solution view of this problem, AND incorporate a Cost vs Benefit analysis of those permanent solutions. IF you INVEST soon, in a strong, permanent solution to this serious problem, you can improve these Blue Ribbon trout fisheries AND continue to reap large, economic benefits for the northern AR region.

Do the RIGHT thing, and the needed investment resources for it WILL be forthcoming.

Response: Please see response to comment from B. Boivin.

Crook, M. (2)

The Norfork Lake Chamber of Commerce is just plain wrong, in stating on their website that a Forebay Oxygen Infusion system would harm fishing in the reservoir in any way. IF you are receiving email input that people oppose the Forebay system because of adverse effects on lake fishing, you simply must treat it as what it is… fearful, misinformation.

Response: The third paragraph in Section 5.4 of the revised report includes a description of why a no-fishing zone was apparently implemented in another lake where a forebay diffuser was installed. The no-fishing zone was not directly caused by the forebay diffuser, but instead by overfishing in that area. The forebay diffuser would not harm lake tourism.

Davison, G.

I have had the honor to fish (Trout) on the White this last October. It would be a great loss to this nation and its people not to mention the huge impact on all the wildlife that depends on it's bounty to see this great resource vanish.

Seeing a Bald Eagle on the banks of the White, taking part in the grand eco system was and is a delight for me. I would hate to see this change due to lack of support and concern to make these waters run pure for all those creatures within them.

Response: ADEQ is committed to protecting the environment of Arkansas so that people can continue to enjoy aquatic and terrestrial wildlife in Arkansas.

Drabant, N.

There should be no projects that have the potential to restrict or limit fishing on Lake Norfork.

Response: Please see response to comment by K. & J. Adams.

Dziemiela, D.

You must realize that this would critically impact the sport of striper fishing as well as have a negative impact on the business of “guide” fishing. Please… the economy is bad enough; please don’t make it worse!!!!

Response: Please see response to comment by K. & J. Adams.

Emerson, H.

I believe that research has shown that use of the Forebay system "in lieu" of the paddle wheel system is superior. Please consider the Forbay system as the system of choice in improving our waters.

I drive 500 miles to Mountain Home often only for trout fishing and visiting the Federation of Fly Fishers' annual Southern Council Conclave and Sowbug Tie-In. I spend a considerable amount of money which helps the local economy. I stay at the Ramada, eat often at K.T.s and shop at Mountain River Fly Shop, to mention only a few. If the waters are not as good and the fish are less plentiful or nor in as good condition, I will find another place to fish, possibly in Southern Oklahoma, about 300 miles closer to home. I have not done this, though and do not plan to, because I love coming to Mountain Home.

What more can I say; aerate and oxygenate the rivers, get the trout as healthy as possible by doing so, and keep the money rolling in! It doesn't take a Harvard accountant to figure this one out!!!

Response: Please see response to comment from B. Boivin.

Engeler, N.

Trout fishing is not the only reason to protect the fragile ecosystem of the White and North Fork Rivers. If we cannot count on ADEQ to enforce water quality standards in Arkansas then to whom do we turn. These streams are vital, life-giving to the Ozark Mountain region; therefore I find it unthinkable that regulatory standards would not be observed in your proposal.

Response: ADEQ does not have authority over the dam or hydropower operations, but ADEQ is fully committed to working towards implementation of measures to bring DO up to the water quality standard.

Fish, A.

Low-DO levels in the tailwaters of both Bull Shoals and Norfork Reservoirs is an extremely serious problem.

Even though it is expensive to correct, especially during this economic crisis, the benefit to the economy should be taken into consideration. The tourism industry brings in millions of dollars every year to the Baxter County area simply because of the trout fishing in the Norfork and White rivers. I have been making at least annual trips to the area to fish for over ten years.

Failure to protect the trout populations and the viability of the trout spawns would be devastating to the economy of Baxter County.

I would highly recommend implementing a solution(s) which would aerate the low BOD water as it comes out of the reservoirs, such as forced air to the turbines.

Response: Please see response to comment from B. Boivin.

Forster, F.

Has this issue been shown in the local newspapers? Get the word out that favorite fishing spots might be on hold and see what your feed back would be.

Response: The draft TMDL report was available on the ADEQ web site for almost 2 months and there was an article in the Arkansas Democrat-Gazette about this project right after Thanksgiving 2008 when the public comment period was extended. A large amount of feedback has been received.

Fowler, C.

I appreciate all you do at ADEQ! I've recently moved to AR, and chose to do so due to my passion for the outdoors and all AR has to offer in this area! In no small part is that due to your groups great efforts.

Thank you so much for trying to address the water quality challenges we are incurring throughout the White River system.

I hope you feel as I do, that it is critical to eliminate: 1)these low-oxygen and 2)high water temperature periods on the North Fork and White Rivers. Currently, both rivers have periods of low DO (and high temperatures) that are sufficient to threaten or kill trout embryo and/or adult trout. A number of trout kills (13) have been observed in the last 20 or so years.

With your groups great efforts, I look forward to seeing these issues resolved and the White River reaching it's full potential as a resource for the people of Arkansas.

Response: Please see response to comment from B. Barksdale.

Gamble, D.

The White and North Fork Rivers continue to grow in popularity as destination sites for fishers, which in turn strengthens the tourism industry of the area. That industry is essential to the economy of North Central Arkansas and any decrease in the quality of the fisheries has a dramatic impact on many Arkansans. Therefore, it is critical to eliminate the seasonal periods of low-oxygen in the North Fork and White Rivers. Today, both rivers have periods of low DO that are sufficient to threaten or kill trout embryo and/or adult trout. The levels of dissolved oxygen periodically result in impaired growth rates of trout living in these streams. Trout kills have been observed.

Response: Please see response to comment from B. Boivin.

Gamble, R.

I believe our hundreds of customers that come to Arkansas each year to spend their money trout fishing would agree with the following:

I assume funding is the actual problem and ADEQ would be happy to do a real solution if it had unlimited funds.

The TMDL should explain WHY your agency is planning to do NOTHING (other than spend $6400) and WHY the funding is not available. I would assume that if your agency is charged with enforcing it must also be charged with identifying the source of funds to do your job and requesting those funds.

What has been done by your agency since 1963 to OBTAIN funding for projects such as this and WHO is stopping the funding?

Give Barack a call and get some of the $700,000,000.

Response: ADEQ is actively pursuing multiple avenues for possible funding for implementing measures to improve tailwater DO. Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative.

Gilbertson, J.

We operate a Resort, Restaurant and Guide Service one mile from the Dam and oppose any Forebay diffuser system being put into the lakes. In-lake systems have the potential of creating sanctuary environments, forcing no fishing seasons or zones and ultimately harming lake tourism! We are opposed to any ideas that involve spending millions of dollars to correct a long running seasonal problem when other less expensive options have yet to be tried.

How can this money be justified without consideration of all impacts???

Response: Please see responses to comments from K. & J. Adams and from M. Crook (2).

Guth, M.

The studies do not suggest that normal lake height severely diminishes the oxygen levels, flood stages (and man made High/Low water levels) have submerged large quantities of organic matter that has decayed and depleted the oxygen levels. Further the studies (oxygen and minimum flow) should not have been implemented at the same time.

Response: Section 3 of the report has been revised to include additional discussion and analysis about the cause of low hypolimnetic DO, particularly in relation to wet and dry years.

Harmeling, G.

I was reviewing ADEQ's Proposed TMDL (Total Maximum Daily Load) for Dissolved Oxygen (DO) on the White and North Fork Rivers. I believe that the proposed solution, mechanical aeration during non-generating periods will be insufficient, by itself, to ameliorate the low d. o. problem and that other solutions should also be implemented.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative.

Haas, B.

Please accept these comments on the Arkansas Department of Environmental Quality's Proposed Total Maximum Daily Load (TMDL) for the pollutant of concern Dissolved Oxygen in the White River below Bull Shoals Dam and North Fork River below Norfork Dam within the State of Arkansas.

Having worked along with many others for the past 4 years to protect Lake Maumelle in central Arkansas, the primary drinking water supply for roughly 400,000 people, I strongly urge you to adopt the proposed TMDL for the above named waterbodies to help protect and preserve them. ADEQ should be doing everything it can to reduce the number of impaired streams, and adopting strong Dissolved Oxygen standards for these waterbodies would be a step in the right direction.

High quality water will only gain in importance in coming years, and that demands that ADEQ and other regulatory bodies continue to increase protections for threatened streams, lakes and other waterbodies all across the state.

Response: Please see response to comment from B. Barksdale.

Heitzman, K.

If oxygen levels in the river are a problem and you want to change them do something in the river, don't mess with the lake. No reason to solve one problem by creating another.

Response: Please see response to comments from K. & J. Adams.

Jacobi, R.

Considerations for the forebay oxygen diffuser should be prioritized to provide a potential solution for the Hybrid Bass / Striper kills during times of low DO levels in the lake. If this method is selected and properly communicated it should also help in smoothing the lake communities concerns that has been expressed.

Response: The priority for selecting an alternative to implement is its effectiveness for raising DO in the tailwaters, not in the lakes. Any added benefits of improving fisheries in the lakes will be considered but not certainly prioritized below improvements to the tailwater.

Johnson, D.

I belong to a fly fishing club in Georgetown TX. Several of our members make annual trips to Arkansas to fish for trout in your tailwater rivers. Please don't let low dissolved oxygen levels in these rivers destroy these fisheries.

Response: Please see response to comment from B. Boivin.

Johnson, V.

The ADEQ TMDL has failed to emphasize the fact that low-DO levels in the tailwaters of both Bull Shoals and Norfork Rivers is an extremely serious problem of long duration. The low-DO situation should be intolerable -- especially to the agency charged with enforcing water quality standards. Not only are DO levels far below the state minimum standard, but they have been shown in your own TMDL to be seasonally deadly to trout! ADEQ should officially include this as a finding within the TMDL. Further, the agency should include proposed fixes for both tailwaters. The proposed installation of a paddle wheel below Norfork Dam should be eliminated as a recommended solution, since it does not address the problem during generation periods. Surely with all your expertise you can find a better method for improving the dissolved oxygen content of both rivers. We want to leave our children a better river system than we found.

Response: Please see response to comment from B. Barksdale.

Kerry

u trout lovers are not the only fisher man in the world get a job u jerks

Response: ADEQ acknowledges the comment.

Marshall, G.

On the subject of low oxygen in the Wite and Norfolk Rivers, Fish gots to breath too. Don't know the best way to increase O2 level, but think the COE needs to get it done. They built the dams that destroyed the warm water fishery. The unintended consequences are that now the fish can't breathe sometimes during the fall months. Hope you can get it fixed.

Response: Please see response to comment from B. Barksdale.

Merrill, C.

If oxygen is needed in the river, then put it in the river, not in the lake.

Response: Please see response to comment from K. & J. Adams.

Michal, L.

I am concerned with the apparently lethal to trout oxygen levels in the water at certain times of the year. Surely there is some way to elevate this level with a one time expense apparatus that has minimal upkeep expense. Being involved with a fishing club, this matter was brought to my attention. Why couldn't an aeration device be installed downstream of the turbine output in addition to the unit for non generation periods?

Response: Section 5 of the revised report briefly describes two alternatives for adding oxygen to the water downstream of the turbines. Those alternatives are an aerating weir and a supersaturated dissolved oxygen (SDOX) injection system. The weir would have very little upkeep, but the SDOX system would have significant operation costs.

Moeller, M.

As a property owner on the White for over 30 years and a frequent Norfolk fisher I am gravely concerned about the oxygen quality levels. It does not appear any proposed solution will solve the problem for both rivers ...at both high and low water levels, which you are mandated to do. To clarify ADEQ intent, the TMDL should state which long-term solution ADEQ believes will solve the problem once and for all. The TMDL could additionally recommend that, should complete funding for a permanent solution not be available, then the paddlewheel be installed as a temporary measure. The TMDL should then reiterate that a paddlewheel implementation will be inadequate to meet the 6 mg/L standard, and thus is not endorsed by ADEQ as the solution to the impaired status of these two trout streams.

Response: ADEQ agrees with the need to implement long-term solutions to improve DO in these tailwaters. ADEQ believes that there are effective solutions that can be implemented at reasonable costs. Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative.

Morrow, S.

I would like to do my part to help these causes by saying. The wright thing to do to taking the path to acheve the best we can to proved the sport and the fish every chance to survive. Less we forget, this water system was once the primeir small mouth and canoe river in the nation. And it was right here in our back yard. Yes we have an ok trout water system now. But it is lacking and much is needed to evey scrach the surface of what we as sportsmen and our children have lost.

Response: Please see response to comment from B. Barksdale.

North, R.

Other techniques than the Forebay system are possible which may cost tens of thousand of dollars but not tens of millions of dollars. Submerged Skimming Weirs in the Kansas City District and the U.S. Bureau of Reclamation project on Shasta Dam on the Sacramento River should be examined for up to date information. TVA’s aerating weirs should be checked out for possible use. Results of the Chatuge Infuser Weir may be outdated by now but improvements of the above projects may prove valuable. Even THE WEST HANDBOOK ON WATER QUALITY ENHANCEMENT TECHNIQUES FOR RESERVOIRS AND TAILWATERS developed partly by the U.S. Army Engineer Research and Development Center at the Waterway Experiment Station at Vicksburg, MS lists several other methods that might be applicable. Have these been researched lately?

Response: ADEQ is open to considering any idea that is effective and has a reasonable cost. TVA’s aerating weirs are discussed in Section 5.4 of the revised report. The 1997 TVA reports on aeration options for each dam consist of a fairly comprehensive review of different alternatives.

O’Neal, G.

I am one of the attorneys who represented Trout Unlimited in the lawsuit that ADEQ brought against Homeport Land Company over sediment runoff and the resulting pollution of the Norfork River. It is my understanding that Governor Beebe has recognized the importance of the dissolved oxygen problem on the Norfork and Bull Shoals tailwaters and has instructed ADEQ to do whatever is necessary to fix this problem.

I strongly urge ADEQ to comply with its legal responsibilities, as well as the governor's instructions, and finally fix the dissolved oxygen problem on these tailwaters, no matter what it takes to do so. This problem has been around for decades, and Arkansas state government has done nothing but talk about it thus far. Immediate action is necessary to protect these tailwaters, the trout that live in them, and the multimillion dollar economy and thousands of jobs that depend on them.

I hope that ADEQ will finally live up to its legal obligation to do whatever is necessary to solve this dissolved oxygen problem now.

Response: Please see the response to the comment from B. Barksdale. ADEQ does not have authority over the dam or hydropower operations, but ADEQ is fully committed to working towards implementation of measures to bring the DO up to the water quality standard.

Parr, E.

Please do not put the oxygen system by the dam on Lake Norfork. This will destroy the Striper fishing in the fall near the dam. Have you thought of this problem. Please let me know the facts concerning Striper fishermen and if there is another way to add oxygen into the North Fork and the White Rivers.

Response: Please see the responses to comments from K. & J. Adams and from M. Crook (2).

Pettit, A.

I am writing to urge a broader ADEQ approach to the dissolved oxygen problem on BOTH the Norfork and White Rivers. Only spending the amount($6,400.) proposed on the apparatus, while just using it during NON- generation periods, plus only installing it on the Norfork River, severely undermines and diminisheds the effort of several state and federal agencies as well as hundreds of interested citizens who have worked tirelessly to find a solution to this problem for decades. This ADEQ proposal needs to be revisited and for sure needs to be published for all interested to see and be given an adequate time to respond as it appears this comment period was not advertised where the public was given sufficient notice. Please consider my comments and I hope you come back with a proposal that addresses my concerns.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative. ADEQ agrees with the need to implement long-term solutions to improve DO in these tailwaters.

Pharis, H.

Somewhat limited options that mostly support your position. The tourist industry in this area is not limited to “Lake” fisherman. Last time I toured the Norfork Lake from the dam to past the Missouri State line there was a lot of striper water to fish. If the boating population on Lake Norfork would stop their illegal macerator discharges into the Lake the lowered level of decaying organic matter might improve the water quality of the lake and lower the need to “add” oxygen. The people who fish the tailwater fishery have many areas that carry fishing restrictions all year or part of the year. The area below Bull Shoals Dam is prime example. I have never been much in favor of catching fish in a barrel or shooting wild animals in fenced in area. There will always be individuals that follow the hatchery truck or fish the lake where fish must concentrate to survive. That is not “Fishing” that is “Catching.” The nay sayers might be pleasantly surprised with the size and vigor of the striper population if they are allowed to have safe haven in a healthy environment for a few months.

Response: Please see response to comment from B. Barksdale.

Phillips, C.

Because trout fishing is important to many individuals in the surrounding states and the citizens of Arkansas and because ADEQ has a responsibility to enforce water quality standards that maintain sportfishing in Arkansas, it is essential that oxygen dilution rates must be addressed to allow trout and other species an appropriate habitat.

Response: Please see response to comment from G. O'Neal.

Reed, T.

I come down there often and oppose anything that would potentially harm the fishing there.

Response: Please see response to comment from K. & J. Adams.

Rogers, B.

I am opposed to having Closed Seasons on the lake. I live and have my boat at a marina by the Dam. This would cause a great expense for me to travel away from the Dam area to fish!

Response: Please see the responses to comments from K. & J. Adams and from M. Crook (2).

Sarle, B.

I oppose any Forebay diffuser system being put into the lakes. In-lake systems have the potential of creating sanctuary environments, forcing no fishing seasons or zones and ultimately harming lake tourism.

Don't change nothing.

Response: Please see response to comment from K. & J. Adams.

Schill, J.

I am a property owner on the White River above Cotter in Marion County. I bought this property in 2001 for the clean White River and the Trout Fishing. This brings me to the low-do problems in both the White and Norfork tail waters.

ADEQ should work with the AFG solving this problem. AFG has the money to help solve this problem. That has been around since 1963. For some unknown reason protection from contaminants entering the White River watershed has not been enforced. The ADEQ is charged with enforcing water quality standards and bringing these rivers up to state requirements. ADEQ is responsible to correct the low-do problem. ADEQ Has know about this problem since 1963 that is 35 years. Yet the ADEQ has yet to find answers to correcting this problem. The time has come to protect these rivers and living up to the Arkansas State slogan The NATURAL STATE. If you let the low-do problem continue the slogan will be the un natural State. The net result of not doing anything will result in the decrease in economy for the State of Arkansas in tax revenue and the lost of revenue for Mountain Home, Cotter, and Bull Shoals communities.

The water wheel for the Norfork is a bandaid for the low-do problem.

Response: Please see response to comment from D. Bolin.

Schneider, R.

If the lake area near the dam needs to be closed to preserve the fishery during summer stress times, how about limiting the closure to July & August? That will give at least some protection to the fish and yet help the fishing industry. If that were to happen, I also suggest strong policing of limits and not allow "culling." Thanks for your consideration, and for all you do.

Response: ADEQ has no plans to pursue an implementation alternative that results in closure of any area to fishing.

Schulte, C.

Your state has something few have, a great trout fishery with the possibility of catching huge fish. As someone who travels to your state for these opportunities I urge you to do all you can to protect and improve the fishery.

Response: Please see response to comment from B. Barksdale.

Smith, J. (1)

I am the owner of a resort on the North Fork River. ADEQ's lack of enforcement of the DO regulation is destroying the reputation of the North Fork River. The pollution form the Overlook Estates problem, two floods this year, unusual high water and now a serious problem with DO. Our business is off 40%. Some of it due to the general economy, but much of it due to the factors listed above. We need your help, it is about time that you bring litigation to the COE and any other parties responsible for not complying to ADEQ regulations. I wish I could go 23 years of not living up to regulation place upon me personally and toward our businesses.

Response: ADEQ agrees with the significant economic impact of trout fishing in these tailwaters.

ADEQ is charged with enforcing water quality standards in Arkansas. These regulatory standards do not allow a diurnal fluctuation of DO below 6 mg/L for trout streams.

While your proposed low-cost paddlewheel aerator may improve water quality during no-generation periods, the AGFC study indicates that this method will not be operable during periods of generation. Because incoming lake water is inherently low in oxygen during certain periods, it appears that this proposed method will NOT resolve the current low-oxygen status of the Norfork tailwater. This is a total farce and bandaid at best. It is will not force the COE to comply with the regs.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low cost alternative.

The proposed TMDL does not address any remediation for the low-oxygen status of the Bull Shoals tailwater, although the study by the Tennessee Valley Authority clearly identifies approaches which would introduce sufficient oxygen to meet the 6 mg/L standard in the tailwater. The fore bay system is the best approck to soving the DO problem on the North Fork. The COE refuses to acknowledge what nearly ALL TVA lakes have implemented. Fore Bay Oxygenation!!

Although your attempt to incur very little costs appears to turn a blind eye to the seriousness of this problem, I do not believe ADEQ really intends that. To clarify ADEQ intent, the TMDL should state which long-term solution ADEQ believes will solve the problem once and for all. The TMDL could additionally recommend that, should complete funding for a permanent solution not be available, then Arkansas needs to implement the fore bay approach and bring suit to recover the expendatures. Make the SWPC pay for the source of Oxygen, or they do not get to continue to generate electricity. Some one once calculataed athe athe cost would be about $2.00 per customer of theirs, per year. The TMDL should then reiterate that a paddlewheel implementation will be inadequate to meet the 6 mg/L standard, and thus is not endorsed by ADEQ as the solution to the impaired status of these two trout streams.
Thank you for the opportunity to express our frustration relative to the ruin of the North Fork reputation. By not enforcing the DO regulation, you are contributing to the poor image of our valued resource and bringing damage to our business. We do not need a bandaid, we need to fix the problem immediately even at the expense of our state. Recover the money later, just get the waters into compliance.

Response: ADEQ does not have authority over the dam or hydropower operations, but ADEQ is fully committed to working towards implementation of measures to bring the DO up to the water quality standard.

Smith, J. (2)

I support the fore bay system. The Norfork Lake Chamber of Commerce is merely creating resistance because of their inactivity in the resolution to the problem of DO noncompliance. Bringing them into the discussion process is a good idea, but they could easily make an appointment with ADEQ and be brought up to speed. Their resistance at the 11th hour brings us back to the same delay tactics that have been used for 23 years. We need to bring the water on the Norfork tailwaters into compliance. TVA has had NO problems with the fore bay system and the idea that sanctuaries will be created is pure speculation and a scare tactic.

Response: Please see response to comment from M. Crook (2).

Smith, W.

It is most disappointing that the actions of the ADEQ were not publicized to the all the Chambers of Commerce, fishing associations, and to all the County Judges, and City mayors where dams are located and directly affected in the regions of the state. If the notice was publicized in the Little Rock Arkansas Democrat-Gazette, this was neither full, nor adequate notification throughout the state!

Response: The draft report was available on the ADEQ web site for nearly 2 months and ADEQ issued a news release when the public review period was extended.

Stewart, H.

While I have a DFW address I own a home in Jordan 2 miles from the Norfork Dam and fish the river along with our guest all during and the year. The abundance of fish, even though we basically catch and release, is important to us.

Response: Please see response to comment from B. Barksdale.

Street, S. (1)

If the rivers need oxygen, oxygenate the rivers. I am against any fishing restrictions near the dam and against the diffusers. Why is everyone trying to change the lake with minimum flow and now diffusers for trout at the lake people's expense? I vote no.

Response: Please see response to comment from K. & J. Adams.

Street, S. (2)

I support the paddlewheel test on Norfork Lake and if successful, I support its implementation if no fishing restrictions are imposed due to it. If oxygenization is need for the rivers, add oxygen to the rivers not the lakes and pay for it out of trout stamp user fees.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative.

Strowger, F.

So far, we have survived these problems. There are many other more important issues to spend money on!!!

Response: ADEQ appreciates the comment.

Teter, R.

During this time of economic recession, I think monies can be better spent elsewhere. I am also opposed to anything that could adversely affect the local economy. In better economic times, I could be for the diffuser system if it didn't mean creating a sanctuary environment in the lake. A no fishing season in the height of the tourist season would probably be very hurtful to the local economy.

Response: Please see responses to comments from K. & J. Adams and M. Crook (2).

Toler, G.

Please do all that is possible to maintain a DO level that supports all stages of fish life in both Norfok and Bull Shoals tailwaters.

Response: Please see response to comment from B. Barksdale.

Turner, D.

Please work to eliminate the seasonal periods of low-oxygen in the North Fork and White Rivers. Both rivers have periods of low DO that are sufficient to threaten trout. It is your responsibility to protect this fishery.

Response: Please see the response to the comment from B. Barksdale. ADEQ does not have authority over the dam or hydropower operations, but ADEQ is fully committed to working towards implementation of measures to bring the DO up to the water quality standard.

Van Scoyoc, M.

It is time for the state and federal government to stop spending our tax dollars like there is no end. The cost of a Forebay diffuser will cost many millions of tax payer dollars only to benefit a few. The DO conditions have existed on our lakes and rivers since the time the dams were built. Just in case no one this noticed; we are in a recession!

Response: ADEQ appreciates the comment.

Waldeck, B. & O.

With respect, this recommendation appears to ignore the problem entirely and will in no way help to reconcile the issue. It's hard to see what installing the paddle wheel will help resolve, especially long term. Why not bite the bullet and recommend what's really needed and see how far you can progress. If money prevents any possibility of doing what's right, so be it, but at least you tried. I think it would make more sense just to do nothing, rather than throw out a bone that won't satisfy anyone.

Thanks for letting us comment.

Response: Based on new information, the paddlewheel aerator is no longer being considered as a low-cost alternative. ADEQ agrees with the need to implement long-term solutions to improve DO in these tailwaters.

Walters, B.

We take a family vacation on Lake Norfork for several weeks in August. There are roughly 20 of us and we participate in every activity available on the lake. Please do not implement something that negatively impacts the lake. Lake marinas and resorts are struggling enough as it is. They do not need anything else that would impact their customer base.

Response: Please see response to comment from K. & J. Adams.

Wenta, R.

I oppose any Forebay diffuser system being put into the lakes. In-lake systems have the potential of creating sanctuary environments, forcing no fishing seasons or zones and ultimately harming lake tourism.

This sounds to me like it will concentrate fish in an off-limits to fishing area BAD IDEA

Response: Please see responses to comments from K. & J. Adams and M. Crook (2).

Whiteaker, W.

Arkansas has spent many years and millions of dollars trying to brand itself as the Natural State. The public understands that to mean a place where the environment it clean and healthy.

I don't represent myself to be an expert on such matters. As an ordinary citizen, I do try to support those who monitor environmental issues; and to pass on to government officials information that I believe would be helpful in making informed decisions that are in the public interest.

Few would take exception to the common belief that good fishing is one of the primary tourist attractions to the Natural State. Trout fishing is especially important to our tourist industry.

If the afore referenced information provided by Friends of the North Fork & White Rivers is anywhere near accurate, It would appear that ADEQ's own minimum standards are not being met with respect to stated Dissolved Oxygen policies and standards.

I urge you to provide the leadership needed to resolve this water quality problem. The public would doubtless support such action. Thank you.

Response: Please see response to comment from B. Barksdale.

Weinmann, G.

I am supportive of a river side of the dam solution. Any lake side solution puts the Norfork Lake fishery at risk. It would be in appropriate to enhance one fishery at the potential expense of another. Please see the attached 11 pages of supporting documents that outline the risks to a lake fishery that a forebay diffuser systems presents. These documents are intended to be included with this comment and the official comment record. Document sources are: Minutes of the July 2004 Southern Division Reservoir Committee – General Discussion The development of an Oxygen Diffuser for Hydropower by Mark H Mobley – Cherokee Lake section Tennessee Striped Bass Association No Fishing Zone announcement as directed by TWRA.

(The 11 pages attached to this comment are shown on the pages following this response.)

Response: Please see responses to comments from K. & J. Adams and M. Crook (2).

- working with multi-discipline teams and stakeholders
- White River case history
- Chattahoochee case history
- Lake Mead case history
- North Carolina case history

Fishery Manager's Toolbox

1. **Aquatic Habitat – Gene Gilliland**
   - challenges to aquatic plant management
   - long-term changes in habitat and fisheries
   - watershed management and impact on reservoir fish habitat
   - regional trends, differences in habitat and fisheries
2. **Human Dimensions – Wade Bales**
   - future of human dimensions research in fisheries assessment and marketing
3. **Catch and Release – Scott Hendricks**
   - does voluntary catch-and-release remove harvest as a "tool" in our toolbox?
   - data from creel surveys and population trends
   - angler motivations regarding catch and release
4. **Stocking – Mark Oliver**
   - Virginia – stripers
   - Texas – largemouth bass
   - North Central Division – walleye
5. **Assessment and Analysis – Fred Janssen**
   - progress since AP:P?
   - linking shifts in fish communities to fishery management
   - spatial analyses as alternatives to traditional population indices
   - tying measures of habitat to fish population metrics

February deadline to identify speakers for the various sections of the symposium.

Scott Hendricks: Report on search for meeting facility in Atlanta. Handout. Checked 10-12 hotels. GA Tech Conf. Ctr (Grand Hyatt/Buckhead) Westin Buckhead. Grand Hyatt picked by group.

Meeting days and dates discussed. Discussion of Sat/Sun travel deals. Thursday through Sunday (same as Spring meeting) was the final consensus.

Workshop details were discussed.

Scott will proceed with finding out what options are available. He'll see what Southern Co. would charge to handle the meeting.

General discussion

There was a discussion regarding TVA's use ofl forebay diffusers. Corps has to meet state water quality standards. Lake Russell has forebay diffusers. Ed Scott and Bill Proctor at TVA River Ops 865-632-1959 are contacts for diffuser information. Douglas and Cherokee in Tennessee (TVA) have diffusers. Lake Thurman is trying to get a diffuser. Some lakes have closed seasons and/or closed seasons on striped bass because of the concentrating effect of the diffusers.

Warren Turner, National Striped Bass Association, is developing partnerships with resource agencies.

Send state fishing regs to Fred Heitmann.

Fred Janssen reported on the continuing golden algae situation that Texas and other states are experiencing: Affected Lakes: Colorado 2,000 acres golden algae total kills, E.V. Spence 20,000 acres total kill, Possum Kingdom Golden algae kills ruined the striper fishery, Lake Whitney had GA kills but still has striper fishery.

Catch and Release Info

Fred Heitman gave a summary of EPA's 316(b) Final Rule Update: The rule update applies to power plants that draw 50 mgd or more a day. A summary is available from Fred or can be downloaded from the RC webpage. Of primary importance to fisheries managers are the reduced permissible levels of impingement and entrainment of aquatic organisms. Facility improvements (engineering technology) or restoration plans can be used to reach permissible impingement levels. If a facility chooses restoration then the state G&F agencies will have approve their plans. There will be increased opportunities for habitat, stocking, etc.

Roundtable Session:

Mike Allen: Water management districts removing huge amounts of gizzard shad. If you remove gizzard shad, you take away the nutrient pump that takes nutrients from the bottom into the water column. Commercial gillnetters were employed. These are very rich lakes with not much sportfishing. They are selling the gizzard shad for $0.25 per pound for catfood. Mike will be doing study to look at reproductive response of removing large shad.

"And Then It Sank..." The Development of an Oxygen Diffuser for Hydropower

By Mark H. Mobley, R. Jim Ruane, and E. Dean Harshbarger

ABSTRACT

Diffuser designs for aeration of hydropower reservoirs have progressed over the past 25 years with improved operation and reduced costs. The porous hose line diffuser design, developed for the Tennessee Valley Authority (TVA), has proven to be an efficient and economical aeration diffuser design at eleven applications. The line diffuser design transfers oxygen efficiently, and minimizes temperature destratification and sediment disruption by spreading the gas bubbles over a very large area in the reservoir. The development of the line diffuser was an iterative process that responded to site-specific requirements and design failures. Each successive application described in this paper provided new challenges and design improvements.

Introduction

Need for DO Enhancement

The water quality of reservoir releases has become a recognized issue for hydropower projects. Many Federal Energy Regulatory Commission (FERC) licensing requirements now include minimum dissolved oxygen standards; and, projects owned by Federal agencies like TVA and the US Army Corps of Engineers are under pressure by State agencies and private interest groups to improve water quality in the releases from their projects. In many reservoirs, solar energy heating causes a stable temperature stratification during the summer months when the warm surface water floats over the colder deep water, referred to as the hypolimnion. Oxygen demands near the sediments and in the water consume the dissolved oxygen (DO) in the hypolimnion, which is sealed off from the most significant sources of oxygen such as wind mixing and algae photosynthesis. Thus, depending on water flows and the magnitude of the oxygen demands, the hypolimnion can become oxygen depleted. If the DO levels are driven low enough, anoxic products like hydrogen sulfide and dissolved iron and manganese can reach troublesome levels in the water nearest the sediments. If this water is then withdrawn through hydropower intakes, the low DO water and anoxic products are released downstream.

Enhancement Alternatives

Each reservoir and hydropower project has site-specific characteristics that impact the need for and the means used to improve reservoir releases. Each project should be evaluated for site-specific requirements and then the best alternative or combination of alternatives should be applied. In 1997, TVA completed the Lake Improvement Plan, a five-year program to improve minimum flow and dissolved oxygen levels at sixteen hydropower projects (Brock and Adams, 1997). Several new and innovative aeration alternatives were developed and applied over the course of the program, including the porous hose line diffuser. The TVA program included 8 applications of turbine venting, 7 of oxygen diffusers, 2 of surface water pumps, 2 of air blowers, 2 of aerating weirs, and 1 application of auto venting replacement turbines. Several projects required combinations of up to three alternatives to meet target aeration requirements.

Reservoir Diffuser Concept

A reservoir diffuser distributes gas bubbles in the reservoir upstream of the turbine intakes to increase DO in the water that will be drawn out by hydropower operations, as shown in Figure 1. The diffuser systems are supplied with compressed air or oxygen from a supply facility located on shore. Pure oxygen gas is usually preferred to avoid potential total dissolved gas problems in the tailrace. The smaller, deeper, and more disperse the bubbles, the better the oxygen transfer efficiency. High oxygen transfer efficiency reduces the amount of gas and the size of the delivery system necessary to meet DO requirements. The placement of the diffusers and distribution of the oxygen input from the bubbles must be designed to meet site-specific water quality and water flow conditions to be effective.

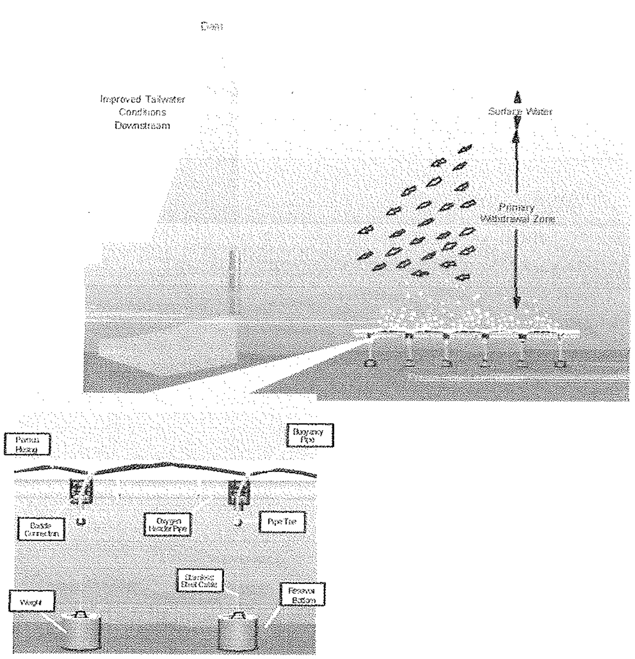


Figure 1: Diffuser Schematic (from Mobley, 1996)

Oxygenation within the reservoir can be an economical means to meet DO requirements for hydropower releases. The purchase of liquid oxygen is expensive, but other aeration alternatives may not be applicable at a specific hydropower site or may be insufficient to meet DO requirements. Oxygen diffuser systems are well suited for use as a topping-off system to augment other less expensive aeration systems that are unable to achieve the water quality objectives alone. Oxygenation within the reservoir can accomplish DO requirements without causing adverse effects on turbine generation, and is usually the only alternative that has the potential to eliminate anoxic products and DO demands that may cause water quality problems (e.g., a DO "sag" or decrease) in the releases.

Early Hydropower Installations Using Ceramic Diffusers

Fort Patrick Henry Dam, TVA: 1973

Some of the earliest research on reservoir diffuser systems for hydropower application was conducted by TVA at Fort Patrick Henry Dam (Ruane and Vigander, 1972). A pilot study and demonstration project were conducted from 1973 to 1976 (Fain, 1978). The installation used a liquid oxygen gas supply and ceramic diffusers that were mounted on diffuser frames supported by columns that extended from the reservoir bottom to the surface. The project provided good test data, but was discontinued due to an unrelated improvement in the incoming water quality conditions at the site and a subsequent loss of funding for the project.

Richard B. Russell Dam, U.S. Army Corps of Engineers, Savannah District: 1985

As a part of the original environmental commitments for the Richard B. Russell hydropower project, the Savannah District developed, designed, and installed a huge reservoir oxygen diffuser system (Mauldin et al. 1988). The system consisted of two distribution components, one for continuous operation approximately 1.5 miles upstream of the dam and one near the dam for instantaneous oxygen input during hydropower operation. The installation utilized 3,888 ceramic diffuser heads and provided a total capacity of 300 tons per day. The system has been operated since 1985 to meet a DO target of 6 mg/L in the releases. Oxygen costs have averaged around one million dollars per year (Peavey, 1994). Extensive maintenance using divers and replacement of the ceramic diffusers has been required over the years, but this system remains one of the largest oxygen diffuser installations in use today.

Design Similarities

Both of these early diffuser system designs used bottom-anchored diffuser frames. At Fort Patrick Henry, an intricate system of guy cables and buoys on the surface was used to position the diffuser frames. The diffusers at Richard B. Russell required divers for installation and maintenance. Both systems were equipped with ceramic diffusers to obtain the smallest bubbles and thus the most efficient oxygen transfer. Both systems also experienced clogging of the ceramic fine pore diffusers. The Richard B Russell system was equipped with a hydrogen chlorine gas injection system to clean the ceramic diffusers and the diffusers were replaced in 1991 with a self-cleaning membrane type. Experience at these projects indicated that ceramic diffusers and requirements for divers should be avoided.

Early Hydropower Installations Using Membrane Diffusers

Douglas Dam, TVA: 1988

In 1988, a pilot oxygen diffuser system was installed on Unit 4 at TVA's Douglas Dam. Three bottom-anchored, steel diffuser frames with adjustable legs to fit bottom topography were lowered from a catamaran crane in front of the intake of Unit 4. Each 6-meter by 10-meter (20-foot by 33-foot) frame supported 78 membrane diffusers, as shown in Figure 2. Oxygen transfer efficiencies of about 72% were measured late in the DO season of 1988 when weak stratification conditions existed (Mobley, 1989). DO improvements in the releases were about 2 mg/L. However, during the peak of the 1989 DO season, the oxygen improvement in the releases dropped to nearly zero. This was attributed to oxygen demands stirred up from near the reservoir sediments and mixed by the strong plumes induced by the diffusers. No clogging of the membrane diffusers was experienced, but the Unit 4 generator cooling system was clogged with sediment and organic growth due to the pumping action of the diffuser plumes. This necessitated outages for cleaning and chemical treatments to reduce organic build-up. This experience indicated a clear need for a means to spread the bubbles over large areas to reduce mixing and entrainment of oxygen demands from the sediments.

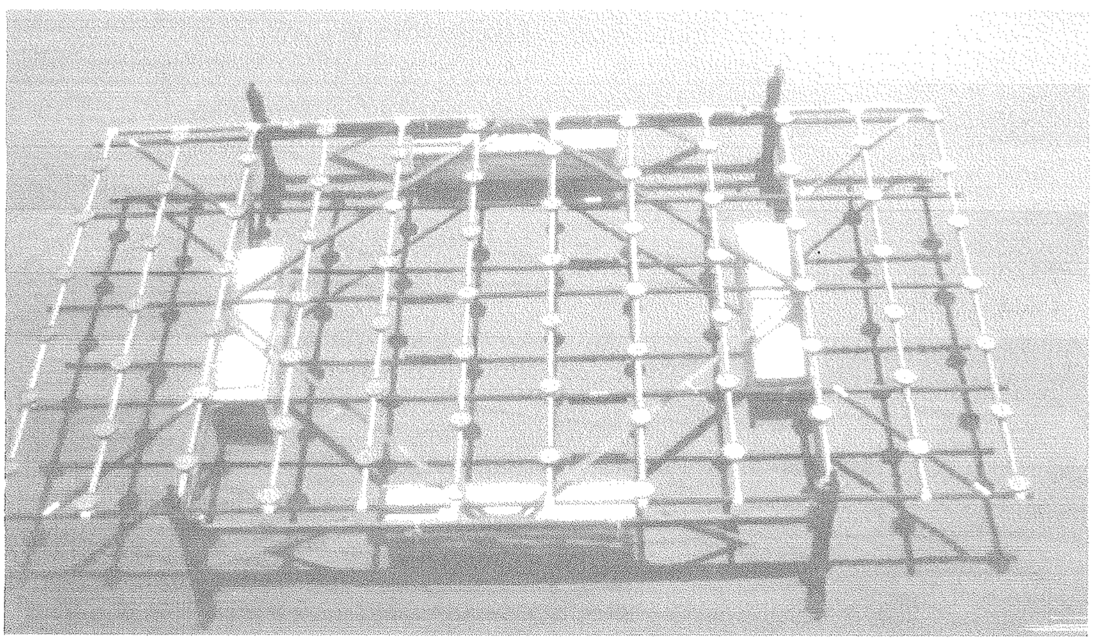


Figure 2: Membrane Diffuser Frame Installation at Douglas Dam

Early Hydropower Installations Using Porous Hose

Douglas Dam, TVA: 1991

In an effort to spread the diffused bubbles, a 122-meter by 36-meter (400-foot by 100-foot) PVC diffuser frame was built to support one hundred 15-meter (50-foot) long porous hoses. The hoses, used to distribute the oxygen bubbles, were common garden variety "soaker hose" made of recycled automobile tires. The hose stretches slightly under pressurization to allow gas or water flow through the walls. The diffusers were designed to have the same flow rate per 15-meter (50-foot) hose as in the 1989 design for a 9-inch membrane diffuser head, thus drastically increasing the distribution of the oxygen. The bubbles formed by the porous hose were observed to be of a similar size as the membrane diffuser (approximately 2 mm). Buoyancy chambers built into the PVC frame supported the entire frame and anchor assembly on the surface until the chambers were flooded to deploy the frame to the reservoir bottom. The huge frame required a fleet of small boats and ropes from the shoreline to position it in the forebay. Unfortunately, the PVC oxygen distribution header shattered due to stresses generated during the initial deployment, "and then it sank..."

Douglas Dam, TVA: 1993

Sixteen smaller PVC diffuser frames, measuring 30 meters by 36 meters (100 feet by 120 feet), as shown in Figure 3, were successfully deployed in Douglas Reservoir in 1993. There are eighty hoses per frame, for a total of over 19 km (12 miles) of porous hose. The system capacity is 3,060 cubic meters per hour (1,800 scfm or 110 tons/day) of oxygen. The redesigned oxygen distribution header was made of flexible hose. Elastic cords were used to attach anchors and absorb some bottom topography differences. These diffusers have been used since 1993 to provide up to 2 mg/L of DO improvement in the 453 cubic meters per second (16,000 cfs) peak hydropower flows of the four turbines at Douglas Dam. Although these diffusers are effective (Mobley and Brock, 1995), and are still in use, the frames and buoyancy connections were too unwieldy and expensive for future designs.

Figure 3: Aerial View of 16 Porous Hose Diffuser Frames in Douglas Reservoir

Installations Using Line Diffusers

Normandy, TVA: 1994

The next diffuser application at TVA was for a non-power reservoir where aeration was desired to remove dissolved metals and hydrogen sulfide in the reservoir through aeration and precipitation. For this application, a linear deployment was required to fit the diffuser in the deepest, most anoxic portion of the reservoir – in the old riverbed. A two-pipe line diffuser system was designed using a buoyancy pipe and gas supply pipe constructed of polyethylene (HDPE), as shown in Figure 1. With both pipes free of water, the entire pipe and anchor assembly will float on the surface and can be pulled with boats to the desired location. Elastic cords were used to attach the anchors and absorb some bottom topography differences. The diffusers were supplied with compressed air and were successfully deployed in a narrow curvilinear channel. Porous hose runs the entire length of the diffuser, distributing the air in small bubbles over as large an area as possible. This installation was the first for the line diffuser design and the clamp-on saddles used for hose connections were found to be expensive and leaky. The drilled screws to provide an orifice for flow control were also found to be expensive and unnecessary.

Blue Ridge, TVA: 1994

At Blue Ridge, a linear arrangement of four 550-meter (1,800-foot) long diffuser lines were deployed in the forebay to provide a 3 mg/L DO improvement using a 22,000 kg/day (400 scfm or 24 tons/day) oxygen system capacity. Steady-state effects of diffuser operation are shown in Figure 4. The design used small check valves at hose connections that were determined to be ineffective since the diffuser sank anyway when left overnight. The long linear arrangement of the diffusers was found to provide insufficient oxygen to the small minimum flow turbine, so an additional diffuser was installed immediately upstream of the intake tower.

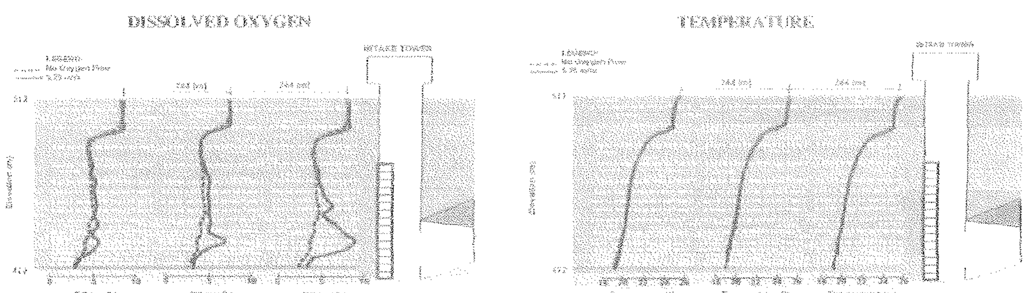


Figure 4: Results at Blue Ridge

Cherokee, TVA: 1994 and 1995

Peak hydropower water flows at Cherokee Dam can approach 20,000 cfs, and despite having operational installations of both turbine venting and surface water pumps, can require up to 2 mg/L of additional DO improvement from the line diffuser system to meet

4 mg/L in the releases. The system capacity is 136,000 kg/day (2,600 scfm or 150 tons/day) with 14,600 meters (48,000 feet) of line diffuser in the forebay. The system has automatic valves that open to provide a high rate of oxygen flow while the turbines are in use. When the turbines are off, a small amount of oxygen flow bypasses the valves to maintain a background buildup of DO in the reservoir. The oxygen input from the diffusers provided oxygenated cold water in the forebay that created a striped bass habitat during the warm summer season (Simmons, 1995). High concentrations of fish led to intense fishing pressure, but despite the repeated anchoring of boats in the area, no significant damage to the diffusers has been experienced. At this installation, the elastic cords for anchor attachment failed, allowing sections of the diffuser to float to the surface creating a boating hazard. A new anchor connection using stainless steel cables was retrofitted by re-floating each diffuser.

Embalse de Pinilla, Spanish Ministry of the Environment: 1995

The Embalse de Pinilla, a small reservoir north of Madrid, Spain, has only 5 MW of hydropower, but provides a source for an important water supply treatment facility. For this application, the reservoir oxygen diffuser was designed to reduce the chemical treatment required at the water supply plant by reducing organic loading and total dissolved metals through aeration in the reservoir. Local materials and labor were used for the installation.

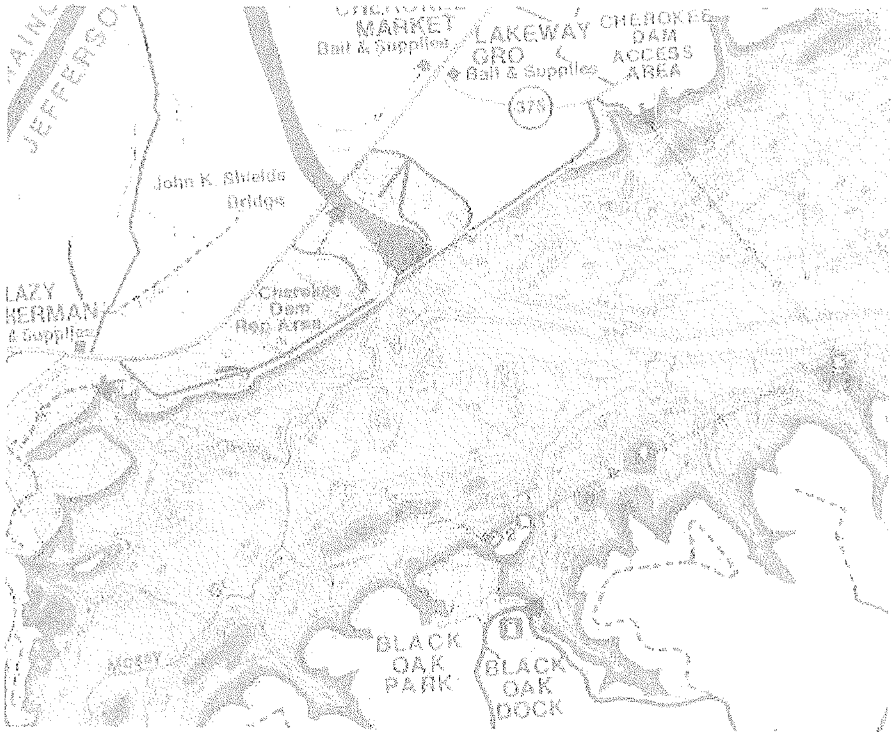
Fort Loudoun, TVA: 1995

This mainstream Tennessee River dam has hydropower flows approaching 38,000 cfs, but required only a small boost in DO – mostly associated with reduced flows during weekends. The Fort Loudoun application, shown in Figure 5, included a single 3-km (10,000-foot) long line diffuser used to spread the oxygen input over the reservoir volume of an average day's generation. The diffuser was equipped with progressive orifice sizes at the hose connections to obtain uniform flow over the entire length. The installation was complicated by intense recreational boat use and commercial navigation traffic. The elastic cord anchor connections were redesigned during this installation and retrofitted on the first diffuser.

Hiwassee, TVA, 1995

The original designs for the Hiwassee Reservoir diffuser system were to use air, but total dissolved gas (TDG) limitations in the tailrace shifted the design from air to oxygen. Hiwassee is a deep, narrow reservoir that caused some difficulties during deployment and retrieval of the diffuser lines. The mid-level hydropower intakes create a strong secondary thermocline in the reservoir that effectively limited the elevation of oxygen input from the diffusers placed in the old riverbed (Figure 6). The diffuser lines were retrieved and equipped with longer stainless steel anchor cables to suspend the line 18 meters (60 feet) above the reservoir bottom to place oxygen into the turbine withdrawal zone. The installation of an onsite pressure swing adsorption (PSA) oxygen generation system was attempted for this application, with unsatisfactory results. The diffusers are now supplied from a liquid oxygen storage tank.

Cherokee Lake "No fishing zone"
July 15th to Sept. 15th 2001 Season



Exceptions to Statewide Creel and Size Limits (2001)
Cherokee Reservoir

A closed fishing zone will be in effect from July 15 to September 15. This zone is enclosed by lines from the boat ramp at the south end of the dam across the lake to Point 2, from Point 2 to Point 3, and from Point 3 back across the lake to the TWRA boat ramp at the north end of the dam. All bank fishing will be open and the coves along the southeast shoreline will the open to boat fishing, but no fishing for any species will be allowed in the described zone from July 15 to September 15.

The TSBA supports the TWRA in its decision to implement a "no fishing zone" on Cherokee lake. We hope that this new regulation will prevent the slaughter of the Striped Bass and Hybrids that has been occurring there over the past summers. We ask that all our members support the regulation as sportsmen.


Thanks for the
help on Cherokee
TSBA and TWRA

The Cherokee Lake "No Fishing Zone"

The organization known as "The People for the Ethical Treatment of Animals" , P.E.T.A., has nothing to do with the now legal "NO FISHING" signs that are posted on public use waterways. We, the fishermen, are the reason for the signs. They are there to protect us from ourselves!

A new "NO FISHING ZONE" will be put into place this year on the lake side of Cherokee Dam beginning on July 15th thru September 15th. After seeing a growing number of fishermen each year abuse the fishery by killing many more fish than is legal to harvest, all ethical conservation minded fishermen should be proud to support the TWRA in it's efforts to enforce this new zone. As responsible fishermen and women, we need to do our part to make other fishermen aware of this new regulation and we need to inform them as to why this action is necessary for this two month period. If you witness any violation of this zone and if a little gentle persuasion does not stop these fishermen from continuing to resist these efforts, then please call for assistance from a TWRA enforcement officer. The judge can help with the explanation. Phone the TWRA at 1-800-332-0900.

Thank you for your support.