RESPONSE TO NRC ENVIRONMENTAL REPORT INFORMATION NEEDS

AQUATIC ECOLOGY (AQ)

This enclosure provides the BLN response to two NRC information needs related to the review of Aquatic Ecology (AQ) in the Bellefonte Nuclear Plant, Units 3 and 4 (BLN) Environmental Report (ER).

Updated Status of "AQ" Information Needs

NRC Information Need Number	Status
• AQ-04	Response provided in this enclosure.
• AQ-30	Response provided in this enclosure.

NRC Review of the BLN Environmental Report

NRC Information Needs - BLN ER Site Audit Exit Meeting

NRC Environmental Category: AQUATIC ECOLOGY

During the BLN Environmental Report site audit exit meeting on April 4, 2008, the NRC staff identified the following information needs:

AQ-04: Page 2.4-18 references the Reservoir Vital Signs Monitoring program. Provide the Vital Signs monitoring reports from 1991 forward that are used to determine species composition and distribution, the basis for assuming uniformity of fish community and habitat in the reservoir, and the trends in aquatic resources over time.

AQ-30: Yellow Creek - Page 9.3-25. The ER discusses annual studies from 1991 - 1994 on the Pickwick Reservoir and states that the studies continue every other year. Provide the references and data from the studies. Specifically include studies that show the list of aquatic species and relative abundance in the Pickwick Reservoir.

BLN INFORMATION NEEDS: AQ-04 and AQ-30

BLN RESPONSE:

During the week of March 31 through April 4, 2008, the NRC staff conducted an audit of the BLN site, including a review of the documentation supporting the BLN ER. At the site audit exit meeting, NRC aquatic ecology reviewers identified additional documentation needs. These requested documents include the Vital Signs monitoring reports from 1991 to present, which are provided as Attachments A through H to this enclosure. Vital Signs monitoring reports for 2002 and 2004, as well as Table 7 from the 2006 report (in preparation), were provided at the site audit. Based on discussions with the NRC's aquatic ecology reviewers, and subsequent confirmation at audit exit meeting, TVA understands that no additional documentation is required in response to this information request.

ASSOCIATED BLN COL APPLICATION REVISIONS:

None.

ATTACHMENTS:

The following documents are provided as Attachments A through H to this enclosure:

A. Tennessee Valley Authority, Water Resources Division, "Reservoir Vital Signs Monitoring – 1991, Summary of Vital Signs and Use Impairment Monitoring on Tennessee Valley Reservoirs," TVA/WR-92/8, July 1992.

B. Tennessee Valley Authority, Water Management, "Reservoir Monitoring – 1992, Summary of Vital Signs and Use Suitability Monitoring on Tennessee Valley Reservoirs," August 1993.

C. Tennessee Valley Authority, Water Management, "Tennessee Valley Reservoir and Stream Quality – 1993, Summary of Vital Signs and Use Suitability Monitoring," Vol. I, May 1994.

D. Tennessee Valley Authority, Water Management, "Tennessee Valley Reservoir and Stream Quality – 1993, Summary of Vital Signs and Use Suitability Monitoring," Vol. II, May 1994.

E. Tennessee Valley Authority, Water Management, "Aquatic Ecological Health Determinations for TVA Reservoirs – 1994: An Informal Summary of 1994 Vital Signs Monitoring Results and Ecological Health Determination Methods," April 1995.

F. Tennessee Valley Authority, Water Management, "Aquatic Ecological Health Determinations for TVA Reservoirs – 1996: An Informal Summary of 1996 Vital Signs Monitoring Results and Ecological Health Determination Methods," April 1997.

G. Tennessee Valley Authority, Water Management, "Aquatic Ecological Health Determinations for TVA Reservoirs – 1998: An Informal Summary of 1998 Vital Signs Monitoring Results and Ecological Health Determination Methods," August 1999.

H. Tennessee Valley Authority, Resource Stewardship, "Aquatic Ecological Health Determinations for TVA Reservoirs – 2000: An Informal Summary of 2000 Vital Signs Monitoring Results and Ecological Health Determination Methods," September 2001.

Tennessee Valley Authority
Water Resources Division

Reservoir Vital Signs Monitoring – 1991
Summary of Vital Signs and Use Impairment Monitoring on Tennessee Valley Reservoirs
TVA/WR-92/8

July 1992

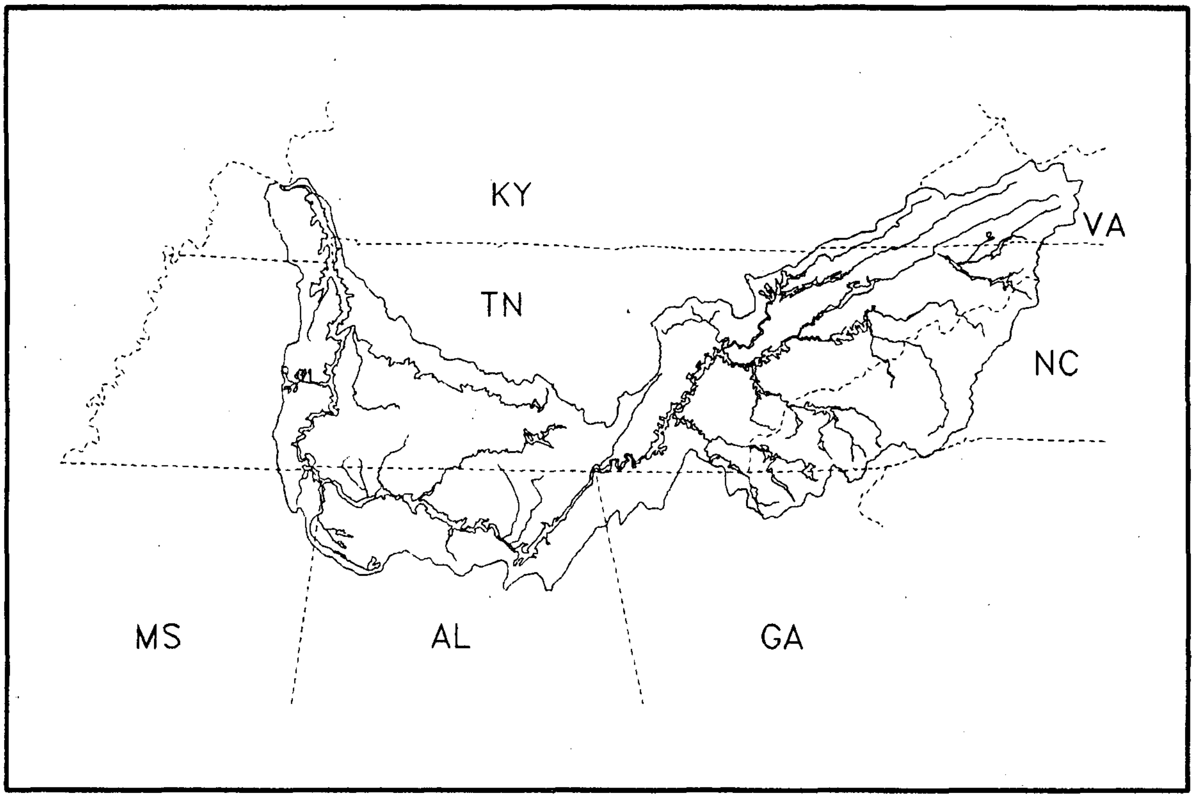
Tennessee
Valley
Authority

Water Resources Division
Chattanooga, Tennessee

TVA/WR--92/8
July 1992

RESERVOIR VITAL SIGNS MONITORING - 1991

SUMMARY OF VITAL SIGNS AND USE IMPAIRMENT MONITORING ON TENNESSEE VALLEY RESERVOIRS



WATER RESOURCES &
ECOLOGICAL MONITORING

WATER RESOURCES MANAGEMENT

TENNESSEE VALLEY AUTHORITY

Resource Group
River Basin Operations
Water Resources

RESERVOIR MONITORING - 1991
SUMMARY OF VITAL SIGNS
AND USE IMPAIRMENT MONITORING ON
TENNESSEE VALLEY RESERVOIRS

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Chattanooga, Tennessee

July 1992

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FIGURES

EXECUTIVE SUMMARY

The Tennessee Valley Authority (TVA) initiated a Reservoir Monitoring Program in 1990 as part of its Water Resources And Ecological Monitoring. Initially, 12 TVA reservoirs were examined--the nine mainstream Tennessee River reservoirs (Kentucky through Fort Loudoun) and three major tributary storage reservoirs (Cherokee, Douglas, and Norris). The Reservoir Monitoring Program was expanded in 1991 to include the system's only two tributary reservoirs with navigation locks (Tellico and Melton Hill). Ten other relatively small tributary reservoirs were also added in 1991 but were sampled less intensively than the other 14 larger reservoirs.

The two objectives of the Reservoir Monitoring Program are to provide basic information on the "health" or integrity of the aquatic ecosystem in TVA reservoirs (referred to as Vital Signs Monitoring) and to provide screening level information for describing how well each reservoir meets the fishable and swimmable goals of the Clean Water Act (referred to as Use Suitability Monitoring).

The basis of Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators. Most standard physical and chemical water quality conditions were monitored during seven months at two strategic locations on each reservoir, one in the forebay immediately upstream of the dam and the other at the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water). Annually, sediment quality and toxicity, benthic macroinvertebrate community, and fish community were examined at these locations. At the inflow or headwater region of the reservoir, the benthic macroinvertebrate and fish communities also were examined annually. All of these monitoring tools were used in 1991 to evaluate the health of the 14 reservoirs identified above. For the other ten reservoirs, fewer locations were sampled, and only water quality and fish community data were collected.

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) and suitability of fish from TVA reservoirs for human consumption (fishable). Bacteriological samples were collected at selected designated swimming areas and other highly used recreational areas. These are rotational studies in which each site is revisited at least once every five years. Fish tissue studies examined fillets from important fish species for metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data were provided to appropriate state agencies to determine need for further study and possibly fish consumption advisories. Fish tissue data reported here represent autumn 1990 collections due to the time delay required for laboratory analysis.

Vital Signs Monitoring

In general, the aquatic health of all nine mainstream Tennessee River reservoirs was satisfactory or better in 1991. However, for most reservoirs, results of at least one monitoring tool indicated poorer conditions than desired. Among the mainstream Tennessee River impoundments, Chickamauga, Nickajack, and Wheeler reservoirs appeared to have the healthiest aquatic environments, while Wilson and Fort Loudoun reservoirs appeared to have the most problems. Similar problems were also observed in 1990 for these two reservoirs: documented or high potential for low dissolved oxygen (DO) in lower strata, poor sediment quality, and one or more atypical features of the macroinvertebrate community. These low ecological health ratings are primarily a result of the physical features of these reservoirs and the way water flows through them. Therefore, more detailed examination of the health of these reservoirs is not recommended at this time. The physical configuration of Wilson Reservoir (a short, deep reservoir with a mid-depth withdrawal for hydroelectric power generation) creates a relatively stagnant pool of water in lower depths of the forebay which exacerbates low DOs. Little can be done to efficiently improve this condition. The situation in Fort Loudoun Reservoir is expected to improve as the quality of water discharged from Cherokee and Douglas dams upstream continues to improve.

Wheeler Reservoir was the only mainstream reservoir which seemed to be substantially different in 1991 than in 1990. The 1990 results had identified several characteristics of concern, but most of these were substantially improved in 1991. Continued monitoring will help determine if this was actually an improvement in conditions or if results were more a reflection of year-to-year variations within a complex reservoir ecosystem.

Three of the five tributary reservoirs which received the same level of monitoring intensity as the mainstream reservoirs showed generally poor conditions. Douglas, Cherokee, and Tellico reservoirs stratified during the summer and had near-anoxic conditions in mid and lower portions of the water column much of the summer. This resulted in poor benthic macroinvertebrate communities in the forebays and, in some cases, the transition zones of these reservoirs. Other indicators of problems (e.g., high nutrients, sediment toxicity, etc.) were observed on a case-by-case basis. The aquatic health of Melton Hill Reservoir appeared good, and that in Norris Reservoir was generally satisfactory although dissolved oxygen concentrations in lower strata were relatively low. The poor ecological health of Cherokee and Douglas reservoirs noted in 1991 had been observed in 1990 Vital Signs Monitoring as well as in previous studies. These reservoirs have been the subject of several investigations, some of which are still underway. The poor ecological health of Tellico Reservoir is due to thermal stratification which is intensified by the way water flows through Tellico Reservoir. Water in Tellico flows through a canal to Fort Loudoun Reservoir. This canal effectively "skims" only warm surface water off the top 20 feet of the pool. The water in lower strata becomes stagnant, and anoxia develops during summer. Significant physical alterations would be required to improve conditions in the Tellico forebay.

Less intensive monitoring on the ten small tributary reservoirs in 1991 found satisfactory or better conditions in six of the reservoirs. Healthy aquatic environments were observed in Watauga, Hiwassee, and Blue Ridge reservoirs. Relatively poor conditions were found in Boone and Parksville reservoirs. Conditions in Boone Reservoir were actually better in 1991 than in past years. Problems have changed from floating sewage sludge with excessive algal growth and extreme oxygen deficits in the mid-1980s, to an enriched ecosystem with areas of high algal activity and low dissolved oxygen concentrations at specific depths in the 1990s. Conditions in Boone Reservoir are expected to continue to improve as wastewater treatment plants are upgraded and as nonpoint source pollution is controlled. Parksville Reservoir is downstream of Copperhill, Tennessee, an area which was denuded of vegetation many years ago due to copper mining and smelting. Given the years of pollution problems in this basin, conditions found in 1991 were no surprise. Almost no primary production and a poor fish community were the primary indicators of problems. However, the mere presence of a viable fish community is an improvement and viewed as a sign of recovery resulting from continuing mitigative actions in the basin.

Use Suitability Monitoring

Bacteriological Studies--During spring and summer of 1991, fecal coliform samples were collected at 16 designated recreation areas (beaches, swimming areas, canoe access sites). All sites were sampled on at least ten occasions within a month. All designated recreation sites sampled on Vital Signs reservoirs except one met EPA guidelines for water contact recreation. The exception was on Norris Reservoir at the Loyston Point Recreation Area which was found to partially support water contact recreation, due to occasionally high fecal coliform bacteria.

In addition, as part of Vital Signs Monitoring, fecal coliform samples were collected in the forebay and transition zone of the nine mainstream Tennessee River reservoirs and Norris, Cherokee, Douglas, Tellico, and Melton Hill. Of these, only Guntersville Reservoir forebay exhibited poor bacteriological water quality.

Fish Tissue Studies--Six TVA reservoirs, Wilson, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, and Melton Hill, were examined intensively in 1990. Intensive studies are conducted on reservoirs where a contaminant problem is known or suspected. PCBs was the contaminant of interest on all these reservoirs. Chlordane was also of interest in some of these reservoirs. Fish consumption advisories which recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all of these six reservoirs except Wilson and Chickamauga. Advice provided in the latest public notice from the Tennessee Department of Environment and Conservation (March 1992) is based in part on the results of these 1990 studies. Most advisories were continued with only minor changes.

Results of screening studies in 1990 were similar to those from 1989, showing an increase in contaminant concentration in fish flesh during these two years of increased turbulence and runoff due to heavy rainfall and flood conditions compared to drought conditions in 1988. The contaminant most commonly found to increase was PCBs, with greatest increases at areas in the upper end of the reservoirs where turbulence is greatest. Largest increases were observed for Wheeler Reservoir for both PCBs and DDT. Because of these results and a warming by the State of Alabama for the public not to eat certain fish species from an embayment on Wheeler Reservoir due to DDT contamination, a more intensive examination of fish from that reservoir was conducted in autumn 1991. Increases on other reservoirs were not sufficient to warrant intensive investigations. Instead, screening level monitoring was conducted again on these reservoirs in autumn 1991.

1.0 INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) initiated a program in 1990 to systematically monitor its reservoirs annually. The Reservoir Monitoring Program was made possible by an increase in federal appropriations to fulfill TVA's stewardship and reservoir management responsibilities. Reservoir Monitoring consolidated several newly-developed activities along with several existing activities to form an integrated program. Reservoir Monitoring is part of TVA's comprehensive Water Resources and Ecological Monitoring Program, which also includes stream monitoring, watershed examinations, and public information/educational activities.

Results of 1990 monitoring were provided in a series of technical reports (see references). A comparable series of technical reports (itemized in section 1.4 below) was prepared based on 1991 results, including this summary report. In addition to these technical reports, a new, nontechnical document was prepared based on 1991 monitoring results. This new public information document, "River Pulse 1991," (TVA, 1992) is being broadly distributed to Tennessee Valley residents and users of TVA reservoirs. Copies of all these documents are available from the address shown in section 1.4.

1.2 Objectives

Objectives of the Reservoir Monitoring Program are to provide basic information on the "health" or integrity of the aquatic ecosystem in each TVA reservoir and to provide screening level information for describing how well each reservoir meets the "fishable" and "swimmable" goals of the Clean Water Act. The ecological integrity of reservoir ecosystems is examined under a task called Vital Signs Monitoring. The basis of Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators in important areas of each reservoir. The information is used to evaluate the health of each reservoir and the overall health of the reservoir system, and to target detailed assessment studies in areas where significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions and monitoring water quality trends for TVA reservoirs.

Use Suitability Monitoring examines how well each reservoir meets the fishable and swimmable goals of the Clean Water Act. Examination of levels of toxic contaminants in fillets from important fish species is the basis for the fishable use evaluation. Swimmable or water contact uses are examined by conducting bacteriological sampling at designated swimming beaches and other highly used recreation areas.

1.3 Summary Report Description

This document summarizes and integrates results from the technical reports described below. Chapter 2 describes the methods and reservoir monitoring tools used in Vital Signs and Use Suitability Monitoring activities.

Chapter 3 provides an overview of 1991 hydrologic conditions. Physical conditions in a reservoir are mostly controlled by streamflow and water temperature, as well as by physical configuration of the reservoir basin and the dam. Given that streamflows and water temperatures vary from year to year, it is essential to consider these variables in evaluating ecological conditions within a reservoir.

The main part of this document is a reservoir by reservoir evaluation and summary of 1991 results in chapter 4, "Reservoir by Reservoir Summary and Conclusions." Within each reservoir presentation, there is a physical description of the reservoir, followed by an evaluation of the reservoir's ecological health. This evaluation is based on an integration of results from the various monitoring tools in Vital Signs Monitoring. The ecological health is followed by a description of Use Suitability results. The final section, "Synopsis of 1991 Conditions," is a detailed data summary for each monitoring tool. These detailed summaries are provided as a ready reference of 1991 results and are intended for the technical audience to see the basis for the evaluation of each reservoir.

It is important to note that these results are from only the second year of the Reservoir Monitoring Program. Conclusions drawn from a newly implemented monitoring program such as this must be considered tentative and subject to revision in future years as more data are acquired on each reservoir. Because of naturally occurring year-to-year variability (i.e., drought, floods, etc.), several years of information will be needed to confidently make definitive statements about the ecological health of each reservoir.

1.4 Reports

Technical reports for each Reservoir Monitoring activity are listed below. Reports are available by contacting TVA, Water Resources Library, 1101 Market Street, HB 2C-C, Chattanooga, TN 37402, Telephone: (615) 751-7338.

Task 1. "Vital Signs" Monitoring

Burns, E. R., A. L. Bates, and D. H. Webb. "Aquatic Plant Management Program - Current Status and Seasonal Workplan - 1992." TVA, Water Resources, Vector and Plant Management Program, Muscle Shoals, Alabama. In preparation.

Masters, A. E., 1992. "Reservoir Vital Signs Monitoring, 1991 - Benthic Macroinvertebrate Community Results." TVA, Water Resources, TVA/WR--92/3.

Meinert, D. L. and J. P. Fehring, 1992. "Reservoir Vital Signs Monitoring, 1991 - Physical and Chemical Characteristics of Water and Sediment." TVA, Water Resources, TVA/WR--92/1.

Moses, J. and D. C. Wade, 1992. "Reservoir Vital Signs Monitoring, 1991 - Acute Toxicity Screening of Reservoir Water and Sediment." TVA, Water Resources, TVA/WR--92/2.

Scott, E. M., G. D. Hickman, and A. M. Brown, 1992. "Reservoir Vital Signs Monitoring, 1991 - Fish Community Results." TVA, Water Resources, TVA/WR--92/5.

Wilson, W. K., 1992. "Reservoir Vital Signs Monitoring, 1991 - Hydroacoustic Estimates of Fish Abundance." TVA, Water Resources, TVA/WR--92/4.

Task 2. Use Suitability Monitoring

Bates, J. A., G. E. Hall, and D. L. Dycus, 1992, "Reservoir Monitoring, 1991 - Fish Tissue Studies in the Tennessee Valley in 1990." TVA, Water Resources, TVA/WR--92/7.

Fehring, J. P., 1992. "Reservoir Monitoring, 1991 - Bacteriological Conditions in the Tennessee Valley." TVA, Water Resources, TVA/WR--92/6.

2.0 MATERIALS AND METHODS

2.1 Vital Signs

The basis of the Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators. Generally, three areas in each reservoir are monitored: the forebay immediately upstream of the dam; the transition zone (the mid-reservoir region where the water changes from free flowing to more quiescent, impounded water); and the inflow or headwater region of the reservoir. Sampling locations and specific monitoring activities for Vital Signs Monitoring during 1991 are shown in figure 2.1 and listed in tables 2.1 and 2.2.

The Vital Signs component of the Reservoir Monitoring Program includes four activities to examine reservoir health:

(1) physical/chemical characteristics of water (section 2.1.1, below);

(2) acute toxicity screening and physical/chemical characteristics of sediment (section 2.1.2, below);

(3) benthic macroinvertebrate community (section 2.1.3, below); and,

(4) fish community evaluations (section 2.1.4, below).

In addition, although Aquatic Plant Management is part of another TVA program activity, a discussion of the aquatic macrophyte communities is included to provide a more comprehensive evaluation of each reservoir's ecological health (section 2.1.5, below).

2.1.1 Physical/Chemical Characteristics of Water

Physical/chemical water quality variables were measured at a total of 45 locations on 24 reservoirs. The Vital Signs water quality monitoring activities on these reservoirs followed a "basic" (28 locations-table 2.1) or "limited" (17 locations-table 2.2) sampling strategy.

Basic--The basic sampling strategy included monthly water quality surveys (January and April through September) at 28 locations, i.e., the forebays and transition zones (inflows not examined) on 14 TVA reservoirs --the nine mainstem Tennessee River reservoirs and five major tributary reservoirs (Cherokee, Douglas, Norris, Melton Hill, and Tellico). Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone composite chlorophyll-a samples; and surface and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved ortho-phosphorus), organic carbon (total and soluble), color (total and apparent), turbidity, and suspended solids.

Limited--The limited sampling strategy included monthly water quality sampling (April through October) for a smaller list of parameters at 17 locations, i.e., the forebays (and at mid-reservoir locations on larger impoundments) on ten tributary reservoirs (Boone, South Holston, Watuaga, Hiwassee, Chatuge, Blue Ridge, Nottely, Ocoee No. 1, Tims Ford, and Beech). The limited water quality sampling was the same as the basic water quality sampling, except that nutrients and organic carbon samples were only collected from the water surface and only in April and August. In addition, no fecal coliform, color, turbidity, and suspended solids samples were collected as part of the limited monitoring strategy.

The physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Specific details and evaluations of the physical/chemical water quality data are available in a TVA technical report (Meinert and Fehring, 1992).

2.1.2 Acute Toxicity Screening and Physical/Chemical Characteristics of Sediment

Annual sediment samples and near bottom water were collected during summer 1991 from 28 locations, i.e., the forebay and transition zone of the 14 basic monitoring reservoirs, table 2.1. Eckman dredge samplers were used to collect the top three centimeters of sediment, and Kemmerer or Isco water samplers were used to collect the near-bottom water.

Acute Toxicity--Sediment pore water and near-bottom water samples were screened for toxicity using acute time-frame Microtox® (light emitting bacteria) and Rotox® (rotifer survival) tests. Microtox® analyses used serial dilutions of the original sample. Samples with a 10 percent reduction in emitted light (EC_{10}) at a dilution of ≤25 percent of the original sample were color corrected and reanalyzed. Color corrected EC_{10} values, ≤25 percent dilution, were reported as indicating toxicity of a chronic nature. Microtox® EC_{50} values were evaluated to indicate acute toxicity. Rotifer acute (24 hour) toxicity was reported if the average survival in three replicates was significantly reduced from controls.

Physical/Chemical Characteristics -- Sediment samples were analyzed for 12 metals, total and volatile solids, particle size, total organic carbon, and 26 selected trace organics (organochlorine pesticides and PCBs).

Specific details and evaluations of the acute toxicity tests results and the physical/chemical characteristics of sediment are available in TVA technical reports (Moses and Wade, 1992; and Meinert and Fehring, 1992, respectively).

2.1.3 Benthic Macroinvertebrate Community Sampling

Benthic macroinvertebrate community samples were collected in spring 1991 from 40 locations, i.e., the forebay, transition zone, and inflow of the 14 basic monitoring reservoirs (inflow samples were not collected on Douglas Reservoir), table 2.1. At each sample location, a line-of-sight transect was established across the width of the reservoir, and ten equally spaced samples were collected along this transect. A Ponar dredge was used to collect samples, except when rocky substrates necessitated the use of a Peterson dredge. Specimens were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter.

Benthic macroinvertebrate data are available in computer readable form from TVA. Specific details and evaluations of the 1991 Vital Signs results are available in a TVA technical report (Masters, 1992).

2.1.4 Fish Community Evaluation

Data from three sampling procedures were used to evaluate the fish community: (1) summer hydroacoustic fish abundance/biomass estimates and (2) autumn electrofishing and gill netting.

Hydroacoustic Estimates of Fish Abundance--The fish community evaluation included open water hydroacoustic surveys during the summer of 1991 on the 14 basic Vital Signs reservoirs. At each of the 41 locations (forebay, transition zone, and inflow on 14 reservoirs), table 2.1, individual transects were established using a zig-zag pattern to ensure adequate sampling of the location. Each transect usually began in an overbank area and went across the navigation channel to the opposite bank. Each sampling location was defined as an approximately two-mile long reach of the reservoir. All surveys were conducted at night because fish are more dispersed throughout the water column and easier to measure acoustically. In addition, trawling was conducted at selected reservoirs (Kentucky, Pickwick, Wilson, Norris, Cherokee, and Douglas) concurrently with the hydroacoustic survey using an eight-foot mid-water trawl to sample fish in the pelagic zone to obtain species composition for determining length/weight relationships necessary for biomass estimates. Numbers of fish per cubic meter and kilograms of fish per cubic meter were obtained for each location (forebay, transition zone, or inflow).

Electrofishing and Gill Netting--In autumn 1991, electrofishing and gill netting were employed on 22 reservoirs, i.e., the 14 basic Vital Signs Monitoring reservoirs and eight of the ten limited monitoring reservoirs, tables 2.1 and 2.2. Ten electrofishing transects were sampled within each location, with all habitats sampled, and dominant habitats receiving the most effort. Habitat distinctions were based on major changes in substrate (e.g., bluff, rip-rap, or clay). Ten experimental gill nets were also set overnight at each location in all habitat types where conditions permitted. At some inflow locations, flow and/or lack of suitable sites limited the number of nets that could be set.

Largemouth bass collected as part of the electrofishing survey were transported to a mobile laboratory for immediate examination of external/internal abnormalities and blood chemistry characteristics. At each sampling location, 15 individuals greater than 250 mm total length were examined and a Fish Health Assessment Index (FHAI) was calculated.

A Reservoir Index of Biotic Integrity (RIBI) was employed using data from the electrofishing samples. The RIBI uses 11 fish community measurements (metrics):

(a) species richness and composition - total numbers of species, sunfish species, sucker species, intolerant species, and percentage of tolerant individuals sampled, excluding shad;

(b) trophic composition - percentage of omnivorous individuals, and percentage of invertivorous individuals;

(c) reproductive composition - numbers of migratory spawning species, and numbers of lithophilic spawning species;

(d) overall fish abundance; and

(e) fish health assessment index (FHAI) of largemouth bass.

Scores of the 11 metrics were summed to produce RIBI values for each of three distinct sampling locations in each reservoir. The RIBI used to evaluate the electrofishing results is in the developmental phase. Substantial efforts have been made to date on selecting and evaluating appropriate metrics. These efforts are continuing and further improvements are expected. Therefore, RIBI values reported are considered preliminary.

A discussion of the ongoing development of the RIBI and results of the fish community evaluations and for the 1991 Vital Signs Monitoring data are available in TVA technical reports (Wilson, 1992; and Scott, Hickman, and Brown, 1992).

2.1.5 Aquatic Macrophytes

Coverage of aquatic macrophytes was determined from large-scale (1 inch=600 feet or 1 inch=1000 feet) color aerial photography flown in the late summer or early fall of 1991, during maximum plant emergence. Ground truth data were conducted at selected sites at the approximate time of the overflight to determine species composition of the dominant macrophyte communities. Aquatic macrophyte colonies were delineated on mylar overlays attached to photographic prints, labeled according to species, and areal coverage determined using an electronic planimeter. Reservoirs flown for aerial photography in 1991 included: Kentucky, Wheeler, Guntersville, Nickajack, Chickamauga, Melton Hill, Tellico, Chatuge, Nottely, Hiwassee, and Blue Ridge. For reservoirs where aerial photography was unavailable, standard field surveys and historical information were used to estimate community composition and coverage. Submersed aquatic plant populations generally are rare in tributary reservoirs because of the wide fluctuations of water surface elevations associated with their operation for floodwater storage. Known populations have been extremely small, short-lived, and of little significance.

A technical report (Burns, Bates, and Webb, 1992) provides details of TVA's Aquatic Plant Management Program for 1991.

2.1.6 Inter-Reservoir Comparisons of Data

In 1991, additional limited Vital Signs Monitoring was conducted on ten smaller tributary storage reservoirs to supplement the basic Vital Signs Monitoring on the nine mainstem reservoirs and Cherokee, Douglas, Norris, Tellico, and Melton Hill reservoirs (see section 2.1.1). In general, only water chemistry and fish community information were collected on this group of ten smaller tributary reservoirs (table 2.2). With the exception of fish tissue and fecal coliform samples collected on Ocoee No. 1, no sediment toxicity, benthic macroinvertebrate, fish tissue, or bacteriological information were collected on these ten limited monitoring tributary storage reservoirs in 1991. Details of the water chemistry and fish community sampling are available in technical reports (Meinert and Fehring, 1992; and Scott, Hickman, and Brown, 1992).

Consequently, in chapter 4.0, "Reservoir by Reservoir Summary and Conclusions," because not all water quality parameters were measured in all reservoirs, comparisons of water quality data between reservoirs were often restricted to the 14 reservoirs at which the basic Vital Signs water quality monitoring was conducted or to the ten reservoirs at which the limited Vital Signs water quality monitoring was conducted. Likewise, inter-reservoir comparisons of fish communities were also categorized. Because of different fish community structures in mainstream or run-of-the-river reservoirs and tributary storage reservoirs, fish community comparisons were limited to a subgroup of either the 11 mainstream and run-of-the-river reservoirs or to the 11 tributary storage reservoirs. Mainstream and run-of-the-river reservoirs were Kentucky, Pickwick, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, Melton Hill, and Tellico. Tributary storage reservoirs were Norris, Cherokee, Douglas, Boone, South Holston, Watuaga, Hiwassee, Chatuge, Blue Ridge, Nottely, and Ocoee No. 1.

2.2 Use Suitability

The Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) and suitability of fish from TVA reservoirs for human consumption (fishable).

The Use Suitability component of the Reservoir Monitoring Program is based on two activities: (1) bacteriological sampling and (2) fish tissue analysis.

2.2.1 Bacteriological Sampling

In 1989, TVA began a program of periodically sampling recreation sites in the Tennessee Valley for fecal coliform bacteria to determine each site's suitability for water contact recreation. In addition to swimming beaches, many other recreation sites are also included in the program, such as canoe launch areas, picnic areas, boat ramps, marinas, etc. The bacteriological sampling program includes approximately 300 sites and is designed to sample all locations on a frequency of about once every five years.

In 1991, fecal coliform samples were collected in spring and summer to evaluate use suitability for whole body water contact recreation at 11 designated swimming beaches and five canoe access sites. (In addition, 11 informal recreation sites where incidental water contact may occur, such as boat launch ramps, picnic areas, parks, etc., and two marinas were also sampled.) These recreational bacteriological samples were collected in a manner to conform with state criteria and federal guidelines, such that at each site, at least ten fecal coliform samples were collected within a 30-day sampling period. Recreation sites were classified as fully supporting, partially supporting, and not supporting water contact recreation based on EPA guidelines for fecal coliform bacteria. In addition 28 forebay and transition zone locations were sampled monthly as part of the basic Vital Signs Reservoir Monitoring Program (table 2.1).

A technical report (Fehring, 1992) provides specific details and evaluations of TVA's 1991 bacteriological monitoring results.

2.2.2 Fish Tissue Analysis

In cooperation with Valley states, TVA's Reservoir Monitoring Program analyzes tissues of Tennessee Valley fish as part of both "screening" and "intensive" evaluations. Screening studies are based on analysis of composited fillets of indicator fish species (primarily channel catfish) and are intended to identify possible problem areas where intensive investigation might be needed.

Intensive studies are conducted on reservoirs where contamination problems are known or suspected and involve analysis of individual fillets from important fish species. This information is used to document the geographical extent and the concentration level of the contamination, so state public health officials can determine whether fish consumption advisories are necessary to protect human health.

Fish collected for screening studies are usually analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List. Fish for intensive studies are usually analyzed only for the contaminant of concern. During the preparation process, external and internal conditions are recorded as well as length, weight, sex, fillet weight, and liver weight.

Screening Studies--Channel catfish from 11 reservoirs (Kentucky, Pickwick, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, Tellico, and Parksville) and below Kentucky Dam

(TRMs 7 and 21) were collected in autumn 1990, composited, and analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List.

Intensive Studies--Six TVA reservoirs were examined intensively in 1990: Wilson, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, and Melton Hill. The contaminant of concern was PCBs in each case. Chlordane was also of concern in some reservoirs. Fish consumption advisories that recommend limiting the quantity of fish eaten or avoiding any consumption are in effect for all these reservoirs except Chickamauga and Wilson.

A technical report (Bates, Hall, and Dycus, 1992) provides specific details and evaluations of TVA's Fish Tissue Studies conducted in 1990.

Table 2.1
SUMMARY OF RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1991

--Basic Monitoring Strategy--

			Reservoir Vital Signs Monitoring Tools					
				Sediment Quality[d]			Fish Community Evaluations[f]	
Reservoir	River Mile[a]	Map ID No.-Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Abundance	Diversity/RIBI
Kentucky	TRM 23	1A-FB	M	A	A	A	A	A
	TRM 112	1B-TZ	M	A	A	A	A	A
	TRM 200-206	1C-I	-	-	-	A	A	A
Pickwick	TRM 207	2A-FB	M	A	A	A	A	A
	TRM 230	2B-TZ	M	A	A	A	A	A
	TRM 256-259	2C-I	-	-	-	A	A	A
Wilson	TRM 261	3A-FB	M	A	A	A	A	A
	TRM 273-274	3C-I	-	-	-	A	A	A
Wheeler	TRM 277	4A-FB	M	A	A	A	A	A
	TRM 307	4B-TZ	M	A	A	A	A	A
	TRM 347-348	4C-I	-	-	-	A	A	A
Guntersville	TRM 350	5A-FB	M	A	A	A	A	A
	TRM 397	5B-TZ	M	A	A	A	A	A
	TRM 420-424	5C-I	-	-	-	A	A	A
Nickajack	TRM 425	6A-FB	M	A	A	A	A	A
	TRM 433	6B-TZ	M	A	A	A	A	A
	TRM 469-470	6C-I	-	-	-	A	A	A
Chickamuaga	TRM 472	7A-FB	M	A	A	A	A	A
	TRM 490	7B-TZ	M	A	A	A	A	A
	TRM 518-529	7C-I	-	-	-	A	A	A
Watts Bar	TRM 531	8A-FB	M	A	A	A	A	A
	TRM 561	8B-TZ	M	A	A	A	A	A
	TRM 600-601	8C-I	-	-	-	A	A	A
	CRM 19-22	8D-I	-	-	-	A	A	A
Fort Loudoun	TRM 603	9A-FB	M	A	A	A	A	A
	TRM 625	9B-TZ	M	A	A	A	A	A
	TRM 652	9C-I	-	-	-	A	A	A

Table 2.1 (Continued)

Reservoir	River Mile[a]	Map ID No.-Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]		Benthic Invertebrates[e]	Fish Community Evaluations[f]	
				Toxicity	Phy/Chem		Abundance	Diversity/RIBI
Norris	CRM 80	10A-FB	M	A	A	A	A	A
	PRM 30	10B-TZ	M	A	A	A	A	A
	CRM 125	10C-TZ	M	A	A	A	A	A
Cherokee	HRM 53	11A-FB	M	A	A	A	A	A
	HRM 76	11B-TZ	M	A	A	A	A	A
	HRM 91	11C-I	-	-	-	A	A	A
Douglas	FBRM 33	12A-FB	M	A	A	A	A	A
	FBRM 61	12B-TZ	M	A	A	A	A	A
	FBRM 72	12C-I	-	-	-	-	A	A
Tellico	LTRM 1	13A-FB	M	A	A	A	A	A
	LTRM 21	13B-TZ	M	A	A	A	A	A
Melton Hill	CRM 24	14A-FB	M	A	A	A	A	A
	CRM 45	14B-TZ	M	A	A	A	A	A
	CRM 59-66	14C-I	-	-	-	A	A	A
		Totals	28	28	28	40	41	41

a. TRM - Tennessee River Mile; CRM - Clinch River Mile; FBRM - French Broad River Mile; PRM - Powell River Mile; HRM - Holston River Mile; LTRM - Little Tennessee River Mile

b. See figure 2.1; FB - forebay; TZ - transition zone; I - Inflow

c. M - monthly water quality surveys (January and April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), organic carbon (total and soluble), color (total and apparent), turbidity, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Microtox and Rotox). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, total organic carbon, and 26 trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual hydroacoustic techniques are used to estimate open water fish community abundance and biomass in summer. Also, in autumn, electroshocking and gill netting techniques are used to evaluate the near shore fish community.

Table 2.2
SUMMARY OF RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1991
--Limited Monitoring Strategy--

Reservoir	River Mile[a]	Map ID No.-Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Reservoir Vital Signs Monitoring Tools: Fish Community Diversity/RIBI[d]
Boone	SFHR 19	15A-FB	M	A
	SFHR 27	15B-TZ	M	A
	WRM 8	15C-TZ	M	A
South Holston	SFHR 51	16A-FB	M	A
	SFHR 62	16B-TZ/I[e]	M	A
Watauga	WRM 37	17A-FB	M	A
	WRM 44	17B-TZ/I[e]	M	A
Hiwassee	HiRM 77	18A-FB	M	A
	HiRM 85	18B-TZ	M	A
	HiRM 90	18C-TZ/I[e]	M	A
Chatuge	HiRM 122	19A-FB	M	A
Nottely	NRM 23	20A-FB	M	A
Blue Ridge	ToRM 54	21A-FB	M	A
Ocoee No. 1	ORM 12	22A-FB	M	A
Tims Ford	ERM 135	23A-FB	M	-
	ERM 150	23B-TZ	M	-
Beech	BRM 36	24A-FB	M	-
		Totals	17	14

a. SFHR - South Fork Holston River; WRM - Watauga River Mile; HiRM - Hiwassee River Mile; NRM - Nottely River Mile; ToRM - Toccoa River Mile; ORM - Ocoee River Mile; ERM - Elk River Mile; BRM - Beech River Mile

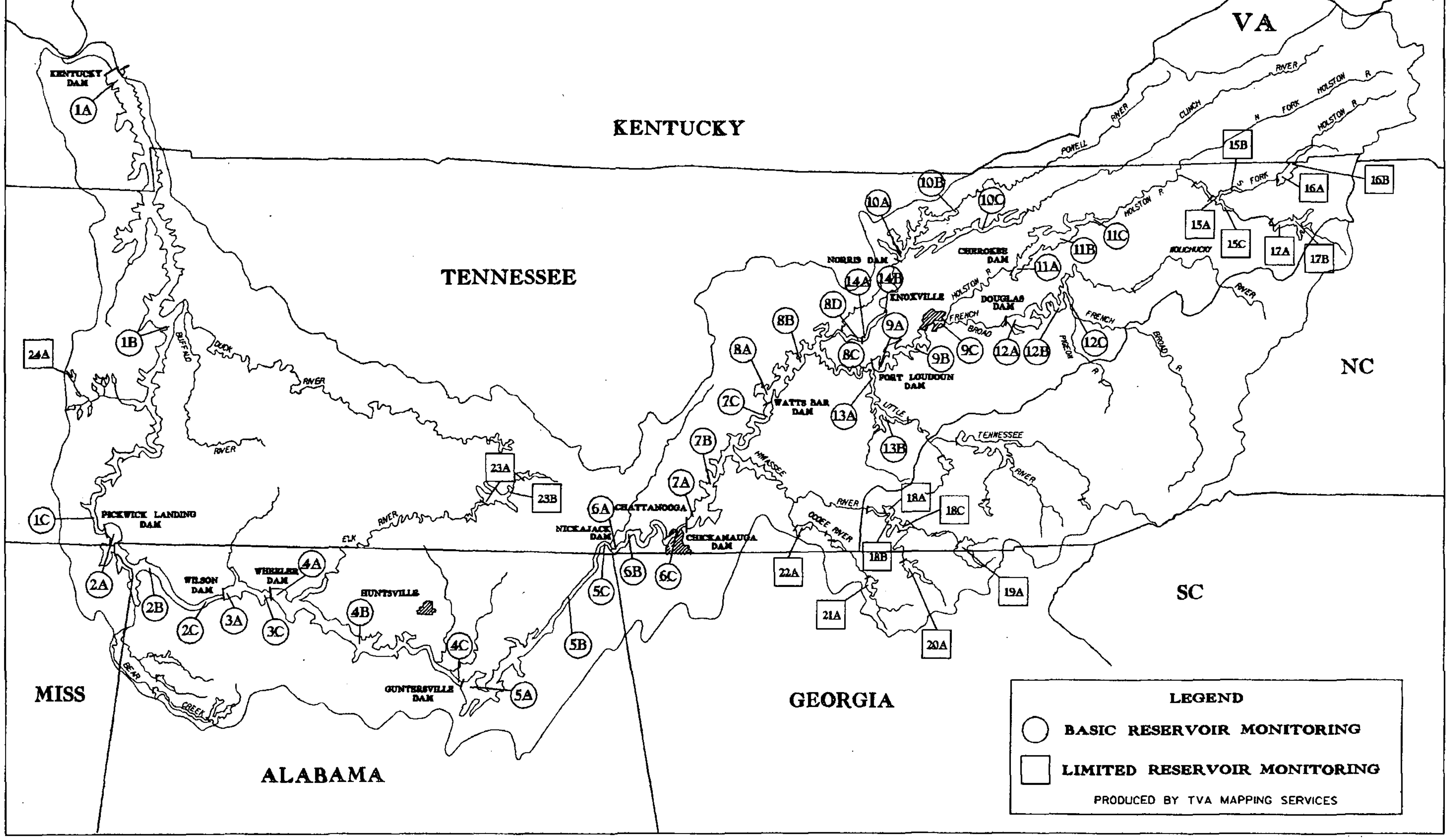
b. See figure 2.1; FB - forebay; TZ - transition zone; I - Inflow

c. M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone chlorophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and organic carbon (total and soluble). No samples are collected for fecal coliforms, color (total and apparent), turbidity, and suspended solids.

d. A - annual autumn electroshocking and gill netting techniques are used to evaluate the near shore fish community.

e. Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations) and as a transition zone location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

FIGURE 2.1
RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1991



3.0 HYDROLOGIC OVERVIEW OF WATER YEAR 1991

Seasonal variations in atmospheric temperature and rainfall have a direct impact on water quality. Consequently, many water quality characteristics (temperature, dissolved oxygen, conductivity, turbidity, suspended solids, etc.) exhibit seasonal effects. During the dry season, when runoff is minimal, streamflow is derived principally from the base flow of groundwater. Groundwater contains greater concentrations of dissolved minerals than does surface drainage because of increased water/soil/rock contact and longer groundwater residence time. During the wet season, streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution. Consequently, lower concentrations of most dissolved constituents are added to a river during heavy rainfall and subsequent high flows. However, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams. This carries large loads of nonpoint source pollutants (nutrients, suspended solids, turbidity, etc.) to streams and rivers. Therefore, examining atmospheric temperature, rainfall, and runoff patterns during 1991 aids in interpretation of the Reservoir Vital Signs Monitoring data.

3.1 Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit (°F), with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce climatic data, during water year (WY) 1991 (October 1990 - September 1991) atmospheric temperatures in the TVA region averaged about 2°F warmer than normal (USDOC, 1990 and 1991), with all 12 months of WY 1991 experiencing above normal temperatures. The greatest monthly departures (about 4°F above normal) were in November and December 1990 and May 1991, figure 3.1. January through April also had departures about 3°F above normal. The result was that the seven-month period (November 1990-May 1991) was unusually warm, averaging over 3.5°F above normal. Although August was near normal, spells of hot, dry weather occurred in the summer, with conditions somewhat worse to the west and south of Chattanooga. This pattern persisted through September.

3.2 Rainfall

The Tennessee River basin averages about 52 inches of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches in the mountains of southwestern North Carolina near Highlands to a low of about 37 inches in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches of the basin average. March is usually the wettest month and October the driest. WY 1991 was wetter than the previous year, but exhibited a pattern of a wetter than average cool season and a dryer than average warm season, figure 3.1. The precipitation in WY 1991 for the Tennessee River basin was slightly in excess of 59 inches, a departure of 15 percent above the 101 year long-term average, with that portion downstream of Chattanooga generally wetter than the portion of the basin upstream of Chattanooga. Precipi- tation in November 1990 and January 1991 was below average, but the other months in the October 1990 through May 1991 period were wet enough to exceed the long-term average for this eight-month period by 11 inches. For the Tennessee River basin, December 1990 was the wettest December on record averaging 11.1 inches of precipitation, which was 6.3

inches above the long-term average. The period of June through September was about 3.5 inches drier than average for the Tennessee River basin (TVA, 1991).

3.3 Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evapotranspiration reduces the amount of runoff somewhat. Watersheds that receive 50 to 60 inches of precipitation annually average about 20 to 30 inches of runoff. In a normal year, the discharge of the Tennessee River (approximately 64,000 cfs) corresponds to about 22 inches of runoff distributed over the 40,900 square mile drainage basin. A larger amount of runoff occurs during the wet winter and spring months when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation and transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and fall months. In WY 1991, there was an unusually high amount of precipitation and runoff, particularly in December and during the period February through May. Much of this runoff was held in storage in tributary reservoirs and later released such that during the subsequent dry period of June through September, even though rainfall was substantially below normal, streamflow of the Tennessee River at Kentucky Dam was near normal (figure 3.1).

The net result for the Tennessee Valley in WY 1991 was an annual 15 percent excess in precipitation with resultant total runoff that was approximately ten inches above the long-term mean of 22.4 inches. Mean flows during 1991 for each of the Vital Signs reservoirs reflect the higher-than-average annual runoff (table 3.1).

Table 3.1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000s	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000s	Average Reservoir Flow 1960-91 (cfs)	Average Hydraulic Residence Time[a] (Days)	CY 1991 Reservoir Flow (cfs)
Mainstem Tennessee River Reservoirs								
Kentucky	40,200	184.0	160.3	88	2,839	63,596	23	90,524
Pickwick	32,820	53.0	43.1	84	924	56,706	9	75,923
Wilson	30,750	15.5	15.5	108	634	53,445	6	69,129
Wheeler	29,590	74.0	67.1	66	1,050	51,053	11	64,474
Guntersville	24,450	76.0	67.9	65	1,018	41,577	13	50,301
Nickajack	21,870	46.0	10.4	60	241	35,608	4	42,731
Chickamauga	20,790	59.0	35.4	83	628	34,192	10	41,269
Watts Bar	17,300	72.0/24.0[b]	39.0	105	1,010	27,849	19	32,533
Fort Loudoun	9,550	50.0	14.6	94	363	15,620	12	22,105
Tributary River Reservoirs								
Norris	2,912	73.0/53.0[b]	34.2	202	2,040	4,098	250	5,675
Cherokee	3,428	54.0	30.3	163	1,481	4,539	168	5,266
Douglas	4,541	43.0	30.4	127	1,408	6,862	105	7,344
Tellico	2,627	33.2	16.5	80	415	5,700(est)	37(est)	6,689[c]
Melton Hill	3,343	44.0	5.7	69	120	4,448	14	6,663
Boone	1,840	17.4/15.3[b]	4.3	129	189	2,509	38	2,622
South Holston	703	24.0	7.6	239	658	983	337	991
Watauga	468	16.0	6.4	274	569	697	412	710
Hiwassee	968	22.0	6.1	255	422	2,072	103	2,391
Chatuge	189	13.0	7.0	124	234	452	261	490
Nottely	214	20.0	4.2	167	170	403	213	453
Blue Ridge	232	11.0	3.3	156	193	613	159	668
Ocoee No. 1 (Parksville)	595	7.5	1.9	115	85	1,416	30	1,711
Tims Ford	529	34.0	10.6	143	530	978	273	1,450
Beech	16	5.3	0.9	32	11	--	280(est)	20

a. Measurements based on normal maximum pool and average flows.

b. Major/minor arms of reservoir.

c. Estimated based on releases from Chilhowee Dam, and adjusted based on the additional drainage area between Tellico and Chilhowee dams.

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FIGURE 3.1. Temperature, Precipitation, and Runoff – Tennessee River Basin, WY–91

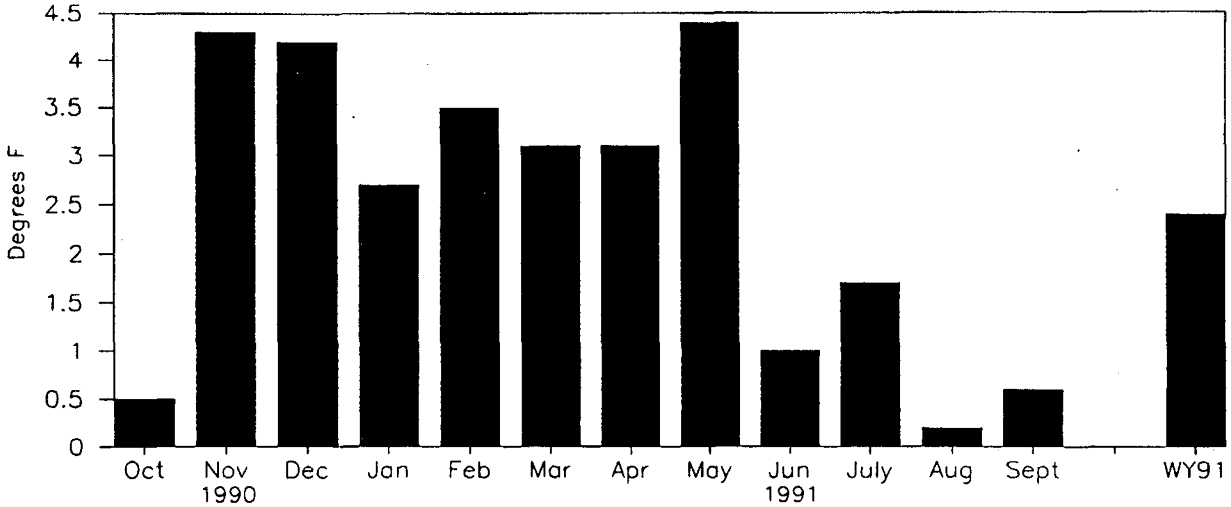

FIGURE 3.1a. Temperature Departures From 1951–1980 Normal (Deg F)
in The TVA Region.

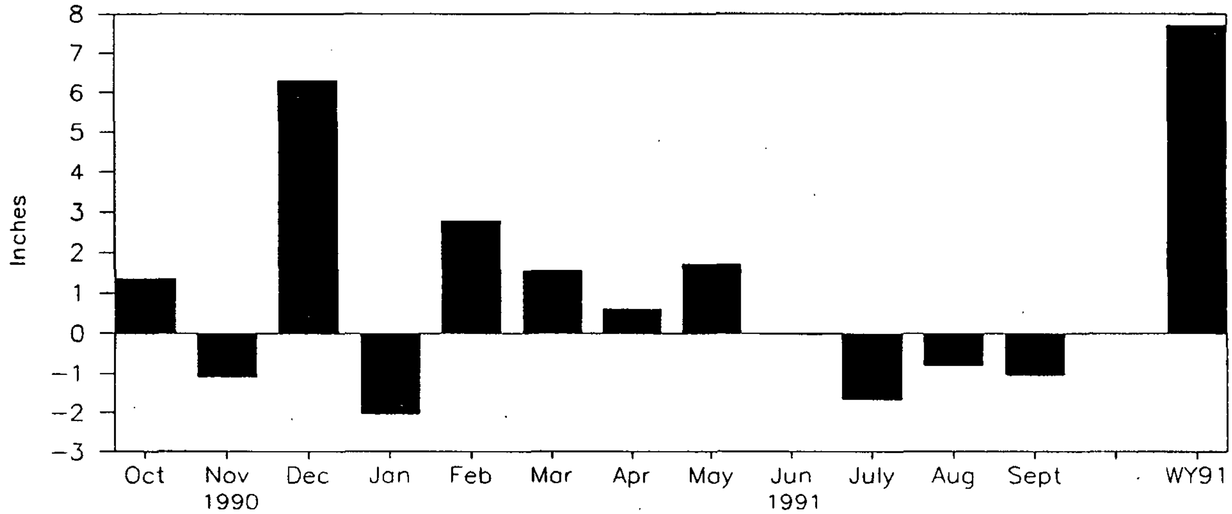

FIGURE 3.1b. Precipitation Departures From 1890–1990 Average (Inches)
For The Tennessee River Basin.

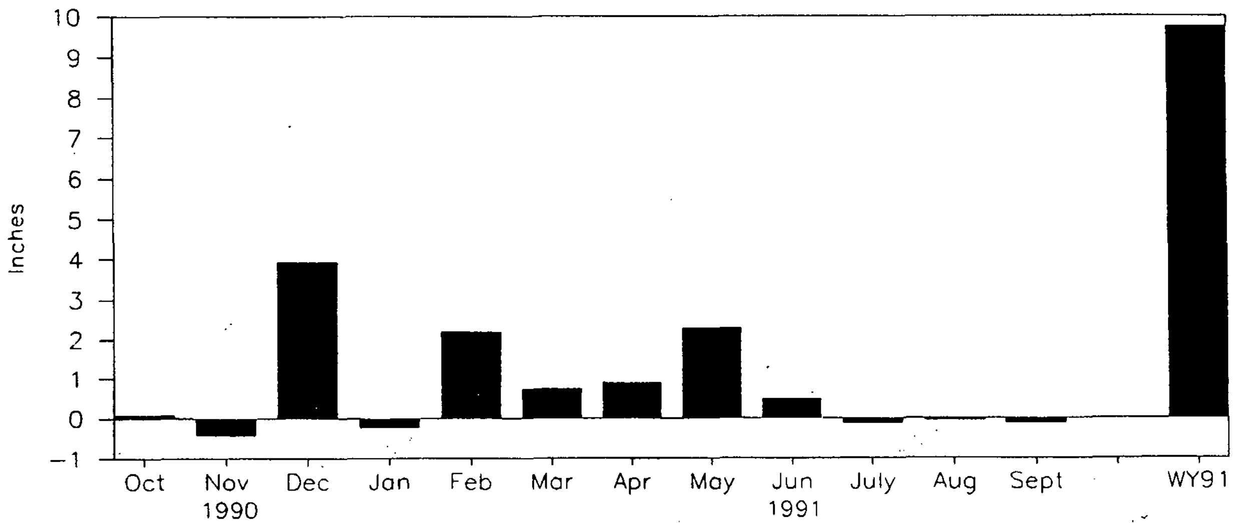

FIGURE 3.1c. Runoff Departures From 1890–1990 Average (Inches)
For Tennessee River Basin, Above Kentucky Dam.

4.0 RESERVOIR BY RESERVOIR SUMMARY AND CONCLUSIONS

4.1 Kentucky Reservoir

4.1.1 Physical Description

Kentucky Reservoir is the first and largest reservoir on the Tennessee River. The dam is located at Tennessee River mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2,280 miles. Average annual discharge is 63,596 cfs which provides an average hydraulic retention time of 23 days. Additional information about Kentucky is provided in table 3.1.

4.1.2 Reservoir Health

Vital Signs Monitoring activities on Kentucky Reservoir in 1991 found generally healthy conditions in all three areas monitored (forebay, transition zone, and inflow). None of the monitoring tools indicated any significant problems, although quite low concentrations of chlorophyll-a and a depauperate benthic macroinvertebrate community indicated unfavorable conditions at the transition zone for these elements of the aquatic community. Overall, results indicated the aquatic resources on Kentucky would rank above average compared to the other mainstem Tennessee River reservoirs.

Within Kentucky Reservoir, the forebay had the healthiest aquatic resources and the transition zone the least, as indicated primarily by the low chlorophyll levels and poor benthos. Similar conditions at the transition zone in 1990, coupled with the relatively high content of sand in sediment samples in both 1990 and 1991, suggest that this site is upstream of the actual transition zone in Kentucky Reservoir. As a result, sample collection for the transition zone has been moved 27 miles downstream in 1992.

4.1.3 Reservoir Use Suitability

Use Suitability Monitoring activities did not identify any impairments on Kentucky Reservoir in 1991. Bacteriological sampling in 1991 was limited to mid-channel collections in association with Vital Signs Monitoring activities. Fecal coliform bacteria were occasionally documented but never at high levels. There are no fish tissue consumption advisories in effect for Kentucky Reservoir. Examination of channel catfish fillets from six locations between Kentucky and Pickwick Dams found only low levels of heavy metals and pesticides at all locations. The only analyte high enough to be of interest was PCBs; however, none of the samples had a concentration above 1.0 µg/g which is commonly used by the State of Tennessee to issue a precautionary consumption advisory.

4.1.4 Synopsis of 1991 Conditions

Water--Surface temperatures ranged from 6.7°C in January to 29.3°C in July at the forebay sampling location and from 7.7°C to 29.3°C for the same months at the transition zone location. DOs at the 1.5-meter depth ranged from 6.1 mg/l in August to 11.8 mg/l in January at the forebay and from 5.3 mg/l in September to 11.3 mg/l in January at the transition zone.

The temperature and DO data depict a seasonal warming and rather weak stratification of Kentucky Reservoir in 1991. The greatest temperature differential (surface-to-bottom) was 2.7°C in June at the forebay. During July and September, a very weak, transient oxycline developed at Kentucky forebay. In July, DOs ranged from 7.6 mg/l at the surface to 0.9 mg/l at the bottom, and in September, DOs ranged from 8.0 mg/l at the surface to 2.8 mg/l at the bottom. The transition zone DOs were much more uniform and well mixed with the minimum bottom DO being 4.9 mg/l in September.

Values of pH ranged from 6.8 to 8.7 on Kentucky Reservoir. Values of 8.5 and higher accompanied by DO saturation values exceeding 125 percent were observed in April and June indicating significant photosynthetic activity. Values of pH measured at the transition zone were lower than at any other Vital Signs Monitoring location on the Tennessee River in 1991.

Average total phosphorus concentrations at the forebay (0.050 mg/l) and the transition zone (0.049 mg/l) were higher than at other monitoring locations on the Tennessee River. Because of high ambient phosphorus concentrations, average TN/TP ratios for samples collected at both the forebay and transition zone were low, indicating conditions highly supportive of photosynthetic activity. The highest chlorophyll-a concentrations were measured in April (18-23 μg/l) and June (16 μg/l) at the forebay. (Values of pH greater than 8.5 and dissolved oxygen concentrations above 100 percent saturation were also measured during this April algal bloom.) Chlorophyll-a concentrations averaged 14 μg/l during 1991 at the Kentucky Reservoir forebay and throughout the summer were higher than at most other Tennessee River monitoring locations. However, at the transition zone, upstream of the mouth of the Duck River, chlorophyll-a concentrations were generally low throughout the year. This is believed to be due to higher water velocities and mixing, higher turbidity, and low available light levels at this location. Secchi depth, turbidity, suspended solids, and color data showed that the Kentucky transition zone had poor water clarity.

Fecal Coliform Bacteria--No bacteriological studies were conducted at designated swimming areas on Kentucky Reservoir in 1991. Monthly sampling in mid-channel at the forebay and transition zone yielded measurable fecal coliform bacteria concentrations on two of seven sample dates (both at the transition): 100 colonies per 100 ml in April and 118 colonies per 100 ml in May.

Sediment--Chemical analyses of sediments did not reveal any metal or organic analyte to be a concern. Likewise, toxicity tests did not detect any acute toxicity. Particle size analysis showed forebay sediments were almost totally silt and clay (98 percent), whereas sediments at the transition zone, given the hydrologic conditions at the site, were quite different (sand 55 percent, silt and clay 45 percent).

Benthic Macroinvertebrates--As expected, substantial differences were observed in the benthic macroinvertebrates at the three locations. The forebay site had 11 taxa and a total of 782 organisms per square meter with chironomids making up most of the organisms collected (Coelotanyopus 31 percent and Chironomus 27 percent of the total). The transition zone exhibited a more limited macroinvertebrate fauna with only five taxa and 124 organisms per square meter with few chironomids collected. Corbicula was the dominant organism (76 percent of the total) and Tubificidae was second (21 percent). The inflow site had 15 taxa and a total of 56 organisms per square meter. Corbicula was the dominant taxon making up 33 percent of the total and Cheumatopsyche was second with 22 percent of the total collected.

Aquatic Macrophytes--Aquatic plants increased from 2106 acres in 1990 to 2813 acres in 1991. Kentucky Reservoir had the third largest amount of aquatic vegetation of any reservoir within the TVA system. Aquatic macrophytes peaked at about 7100 acres on Kentucky Reservoir in 1987. Significant declines in spinyleaf and southern naiad populations have occurred in recent years, and Eurasian watermilfoil is now the dominant macrophyte. Aquatic vegetation on Kentucky Reservoir was primarily found from TRM 110 downstream to near Kentucky Dam.

Fish Community--Fish data for open-water areas of the forebay and inflow showed threadfin shad was the most abundant species comprising 96 and 99 percent, respectively, of the total trawl sample. The transition zone had a quite different assemblage with blue catfish dominant (42 percent), skipjack herring second (28 percent), and threadfin shad third (13 percent). Relative to other mainstem reservoirs, fish densities in the open-water areas were about average in the forebay and inflow, and low at the transition zone. Biomass increased from the inflow to the forebay. In comparison with equivalent areas on Pickwick Reservoir, the next impoundment upstream, biomass values were less for the forebay area and higher for the transition zone and inflow. Average fish size for each area was essentially the same as the mean size calculated for equivalent reservoir reaches in all mainstream reservoirs.

Fish data collections at near shore areas and offshore bottom areas showed a diverse fish assemblage of 45 species dominated by threadfin shad (62 percent) and gizzard shad (13 percent), bluegill (8 percent), emerald shiners (3 percent), and largemouth bass (2 percent). Total numbers of fish were greatest in the inflow zones due to the presence of Young-of-Year (YOY) gizzard and threadfin shad. Threadfin shad were sampled at the rate of 3310 per electrofishing hour. If YOY shad were not considered in the inflow samples, electrofishing indicated higher fish abundances in the transition zone (729 fish per hour) and forebay (673 fish per hour) than the inflow zone (466 fish per hour). Gill netting catch rates of all species combined were three times greater in the forebay (33.1 fish per net-night) than the other zones and were dominated by adult gizzard and threadfin shad. Although relatively poor at all three sites, the fish health assessment of largemouth bass showed the healthiest individuals in the inflow zone (FHAI = 63), compared to the forebay (FHAI = 71) and transition zone (FHAI = 83).

The Reservoir Index of Biotic Integrity (RIBI) showed the littoral fish community (based on results of electrofishing samples) in all three areas of Kentucky Reservoir to be among the best found in TVA reservoirs during 1991. The inflow and transition zones (both with scores of 45) were ranked number one, while the forebay (score 39) was ranked number two of the mainstream forebays. The overriding factor in the good ratings was the high degree of species diversity which directly influenced six of the 11 RIBI metrics. The inflow zone had the highest total number of species (30) followed by the transition zone (28) and the forebay (25). High numbers of sucker species (3-5), migratory spawning species (6-11), and lithophilic broadcast spawning species (6-7) in most cases resulted in good scores for those metrics. The only apparent problems detected were a percentage of omnivores in the inflow zone and poor health of largemouth bass in the transition zone and forebay.

Fish Tissue--Five channel catfish were collected in autumn 1990 from each of six locations (TRMs 23, 61, 100, 135, 173, and 200). Fillets were composited by location, and analyzed for metals, PCBs and pesticides on EPA's priority pollutant list. Concentrations of all metals and pesticides were relatively low. PCB concentrations ranged from 0.1 to 0.9 µg/g. The 0.9 µg/g from TRM 173 was considered high enough to be of interest with need of resampling in autumn 1991. Catfish had been examined from this location in 1987, 1988, and 1989, and PCB concentrations were always lower than found in 1990. Catfish were resampled at these same locations in autumn 1991.

4.2 Pickwick Reservoir

4.2.1 Physical Description

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is 56,706 cfs which provides an average hydraulic retention time of about nine days. Additional information about reservoir characteristics is in table 3.1.

4.2.2 Reservoir Health

Vital Signs Monitoring activities in 1991 indicated overall healthy conditions in Pickwick Reservoir. One undesirable condition was the presence of mercury in sediments at the transition zone and forebay locations. This is a known concern for this reservoir because substantial quantities of this heavy metal were discharged between 1955 and 1970 from a chlor-alkali plant just downstream of Wilson Dam. Investigations in the late 1960s and early 1970s found high concentrations of mercury in sediments and fish. Subsequent studies in the late 1970s identified substantial reductions in both sediments and fish (Milligan and Wallace, 1983). Although this legacy exists, its environmental effects are small given the overall health of the aquatic community observed in this monitoring in 1991 and previously in 1990 (Dycus and Meinert, 1991) and the relatively low concentrations of mercury in fish from Pickwick Reservoir documented in 1988, 1989, and 1990 collections (Dycus, 1990; Hall and Dycus, 1991; and Bates et al., 1992, in preparation).

Overall, the health of aquatic resources of Pickwick Reservoir in 1991 was among the best of the Tennessee River reservoirs. Within Pickwick Reservoir, the forebay and transition zone had the healthiest aquatic resources as indicated by "good" observations from essentially all sampling tools used in this monitoring. The aquatic resources at the inflow were basically what would be expected in an area with quite high flows which significantly limit sediment deposition and development of a diverse and abundant benthic macroinvertebrate community.

4.2.3 Reservoir Use Suitability

Use Suitability Monitoring did not identify bacteriological problems at the forebay or transition zone (swimming areas not monitored in 1991) nor with fish tissue contamination. Concentrations of metals, PCBs, and pesticides in composited catfish fillets were relatively low. Chlordane concentrations were also low at the forebay and transition zone but slightly elevated at the inflow. As a result, fish were again collected from that location in autumn 1991.

4.2.4 Synopsis of 1991 Conditions

Water--Surface temperatures ranged from 8.0°C in January to 31.1°C in July at the forebay and from 8.1°C to 30.7°C for the same months at the transition zone. Temperatures above 30.0°C exceed State of Alabama criteria for fish and aquatic life. Values for DO at the 1.5-meter depth ranged from 10.6 mg/l in January to 6.1 mg/l in August at the forebay and from 10.3 mg/l to 6.4 mg/l for the same months at the transition zone.

Temperature and DO data depict a seasonal warming and rather weak stratification of Pickwick Reservoir. The maximum temperature differential (surface to bottom) was 3.6 °C at the forebay in June. In June at the forebay, DOs ranged from 8.5 to 2.9 mg/l (from the surface to the bottom) and in July from 8.5 to 2.1 mg/l. The transition zone was well mixed and lacked any stratification with a minimum DO of 4.4 mg/l measured in September at the bottom.

Values of pH ranged from 7.0 to 8.8 on Pickwick Reservoir. Near surface pH values of 8.5 and higher (and DO saturation values exceeding 110 percent) were observed during periods of high photosynthetic activity in July and September at the forebay and in June at the transition zone.

Average concentrations of total nitrogen (0.72 mg/l-forebay and 0.78 mg/l-transition zone) in Pickwick Reservoir were among the highest observed among the Tennessee River reservoirs in 1991.

Highest concentrations of chlorophyll-a were measured in September in Pickwick Reservoir, during which time chlorophyll-a concentrations of 14 µg/l and 22 µg/l were measured at the forebay and transition zone, respectively. Chlorophyll-a concentrations averaged about 7 µg/l at both Pickwick Reservoir sampling locations.

Fecal Coliform Bacteria--No bacteriological studies were conducted at designated swimming beaches in Pickwick Reservoir in 1991. Monthly sampling at mid-channel forebay and transition zone locations in 1991 frequently found low concentrations of colonies, with a maximum of 545 colonies per 100 ml at the forebay and 109 colonies per 100 ml at the transition zone, both in September. All other samples had less than 100 colonies per 100 ml.

Sediment--The presence of mercury in sediments of Pickwick Reservoir was documented many years ago and remains of interest today. High concentrations of mercury in sediment were measured in Pickwick Reservoir at both the forebay and transition zone, 0.39 and 0.90 µg/g, respectively. The transition zone concentration was the highest mercury in sediment measured in 1991 at Vital Signs reservoirs. Chemical analyses of sediments revealed no other metal or organic analyte to be a concern.

One of the acute toxicity screening tests (Microtox) indicated acute toxicity in test pore water (but not water column) from the forebay with no indication of toxicity at the transition zone. Test results indicated an EC_{10} (the concentration indicated by literature to correlate with instream effects to invertebrates) of 18.9 percent after five minutes exposure and 15.8 percent after 15 minutes exposure. Theoretically, these results would indicate most of the toxicity was due to organics with a minor influence by metals. There was no toxicity to rotifers. These results generally agree with 1990 results when "an indication" of toxicity was found. Absence of color correction in 1990 tests precluded more firm conclusions. Results from 1992 tests will be closely scrutinized for confirmation of these results.

Particle size analyses surprisingly showed sediments at the forebay were 65 percent sand and only 34 percent silt and clay. The high sand content was much different than expected for a forebay location and much different than found in 1990. Sediment composition at the transition zone was similar to 1990 with silt 74 percent and sand 26 percent.

Benthic Macroinvertebrates--The forebay site had 12 taxa, which was the second most taxa found and a total of 552 organisms per square meter. *Coelotanyopus* was the most numerous taxon present (31 percent of the total) followed by *Corbicula* (26 percent). The transition zone contained 16 taxa which was the maximum found in any of the transition sites. A total of 390 organisms per square meter were collected, *Corbicula* being dominant with 35 percent of the total. The inflow site was represented by mostly *Corbicula* (74 percent). There were 10 taxa; however, only 39 organisms per square meter were collected which is the lowest collected in the mainstream inflow sites.

Aquatic Macrophytes--There was an estimated 25 acres of submersed plants on Pickwick Reservoir in 1991, primarily in the upstream portion of Yellow Creek embayment. Historically, most of the aquatic vegetation on Pickwick Reservoir has been in Yellow Creek embayment, and spinyleaf naiad has been the most abundant macrophyte.

Fish Community--In open-water areas, threadfin shad was the most abundant species comprising 97, 82, and 100 percent at the forebay, transition zone, and inflow sites, respectively. Relative to other mainstream reservoirs, fish densities in the open-water areas of Pickwick were about average in the transition zone and inflow, and lower at the forebay. Average fish size for each area was slightly less than the mean calculated for equivalent areas in all mainstream reservoirs. Values for the forebay, transition zone, and inflow were 4.3, 4.3, and 3.2 cm, respectively.

Fish collections at near shore areas and offshore bottom areas showed that the fish community in Pickwick was not quite as rich in fish species diversity as Kentucky Reservoir, 41 species were found in Pickwick Reservoir overall, with each zone having 30-33 species. Clupeids were the dominant taxa present, accounting for 84 percent of the total sample. The majority of the shad were YOY threadfin shad sampled in the forebay, where an electrofishing catch rate of 3015 fish per hour was found. Other dominant taxa included bluegill (4 percent), emerald shiner (2 percent), and largemouth bass (1 percent). Fish abundance was greatest in the forebay (6282), least in the inflow zone (359), and intermediate in the transition zone (1023). Health of largemouth bass was best in the transition zone (FHAI = 59), but relatively poor at the forebay (FHAI = 76) and the inflow (FHAI = 91).

The quality of the littoral fish community in Pickwick was not quite as good as that found in Kentucky Reservoir. Although the forebay rated good (RIBI = 41), the inflow (RIBI = 29), and transition (RIBI = 33) zones only rated fair. Factors influencing the lower RIBI scores were a generally low species richness, over-abundance of omnivorous individuals, low total numbers of fish sampled, and depressed FHAI. However, all three zones scored good for migratory spawning species (4-8), and the transition zone and forebay scored good for sunfish diversity. Compared to the other mainstream reservoirs, the forebay ranked third, the transition zone fifth, and the inflow ranked among the worst at ninth.

Fish Tissue--One composite sample of five channel catfish was collected at the forebay, transition zone, and inflow. Concentrations of all metals were low. Mercury was not detected in the forebay or transition zone samples (detection limit of 0.1 μg/g), but was found in the inflow sample at the detection limit. Pesticides were generally low. Only DDTr (range 1.0 to 1.3 μg/g) and chlordane (range 0.05 to 0.12 μg/g) were found in all three samples. The chlordane result of 0.12 μg/g at the inflow was near the value used in this monitoring program to indicate a need to reexamine the area. Consumption advisories are not usually envoked unless higher concentrations are found (generally $\geq$0.3 μg/g). A more conservative level (0.1 μg/g) is used to indicate a need to resample to ensure a potential problem is not overlooked. The only other pesticide detected was endrin, found at the detection limit (0.1 μg/g) in the forebay sample. PCBs were detected in all samples (range 0.6 to 0.7 μg/g). Samples were recollected at these sites in autumn 1991.

4.3 Wilson Reservoir

4.3.1 Physical Description

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 53,445 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

4.3.2 Reservoir Health

Vital Signs Monitoring results in 1991 indicated generally fair conditions at both the forebay and inflow sites. There is no transition zone monitoring site because Wilson Reservoir is so short. Results of 1991 monitoring on Wilson were of particular interest because the 1990 results identified several undesirable conditions, mostly at the forebay, apparently due to low DO conditions there. Some of the same undesirable conditions were again observed at the forebay. These were the low DO concentrations (<1.0 mg/l) in deeper strata during summer months, indications of toxic conditions in the sediments, and relatively low diversity of benthic macroinvertebrates (the latter two conditions possibly related to the first). Interestingly, the undesirable fish community characteristics observed in 1990 were not found in 1991, and a greater number of benthic macroinvertebrates were found in 1991 compared to 1990.

Despite the apparent improved conditions in 1991, the aquatic resources of Wilson Reservoir would rank in the lower third of the mainstream Tennessee reservoirs. However, compared to several of the tributary reservoirs, which Wilson resembles in several physical characteristics more so than a mainstream reservoir, Wilson would rank average or slightly better.

4.3.3 Reservoir Use Suitability

Use Suitability Monitoring found low or nondetectable levels of fecal coliform bacteria at the forebay during monthly sampling (no swimming beaches were examined). Concentrations of pesticides and PCBs in composited catfish fillets were relatively low. The only metal with a concentration in fish flesh high enough to be of potential concern was lead at the forebay. Lead was not detected in the inflow sample and was low in the previous sample collected from the forebay area in 1988. This area was sampled again in autumn 1991 to further examine this situation.

4.3.4 Synopsis of 1991 Conditions

Water--Surface temperatures ranged from 7.8°C in January to 31.2°C in July at the forebay sampling location. The 31.2°C in late July was the highest temperature measured at any of the Tennessee River monitoring locations in 1991 and exceeded Alabama's maximum water temperature criteria of 30.0°C. Values for DO at the 1.5-meter depth ranged from 10.5 mg/l in January to 6.2 mg/l in August.

Temperature and DO data show some seasonal warming and weak thermal stratification in 1991. In June, temperature ranged from 27.0°C (surface) to 21.1°C (bottom). Periods of apparently intermittent DO stratification were observed in June, July, and September with DO differentials of greater than 8 mg/l observed during these three months. Dissolved oxygen concentrations near the bottom of Wilson Reservoir were measured at or below approximately 1 mg/l during this time. Elevated ammonia nitrogen concentrations (0.11 mg/l) occurred near bottom in July.

Values of pH ranged from 7.0 to 8.9. In late June, July, and September near-surface values of pH were greater than 8.5. These coincided with high photosynthetic activity, high temperatures, and high dissolved oxygen measurements. With the exception of Boone Reservoir in northeastern Tennessee and Beech Reservoir in west Tennessee, chlorophyll-a concentrations on Wilson Reservoir were the highest among the Vital Signs reservoirs in 1991. Chlorophyll-a concentrations of 28 μg/l were measured in September, and averaged about 15 μg/l.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches in Wilson Reservoir in 1991. Monthly sampling at the mid-channel forebay location in 1991 usually found less than detectable concentrations of colonies. Detectable concentrations (>10 per 100 ml) were found only in April and September with 73 colonies per 100 ml on both occasions.

Sediment--The sediment sample collected in the forebay of Wilson Reservoir had a measured concentration of 130 μg/kg of p,p-DDT in 1991. Samples collected in 1990 did not detect any (<10 μg/kg) DDT in sediment samples from Wilson or any other reservoir examined. Validity of this finding will be tested with further sediment sampling in 1992. There was no other metal or organic analyte of concern.

Acute toxicity screening of the sediment pore water at the forebay found substantially reduced survival of rotifers (56.7 percent survival). Microtox did not indicate toxicity. Only three other locations in the Vital Signs Monitoring network showed toxicity to rotifers in 1991. The level of toxicity on Wilson was second only to that observed on Tellico Reservoir (only 0.1 percent survival). Similar to 1990, particle size analysis showed sediments at the forebay were comprised almost entirely (>99 percent) of silt and clay.

Benthic Macroinvertebrates--The forebay site had 10 taxa and 813 organisms per square meter. This represents a substantial increase in number of organisms over that observed in 1990. The inflow site had 16 taxa and 1030 organisms per square meter. These were both high relative to other mainstream sites monitored in 1991. The forebay site was composed of mostly Chironomus (52 percent of the total) and Tubificidae (26 percent). The Asiatic clam was dominant at the inflow comprising 41 percent of the total and the fingernail clam Musculium was second (24 percent).

Aquatic Macrophytes--No aquatic plants were observed on Wilson Reservoir in 1991. However, the reservoir historically has had small populations of Eurasian watermilfoil, naiads, muskgrass, and filamentous algae.

Fish Community--Fish information for open-water areas of Wilson was based primarily on hydroacoustic gear; trawling was conducted only at the inflow site. Trawling results indicated the open-water assemblage to be dominated by threadfin shad (96 percent of the total sample). These data also indicated that the Wilson inflow had the highest biomass of any of the four mainstream reservoirs where trawl samples were collected. Relative to other mainstream reservoirs, fish densities were higher for both the inflow and forebay with the difference being prominent at the forebay. Average fish size at the forebay was less, while the inflow average was greater, than the mean size calculated for equivalent areas in all mainstream reservoirs. Average length at the forebay was 4.2 cm and at the inflow was 4.5 cm.

Shoreline electrofishing and deep/offshore gill netting at the forebay and inflow of Wilson Reservoir produced 2027 individuals of 37 species, and showed fish were most abundant in the inflow (74 percent of the total fish collected). Dominant species included gizzard shad (30 percent), white bass (14 percent), bluegill (9 percent), channel catfish (7 percent), skipjack herring (5 percent), and emerald shiners (4 percent). All of these species, except bluegill, were at least twice as abundant in the inflow. Health of largemouth bass was better in the forebay (FHAI = 59) than the inflow zone (FHAI = 80).

The 12 electrofishing RIBI metrics described the littoral fish community of the inflow zone as fair (RIBI = 38) and the forebay as good (RIBI = 46), The forebay ranked third, while the inflow ranked fifth among mainstream reservoirs. Metrics that were better at the forebay than at the inflow despite their relative short separation distance included sucker species, percent tolerant individuals, omnivores, and FHAI. Both zones scored high for inventories, piscivores, and migratory spawning species. One forebay metric scored poor: the total number of fish sampled (210). Three inflow metrics scored poor: percent tolerant individuals (21), percent omnivores (15), and FHAI (80).

Fish Tissue--Composited channel catfish samples were collected from the forebay and inflow areas in autumn 1990. Results of most metals, pesticides, and PCB analyses were low or not detected. The exception for the metal analyses was the sample from the forebay with a lead concentration of 0.75 µg/g. This was one of the highest concentrations found in the Tennessee Valley in 1990. The sample from the inflow did not have detectable levels of lead (detection limit 0.02 µg/g) and the sample from the forebay collected in 1988 had 0.13 µg/g of lead. This area was resampled in autumn 1991 to further evaluate the situation.

In addition to these composite samples, individual catfish were analyzed from these two locations plus two other locations which had been sampled in previous intensive studies on this reservoir. The intensive studies were conducted in conjunction with a PCB problem in catfish discovered in 1984. The problem basically disappeared by 1987, but there was a remaining concern over what had been the actual source of PCBs causing the problem in the first place. One theory held that very high river-flows in 1983 and 1984 had washed in contaminated soils and resuspended contaminated sediments resulting in increased exposure and uptake during these periods. Intensive studies were suspended after 1987, but plans were made to repeat these studies when similar flood situations reoccurred. This happen in 1989 and again in 1990 and the intensive studies were conducted. The 1989 results indicated a slight increase in PCB concentrations over those in 1987 but not nearly as high as those in 1984 (Hall and Dycus, 1991). Intensive studies conducted in 1990 identified similar concentrations to those observed in 1989. The maximum concentration in 1990 was 1.2 μg/g and 34 of the 36 catfish tested had concentrations below 1.0 μg/g.

4.4 Wheeler Reservoir

4.4.1 Physical Description

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is 51,053 cfs which provides an average hydraulic retention time of about 11 days.

4.4.2 Reservoir Health

Vital Signs Monitoring results for 1991 identified basically healthy conditions in Wheeler Reservoir. Several of the undesirable characteristics observed in 1990 were not evident. Improvements were apparent in most measurements on the fish community, reduced occurrence of fecal coliform bacteria, and reduced levels of ammonia nitrogen in the water column. One potential area of concern identified in 1991 yet not observed in 1990 was occurrence of low bottom water DO concentrations (near 1.0 mg/l) at the forebay during July and again in September. Overall, the health of the aquatic resources in Wheeler Reservoir in 1991 was good.

Most monitoring tools indicated relatively good conditions in all three study areas. Physical, chemical, and toxological characteristics of water and sediment were good as well as fish community characteristics, as evidenced by relatively high scores on the RIBI. The benthic macro-invertebrate community was not as diverse and abundant as in some of the other mainstream reservoirs. This was especially evident at the transition zone.

One bothersome part of the 1990 results was concern over the transition zone sample site being too far upstream. Results from several of the monitoring components in 1990 were more representative of riverine habitat than transition zone habitat. Some of these same concerns (poor benthic macroinvertebrate community, low primary productivity, and high sand content of the sediments) were again observed in 1991. As a result, the collection site was moved about 11 miles downstream for 1992 sample collections.

4.4.3 Reservoir Use Suitability

Use Suitability Monitoring did not identify concerns about bacterial levels at the forebay or transition zone (no swimming beaches sampled in 1991). Concentrations of all metals in fish flesh were low. However, concentrations of chlordane, DDTr, and PCBs were high enough to be of potential concern. An intensive study to further examine this situation was conducted in coordination with the State of Alabama in autumn 1991. Results should be available in summer 1992.

4.4.4 Synopsis of 1991 Conditions

Water--Wheeler Reservoir was generally well mixed and lacked persistent thermal stratification in 1991. Surface temperatures ranged from 7.0°C in January to 30.8°C in July at the forebay sampling location and from 7.4°C to 30.3°C for the same months at the transition zone. Temperatures in the forebay also slightly exceeded 30.0°C (Alabama's criterion for protection of fish and aquatic life) in September. DO at the 1.5-meter depth ranged from 10.7 mg/l in January to 7.0 mg/l in August at the forebay and from 10.1 mg/l in January to 5.5 mg/l in September at the transition zone.

Temperature data for the period January through the end of September for both the forebay and the transition zone show seasonal warming and rather weak stratification of Wheeler Reservoir in 1991. Greatest temperature differentials of 2.2°C were measured in July and September at the forebay. Concentrations of DO were significantly lower in 1991 than in 1990, despite higher flows during the April-September period of 1991 than 1990. In July and September, DO differentials of about 8 mg/l or greater were measured at the forebay, with minimum near-bottom DOs of 0.7 mg/l in July and 1.4 mg/l in September. Although the transition zone was well mixed and lacked any stratification with a minimum DO of 5.4 mg/l, the average dissolved oxygen concentration at the transition zone in 1991 (6.6 mg/l) was the lowest average DO among the Vital Signs Monitoring locations on the Tennessee River.

Values of pH ranged from 6.4 to 8.8 during 1991. Values of pH greater than 8.5 were observed in June, July, and September at the forebay, but no pHs exceeded 7.6 at the transition zone. During these same months (June, July, and September), DO concentrations measured at the forebay at the 1.5-meter depth were super-saturation (>125 percent).

Organic nitrogen concentrations measured at the forebay were higher than any other Vital Signs Monitoring location on the Tennessee River in 1991. Average total nitrogen (0.78 mg/l) and total phosphorus (0.048 mg/l) concentrations in the forebay of Wheeler Reservoir, were also high compared with other Vital Signs Monitoring locations on the Tennessee River.

The highest chlorophyll-a concentrations were measured in May at the forebay (17 µg/l) and averaged about 9 µg/l. At the transition zone, chlorophyll-a concentrations were lower, averaging about 4 µg/l.

Organic carbon concentrations (both total and soluble) at the forebay averaged 3.3 and 3.0 mg/l, respectively, and were quite high, greater than those measured at any other of the Vital Signs Monitoring locations on the Tennessee River in 1991. True color values showed relatively large increases (as did organic carbon concentrations, above) from an average of 10.6 PCU at the transition zone to 15.3 PCU at the forebay. These increases may be the result of the discharge from a large paper mill (Champion International) about five miles upstream of the forebay.

Fecal Coliform Bacteria--No swimming beaches were examined on Wheeler Reservoir in 1991. Monthly sampling found less than detectable concentrations of fecal coliform bacteria at the transition zone on all sample dates and detectable concentrations at the forebay on only two dates (maximum 127 colonies per 100 ml).

Sediment--Chemical analysis of sediments did not detect concentrations of any organic or metal analyte of concern. Toxicity tests revealed no indications of toxicity at either test location. Sediments were 99.5 percent silt and clay at the forebay but were quite different at the transition zone--35 percent silt and clay and 65 percent sand. The high sand content is one characteristic used to indicate that the transition zone site needed to be moved downstream to be more representative of transition zone conditions.

Benthic Macroinvertebrates--The forebay location had a relatively low number of taxa (11) and organisms (437 per square meter) and was dominated by the chironomids Chironomus (34 percent) and Coelotanyopus (25 percent). The transition site had nine taxa and the fewest organisms per square meter (35) of the mainstream sites. The dominant taxa was Tubificidae which was 29 percent of the total. The inflow had a high number of taxa (20) and an average number of organisms (345 per square meter), dominated by Corbicula (72 percent of the total).

Aquatic Macrophytes--Aquatic plants increased from 1981 acres in 1990 to 3462 acres in 1991. Aquatic macrophytes peaked at about 9800 acres in 1988. In 1991 Wheeler Reservoir had the second-largest amount of aquatic vegetation within the TVA system. Dominant submersed species were Eurasian watermilfoil and spinyleaf naiad. These were most abundant in shallow overbank habitats from TRM 297 upstream to TRM 309. Wheeler Reservoir also had large populations (732 acres in 1991) of American lotus concentrated in Flint Creek embayment, overbank sloughs upstream of Flint Creek, and in Swan Creek embayment.

Fish Community--Fish collections in open-water areas of Wheeler Reservoir were limited to hydroacoustic gear; no trawling was conducted. Fish densities in all three areas of the reservoir were similar to the average for other mainstream reservoirs. The calculated average fish size was higher at the forebay and inflow areas and less at the transition zone when compared to the mean size calculated for equivalent areas in all mainstream reservoirs. Values observed in Wheeler Reservoir for the forebay, transition zone, and inflow were 6.2, 3.3, and 4.4 cm, respectively.

Fish data collected in near shore and offshore bottom areas showed adult gizzard shad were the most abundant species in the transition zone (48 percent of the total collected) and the forebay (43 percent) with YOY threadfin shad dominant in the inflow (95 percent). The YOY threadfin shad in the inflow electrofishing sample (8506 fish per hour) was 79 percent of all fish sampled in Wheeler Reservoir during fall 1991. If the threadfin shad were subtracted from the inflow total, adult gizzard shad would be the dominant species (50 percent) for that reservoir zone, as it was in the other two zones. Gizzard shad adults comprised 10 percent of the total fish sampled. Other common species found in the reservoir as a whole included bluegill (2 percent), emerald shiner (3 percent), and largemouth bass (1 percent). Overall, 39 species of fish were found in Wheeler Reservoir and appeared to be rather evenly distributed with 30 species in the inflow, 28 in the transition, and 31 in the forebay. Health of largemouth bass as described by FHAI was relatively poor compared to other mainstream reservoirs with values of 80, 71, and 68, for the inflow, transition, and forebay, respectively.

The quality of the littoral fish communities in all three zones was among the best of TVA mainstream reservoirs, as determined by RIBI analysis of the shoreline electrofishing data. The inflow and transition zones each had a RIBI score of 39, which ranked them second best in their respective categories. The forebay score was 47, ranking the Wheeler forebay best of the ten mainstream forebays. Furthermore it was the highest score measured during 1991. Commonalities between the three zones supporting the good designations included the low percentages of tolerant individuals (1-2 percent) and the high number of migratory spawning species (3-9). The inflow and forebay scored good for the number of intolerant species, each having four, and for the number of lithophilic broadcast spawning species (6-7). The transition zone and forebay scored good for percent omnivores (2-3) and percent inventories (86-87). The inflow alone scored good for total species (30) and sunfish species (5), while the forebay was the only zone scoring good for the number of sucker species found (5). The only poor scores were found for the omnivore percentage in the inflow (9) and the FHAI metric for the inflow (80) and transition (71) zones.

Fish Tissue--Composite catfish samples were collected from the forebay, transition zone, and inflow in autumn 1990. All metals were relatively low. Most pesticides were not detected; however, chlordane and DDTr were and at levels high enough to be of potential concern. Chlordane concentrations were 0.12, 0.36, and 0.11 μg/g while DDTr levels were 3.3, 2.3, and 0.75 μg/g at the forebay, transition zone, and inflow, respectively. Also, PCB concentrations were relatively high with 0.9, 1.4, and 1.3 μg/g at the lower to upper locations. Concentrations of each of these organics were among the highest observed in the Tennessee Valley in 1990. TVA met with the State of Alabama officials and designed an intensive study which was conducted in autumn 1991 to further examine these potential concerns. Results from those samples should be available in summer 1992.

4.5 Guntersville Reservoir

4.5.1 Physical Description

Guntersville Dam, located at TRM 349.0, creates a 76-mile-long reservoir which has a surface area of 67,900 acres and shoreline of 949 miles at full pool. Average annual discharge is 41,577 cfs which corresponds to an average hydraulic retention time of about 13 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics; however, it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. Because of large areas of shallow water that preclude water level drawdowns for flood protection and aquatic plant control, drawdown on Guntersville Reservoir during winter months is nominal and is manifested in an abundance of aquatic macrophytes in the expansive, shallow overbank and embayment areas. Guntersville has the greatest areal coverage of aquatic plants of any TVA reservoir.

4.5.2 Reservoir Health

Vital Signs Monitoring in 1991 showed the health of the aquatic resources in Guntersville Reservoir were generally fair. Some monitoring tools indicated good conditions, whereas others indicated undesirable conditions. There did not appear to be problems with dissolved oxygen at either the forebay or transition zone, and chlorophyll and nutrients at the forebay were at desirable levels. The fish community rated about average at all three areas compared to the other mainstream reservoirs. The undesirable conditions were an indication of potential toxicity in pore water from forebay sediments (this had also been observed in 1990 monitoring), poor chlorophyll levels and poor fish community at the transition zone, and poor benthos at the inflow. Toxicity tests results from forebay pore water were inconclusive. There was a reduction in light emitted in the Microtox test; however, the reduction was not sufficiently high to be considered conclusive. The conditions at the transition zone were related to that sample site being too far upstream and actually being in a riverine environment. This potential was recognized based on 1990 results and validated in 1991. As a result, the sample site was moved 22 miles downstream prior to initiating 1992 monitoring. The poor benthic macroinvertebrate community at the inflow was most likely related to lack of desirable substrate for colonization due to high flows from Nickajack Dam.

4.5.3 Reservoir Use Suitability

Use suitability monitoring identified presence of fecal coliform bacteria at the forebay in excess of a water-contact recreation guideline of 200/100 ml on several sample dates. There is no readily available explanation to account for the presence of significant concentrations of fecal coliforms at this location, but it was also observed in 1990 monitoring. Additional bacteriological sampling will be conducted in 1992 at swimming beaches and other water contact recreation areas to determine if these areas are also impacted by fecal coliform bacteria. No swimming beaches were sampled on Guntersville Reservoir in 1991.

Analysis of composited catfish fillets from the forebay, transition zone, and upper part of the reservoir (near the inflow) did not find any metals to be of concern. Pesticide concentrations were generally low; however, concentrations of PCBs and chlordane were high enough to warrant further examination in autumn 1991.

4.5.4 Synopsis of 1991 Conditions

Water--Guntersville Reservoir was well mixed and lacked any strong thermal stratification during 1991. Surface water temperatures ranged from 7.8°C in January to 30.1°C in July in the forebay and from 7.9°C to 30.3°C for the same months at the transition zone. The State of Alabama criteria for fish and aquatic life is 30.0°C. Values for DO at the 1.5-meter depth ranged from 10.4 mg/l in January to 7.4 mg/l in August at the forebay and from 10.1 mg/l in January to 5.4 mg/l in July at the transition zone.

Temperature data for the period January through the end of September for both the forebay and the transition zone depict the lack of thermal stratification of Guntersville Reservoir in 1991. Maximum temperature differential was 3.5°C in May. However, June showed the temporary development of an oxycline in the forebay, with surface DOs of 8.4 mg/l and bottom DOs of 1.6 mg/l. The transition zone was completely mixed throughout the year with a minimum DO of 5.3 mg/l measured in July at the bottom.

Values of pH ranged from 6.8 to 8.7. Surface water pH values in excess of 8.5 were observed in May and July at the forebay, but pHs did not exceed 7.8 at the transition zone. There was a 35 percent decrease in average nitrite plus nitrate concentrations from 0.32 mg/l at the transition zone to 0.21 mg/l at the forebay (along with corresponding increases in organic nitrogen and organic carbon) suggesting the photosynthetic uptake of nutrients and primary production processes occurring in the lower end of Guntersville Reservoir. At the forebay, the highest chlorophyll-a concentration of 20 µg/l was measured in July (average chlorophyll concentration was about 7 µg/l in 1991). This, coupled with the pH value of 8.6 and DO percent saturations in excess of 125 percent during July, indicated significant photosynthetic activity. However, at the transition zone, station chlorophyll-a concentrations were very low, ranging from 1 to 2 µg/l (averaging less than 2 µg/l) and were lower than any of the other mainstream Vital Signs Monitoring locations.

Fecal Coliform Bacteria--There were no swimming beaches examined on Guntersville Reservoir in 1991. Monitoring at the forebay and transition zone identified several occasions when concentrations were relatively high (>200 colonies per 100 ml). These were May, June, August, and September at the forebay and June at the transition zone. Concentrations during September at the forebay were greater than 2000 per 100 ml. There is no readily available explanation for these occurrences, and the source of these high concentrations is being investigated. Midchannel locations such as these would be expected to have lower concentrations than near shore locations.

Sediment--Relatively high concentrations of lead (120 µg/g dry weight) and nickel (63 µg/g dry weight) were observed at the forebay in 1990. Similarly high concentrations did not occur in 1991 nor were any other metal or organic analyses high enough to be of concern. However, a slight indication of toxicity was identified by the Microtox test during both 1990 and 1991. It is interesting that inconclusive test results would be found at the same place during successive years. If there were toxic materials in the sediments, it would seem that a more conclusive result would occur in one or both years. However, occurrence in two years indicates need for continued attention--results from 1992 will be closely examined for recurrence of toxicity at this site. Particle size analysis showed the substrate at the forebay to be comprised of 88 percent silt and clay, 12 percent sand. At the transition zone, sand comprised 71 percent and silt 29 percent of the substrate. The high sand content and low chlorophyll-a concentrations in both 1990 and 1991 indicate this station was too far upstream.

Aquatic Macrophytes--Although there was a decline in aquatic macrophytes from 7891 acres in 1990 to 5165 acres in 1991 (the lowest level since the 1970s), Guntersville Reservoir had the largest acreage of aquatic plants within the TVA system. About 98 percent of the total amount of vegetation was upstream of TRM 373 and primarily confined to shallow embayments and overbank areas adjacent to the river channel. Eurasian watermilfoil was the dominant submersed macrophyte species and colonized about 4700 acres in 1991. Significant declines have occurred in Eurasian watermilfoil, hydrilla, spinyleaf naiad, southern naiad, and American lotus since 1988 when vegetation peaked at about 20,200 acres. Only one acre of "topped out" hydrilla occurred on Guntersville Reservoir in 1991 compared to about 2900 acres in 1988.

Benthic Macroinvertebrates--The second-largest number of organisms was collected at the forebay (1033 per square meter) represented by the second-largest number of taxa (12). The chironomid *Coelotanyopus* composed 46 percent of the total. One of the lowest total numbers of organisms (37 per square meter) collected in mainstream transition zones and number of taxa (7) was in Guntersville. The dominant taxon was *Corbicula* (36 percent of the total) and *Gammarus* was second with 23 percent of the total. The inflow was comprised of a relatively high number of taxa (14) and organisms per square meter (662). The dominant species was *Corbicula* (72 percent of the total).

Fish Community--Results from hydroacoustic examination of fish in open-water areas of Guntersville Reservoir showed that fish densities at the forebay were the lowest observed at any mainstream reservoir (<0.2 fish per cubic meter). Densities at the transition zone and inflow were also lower than at comparable areas of other mainstream reservoirs. Fish size was higher than average at the inflow and less than average at the transition zone and forebay areas when compared to equivalent areas of all mainstream reservoirs. Values for the forebay, transition zone, and inflow were 4.5, 4.7 and 4.1 cm, respectively.

Shoreline electrofishing and offshore/benthic gill netting produced 1972 fish representing 39 species. Both gears showed fish abundances were lowest in the transition zone and highest in the forebay, which was slightly higher than the inflow zone abundance. No YOY shad were encountered in the sampling. Gizzard shad were the dominant species, comprising 23 percent of the total collection. Other dominant species included bluegill (13 percent), threadfin shad (9 percent), spotfin shiner (7 percent), emerald shiner (6 percent), redear sunfish (5 percent), and largemouth bass (3 percent). Threadfin shad, skipjack herring, emerald shiners, channel catfish, and smallmouth bass were most abundant in the inflow zone. Curiously, in spite of the lowest overall fish abundance found in the transition zone, gizzard shad and largemouth bass were more abundant there than the other zones. Bluegill, redear sunfish, and flathead catfish were most abundant in the forebay. FHAI showed the health of largemouth bass in the transition zone (FHAI = 58) was better than that of the forebay (FHAI = 81). An insufficient sample size in the inflow precluded determination of a FHAI in that zone.

Electrofishing RIBI analysis detected substantial variation among the three zones. The quality of the littoral fish community in the inflow (RIBI = 36) scored fair, the transition zone (RIBI = 30) scored poor, and the forebay zone (RIBI = 40) scored a borderline good. Compared to the other mainstream reservoirs, all three zones ranked seventh, or stated otherwise, slightly below the averages for their respective zones. Relatively high species diversity in the forebay resulted in the good designation, with top scores for the total species (29), sunfish species (6), sucker species (3), and migratory spawning species (5) metrics. The poor designation of the transition zone was attributed to lower species diversity (25 total, particularly suckers [1], intolerant species [1], and lithophilic spawning species [2]), relatively low total abundance (227 individuals), high proportion of tolerant individuals (17 percent), and a low proportion of inventories (63 percent). The inflow zone had mixed results for trophic composition and reproductive composition metrics. While the percentages of omnivores (2) and inventories (86) scored good, the numbers of migratory spawning species (1) and lithophilic broadcast spawning species (2) rated poor. All three zones rated poor for having high percentages of tolerant individuals (17-25) in the samples. The inflow and transition zones both received low scores for sucker species and lithophilic spawning species, indicating absence of required spawning habitat.

Fish Tissue--Composite catfish samples were collected from the forebay, transition zone, and near the inflow in autumn 1990. All metals were relatively low. Most pesticides were not detected; however, chlordane levels at the forebay (0.10 μg/g) and from near the inflow (0.11 μg/g) were high enough to warrant follow up examination in 1991. Likewise, PCB concentrations at these two locations (1.2 and 1.3 μg/g, respectively) indicated need for additional examination in 1991. Results from those samples should be available in summer 1992.

4.6 Nickajack Reservoir

4.6.1 Physical Description

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is 35,608 cfs which provides average hydraulic retention time of only about four days, the shortest retention time among the reservoirs monitored in this program.

4.6.2 Reservoir Health

Vital Signs Monitoring results for 1991 were quite similar to those from 1990. Monitoring during both years found generally good quality aquatic resources in Nickajack Reservoir. Concentrations of DO remained relatively high throughout both years, there was no thermal or chemical stratification, and the biological monitoring tools indicated basically healthy conditions for each variable examined.

Although the aquatic resources were healthy overall, monitoring during both years identified basically the same points of concern, primarily with sediment quality and the fish community at the forebay. Toxicity tests on forebay sediments found slight to moderate toxicity, and lead concentrations were elevated compared of other sites. The fish community was also somewhat depressed. One potentially undesirable condition observed in 1990 (but not in 1991) was a low density of benthic macroinvertebrate organisms (the lowest observed at any mainstream forebay). These conditions are noteworthy; however, they are not sufficiently serious to indicate need for investigation beyond planned monitoring activities in 1992, especially considering that overall the aquatic resources in Nickajack were average or better compared to other mainstream reservoirs.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sites were not needed because they are relatively close together (separated by only 7.5 miles), and Nickajack is a well-mixed, run-of-the-river reservoir; therefore, sampling at the transition zone was discontinued prior to initiating 1992 monitoring.

4.6.3 Reservoir Use Suitability

Use Suitability Monitoring did not identify concerns about bacterial levels at the forebay or transition zone (no swimming beaches were sampled in 1991). Fish tissue studies in autumn 1990 found PCB concentrations comparable to previous years (generally 1 μg/g). A precautionary advisory on catfish is in effect for Nickajack Reservoir. Children, pregnant women, and nursing mothers should not eat any catfish from Nickajack and all persons should limit consumption to 1.2 pounds a month.

4.6.4 Synopsis of 1991 Conditions

Water--Surface water temperatures ranged from 8.2°C in January to 29.0°C in July in the forebay and from 8.2°C to 28.2°C for the same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 9.7 mg/l in January to 5.7 mg/l in August at the forebay and from 10.0 mg/l in January to 5.1 mg/l in July.

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only four days (table 3.1), results in it being the best mixed of any of the Vital Signs reservoirs. Temperature and DO data depict this lack of stratification in Nickajack reservoir in 1991. The maximum temperature differential of only 0.7°C was measured in July at the forebay. In July, minimum DOs near the bottom were 4.7 and 4.9 mg/l, respectively, for the forebay and transition zone.

Values of pH and conductivity varied over a rather narrow range, from 7.1-7.8 and from 147-185 μmhos/cm. Conductivity and pH were essentially the same at both the forebay and transition zone, again indicative of the well mixed character of the reservoir.

At the forebay, the highest chlorophyll-a concentration of 10 µg/l was measured in July and averaged about 4 µg/l in 1991. At the transition zone, chlorophyll-a concentrations were lower, never exceeding 2 µg/l in 1991. Values of pH of 7.8 and DO saturation of 90 percent (which were the highest pH and DO saturations observed in Nickajack reservoir in 1991) were measured coincident with the high chlorophyll-a observation in July at the forebay.

Fecal Coliform Bacteria--There were no swimming beaches on Nickajack Reservoir examined in 1991. Fecal coliform bacteria concentrations were always low in monthly samples from the forebay (at or below the detection limit of 10 colonies per 100 ml). This was generally true at the transition zone except for the mid-winter sample which had 280 colonies per 100 ml and the April sample which had 120 colonies per 100 ml.

Sediment--An elevated lead concentration of 63 µg/g was detected in sediment collected from the forebay of Nickajack Reservoir in 1991. This sample result concurs with the lead concentration measured in the forebay in 1990 of 92 µg/g. The 1990 results from the Microtox acute screening test identified a toxic response to sediment pore water from the forebay. This appeared to be related to metal toxicity. Results from the 1991 acute toxicity tests did not find toxicity in the Microtox test from the forebay or transition zone but did in Rototox, at the forebay only. Although there was a toxic response, it was not as severe as indicated by 83.3 percent survival of test organisms. Results from these tests in 1992 will continue to be closely examined in association with benthic macroinvertebrate results to evaluate the need for more thorough testing in subsequent years.

Particle-size analyses showed substrates were mostly silt and clay (91 percent silt and clay and 9 percent sand) at the forebay and sand (69 percent sand and 31 percent silt and clay) at the transition zone.

Benthic Macroinvertebrates--The benthic macroinvertebrate community in Nickajack reservoir was healthy, being represented by the highest number of taxa found in both the forebay (15) and the transition (16) compared to other mainstream reservoirs. Contrary to 1990 results, a relatively high number of organisms was also found in the forebay (780 per square meter) and in the transition (655 per square meter). The most abundant taxon in the forebay was Hexagenia which comprised 45 percent of the total. The transition site was composed of Tubificidae (21 percent) and Corbicula (21 percent). The inflow site yielded a relatively low number of organisms (296 per square meter) yet had the third-highest number of taxa (18). Corbicula was the most numerous taxon (31 percent of the total).

Aquatic Macrophytes--The 832 acres of aquatic plants on Nickajack Reservoir in 1991 are comparable to the estimated coverage of 800 acres in 1990. Eurasian watermilfoil was the dominant species and was most abundant from TRM 425 upstream to TRM 440. Coverage over the past decade has ranged from about 800 to 1500 acres.

Fish Community--Fish data for the open-water areas based on hydroacoustic methods showed less than the average density of fish at the forebay and transition zone compared to other mainstream reservoirs. Densities were higher than average at the inflow. Average fish size was less at all areas (3.4, 4.4, and 4.7 cm from downstream to upstream, respectively) compared to the mean size calculated for equivalent areas in all mainstream reservoirs.

Fish collections in the littoral and offshore/benthic areas of Nickajack Reservoir found fish to be most concentrated in the transition zone (N = 2170), compared to the forebay (N = 743) and inflow zone (N = 781). No YOY shad were identified in the samples. For the reservoir as a whole, bluegill was the dominant species (25 percent). Other abundant species included threadfin shad (21 percent), spotfin shiner (8 percent), brook silverside (8 percent), emerald shiner (6 percent), gizzard shad (4 percent), and largemouth bass (4 percent). Health of largemouth bass was fair in the forebay (FHAI = 65) but poor in the inflow (75) and transition (88) zones.

The quality of the littoral fish communities of Nickajack Reservoir was fair to good based on the electrofishing RIBI. The inflow zone with an RIBI value of 39 ranked second. The transition zone (RIBI = 33) scored fair and ranked fifth. The forebay (RIBI = 29) also scored fair, but relative to the other mainstream forebays, the Nickajack forebay was determined to be the worst. A complete absence of sucker species and migratory spawning species, coupled with only one intolerant species, one lithophilic spawner, and a high abundance of tolerant individuals, caused the overall RIBI score to be low. It would have been even lower had it not been for the desirable percentages of omnivores (2) and inventories (86), which rated good. Metrics associated with the good rating in the inflow were total fish abundance (653), sunfish species (6), intolerant species (4), migratory spawning species (4), and percentages of tolerant individuals (5) and omnivores (2). Inflow metrics, contrary to the good rating, included sucker species (2), percentage of inventories (55), and FHAI (75). The transition zone had four metrics rated good, four rated fair, and four rated poor. Considering the reservoir as a whole, all three zones scored poor for sucker species, and the transition and forebay zones scored poor for lithophilic spawning species. Also, there was only one migratory spawning species found outside the inflow zone (in electrofishing samples). This could be an indication of degraded spawning conditions in the inflow zone of Nickajack Reservoir for species that migrate to the flowing headwaters to broadcast spawn their eggs over rocky substrates.

Fish Tissue--The Tennessee Department of Environment and Conservation (TDEC) has issued a precautionary advisory due to PCB contamination in catfish from Nickajack Reservoir. This means that children, pregnant women, and nursing mothers should not consume catfish, and all others should limit consumption to 1.2 pounds per month.

Fish tissue studies conducted in autumn 1990 included collections at two sites, one near the forebay, and the other in the upper end of the reservoir about 13 miles downstream of the inflow. PCB concentrations in fillets from ten channel catfish at each site were quite similar (forebay average 1.0 µg/g and range 0.6 to 1.6 µg/g and upper reservoir average 1.0 µg/g and range 0.4 to 1.7 µg/g). Chlordane concentrations have also been generally elevated in previous studies. In samples collected in autumn 1990 the ten channel catfish from the forebay averaged 0.09 µg/g chlordane and had a range of 0.05 to 0.17 µg/g; whereas the ten catfish from the upper reservoir location averaged 0.11 µg/g and had a range of 0.06 to 0.18 µg/g.

Metals were also examined in composited catfish fillets from these two sites. Of the 12 metals examined, only lead at the upper site appeared relatively high. The concentration of 0.78 µg/g was one of the highest observed in 1990 samples (maximum was 1.5 µg/g from TRM 7).

4.7 Chickamauga Reservoir

4.7.1 Physical Description

Chickamauga Reservoir can be described as an "average" mainstream Tennessee River reservoir. Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is 34,192 cfs which provides an average hydraulic retention of about ten days.

4.7.2 Reservoir Health

Vital Signs Monitoring on Chickamauga Reservoir in 1991 identified generally healthy conditions, although some undesirable conditions were found at the inflow site. Overall, the "health" of the aquatic resources in Chickamauga Reservoir would rate above average compared to the other mainstem reservoirs.

Lack of thermal and DO stratification, presence of an active (but not overly active) algal community, good water clarity, generally good sediment quality, and healthy/diverse benthic and fish communities at the forebay and transition zone were all desirable characteristics. Undesirable conditions at the inflow site included relatively few benthic macroinvertebrate taxa (dominated by one taxon), low number of fish species, and presence of a large proportion of tolerant fish species in electrofishing collections. These conditions and the overall evaluation of Chickamauga Reservoir were quite similar to those based on 1990 monitoring results.

A question arose from the 1990 results related to relocation of the transition zone sample site. Consideration of results from both 1990 and 1991 resulted in the decision not to change the location of this site.

4.7.3 Reservoir Use Suitability

Use Suitability Monitoring activities did not identify any impairments on Chickamauga Reservoir. Bacteriological sampling in 1991 was limited to mid-channel collections in association with Vital Signs Monitoring activities. Fecal coliform bacteria were seldom documented, and when present they occurred at very low levels.

There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Composite fillets from channel catfish collected in autumn 1990 from the forebay, transition zone, and inflow were analyzed for metals, pesticides, and PCBs on the EPA priority pollutant list. Samples had low or nondetectable levels of most metals (except a relatively high concentration of lead in one sample) and pesticides (except slightly elevated levels of chlordane). PCBs were detected, but even the maximum was relatively low. An intensive examination of PCB concentrations in catfish was also conducted in 1991 on Chickamauga Reservoir because of the PCB problems upstream in Watts Bar Reservoir and downstream in Nickajack Reservoir. Ten catfish were collected from five locations and examined individually. Average PCB concentrations were relatively low in all samples, and few samples had a concentration which approached or exceeded 1.0 µg/g. Many samples had less than detectable concentrations. As a result of these analyses, the TDEC did not include any fish species from Chickamauga Reservoir in their annual update on fish consumption for state waters issued February 27, 1992.

4.7.4 Synopsis of 1991 Conditions

Water--Surface temperatures ranged from 8.3°C in January to 29.9°C in July in the forebay and from 7.1°C to 27.6°C for the same months at the transition zone. Values for DO at the 1.5-meter depth ranged from

10.4 mg/l in April to 6.0 mg/l in August at the forebay and from 10.1 mg/l in January to 5.5 mg/l in August at the transition zone.

Like many other mainstem Tennessee River reservoirs, Chickamauga is generally well mixed and lacks any strong thermal stratification. In May, a maximum temperature differential of 3.5°C was observed at the forebay. Minimum bottom DOs were measured in June of 3.0 mg/l and 3.4 mg/l, respectively, at the forebay and the transition zone.

Values of pH ranged from 7.0 to 8.2. Conductivity ranged from 117 to 182 µmhos/cm, and averaged about 165 µmhos/cm. Comparison of pH and conductivity at the transition zone with upstream pH and conductivity at Watts Bar Dam forebay shows these are lowered by Hiwassee River inflows to Chickamauga Reservoir about nine miles upstream of the transition zone.

Average total nitrogen concentrations were the lowest measured among Vital Signs Monitoring locations on the Tennessee River in 1991. In addition, both total phosphorus and dissolved ortho phosphorus concentrations were also among the lowest observed at any of the Vital Signs Monitoring locations on the Tennessee River.

The highest chlorophyll-a concentrations were measured in May ranging from 8-10 µg/l and 11-13 µg/l, respectively, at the forebay and transition zones. Concentrations of chlorophyll-a averaged about 7 µg/l at both the forebay and the transition zone in 1991.

Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.4 meters, 5.7 NTU's, and 4.8 mg/l, respectively. Transition zone Secchi depths, turbidity, and suspended solids averaged 1.4 meters, 4.6 NTUs, and 4.2 mg/l, respectively. In addition, true color values averaged about 10 PCUs at the forebay and transition zones. Together these values indicate the light transparency of Chickamauga Reservoir to be high compared with the other mainstem Tennessee River reservoirs.

Fecal Coliform Bacteria--There were no swimming beaches on Chickamauga Reservoir examined in 1991. Monthly sampling as part of Vital Signs Monitoring did not detect any fecal coliform bacterial colonies in mid-channel at the forebay. Only one sample from the transition zone had a detectable concentration (20 colonies per 100 ml in April).

Sediment--A sediment sample collected from the forebay of Chickamauga Reservoir had a measured concentration of 67 µg/kg of p,p-DDT. Samples collected in 1990 did not detect (<10 µg/kg) DDT in sediment from any locations in the Tennessee Valley. Sediment samples collected from Chickamauga Reservoir in 1992 will be used to validate results from the single sample in 1991. There were no other points of concern about sediment quality in Chickamauga Reservoir. All metal and organic analyses were either not detected or found in low concentrations, and toxicity screening tests did not identify any toxic conditions.

Particle-size analysis showed sediments were 97 percent silt and clay at the forebay. Transition zone sediments were also mostly silt and clay (83 percent) and sand (17 percent).

Benthic Macroinvertebrates--Collections from the forebay included 797 organisms representing 11 taxa. The chironomid *Coelotanyopus* (40 percent of the total) and the mayfly *Hexagenia* (20 percent) were the most numerous taxa collected. The transition zone had an average number of taxa (10) but had the greatest number of organisms collected (1283 per square meter) compared to other mainstream transitions zones. *Corbicula* accounted for 49 percent of the total, and *Hexagenia* accounted for 22 percent. The inflow site had relatively few taxa (8) and an average number of organisms (492 per square meter), however, *Corbicula* comprised 80 percent of the animals collected.

Fish Community--Fish information for open-water areas collected with hydroacoustic equipment showed fish densities at the forebay were similar to most mainstream reservoir forebays. Densities at the transition zone were the highest found in the comparable area of any of the mainstream reservoirs. However, these results had very wide confidence intervals indicating the high mean density may have been due to encountering one or more unusually large school(s) of fish. Average fish size was greater at the inflow and lower at the transition zone and forebay when compared to the mean size calculated for equivalent areas of all mainstream reservoirs. Mean values were 4.1, 3.4, and 4.5 cm at the forebay, transition zone, and inflow.

Fish data collected in littoral and profundal zones of the forebay documented emerald shiner was the most abundant species (collected at the rate of 677 fish per electrofishing hour). Overall, emerald shiners accounted for 33 percent of the total number of fish collected. Other dominant species included bluegill (19 percent), gizzard shad (14 percent), YOY threadfin shad (9 percent), redear sunfish (4 percent), largemouth bass (2 percent), spotted bass (2 percent), and yellow perch (1 percent). Total fish abundance was greatest in the forebay due to the large number of emerald shiners, otherwise fish abundance at all three zones was similar.

Electrofishing RIBI analysis showed a fair quality littoral fish community in the inflow zone (RIBI = 33), and good quality communities in the transition zone (RIBI = 39) and forebay (RIBI = 35). The inflow score ranked fifth among other mainstream reservoir inflows, or about average. The transition zone appeared better and ranked second. The forebay ranked seventh (three other mainstream forebays had identical RIBI scores) which would be below average for mainstream forebays. (A below average value can still be ranked good because all the forebays, including those of storage reservoirs, were included in the original trisection of values to determine good, fair, and poor rankings.) All three zones scored good for total fish abundance, number of sunfish species, and percentage of inventories. However, total species diversities (21-25) only scored fair for the three zones, indicating some expected species were absent from the samples. This was especially true for suckers and intolerant species, and also apparent in the numbers of lithophilic broadcast spawning species and migratory spawning species.

Only one species of sucker was found at the inflow and transition zones and none in the forebay. The inflow was rated fair because of the relatively high percentages of tolerant individuals and omnivorous individuals. The other two zones were rated good. The health of largemouth bass was depressed at all three zones, as FHAI values ranged from 75 to 83.

Fish Tissue--There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Two types of fish tissue studies were conducted on this reservoir in autumn 1990. In one study, fillets from five channel catfish were composited from each site and examined for a broad array of analyses (metals, pesticides, and PCBs on the EPA priority pollutant list). Results from samples collected from the forebay, transition zone, and inflow had low or nondetectable levels of most metals (except lead at 0.80 μg/g in one sample) and pesticides (except chlordane at 0.10 μg/g). PCBs were detected but even the maximum was relatively low. In the other study, fillets from ten channel catfish from five locations within the reservoir were examined individually for PCBs. This intensive study was conducted because of the PCB problems upstream in Watts Bar Reservoir and downstream in Nickajack Reservoir. Average PCB concentrations were relatively low in all samples (maximum mean 0.7 μg/g) near Watts Bar Dam. Many samples had less than detectable concentrations, and few exceeded 1.0 μg/g. As a result of these analyses, the TDEC did not include any fish species from Chickamauga Reservoir in their annual update on fish consumption advisories for state waters issued February 27, 1992.

4.8 Watts Bar Reservoir

4.8.1 Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are Watts Bar Dam (located at TRM 529.9), Fort Loudoun Dam (located at TRM 602.3), and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is 27,849 cfs providing an average hydraulic retention time of about 19 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the inflow on the Tennessee River and the inflow on the Clinch River. Water entering from the Clinch River arm from Melton Hill Reservoir is quite cool due to hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

4.8.2 Reservoir Health

Vital Signs Monitoring results for Watts Bar Reservoir in 1991 identified generally fair conditions, but there was at least one undesirable condition at each sample site. As a result, aquatic environmental resources in Watts Bar ranked below the mid-range compared to the other mainstem reservoirs.

The most significant problems were presence of a strong oxycline with near anoxic conditions during summer at the forebay, presence of mercury in the sediments at the forebay and transition zone, and relatively poor benthic macroinvertebrate fauna at the Tennessee River inflow. Within Watts Bar Reservoir the highest quality aquatic resources were at the transition zone.

4.8.3 Reservoir Use Suitability

Use Suitability Monitoring activities did not identify any bacteriological problems on Watts Bar Reservoir in 1991. Bacteriological sampling was limited to mid-channel collections in association with Vital Signs Monitoring activities. Fecal coliform bacteria were below levels of detection in all samples.

As a result of PCB contamination, the TDEC has issued advisories on consumption of several species of fish from Watts Bar. TVA participates on a study team with state agencies and the Oak Ridge National Laboratory to monitor this situation. A variety of species from several locations on the main portion of reservoir (i.e., not in embayments) are examined each year. Results from fish collected in these areas in autumn 1990 showed little differences from those collected the previous year. Details of these results are provided in Bates et al. (1992).

A special embayment study was conducted on Watts Bar Reservoir in autumn 1990 because of the importance of embayments as fishing areas. Channel catfish, largemouth bass, and crappie (black and white mixed) were analyzed for PCBs and chlordane from two places in the Piney River embayment and one place in the Whites Creek embayment (the two largest embayments on the reservoir). All crappie and largemouth bass had either nondetectable or only low levels of PCBs and chlordane. Concentrations in catfish from Whites Creek were also nondetectable or quite low. Most catfish from Piney River had detectable concentrations of PCBs which did not differ greatly from those in catfish from the forebay sample site.

4.8.4 Synopsis of 1991 Conditions

Water--Surface water temperatures ranged from 7.2°C in January to 30.2°C in July in the forebay and from 7.7°C to 28.4°C for these same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 12.8 mg/l in April (due to high photosynthetic activity) to 8.1 mg/l in September at the forebay and from 11.2 mg/l in January to 6.6 mg/l in September at the transition zone.

Temperature and dissolved oxygen data show the reservoir to be well mixed early in the year and developing a moderate degree of thermal stratification at the forebay in July and August. A maximum temperature differential (surface to bottom) of 8°C occurred in May. DO versus depth data show a rather strong oxycline to develop in the forebay of Watts Bar Reservoir in June and July. In June and July, about a 10 mg/l decrease (surface to bottom) in DO was measured in Watts Bar forebay; near bottom DO concentrations in the hypolimion were less than 1 mg/l. The transition zone was well mixed. Minimum bottom DO measured at the transition zone was 4.4 mg/l.

Values of pH ranged from 7.0 to 9.2 on Watts Bar Reservoir. In April, May, June, and July, near surface values of pH in the forebay were high, equal to or exceeding 9.0, and DO saturation values were high, ranging from 125-150 percent, indicating high rates of photosynthesis.

The average total phosphorus concentrations observed at the forebay were lower than any of the other Tennessee River Vital Signs Monitoring locations. The average dissolved ortho phosphorus concentrations of 0.008 and 0.009 mg/l, respectively, at the forebay and transition zones were essentially identical to the average concentrations of dissolved ortho phosphorus in Chickamauga Reservoir and were among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1991.

The highest chlorophyll-a concentrations were measured in August at the forebay (19 µg/l) and in July at the transition zone (13 µg/l). Surface concentrations of chlorophyll-a averaged about 12 µg/l at the forebay and about 8 µg/l at the transition zone in 1991.

Forebay Secchi depth, turbidity, and suspended solids measurements averaged 1.5 meters, 4.4 NTU's, and 5.7 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be among the highest of the mainstem Tennessee River reservoirs in 1991.

Fecal Coliform Bacteria--These were no swimming beaches on Watts Bar Reservoir examined as part of this monitoring program in 1991. Monthly samples collected in mid-channel at the forebay and transition zone as part of Vital Signs Monitoring activities had less than detectable concentrations in all samples.

Sediment--Elevated concentrations of mercury were again detected in the sediment of Watts Bar reservoir in 1991. Concentrations of 0.51 and 0.69 µg/kg were measured in the forebay and transition zone, respectively. The most likely source of this contamination is past operations at Oak Ridge National Laboratory where major environmental cleanup activities are now underway. Although Microtox provided an indication of toxicity in transition zone pore water in 1990, there was no toxicity in either Microtox or Rototox tests in 1991. Sediments were almost entirely silt and clay (99 percent) at both the forebay and transition.

Benthic Macroinvertebrates--An average number of taxa (11) were collected in the forebay; however, there were relatively few organisms compared to other mainstream forebays (455 per square meter) and 43 percent of the total was Chironomus. The transition zone site and both inflow sites had a relatively high number of organisms. The transition site had 750 organisms per square meter (12 taxa) with the most numerous taxa being Hexagenia (20 percent) and Coelotanyopus (19 percent). The Tennessee River inflow site had 12 taxa and 513 organisms per square meter. The Clinch River had the most taxa (21) found in the mainstream inflow sites and 545 organisms per square meter. Corbicula was the dominant taxon in both inflow sites comprising 66 percent in the Tennessee River and 73 percent in the Clinch River samples.

Aquatic Macrophytes--An estimated 10 acres of aquatic plants were on Watts Bar Reservoir in 1991. Only 80 acres were present in 1990. In the late 1980s, populations were at about 600 to 700 acres and were dominated by Eurasian watermilfoil and spinyleaf naiad.

Fish Community--Fish information from open-water areas based on hydroacoustic equipment showed unusually high numbers of fish and extremely wide confidence interval when compared to equivalent areas on other mainstream reservoirs. This reflects a dense school of fish in the area at the time of the survey. There was also a reduced number of transects in this area resulting in a small volume of water being sampled acoustically. Both of these factors resulted in an estimate of fish density higher than what might be expected for this area. Fish densities at the remaining three Tennessee River sample areas were about average. Average fish size was the smallest at the Clinch River inflow and largest at the transition zone. Each of the other areas had values less than the mean size calculated for equivalent areas in all mainstream reservoirs. Values for the forebay, transition zone, Tennessee River inflow, and Clinch River inflow were 3.7, 4.7, 3.1 and 1.8 cm, respectively.

Shoreline electrofishing and offshore/deep gill netting sampled a total of 4432 fish represented by 43 species. Three species made up the majority of the overall sample: gizzard shad (20 percent), bluegill (18 percent), and brook silverside (17 percent). Other subdominant species included threadfin shad (7 percent), skipjack herring (5 percent), emerald shiner (5 percent), spotfin shiner (4 percent), carp (2 percent), and largemouth bass (2 percent). Fish were most abundant in the transition zone (2021), followed by the forebay (1339), and the Tennessee River inflow zone (723) and were least abundant in the Clinch River inflow (349). Each of the four zones sampled yielded 30-31 species. YOY threadfin shad were found only in the forebay. FHAI analysis found largemouth bass health to be fair in the Tennessee inflow (52) and the transition (65), and poor in the forebay (73). No FHAI was possible in the Clinch inflow due to low numbers of largemouth bass collected.

RIBI analysis of shoreline electrofishing data indicated fair littoral fish communities in the two inflow zones (Clinch Arm RIBI = 35, Tennessee Arm RIBI = 31) and the forebay (RIBI = 33). The transition zone (RIBI = 37) was designated good. Compared to other mainstream reservoirs, the Clinch inflow ranked fourth, while the Tennessee inflow ranked seventh. The transition zone ranked fourth, slightly better than average, and the the forebay ranked tenth, next to the worst. In spite of the lower total numbers of fish sampled in the inflow stations, more diversity was found in sucker species, intolerant species, migratory spawning species, and lithophilic spawning species there than either the transition zone or the forebay. Sunfish diversity was rated good in the transition zone and the forebay. Other metrics supporting the good transition designation were percentages of tolerant individuals, omnivores, and inventories, and overall number of fish sampled.

<u>Fish Tissue</u>--Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning to the public not to eat certain species and to limit consumption of other species. Two of these species (channel catfish and striped bass, including striped bass X white bass hybrids) were reexamined in autumn 1990 as part of the continuing study to remain abreast of conditions in this reservoir. These fish were examined individually for PCBs and pesticides. Results showed maximum PCB concentrations were generally higher in 1990 than in 1989; however, mean concentrations were generally similar between the two years. The maximum concentration in an individual channel catfish in 1990 was 5.8 µg/g, and the greatest average concentration in channel catfish at the site was 1.6 µg/g. Parallel concentrations in striped bass were maximum individual 4.7 µg/g and maximum average 1.3 µg/g. Concentrations tended to be greater in upstream reservoir areas, especially toward the Tennessee River inflow, than in lower reservoir areas near the forebay. Overall, PCB concentrations were lower in 1989 and 1990 compared to those in 1988. Most pesticides were not detected in any of the 1990 samples. Only chlordane was routinely detected with concentrations in most samples <0.10 µg/g. However, a few samples

exceeded this level and one channel catfish (concentration of 0.34 µg/g) exceeded the FDA action limit of 0.30 µg/g for chlordane. The maximum average chlordane concentration at each sample site was 0.11 µg/g for channel catfish and 0.13 µg/g for striped bass.

Channel catfish composites from selected sites were analyzed for metals. All 12 metals included in the analyses were relatively low. Even mercury, which was found in sediments at the forebay and transition zone, was low with a maximum of 0.2 µg/g.

A special embayment study was conducted on Watts Bar Reservoir in autumn 1990. Fish for the continuing study referenced above are collected from the main river portion of the reservoir and are not collected from embayments. Ten individuals each of channel catfish, largemouth bass, and crappie (black and white mixed) were analyzed for PCBs and chlordane from two places in the Piney River embayment and one place in the Whites Creek embayment. There were no PCBs or chlordane detected in any of the 30 crappie examined. Only a few (7 of 30) of the largemouth bass had detectable concentrations and most of the seven had concentrations at the level of detection (0.1 µg/g). The maximum found in a largemouth bass was 0.5 µg/g. Chlordane was detected in only one largemouth bass at a concentration of 0.05 µg/g. As expected, catfish tended to have higher concentrations of both PCBs and chlordane than crappie or largemouth bass. Averages at the two locations in Piney River embayment were 0.6 µg/g and 0.4 µg/g with a maximum of 1.1 µg/g at both sites. Chlordane concentrations averaged 0.05 and 0.02 µg/g at the two Piney River sites. PCB concentrations in catfish from Piney River were generally similar to those observed out in the main portion of the reservoir near the forebay. Catfish from Whites Creek had lower PCB concentrations with detectable levels in only two of the ten examined and as average of 0.1 µg/g.

4.9 Fort Loudoun Reservoir

4.9.1 Physical Description

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 15,620 cfs which provides an average hydraulic retention time of about 12 days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments with long retention times. Both of these deep storage impoundments become strongly stratified during summer months and release cool, low DO water during operation of hydroelectric units. Although some warming and reaeration of the water occurs in transit, both the temperature and DO levels are still low when the water reaches Fort Loudoun Reservoir. These characteristics of the inflow water coupled with the deep turbine withdrawals from Fort Loudoun Dam create an underflow through Fort Loudoun Reservoir during the summer, resulting in thermally stratified conditions. The discontinuous operations of the hydroelectric units at the upstream dams create pulses of flow through Fort Loudoun. The degree of thermal and DO stratification can vary depending on these pulses.

Fort Loudoun Reservoir receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. Water quality characteristics of inflows from the Little Tennessee River differ substantially from that in Fort Loudoun Reservoir. Under certain conditions, water can flow from Fort Loudoun to Tellico Reservoir. Although Fort Loudoun is a mainstream reservoir, this complex set of conditions causes it to exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than that in other mainstream reservoirs.

4.9.2 Reservoir Health

Vital Signs Monitoring results for 1991 indicated poor ecological health based on some, but not all, monitoring tools. The benthic macroinvertebrate community at the forebay and transition zone was represented by a low number of taxa, had a large proportion of the community comprised by tolerant tubificid worms, and had few mayfly larvae (intolerant of low DOs). The fish community at the transition zone and inflow was represented by low fish density and diversity, a substantial proportion of the community comprised by tolerant species (especially carp), and low percentages of intolerant species. These results indicate a stressed environment. Given the physical features of Fort Loudoun Reservoir, these poor conditions would ordinarily be attributed to low DO concentrations. However, monitoring results for 1991 did not document the expected temperature and DO stratification. Monitoring in 1990 had documented the expected stratification and near anoxic conditions occurring in the hypolimnion of the forebay during late summer. It appears from these results that the monthly monitoring missed pulses of cool, low DO water passing through the reservoir. This assumption is warranted because the biological communities which are continuously exposed to ambient conditions indicate a stressed environment. Considering results from all monitoring tools, the aquatic resources in Fort Loudoun Reservoir rank below average compared to the other mainstream reservoirs.

4.9.3 Reservoir Use Suitability

Use Suitability Monitoring did not find any bacteriological problems at the forebay or transition zone during monthly Vital Signs Monitoring. Water at swimming beaches was not examined in 1991.

Fort Loudoun Reservoir has had a PCB problem for more than 20 years. The TDEC has advised the public not to eat any largemouth bass from the Little River embayment or largemouth bass greater than two pounds from other parts of the reservoir. Also, catfish should not be eaten from any part of the reservoir. Initially, TVA and state agencies examined a variety of species from throughout the reservoir to document the geographical and species variation. The study now continues as a trend study in which there is an annual collection of catfish from one location. PCB concentrations in catfish have varied over the years with no distinct trend. Catfish collected in autumn 1990 had slightly lower PCB levels than those found in previous years. In addition to the continuing study, channel catfish were collected from the forebay, transition zone, and inflow in autumn 1990 and analyzed for a broad array of contaminants because it had been several years since contaminants in addition to PCBs had been examined. All metals were low except lead which was slightly elevated compared to most other Tennessee River reservoirs. Most pesticides (except chlordane) were low or not detected. Chlordane concentrations were elevated at the transition zone and forebay, but not to problematic concentrations.

4.9.4 Synopsis of 1991 Conditions

Water--Temperature and dissolved oxygen (DO) data show the reservoir was well mixed early in the year but developed thermal stratification from June through September. Surface water temperatures ranged from 7.5°C in January to 28.2°C in July at the forebay and from 6.8°C to 29.6°C for the same months at the transition zone. The forebay was thermally stratified in July and August with up to 8°C difference between surface and bottom.

DO at the 1.5-meter depth ranged from 12.3 mg/l in April (algal bloom) to 8.9 mg/l in August at the forebay and from 14.6 mg/l in July (algal bloom) to 5.7 mg/l in August at the transition zone. Forebay DO concentrations showed a metalimnetic minimum at about 14 meters in August and September of 3.7 and 3.3 mg/l, respectively. The transition zone was well mixed with minimum bottom DOs of 5.1 in July. Hypolimnetic DO concentrations measured in the forebay in 1991 were higher than in 1990. For example, in the hypolimnion in 1990, DOs were measured below 2 mg/l in July and August; but in 1991, no DOs were measured below 3 mg/l.

Values of pH ranged from 6.7 to 9.1. At the forebay, pH values exceeding 8.5, and DO saturation values exceeding 120 percent were measured from April through September giving evidence of substantial photosynthetic activity. During these same months, the same pattern of high pHs and high DO saturations was observed, although to a lesser extent, at the transition zone.

Conductivity ranged from 93 to 250 µmhos/cm, averaging 170 µmhos/cm at the forebay and 200 µmhos/cm at the transition zone. The appreciably lower conductivities measured at the forebay area were caused by inflows from the Little Tennessee River, via the Tellico Reservoir canal. For example, during summer, water from Tellico Reservoir is colder than the surface water of Fort Loudoun Reservoir causing it to flow under the warmer water of Fort Loudoun Reservoir. This was the case in August and September, 1991, when water surface conductivity was greater than 200 µmhos/cm and near bottom conductivity was less than 100 µmhos/cm in the forebay of Fort Loudoun Reservoir. In the winter, the water from Tellico Reservoir often flows across the top and "floats" on the surface of the Fort Loudoun Reservoir, such as was the case in January 1991, when the Fort Loudoun forebay had surface conductivity less than 100 µmhos/cm and near bottom conductivity near 200 µmhos/cm. Other months (e.g., April, May, June, etc.) give evidence of partially mixed "lenses" of low conductivity water from Tellico Reservoir merging with the higher conductivity water from Fort Loudoun Reservoir forebay at two or more depths.

Near surface concentrations of organic nitrogen were high at both the forebay and the transition zone. At the transition zone, the average nitrite plus nitrate nitrogen concentration of 0.41 mg/l was the highest average concentration of this nutrient measured in 1991 at any of the Tennessee River Vital Signs Monitoring locations. The average total nitrogen concentration (organic nitrogen plus ammonia plus nitrite+nitrate nitrogen) of 0.78 mg/l was also quite high. These high concentrations of nitrogen are due to a combined effect of the wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad rivers, which also have relatively high nitrogen concentrations.

The highest chlorophyll-a concentrations in the forebay occurred in August and September (10 µg/l) and in the transition zone in June (22 µg/l). Surface concentrations of chlorophyll-a averaged about 6 µg/l and 8 µg/l, at the forebay and transition zone, respectively.

Fecal Coliform Bacteria--There were no fecal coliform colonies detected in water from the forebay or transition during monthly Vital Signs Monitoring. Studies were not conducted at swimming beaches in 1991.

Sediment--Chemical analyses of sediments did not reveal any single metal or organic analyte to be a concern and there appeared to be no sediment toxicity. However, the forebay sediment sample had one of the highest cummulative heavy metal concentrations (sum of Cr, Cu, Pb, Hg, Ni, and Zn) among all the Vital Signs Monitoring locations. Particle-size analysis showed forebay sediments and transition zone sediments were almost totally silt and clay (99 percent).

Benthic Macroinvertebrates--The number of taxa was low at all three sites (7, 10, and 6, from downstream to upstream). The forebay had the fewest taxa (7) found in any of the mainstream reservoirs' sample sites. An average number of organisms were collected from all three sites (611, 648, and 513, per square meter from downstream to upstream). The forebay and transition sites were both dominated by Tubificidae (58 and 48 percent respectively), while the inflow site was dominated by Corbicula (74 percent). Tubificidae (23 percent) was the second most abundant species in the inflow.

Aquatic Macrophytes--Aquatic plants on Fort Loudoun Reservoir were primarily upstream of TRM 635. An estimated 25 acres of aquatic plants were present in 1991. Historically, Eurasian watermilfoil has been the dominant aquatic plant. Coverage over the past decade has ranged from about 25 to 140 acres.

Fish Community--Hydroacoustic evaluation of fish in open-water areas showed fish densities were about average for the forebay and transition zone compared to equivalent areas on other mainstream reservoirs, but were lower than those observed for similar areas in storage impoundments. However, the inflow showed the second-highest density of any of the mainstream reservoir inflows and exceeded the values for similar storage impoundments areas. Average fish size was essentially equal at the transition zone and less at the inflow and forebay areas when compared to the mean size calculated for equivalent areas in all mainstream reservoirs. Values for the forebay, transition zone, and inflow were 3.9, 4.8, and 2.8 cm, respectively.

Fish samples from the littoral and profundal areas of Fort Loudoun Reservoir produced 2997 individuals, representing 37 species. The two most abundant taxa were bluegill and gizzard shad which accounted for 27 and 26 percent, respectively, of the total number collected. Overall, fish were three times more abundant in the forebay than the other two zones. Gizzard shad and carp were abundant in all three zones. Channel catfish and golden redhorse were most common in the inflow zone. All three zones had either 27 or 28 species total. Fish health analysis showed largemouth bass from Fort Loudoun Reservoir were among the healthiest from any of the mainstream reservoirs. The FHAI was 44 at the transition zone and 50 at the forebay. FHAI analysis in the inflow was not possible due to an insufficient number of largemouth bass found.

RIBI analysis of shoreline electrofishing data showed the littoral fish communities were poor in both the inflow (RIBI = 27) and the transition (RIBI = 19) zone, while a good littoral community was found in the forebay (RIBI = 35). The RIBI scores for the inflow and transition zone were among the lowest found in mainstream reservoirs, each being ranked tenth. Metrics associated with the poor designations were high percentages of tolerant individuals, high percentages of omnivores, low percentages of inventories, and low totals of fish in the samples, all of which rated poorly in the inflow and transition zones. The high relative abundance of carp, a tolerant, omnivorous species, in Fort Loudoun Reservoir had a major influence on three of the four metrics just discussed. Additional problems found in the transition zone were related to a low overall fish diversity (19 species total), low numbers of sucker species (1), intolerant species (1), and lithophilic broadcast spawning species (2). (This could possibly be related to high NH_3 measurements in the sediments, as noted in Moses and Wade [1992]). In contrast to the many low scores at the transition zone, the health of largemouth bass (FHAI =44) received a good score, and was better than the fair forebay FHAI (50).

<u>Fish Tissue</u>--The sample site for the PCB trend study is near the transition zone at TRM 625. Ten channel catfish collected from there in autumn 1990 had an average PCB concentration of 1.0 μg/g and range of 0.3 to 1.9 μg/g. In addition to the trend study on Fort Loudoun Reservoir, composites of five channel catfish were collected in autumn 1990 from the forebay, transition zone, and inflow and analyzed for PCBs, pesticides, and metals on EPA's priority pollutant list. These additional analyses had not been examined in Fort Loudoun fish for several years. PCB concentrations in the three samples were 0.9, 2.0, and 0.7 μg/g at the forebay, transition zone, and inflow, respectively. Other than chlordane discussed above (concentrations 0.16, 0.12, and 0.07 μg/g from downstream to upstream), all pesticides were below detection limits or found at only low concentrations. Most metals in these samples were likewise low. Only lead appeared elevated compared to fish samples from most other TVA reservoirs. Lead concentrations were 0.74, 0.07, and <0.02 μg/g at the three locations from the forebay to the inflow. The highest lead found in all of the samples collected in autumn 1989 from throughout the Tennessee Valley was 1.5 μg/g at TRM 7, downstream of Kentucky Dam. There were five other locations (including the Fort Loudoun forebay) with concentration between 0.74 and 1.0 μg/g. All other samples had much lower concentration (between <0.02 and 0.20 μg/g).

4.10 Norris Reservoir

4.10.1 Physical Description

Norris Reservoir, formed by Norris Dam at Clinch River mile 79.8, is a large dendritic storage impoundment. It is one of the deeper TVA tributary reservoirs with depths over 200 feet. Norris Reservoir has a potential controlled storage drawdown of 74 feet, from 1034 to 960 (feet MSL) for flood control; however, annual drawdowns average only 32 feet, given that full pool levels are not reached before annual drawdown begins. The surface area of the reservoir is 34,200 acres at full pool, and the shoreline is 800 miles long. The confluence of the Powell River and the Clinch River is nine miles upstream of Norris Dam. At full pool, water is impounded 73 miles up the Clinch River and 53 miles up the Powell River. Because the confluence of the Clinch and Powell Rivers is relatively close to the dam, two transition zone sites were established: one in the Clinch River and one in the Powell River. Norris Reservoir has a long average retention time (about 250 days), and average annual discharge from Norris Dam is 4,100 cfs. Additional information about the characteristics of Norris Reservoir is given in table 3.1.

Due to the great depth and long retention time, significant vertical stratification is expected. Norris is known as an oligotrophic reservoir with high water clarity, mostly due to phosphorus limitations to primary production.

4.10.2 Reservoir Health

Vital Signs Monitoring on Norris Reservoir in 1991 provided results similar to those in 1990. Both years documented expected trends and ranked the water resources in Norris Reservoir average or better compared to the other tributary reservoirs. The most obvious problems during both years were strong vertical stratification and low primary productivity. At the transition zone, near-anoxic bottom conditions occurred from May through September both years.

Low primary productivity coupled with strong vertical stratification and accompanying anoxic conditions restrict productivity at higher trophic levels. The benthic macroinvertebrate community was generally depressed; however, the quality was better than expected given the severity of oxygen depletion. The species richness of the fish community was relatively low in all study areas.

In 1990 the high number of young threadfin shad in the open-water area of the forebay was surprising given that this area of Norris Reservoir is one of the most oligotrophic sites in the Tennessee Valley. It was thought that this very large forage base was a one-time occurrence that would be short-lived based on a limited food supply; however, threadfin shad abundance was again high in 1991. Currently, this phenomenon and how it relates to other trophic levels in Norris Reservoir is not understood.

4.10.3 Reservoir Use Suitability

Use Suitability Monitoring in 1991 showed the swimming beach at Big Ridge Lake State Park to fully support water contact recreation and the swimming beach at Loyston Point recreation area to partially support water contact recreation. There were no fish tissue studies conducted on Norris Reservoir in autumn 1990.

4.10.4 Synopsis of 1991 Conditions

Water--Surface water temperatures ranged from 9.0°C in January to 30.3°C in July in the forebay, from 6.7°C to 30.5°C for the same months at the Clinch transition zone, and from 7.9°C to 30.7°C for the same months at the Powell transition zone. The State of Tennessee maximum water temperature criterion for fish and aquatic life is 30.5°C. These warmer water temperatures in July resulted from the unusually warm and persistent atmospheric temperatures antecedent to the July sampling.

DO at the 1.5-meter depth ranged from 11.4 mg/l in April to 7.8 mg/l in September at the forebay, from 11.7 mg/l in January to 7.9 mg/l in August at the Clinch transition zone, and from 11.4 mg/l in January to 8.3 mg/l in September at the Powell transition zone.

Thermal stratification began in April which was well established by May. Maximum water column temperature differentials occurred in July, at the forebay, where the temperature decreased over 20°C from the water surface to the bottom. Strong stratification persisted through September. DOs less than 1 mg/l developed in June at the transition zones; however, DOs less than 1 mg/l were not observed in the forebay in 1991, as was the case in 1990. In July, the anoxia development in the Clinch and Powell transition zones resulted in hypolimnetic DO concentrations being less than 1 mg/l over approximately 75 percent and 50 percent, respectively, of the water column depths. This hypolimnetic anoxia also resulted in the reduction and dissolution and release of nutrients trapped in the sediment.

Values of pH ranged from 7.0 to 8.8 at the three monitoring locations. Surface water pH values usually exceeded 8.5 during summer when DO concentrations were high indicating substantial photosynthetic activity.

The conductivity of the water is among the highest of the Vital Signs reservoirs. Reservoir-wide, conductivities ranged from 203 to 360 µmhos/cm. They averaged about 242 µmhos/cm at the forebay, about 271 µmhos/cm at the Clinch transition zone, and about 276 µmhos/cm at the Powell transition zone.

As expected, concentrations of nutrients were quite low. The average total phosphorus and dissolved ortho phosphorus concentrations of 0.008 and 0.006 mg/l, respectively, measured at the forebay were among the lowest average total phosphorus concentrations measured in 1991. TN/TP ratios as high as 185 were measured in individual samples on Norris reservoir, in 1991, indicating severely limiting phosphorus conditions in Norris reservoir.

Concentrations of chlorophyll-a averaged only about 2 µg/l at the Norris Reservoir forebay. At both the Powell and Clinch transition zones, chlorophyll-a concentrations averaged about 4 µg/l. Further evidence of the low productivity of Norris Reservoir was the low organic carbon concentrations (both total and soluble) measured in 1991.

Norris Reservoir was quite clear at both the forebay and the transition zone. Forebay Secchi depth measurements averaged 2.0 meters. Transition zone Secchi depths averaged 1.8 meters on the Clinch and 1.9 meters on the Powell.

Fecal Coliform Bacteria--Two designated swimming areas on Norris Reservoir were sampled in 1991. Details of these results and methods used are provided in Fehring (1992). Fecal coliform bacteria concentrations at the Big Ridge Lake State Park swimming beach were low allowing a Fully Supports classification. However, the swimming area at the Loyston Point recreation area received a Partially Supports classification because of relatively high fecal coliform bacteria concentrations. Vital Signs sampling at the forebay and both transition zones never found bacterial concentrations above the detection level.

Sediment--Among the 28 Vital Signs locations sampled for sediment in 1991, Norris forebay had the highest lead concentration (110 µg/g). (The 1990 sediment sample collected at Norris forebay also had a high lead concentration of 88 µg/g.) Also, a small amount of p,p-DDT was measured in the forebay sediment of Norris Reservoir.

Presence of DDT needs to be confirmed with additional samples. There was no toxicity in either the Microtox or Rototox tests. Presence of PCBs in sediments from the Clinch River transition zone in 1990 was not found in 1991. Particle size analysis showed the substrates at the forebay and Powell River transition zone were mostly silt and clay (>96 percent), whereas sand was the dominant substrate at the Clinch River transition zone (sand 84 percent and silt and clay 14 percent).

Benthic Macroinvertebrates--Compared to Cherokee and Douglas Reservoirs (two similar storage impoundments), the Norris forebay had the highest number of taxa (11) and greatest density of organisms (1012 per square meter, with Tubificidae comprising 62 percent of the total number) possibly owing to the absence of anoxic conditions there. The transition zones were similar to one another in number of taxa (Clinch 125, 7 taxa and Powell 30, 9 taxa) and density of organisms (Clinch 125, 723 per square meter and Powell 30, 550). The Clinch mile 125 was dominated by the Chironomids *Procladius* (34 percent of the total) and *Chironomus* (32 percent). The Powell mile 30 was dominated by Tubificidae (61 percent).

Aquatic Macrophytes--Physical conditions, primarily deep reservoir drawdowns, preclude development of aquatic macrophytes in Norris Reservoir.

Fish--Fish data collections in the open-water areas of Norris Reservoir included both hydroacoustic and trawling methods. Threadfin shad was the most numerous species encountered in all three areas comprising 93, 99, and 100 percent at the forebay and Powell and Clinch transition zones, respectively. Relative to other storage impoundment forebays, fish densities and biomass at the Norris forebay were the highest observed. This is unusual given the low primary productivity there. However, similar results were found in 1990. Densities and biomass at the two Norris transition zones did not differ greatly from that at the Cherokee and Douglas transition zones. Average fish size at the Norris forebay was similar to that at Douglas but larger than that at Cherokee Reservoir forebay. At the transition zones, average fish size was similar to average size on Cherokee but smaller than that at the Douglas transition.

The fish samples from the littoral and profundal areas of Norris Reservoir produced a total of 1635 individuals representing 30 species. Highest concentrations of fish were found in the forebay (43 percent) due to the abundance of bluegill in the electrofishing samples (206 fish per hour), but only 19 species were found. Abundances in the Clinch and Powell transition zones were nearly identical (29 and 28 percent, respectively), although the Powell samples were more diverse (28 species) than the Clinch (21 species). Dominant species reservoir-wide were bluegill (27 percent), walleye (9 percent), spotfin shiner (6 percent), gizzard shad, smallmouth bass, spotted bass, black crappie (5 percent each), striped bass, brook silverside (4 percent each), and largemouth bass (3 percent).

The quality of the littoral fish communities of Norris Reservoir was determined to be fair in the Powell transition zone (RIBI = 36) and poor in the Clinch transition zone (RIBI = 30) and forebay (RIBI = 32) based on shoreline electrofishing results. Compared to other storage reservoir transition zones and forebays, the Norris communities rank slightly below average. The Powell and Clinch transition zones ranked fourth and sixth of seven total transition zones, respectively, while the forebay tied for sixth of ten total storage reservoir forebays. All of the Norris zones scored poor for total fish diversity (13-17 species), the number of sunfish species (1 species), and the percentage of invertivores (43-79). The two transition zones scored poor for the total number of fish in the sample (267-275). Metrics supporting the fair designation of the Powell transition, but not found at the other zones, included numbers of sucker species (5), lithophilic spawning species (6), and intolerant species (4), which scored good. Both transition zones scored good for the migratory species metric (4-6 species). The Powell transition, and the forebay scored good for low percentages of tolerant individuals (4-6 percent). No omnivores were found in the Clinch transition or the forebay. Fish health was rated poor in the Powell (FHAI = 79) and fair in Clinch (FHAI = 51) transition zones.

<u>Fish Tissue</u>--There were no fish tissue studies conducted on Norris Reservoir in autumn 1990.

4.11 Cherokee Reservoir

4.11.1 Physical Description

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile 52.3. Like Norris and Douglas reservoirs, it is a large, deep, tributary storage impoundment with a substantial drawdown in late summer and autumn. At full pool, drawdown is 53 feet. However, full pool is not reached each year, and the long-term average drawdown is 28 feet. Cherokee Reservoir extends 53 miles upstream, has a surface area of 30,300 acres, and has a shoreline of 393 miles. Average annual discharge is 4539 cfs which provides an average hydraulic retention time of about 168 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit is greater on Cherokee than any of the other Vital Signs Monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

4.11.2 Reservoir Health

Vital Signs Monitoring results from Cherokee Reservoir in 1991 agreed with results from 1990 monitoring and documented several undesirable conditions, the most obvious of which was the expected stratification of DO and temperature beginning in May. Anoxic conditions existed during most of the summer at both the forebay and transition zone. As would be expected, poor DO conditions in bottom waters resulted in relatively poor benthic macroinvertebrate communities. However, presence of aerobic benthos in these areas (which had experienced such adverse conditions about six months prior to sample collection in March) shows the ability of these organisms to reestablish quickly. Another condition considered undesirable was presence of relatively few fish species at all three sites. The health of the aquatic resources in Cherokee Reservoir would rate poor and rank below average compared to other storage reservoirs.

4.11.3 Reservoir Use Suitability

Use Suitability Monitoring on Cherokee Reservoir was quite limited in 1991. There were no swimming beaches examined, and there were no fish tissue studies conducted. Bacteriological monitoring at the forebay and transition zone were conducted only in January and September. No indication of bacteriological contamination was found.

4.11.4 Synopsis of 1991 Conditions

Water--Surface water temperatures ranged from 7.8°C in January to 29.4°C in July in the forebay and from 7.4°C to 31.4°C for the same months at the transition zone. Tennessee maximum water temperature criterion for fish and aquatic life is 30.5°C. Like Norris Reservoir, these warmer surface water temperatures exceeded this criterion in July as a result of unusually warm and persistent regional atmospheric temperatures during the July sampling period.

DO at the 1.5-meter depth ranged from 11.1 mg/l in January to 6.3 mg/l in August at the forebay and from 12.4 mg/l in June (algal bloom) to 8.1 mg/l in August at the transition zone. Thermal stratification began in April and was well established by May. In May, June, and July at the forebay, the data show a 14°C (or greater) decrease in temperature and approximately an 8 mg/l decrease in DO from the surface to the bottom of the reservoir. This strongly stratified condition persisted through mid-September with strong anoxia development in July and August. In July, hypolimnetic DO concentrations less than 1 mg/l were measured from the bottom of the reservoir (42 meters) to within 10 meters of the surface at the forebay, i.e., 75 percent of the water column. At the transition zone, large anoxic hypolimnetic effects were also observed in July. Hypolimnetic DO concentrations less than 1 mg/l were measured from the bottom of the reservoir to within 8 meters of the surface. (The depth of the water in July at the transition zone was about 22 meters.) At both the forebay and the transition zone, highly reducing conditions were evident during this period of anoxia, characterized by the high concentrations of ammonia nitrogen, total phosphorus, and dissolved ortho phosphorus measured in the hypolimnion.

Values of pH ranged from 7.0 to 9.0 in Cherokee Reservoir. At the transition zone, pH values equal to or exceeding 8.5 and DO saturation values frequently exceeding 100 percent were measured every month, April through September, giving evidence of a great deal of photosynthetic activity. Similar conditions were also observed at the forebay during these same months, although at lesser magnitudes.

The average nutrient concentrations (both total nitrogen and total phosphorus) measured at the transition zone in 1991 were higher than any other Vital Signs Monitoring location, indicating large nitrogenous waste discharges to the Holston River upstream of the reservoir. TN/TP ratios indicate a higher productivity potential at the transition zone and occasional severe phosphorus limiting conditions at the forebay. The transition zone is consequently much more supportive of photosynthetic activity than the forebay, evidenced by the higher near-surface chlorophyll-a, and the high pH, and DOs discussed above. The highest chlorophyll-a concentrations were measured in May and August at the transition zone (13 µg/l) and in January and May at the forebay (10 µg/l). Surface concentrations of chlorophyll-a averaged about 6 µg/l at the forebay and 8 µg/l at the transition zone. These average concentrations of chlorophyll-a, measured in the transition zone in 1991 are approximately half the chlorophyll-a concentrations measured in 1990. In 1990, concentrations of chlorophyll-a exceeded 10 µg/l each month from April through September at the transition zone, while in 1991 chlorophyll-a concentrations only exceeded 10 µg/l on three occasions.

Light transparency and color measurements show the forebay water to be relatively clear with lower water clarity in the transition zone.

Fecal Coliform Bacteria--No swimming beaches were monitored in 1991. Bacteriological samples for Vital Signs were collected only in January and September and concentrations were below the level of detection at both the forebay and transition zone.

Sediment--Chemical analyses of sediments revealed no metal or organic analyte to be a concern and there was no apparent toxicity. However, chromium, copper, and mercury concentrations in sediment from the transition zone were higher than those measured in most Vital Signs reservoirs in 1991. Chromium (72 µg/g) at the transition zone was the highest concentration measured for this metal in 1991. Particle-size analysis showed both forebay and transition zone sediments were almost totally silt and clay (>99 percent).

Benthic Macroinvertebrates--The benthic macroinvertebrate community was represented by a relatively low number of taxa at the forebay (4) and transition zones (7) and a relatively high number at the inflow (11). The density of organisms was relatively low at the forebay (270 per square meter) and average at the transition (493) and inflow zones (418). Tubificidae dominated in all locations (77, 50, and 36 percent, respectively); however, the chironomid Procladius (36 percent of the total) was equally abundant in the inflow zone.

Aquatic Macrophytes--Physical characteristics, especially deep reservoir drawdown, preclude development of aquatic macrophytes in Cherokee Reservoir.

Fish--Data for pelagic areas were based on hydroacoustic and trawling techniques. Contrary to 1990 results which showed high fish densities and biomass, domination by gizzard shad, and near absence of threadfin shad at all three sites, results for 1991 showed generally average densities and biomass, near absence of gizzard shad, and dominance by threadfin shad. The shift from gizzard to threadfin shad is noteworthy. Cherokee Reservoir has been known for its large gizzard shad population. Electrofishing data discussed below indicate this species was present in 1991 in large numbers at near shore areas. Average fish sizes in 1991 at the forebay, transition zone, and inflow were 3.8, 4.7, and 3.2 cm, respectively.

Fish sampling in shoreline and offshore/deep areas of Cherokee Reservoir produced a total of 4873 individuals of 31 species. The three most common species were bluegill (35 percent), gizzard shad (22 percent), and threadfin shad (24 percent). Bluegill were most abundant in the forebay, and the two shad species were most abundant in the transition zone. Species richness ranged from 21 in the forebay to 27 in the transition zone, while 23 were found in the inflow zone. FHAI analysis found excellent health of largemouth bass in the transition zone (27) compared to the forebay (57) and inflow zone (91).

RIBI analysis of shoreline electrofishing data determined the quality of the littoral fish communities of the transition zone (RIBI = 35) and forebay (RIBI = 31) to be fair, while that of the inflow zone (RIBI = 23) was poor. The transition zone ranked third best of seven storage transition zones, while the forebay tied for second best of ten forebays. The inflow ranked fourth best of five storage reservoir inflow zones sampled. Metrics scoring better in the transition zone and forebay than the inflow included percentages of tolerant individuals (7 and 2 vs. 8), percentages of omnivores (3 and 0 vs. 7), percentages of invertivores (85 and 94 vs. 53), number of fish sampled (661 and 1236 vs. 287), and FHAI (27 and 57 vs. 91). A high percentage of piscivores in the inflow zone (40) was responsible for the relatively low percentage of invertivores. Species richness appeared depressed in all three zones. With 13 to 16 species found in each zone, all scored poor in total species. The transition and forebay scored poor for sunfish and intolerant species, while the inflow and forebay scored poor for sucker species diversity. Furthermore, all zones rated poor for the number of lithophilic spawning species encountered.

Fish Tissue--There were no fish tissue studies conducted on Cherokee Reservoir in autumn 1990.

4.12 Douglas Reservoir

4.12.1 Physical Description

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston rivers which form the origin of the Tennessee River. Reservoir drawdown during late summer and autumn in preparation for winter and spring floods is rather large, with up to a 60-feet decrease in elevation (assuming full pool when drawdown begins). Given that full pool elevations are not reached every year, the average annual drawdown is 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is 7344 cfs which provides an average hydraulic retention time of about 105 days.

Due to depths and lengthy retention times, storage impoundments typically have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extend from the forebay to the transition zone.

4.12.2 Reservoir Health

Vital Signs Monitoring on Douglas Reservoir in 1991 provided similar results to those in 1990. Several undesirable conditions were identified both years. The health of aquatic resources in Douglas Reservoir grades below all reservoirs, tributary or mainstream, included in Vital Signs Monitoring.

The most significant problems in Douglas Reservoir were strong stratification in water temperature and DO concentrations (both forebay and transition zone), anoxic or near anoxic conditions throughout much of the water column (both locations), excessively high nutrient levels (transition zone), sediment toxicity (primarily transition zone), poor benthic macroinvertebrate communities, and poor fish communities (forebay, transition zone, and inflow).

4.12.3 Reservoir Use Suitability

Use Suitability Monitoring on Douglas Reservoir in 1991 was limited to only one bacteriological sample collection at the forebay and transition zone in January and September (no detectable quantities found). Bacteriological studies were not conducted at any swimming beaches, and there were no fish tissue studies conducted.

4.12.4 Synopsis of 1991 Conditions

Water--Surface water temperatures ranged from 7.2°C in January to 28.9°C in July in the forebay and from 3.2°C to 32.0°C for the same months at the transition zone. The transition zone surface water temperatures in July (up to 32.0°C) were the highest measured among the Vital Signs Monitoring locations in 1991. Tennessee maximum water temperature criterion for fish and aquatic life is 30.5°C. These warmer water temperatures resulted form the unusually warm and persistent regional atmospheric temperatures antecedent to the July sample period.

DO at the 1.5-meter depth ranged from 10.5 mg/l in January to 4.9 mg/l in August at the forebay and from 13.3 mg/l in January to 7.8 mg/l in May at the transition zone. The August forebay dissolved oxygen concentrations at 1.5-meter depth were below the Tennessee criterion for fish and aquatic life of 5.0 mg/l. In fact, all August DO measurements made from the water surface to the bottom of the water column were below 5.0 mg/l at the Douglas forebay.

Thermal stratification began in April and was established by mid-June. In May, June, and July, there was about a 12°C decrease in temperature and an 8 mg/l decrease in DO from the surface to the bottom of the reservoir at the forebay. This strongly stratified condition persisted through mid-September with strong anoxia in July, August, and September. In July, hypolimnetic DO concentrations less than 1 mg/l were measured from the bottom of the reservoir (35 meters) to within about 7 meters of the surface at the forebay, i.e., 80 percent of the water column. Further, as mentioned above, DO concentrations never exceeded 5.0 mg/l at the forebay location in August. As was the case in Cherokee Reservoir, the period of hypolimnetic anoxia at the transition zone preceded the period of hypolimnetic anoxia at the forebay by about one month. At the transition zone in May, June, and July, DO concentrations less than 1 mg/l were measured in the bottom four meters of the reservoir. (The depth of the water in May, June, and July at the transition zone was about 16 meters.) During this period of summer anoxia, hypolimnetic ammonia nitrogen, total phosphorus, and dissolved ortho phosphorus concentrations were high giving evidence of the highly reducing conditions.

Values of pH ranged from 6.6 to 9.3. The were among the highest pH values observed at the Vital Signs Monitoring locations in 1991. From June through September, values of pH exceeding 8.5 and DO saturation values sometimes exceeding 125 percent were measured at the transition zone. During this same time period, a similar pattern of high pH and DO values was also observed at the forebay, although at lower levels than the transition zone.

Concentrations of organic nitrogen, ammonia nitrogen, nitrite plus nitrate nitrogen, and total phosphorus were quite high. The data show that the transition zone of Douglas Reservoir, like the transition zone in Cherokee Reservoir, is more productive than the forebay region. This is evidenced by the higher near surface chlorophyll-a concentrations and the higher pH and DO values discussed above. Surface concentrations of chlorophyll-a averaged about 5 µg/l at the forebay, but at the transition zone averaged about 8 µg/l. These average chlorophyll-a concentrations at the transition zone were less than half the average chlorophyll-a concentrations observed at the transition zone in 1990 when concentrations of chlorophyll-a equaled or exceeded 9 µg/l each month from May through September at the transition zone.

Coincident with these algal blooms were high concentrations of organic nitrogen and organic carbon. Organic carbon concentrations measured in 1991 at the transition zone were among the highest measured in 1991.

Comparisons of water clarity data collected at the transition zone and forebay of Douglas Reservoir show a decrease in suspended loads and increase in water clarity as the velocity of the water slows and suspended matter settles out. True color measurements showed the water to be very highly colored. True color values, averaged 22 and 19 PCUs at the forebay and transition zones, respectively. These color values were the highest among the Vital Signs Monitoring locations.

Fecal Coliform Bacteria--Samples were not collected from any swimming beaches on Douglas Reservoir in 1991. Bacteriological sampling was limited to mid-channel samples at the forebay and transition zone in January and September. None of these samples contained detectable levels of bacterial colonies.

Sediment--Chemical analysis of sediments revealed no metal nor organic analyte to be a concern. Also, toxicity tests did not indicate toxicity. However, analysis of pore water and water overlying bottom substrates had high concentrations of ammonia, probably due to the anoxic conditions. Particle-size analysis showed the substrate to be essentially all silt and clay (>99 percent) at the forebay and to be 76 percent silt and clay, 24 percent sand at the transition zone.

Benthic Macroinvertebrates--The number of taxa was relatively low at both the forebay (3) and transition zone (5). The density of organisms was also relatively low at the forebay (260 per square meter) and transition zone (89). The forebay was dominated by Tubificidae (75 percent of the total) and the transition zone was dominated by the chironomid Polypedilum (57 percent).

Fish--Data on fish in pelagic areas were based on hydroacoustic and trawling collections. Gizzard shad was the most abundant species comprising 94, 98, and 98 percent of the total catch at the forebay, transition zone, and inflow, respectively. These results differ from the 1990 results when both threadfin and gizzard shad were absent in collections from the forebay and transition zone sites. Ninety-nine percent of the fish encountered at the forebay were small bluegill, and small white crappie made up 99 percent of the fish at the transition zone. The 1990 compositions were noted as being quite different from those found in any other reservoir. The 1991 hydroacoustic information indicated fish densities at the Douglas forebay and transition zone were lower than comparable areas on Norris and Cherokee Reservoirs. Densities were similar for Douglas and Cherokee inflows. Average fish size for each area was higher than that observed for equivalent areas in other impoundments. Mean lengths were 4.9, 6.9, and 4.8 cm at the forebay, transition zone, and inflow, respectively.

Shoreline electrofishing and offshore/deep gill netting samples collected 20,803 fish of 29 species. Species diversity was greatest in the transition zone (but only 24 species), while the forebay and the inflow zone had 21 and 20 species, respectively. The dominant taxon was YOY gizzard shad (74 percent of total sample), being found in all three zones, but most abundantly in the transition zone (9072 per hour of electrofishing). Adult gizzard shad made up 21 percent of the total sample and were also most abundant in the transition zone. The health of largemouth bass was best in the forebay (FHAI = 58), followed by the inflow (FHAI = 64), and transition zone (FHAI = 76).

The RIBI analysis of shoreline electrofishing data showed all three zones of Douglas Reservoir among the poorest littoral zone fish communities of the storage reservoirs sampled in 1991. The inflow (RIBI = 21) ranked last among storage reservoir inflows, the transition zone (RIBI = 29) ranked fifth of seven transition zones, and the forebay (RIBI = 25) was eighth of ten forebays sampled. All three zones scored poorly for total species (17-18), intolerant species (0-1), percent invertivores (31-63), and overall number of fish in the sample (232-279). The inflow also received a poor score for sucker species (1), percent omnivores (11), and lithophilic spawning species (2). Besides the metrics previously mentioned for all three zones, the transition was scored poor for fish health due to the high FHAI (76) found there. Three metrics did score good in the transition, however: percent tolerant individuals (3), percent omnivores (4), and the number of migratory spawning species. The forebay also scored good for migratory spawners, but like the inflow zone, scored poor for lithophilic spawners. Total numbers of fish in Douglas were depressed, affecting species diversity, particularly invertivores, and lithophilic spawning species.

Fish Tissue--There were no fish tissue studies conducted on Douglas Reservoir.

4.13 Tellico Reservoir

4.13.1 Physical Description

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It was the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of 15,860 acres at full pool. The average estimated discharge from Tellico Reservoir in 1991 was 6689 cfs which provided an average retention time of 31 days. Very little of this water is discharged from Tellico Dam. Rather, it is diverted through a canal to adjacent Fort Loudoun Dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably as discussed previously under Fort Loudoun Reservoir. The hydrodynamics set up by the canal significantly affect water quality within Tellico Reservoir. The canal is only 20-25 feet deep, but the depth at the forebay is about 80 feet. Thus water at strata below about 25 feet is stagnant and becomes anoxic during much of the summer.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico rivers. The transition zone site selected for sample collection is in the Little Tennessee River arm upstream of the confluence with the Tellico River. Water conditions at that site are controlled by discharges from Chilhowee Dam. This water is cold, nutrient poor, and has a low mineral content. Conditions at both the forebay and transition zone are not conducive to establishing a diverse, abundant aquatic community.

4.13.2 Reservoir Health

Vital Signs Monitoring on Tellico Reservoir in 1991 (the first year of Vital Signs Monitoring on this reservoir) documented several undesirable conditions. At the forebay these included anoxic conditions, poor benthic macroinvertebrate community, and a relatively poor fish community. At the transition zone these included low primary productivity levels and a poor fish community. Another undesirable observation was toxicity of sediment pore water at the forebay and overlying water at the transition zone. Very low water hardness may have contributed to these toxicity results.

Because of these undesirable conditions, water resources within Tellico Reservoir would rate poor. However, it appears that most of these conditions were related to physical attributes of the reservoir and location of sample sites, not to controllable pollution sources.

4.13.3 Reservoir Use Suitability

Use Suitability Monitoring on Tellico Reservoir in 1991 did not include examination of water at any swimming beaches for fecal coliform bacterial contamination. Bacteriological sampling at mid-channel at the forebay and transition zone as part of Vital Signs Monitoring did not identify any samples with detectable concentrations. Because of PCB contamination, the TDEC has warned the public not to eat catfish from Tellico Reservoir. Composite catfish samples collected in autumn 1990 from two sites had PCB concentrations of 1.3 and 1.5 μg/g. These samples were also analyzed for pesticides, of which only one, chlordane, was high enough to be of interest. The chlordane concentrations were among the highest observed in the Tennessee Valley in 1990, although they did not exceed the concentration at which the state typically issues a fish consumption advisory. This would be an academic exercise because the state has already advised that catfish should not be eaten. Metals in fish flesh were also analyzed, and all except mercury were low or not detected. Mercury was slightly elevated at 0.5 μg/g.

4.13.4 Synopsis of 1991 Conditions

Water--Temperature and dissolved oxygen data in Tellico Reservoir in 1991 show thermal stratification beginning in May and persisting through early September at both the forebay and transition zone. Temperature differentials between the water surface and bottom exceeded 12°C from June through September at the forebay and exceeded 10°C in June and July at the transition zone. These differentials were due to a combination of atmospheric warming of surface water and the intrusion of surface waters from Fort Loudoun forebay contrasted with the inflow of cool bottom water from the releases of Chilhowee Dam upstream. Seasonally, surface water temperatures ranged from 7.7°C in January to 27.7°C in July at the forebay and from 7.7°C to 28.1°C for the same months at the transition zone. Water in Tellico Reservoir in 1991 was relatively cool compared with other Vital Signs reservoirs, particularly at the transition zone which is influenced by the releases from Chilhowee Dam. Transition zone water temperature averaged 17.5°C in 1991.

DO at the 1.5-meter depth ranged from 10.6 mg/l in January to 8.7 mg/l in August at the forebay and from 10.7 mg/l in January to 8.4 mg/l in July at the transition zone. In July, August, and September a persistent oxycline was present in the forebay with differences between surface and bottom DOs of 8 to 9 mg/l, with near bottom concentrations less than 1 mg/l. This near bottom, cool, low DO water was very low in conductivity, indicating that it was water released from Chilhowee Dam. The transition zone was well mixed with minimum DOs of 7.2 mg/l measured in September. In 1991, the average dissolved oxygen concentration at the transition zone of 9.4 mg/l was higher than any of the other Vital Signs Monitoring locations.

Tellico Reservoir pH values ranged from 6.0 to 8.9. Surface water pH exceeded 8.5 at the forebay in June and July coincident with DO super-saturation values indicative of photosynthetic activity. Values of pH, particularly at the transition zone, were among the lowest of any of the Vital Signs reservoirs. Values of pH below the State of Tennessee minimum criterion of 6.5 were observed in the hypolimnion of Tellico Reservoir at both the forebay and transition zone in August and September in 1991.

The conductivity of water in Tellico Reservoir was also quite low ranging from 20 to 144 μmhos/cm and averaging about 31 μmhos/cm at the transition zone and 63 μmhos/cm at the forebay. Mixing of forebay surface waters between Fort Loudoun and Tellico reservoirs via the inter-reservoir canal influences water quality and causes the higher measured conductivity at Tellico forebay compared with Tellico transition zone.

Nitrite plus nitrate nitrogen concentrations were among the lowest observed for Vital Signs locations in 1991. Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only 0.008 and 0.005 mg/l at the forebay and transition zone, respectively, among the lowest measured concentrations at Vital Signs Monitoring locations in 1991. Consequently, average chlorophyll-a concentrations of 5 μg/l at the forebay and only 2 μg/l at the transition zone were among the lowest observed in 1991 on Vital Signs reservoirs. The highest chlorophyll-a concentrations were 7 μg/l at the forebay and only 3 μg/l at the transition zone.

Water clarity (Secchi depth, suspended solids, turbidity, etc.) was comparatively high with little relative variation throughout the year. This is because inflows to Tellico Reservoir are primarily from the Chilhowee Dam discharges which are of high clarity and low color, rather than rainfall runoff events.

Fecal Coliform Bacteria--As stated above, there were no swimming beaches examined in 1991, and concentrations of fecal coliform bacteria were below detectable levels on all Vital Signs Monitoring periods (January and April through September).

Sediment--There were no organic analytes detected, and metal analytes approximated background concentrations. However, toxicity tests revealed rather toxic conditions at the forebay and transition zone. Results on the Microtox test on forebay pore water showed an EC_{10} of about 7 percent after 15 minutes, indicating the toxicity was possibly from metals. This was the lowest volume of test water resulting in an EC_{10} of all test conducted as part of Vital Signs Monitoring in 1991. Results from the Rototox test on transition zone pore water showed a very toxic condition with rotifer survival of only 0.1 percent. This was the lowest survival of rotifers in all tests conducted as part of this program in 1991. These toxic responses indicate very undesirable conditions. They were likely negatively influenced by the very low water hardness.

This was the first year of Vital Signs Monitoring on Tellico Reservoir. Results from 1992 monitoring will be reviewed closely to determine the need for more detailed toxicity testing.

Particle-size analysis showed sediments at the forebay were comprised almost entirely of silt and clay (>99 percent). Sediments at the transition zone were 68 percent sand and 32 silt and clay.

Benthic Macroinvertebrates--The forebay site had 6 taxa and 489 organisms per square meter dominated by Tubificidae (89 percent of the total). The transition location had one of the lowest number of taxa (5) and a low number of organisms (38). The chironomid *Zalutschia zalutschicoia* was the dominant species (65 percent). This species normally has a northern distribution although it has been found in both North and South Carolina. This species has never been recorded in Tennessee and prefers oligotrophic coldwater lakes and standing water. Interestingly, these are the conditions which exists at the transition zone due to underflows of the cold water released from Chilhowee Dam.

Aquatic Macrophytes--The 340 acres of aquatic plants in Tellico Reservoir in 1991 are comparable to the 368 acres in 1990. The dominant macrophyte was Eurasian watermilfoil and was most abundant in the Tellico River portion (TRM 1 to TRM 13) of the reservoir and along the Little Tennessee River portion from LTRM 9 to 19.

Fish Community--Information on fish in open-water areas of Tellico Reservoir was based on hydroacoustic assessment; no trawling was conducted. Fish densities were low at both the forebay and transition zone and the average fish length (5.9 cm at both locations) was relatively large.

Electrofishing and gill netting samples in the transition zone and forebay produced 1182 individuals of 30 species. More fish (66 percent) as well as more species (28 vs. 21) were found in the forebay than in the transition zone. Bluegill and gizzard shad were the dominant species, comprising 31 and 26 percent of the total sample, respectively. Other frequently occurring species included redbreast sunfish (8 percent), largemouth bass (5 percent), smallmouth bass (4 percent), brook silverside (4 percent), carp (3 percent), and spotfin shiner (3 percent). All of these species were more abundant in the forebay except for spotfin shiners and brook silversides. FHAI analysis was only possible in the forebay, due to unavailability of largemouth bass at the transition zone. Health of largemouth in the forebay bass was poor (FHAI = 74).

The littoral fish community at the transition zone (RIBI = 25) was poor, and the forebay (RIBI = 35) community was good, based on electrofishing data. Both zones tied for seventh rank, compared to their respective zones of the other mainstream reservoirs, putting them either slightly below average or near the worst found. (Note: Results from monitoring on Tellico Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs in storage impoundments.) Both zones received poor scores for total species, percent tolerant individuals, and lithophilic species. The forebay appeared better than the transition in the numbers of sunfish, sucker, intolerant, and migratory species. Both zones, however scored good for the three trophic composition metrics (percentages of omnivores, invertivores, and piscivores).

Fish Tissue--An advisory not to eat catfish from Tellico Reservoir has been in effect for several years. Documentation of the PCB problem in what was thought to be a background study in 1985 came as a surprise because there was basically no industrial development in the watershed. Subsequently, more intensive studies supported the initial results and showed very little change in concentrations during the late 1980s. Several attempts at locating potential sources were fruitless and the source remains unknown. A less intensive sampling effort was begun in autumn 1990. One composite of five channel catfish was collected from the forebay and one from an area about 10 miles upstream of there (several miles downstream of the transition zone). Analysis of metals found either nondetectable or low concentrations, except for mercury (0.5 μg/g), which was slightly elevated. Past studies have shown this concentration is typical in catfish samples from reservoirs on the Little Tennessee River and the nearby Hiwassee River. Detectable organics were DDTr, chlordane, and PCBs. DDTr concentrations were low with a maximum of 0.24 µg/g. Chlordane concentrations were relatively high, 0.22 and 0.25 µg/g at the forebay and upstream site, respectively. PCB concentrations at these locations were at expected levels (1.3 and 1.5 µg/g, respectively).

4.14 Melton Hill Reservoir

4.14.1 Physical Description

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream about 44 miles. Melton Hill Reservoir has 173 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is 4448 cfs which creates an average retention time of 14 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant feature influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and mid-reservoir areas, is the cold water entering from Norris Dam discharges. During summer water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a reregulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

4.14.2 Reservoir Health

Vital Signs Monitoring was initiated on Melton Hill Reservoir in 1991. The aquatic resources were found to be healthy by most monitoring tools. There appeared to be no major problems with DO concentrations, even at lower strata in the forebay; bottom substrates had no chemical or toxicity problems; and chlorophyll concentrations, although slightly low, indicated algal growth sufficient to support the aquatic food web.

However, the fish community at the inflow and transition zone was relatively poor, probably due to the cool water temperatures at these sites discussed above.

4.14.3 Reservoir Use Suitability

Use Suitability Monitoring for water contact recreation was limited to monthly samples collected at mid-channel at the forebay and transition zone as part of Vital Signs Monitoring. Most samples had less than detectable concentrations. January, April, and May samples had concentrations up to 80 colonies per 100 ml, well below maximum recommended for water contact recreation.

TDEC has advised the public to avoid consumption of catfish from Melton Hill Reservoir because of PCB contamination. Samples were collected in 1990 from the transition zone and near the inflow by TVA and from the forebay by the Oak Ridge National Laboratory as part of ongoing, cooperative studies. PCB concentrations were generally lower than in previous years with averages of 0.5, 0.7, and 1.2 µg/g at the forebay, transition zone, and inflow, respectively.

4.14.4 Synopsis of 1991 Conditions

Water--Thermal stratification began in May and persisted through early September at both the forebay and the transition zone. This early stratification probably resulted from the unusually warm winter and spring in 1991. Temperature differentials of approximately 12°C between the water surface and the bottom existed at the forebay in May and June. Seasonal surface water temperatures ranged from 8.5°C in January to 27.2°C in June at the forebay and from 10.2°C in January to 26.8°C in May at the transition zone. The water in Melton Hill Reservoir in 1991 was relatively cool, with the average temperature of the transition zone (17.2°C) cooler than all but two other (Watauga and Tims Ford) Vital Signs transition zone sample locations, due to the upstream cool water discharges from Norris Reservoir. In late summer (July-August-September), water surface temperatures were 3-7°C cooler at the transition zone than at the forebay.

DO at the 1.5-meter depth ranged from 12.3 mg/l in June (possible algal bloom) to 8.0 mg/l in April at the forebay and from 10.5 mg/l in January to 6.2 mg/l in September at the transition zone. The lowest DOs measured in Melton Hill were 2.7 mg/l in May at the forebay and 6.2 mg/l in September at the transition zone.

Values of pH ranged from 6.6 to 9.0. Surface water pH exceeded 8.5 at the forebay in April, May, and June, usually coincident with DO super-saturation values indicative of photosynthetic activity.

Nitrite plus nitrate nitrogen concentrations were the highest observed among the Vital Signs locations sampled in 1991. Concentrations of nitrate nitrogen increase by over 35 percent between Norris forebay (CRM 80.0) and Melton Hill transition zone (CRM 45.0). These higher concentrations of nitrate are obviously entering the Clinch River downstream of Norris Reservoir and upstream of the Melton Hill transition zone sampling location.

TN/TP ratios were quite high ranging from 22 to 120, indicating a chronic phosphorus limitation to algal productivity in Melton Hill Reservoir in 1991. Further, dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only 0.007 and 0.006 mg/l at the forebay and transition zone, respectively, among the lowest measured concentrations at Vital Signs Monitoring locations in 1991. Consequently, it is not surprising that average chlorophyll-a concentrations of 6 µg/l at the forebay and 5 µg/l at the transition zone were generally low compared with other Vital Signs reservoirs. The highest chlorophyll-a concentrations were measured in May and June in the transition zone (11 µg/l) and in July in the forebay (11 µg/l).

Water clarity (Secchi depth, suspended solids, turbidity, etc.) of Melton Hill Reservoir was comparatively high and measurements were generally stable throughout the year, being influenced to a relatively small degree by reservoir flows. This is due in large part because flows in Melton Hill Reservoir are largely controlled by discharges from Norris Dam rather than rainfall runoff events.

Fecal Coliform Bacteria--No swimming beaches on Melton Hill Reservoir were examined in 1991. Bacteriological sampling in conjunction with Vital Signs Monitoring found less than detectable concentrations on all sample dates except for winter, April, and May (30, 80, and 10 colonies per 100 ml, respectively) at the transition zone.

Sediment--There were no metal or organic analytes of concern, and neither Microtox nor Rototox tests identified toxicity.

Benthic Macroinvertebrates--The number of taxa was relatively high in the forebay (9), transition zone (11), and inflow (11). The density of organisms collected was relatively high in the forebay (348 per square meter) and transition zones (500), and low in the inflow (27). The chironomid *Chironomus sp.* dominated in the forebay (44 percent of the total) and transition (43 percent), while *Corbicula* was the most common organism in the inflow. Tubificidae was second most abundant at the forebay and transition zone.

Aquatic Macrophytes--Eurasian watermilfoil has been the dominant aquatic plant on Melton Hill Reservoir since the 1960s and colonized 240 acres in 1991. The plant was most abundant from CRM 24 to 51. Coverage over the past decade has generally ranged from about 100 to 250 acres.

Fish Community--Open-water fish data for Melton Hill Reservoir were based on hydroacoustic equipment only. Fish densities were relatively low in all three areas. Average fish size was also relatively small.

Electrofishing and gill netting efforts on Melton Hill Reservoir produced a total of 18,163 fish representing 35 species. By far, the dominant species was YOY threadfin shad in the forebay, which was 80 percent of the total number of fish sampled. YOY gizzard shad were also found in the forebay, but they amounted to only 2 percent of the sample. Most species were most abundant in the forebay, but carp, spotfin shiner, bluegill, and largemouth bass had higher catch rates in the transition zone. Fish were least abundant in the inflow zone, except for several species of suckers and yellow perch. More species were collected in the forebay (27) than the transition zone (24) or the inflow zone (13). The health of largemouth bass was fair based on FHAI values of 45 and 51 at the transition zone and forebay, respectively. No FHAI was calculated for the inflow sample due to low numbers of largemouth bass located there.

Littoral zone fish communities rated poor in the inflow and transition zones based on RIBI analysis of shoreline electrofishing samples. RIBI values of 19 and 25 ranked the two zones last and tied for last of all the mainstream inflow and transition zones, respectively. (Note: Results from monitoring on Melton Hill Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs on storage impoundments.) The forebay, however, rated good. Metrics which caused the inflow and transition zones to be rated poor included low overall species diversity (13 and 18 total species, respectively), low numbers of intolerant species (1 in each zone), low numbers of lithophilic spawning species (2 and 0, respectively), high percentages of tolerant individuals (28 and 31), and percentages of omnivores (57 and 11). Other metrics scored as poor in the inflow zone were sunfish species (2), percent invertivores (40), and total fish in the sample (47). The inflow received only one good score, that being for the number of migratory spawners found (5). The transition zone had two good scores: number of sunfish species (5) and percent of invertivores (84). The forebay received five good scores for the following metrics: sunfish species (5), percent tolerant individuals (6), percent omnivores (4), percent invertivores (92), and total fish in sample (633). The only forebay metric scored poor was for the number of lithophilic spawning species (1). All three zones received a poor score for this metric, indicating that this group of species is particularly depressed in this reservoir, possibly because they lack suitable spawning habitat in the headwaters due to cold discharges from Norris Dam.

Fish Tissue--PCB contamination in catfish from Melton Hill Reservoir has been under study for the past few years. Because of this contamination, the TDEC has advised the public not to eat these catfish.

TVA participates on a study team with TDEC, TWRA, and ORNL to investigate PCBs and other contaminants in fish from east Tennessee Reservoirs. In 1990 ORNL collected and analyzed channel catfish from the forebay, while channel catfish from near the transition zone and inflow were collected by TWRA and analyzed by TVA. The average PCB concentrations were 0.5 μg/g (range <0.1 to 0.8 μg/g), 0.7 μg/g (range 0.2 to 1.2 μg/g) and 1.2 μg/g (range <0.1 to 4.4 μg/g) at the three sites from downstream to upstream. Samples from the upper sites were also analyzed for chlordane and had an average of 0.11 μg/g at each site.

4.15 Boone Reservoir

4.15.1 Physical Description

There were three tributary storage impoundments monitored as part of the 1991 Vital Signs program in the South Fork Holston River Watershed (Boone, South Holston, and Watauga). Boone Reservoir, the smallest of these three storage impoundments, is located in northeastern Tennessee and is formed by Boone Dam at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, and an average depth of 44 feet. (Boone Reservoir is over 100-feet deep near the dam.) Annual average discharge from Boone Dam is about 2500 cfs which results in an average hydraulic residence time of about 38 days. Large fluctuations of the water surface of Boone Reservoir for flood protection are reflected in the useful controlled storage drawdown on Boone Reservoir of 55 feet, from 1385 to 1330 (feet MSL); however, annual drawdowns are usually much less and average 25 feet.

4.15.2 Reservoir Health

Vital Signs "Limited" Monitoring in Boone Reservoir indicated relatively poor reservoir health in 1991. Most significant problems were low DO, high nutrients and primary productivity, and poor fish community.

Primary production (estimated using chlorophyll-a concentrations) was higher on Boone than on any other reservoir monitored in the

Tennessee Valley in 1991. The transition zone sampling location on the South Fork Holston River arm of the reservoir had low metalimnetic dissolved oxygen concentrations. These low DO conditions were due to effects of nutrient enrichment from nonpoint sources and two municipal wastewater discharges but also are partly due to unusual flow patterns that are characteristic of Boone Reservoir, particularly the South Fork Holston River arm. (These conditions may have been exacerbated in 1991 by work upstream at South Holston Dam which resulted in significantly lower-than-normal flows.) Water discharged from South Holston Dam is very cold but has relatively high oxygen levels by the time it reaches Boone Reservoir due to atmospheric reaeration in the river. In summer, this colder, denser, higher DO water "ducks under" the pooled water in Boone Reservoir and travels along the lake bottom. Consequently, the South Fork Holston River arm of Boone behaves much like a lake suspended above a flowing river.

The results of the fish community sampling indicated the health of the fish community was good at the transition zone on the South Fork Holston River arm, probably owing to the oxygen problem only at mid-depth, leaving both the upper and lower depths with adequate oxygen. The fish communities at the Watauga River arm transition zone and at the forebay were poor. Satisfactory primary production and oxygen levels in the forebay and in the Watauga River arm of the reservoir provide little help in speculating on the cause(s) of these poor fish communities. Previous problems with high concentrations of metals from an industrial effluent on the Watauga River may be a contributing factor. In addition, there are three municipal wastewater discharges to the Watauga River either in Boone Reservoir or slightly upstream that may contribute to the poor fish community conditions.

4.15.3 Reservoir Use Suitability

Use Suitability Monitoring--No information was collected for bacteriological contamination at recreation areas in 1991. However, fecal coliform bacteria in 1989 (the most recent data collected) found that the Boone Dam Day Use Area fully supported water contact recreation. No samples were collected for analysis for pesticide, PCB, and metal contamination of fish tissue in Boone Reservoir in 1990. However, the TDEC has issued a precautionary fish consumption advisory for carp and catfish in Boone Reservoir due to PCB and chlordane contamination.

4.15.4 Synopsis of 1991 Conditions

Water--Boone Reservoir was thermally stratified throughout the study (April-October) with a maximum temperature difference (surface to bottom) of 14°C at the forebay and a maximum surface temperature of 28.6°C at the Watauga River transition zone in August. Dissolved Oxygen (DO) in the photic zone exceeded saturation on all sample dates during the study period, with a maximum saturation of 134 percent at the forebay, 156 percent at the Watauga River transition zone location, and 175 percent at the South Fork Holston River transition zone location. In October, DO dropped below saturation at all three locations. Low DO was more pronounced in the metalimnion than at the bottom of the reservoir. The lowest DO occurred in the South Fork Holston River where metalimnetic DO was below 1 mg/l from June through August. Photic zone pH exceeded 9.0 at each of the three locations at least once during the survey. The highest pH was 9.3 at the forebay in September. Hypolimnetic and metalimnetic pH never dropped below 7.0.

Conductivity in the Watauga River was normally between 150 and 200 µmhos/cm and between 200 and 250 µmhos/cm in the South Fork Holston River. Periods of very low DO coincided with higher conductivities (wastewater discharges), especially in the South Fork Holston River where conductivities exceeded 300 µmhos/cm at the bottom of the reservoir in May and in the metalimnion in June, July, and August.

Boone Reservoir had high total nitrogen concentrations, on occasion approaching or exceeding 1.0 mg/l. Nitrate plus nitrite concentrations represented most of the total nitrogen in April, while organic nitrogen comprised virtually all of the total nitrogen in August. Boone Reservoir also experienced high total phosphorus (>0.03 mg/l) and chlorophyll-a (>30 µg/l) concentrations. In April, TOC concentrations were slightly above average for the ten "limited" monitoring reservoirs, while August concentrations were the highest of the ten reservoirs. DOC ranged from 75 to 89 percent of TOC.

The high nutrient and organic loadings of Boone Reservoir from both nonpoint and point source discharges result in a high productivity and oxygen demand and high DO depletion just below the photic zone in the metalimnion. This is particularly true in the South Fork Holston River arm of Boone Reservoir where cool, dense water released from South Holston Dam acts as an underflow, helping to trap the water at mid-depth and create the low DO conditions in the metalimnion. Boone Reservoir had an average residence time of about 40 days during the survey period. With the exception of Ocoee No. 1 Reservoir, this is less than half the residence time of any of the other ten "limited" monitoring reservoirs. Consequently, hypolimnetic DO depletion is less than other deeper, longer residence time tributary reservoirs. Discharges from Boone Dam during the sampling period (April-October) were slightly below the long-term average, with flows through the South Fork Holston River arm (releases from South Holston Dam) minimal in April and May. This may have contributed to lower DO in the South Fork Holston River arm of Boone Reservoir in May and June than in prior years.

Fish--Fish sampling in shoreline areas and offshore/deep areas produced a total of 2573 individuals of 24 species. The Watauga River transition zone had the greatest fish abundance (44 percent), followed by the South Fork Holston River transition zone (36 percent), and the forebay (20 percent). Each zone had between 16 an 19 species. The three most abundant species were bluegill (33 percent), gizzard shad (17 percent), and spotfin shiner (16 percent). Health of largemouth bass was better in the two transition zones (FHAI = 43 and 46) than the forebay (FHAI = 71).

RIBI analysis of the shoreline electrofishing samples found a wide variation in the quality of the littoral fish community among sampling zones. The best fish community in Boone Reservoir was found in the South Fork Holston transition zone (RIBI = 37) and was designated good compared with other transition zones of TVA storage reservoirs. This zone ranked second best of the seven storage reservoir transition zones sampled in 1991 (i.e., Boone-2, Hiwassee, Cherokee, Douglas, and Norris-2). It was in much better condition than the Watauga River transition (RIBI = 23), which was ranked seventh, or poorest among storage reservoir transition zones. The forebay (RIBI = 19) also ranked as having the poorest littoral fish community among the 11 tributary storage reservoirs. Metrics associated with the good designation of the South Fork Holston transition zone included the metrics for omnivores (3 percent), invertivores (85 percent), migratory spawning species (4), and FHAI (43). All other metrics for the South Fork Holston zone were scored fair, except total species and percent tolerate, which scored poor. Metrics of the Watauga zone and forebay that scored worse than those of the South Fork Holston zone were sucker species (0 at each zone), intolerant species (1 at each zone), migratory spawning species (0-1), lithophilic spawning species (0-1), and FHAI (46-74). Also, as in the South Fork Holston zone, total species and percent tolerant individuals scored poor in the other two zones. So the major problem with the littoral fish communities of the two zones rated poor are related to decreased species diversity, particularly suckers, intolerant species, and those species with specialized spawning requirements.

4.16 South Holston Reservoir

4.16.1 Physical Condition

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles in length, over 230-feet deep near the dam, an average depth of 86.5 feet, and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, this results in an average hydraulic residence time of almost one year (337 days)--one of the longest residence times of any TVA reservoir. Large fluctuations of the water surface of South Holston Reservoir for flood protection are reflected in the useful controlled storage drawdown on South Holston Reservoir of 67 feet, from 1742 to 1675 (feet MSL), although average annual drawdown is about 33 feet.

4.16.2 Reservoir Health

Vital Signs "Limited" Monitoring data collected in 1991 indicated the overall health of South Holston Reservoir to be satisfactory. Algal productivity was good and reservoir nutrient concentrations were moderate. South Holston Reservoir had poor dissolved oxygen levels at both the forebay and transition zone. The low DO levels may have been exacerbated in 1991 because of the reduced early summer flows (and longer residence times) due to construction of a reaeration weir in the tailrace of the dam, but South Holston Reservoir with its great depth and long hydraulic residence times has historically had low hypolimnetic dissolved oxygen levels. (In 1991, TVA constructed a reaeration weir in the tailrace of South Holston Dam to enhance minimum streamflows and increase minimum instream dissolved oxygen concentrations.) Fish communities in the forebay were poor, perhaps a consequence of the low DO, however, inflow fish communities were good.

4.16.3 Reservoir Use Suitability

Use Suitability Monitoring--No information was collected for bacteriological contamination at recreation areas on South Holston reservoir in 1991. Samples for analysis for pesticide, PCB, and metal contamination of fish tissue were not collected in 1990 in South Holston Reservoir. There are no fish consumption advisories for South Holston Reservoir.

4.16.4 Synopsis of 1991 Conditions

Water--South Holston Reservoir was thermally stratified throughout the survey period (April-October) with a maximum temperature difference (surface to bottom) of 21°C, a maximum surface temperature of 28.0°C in August, and a near constant bottom temperature (about 6°C) throughout the survey. The bottom waters of South Holston Reservoir are the coldest of any of TVA's reservoirs. Photic zone DO was super-saturated from April through September, maximum saturation of 136 percent in June at transition zone. Low DO (less than 2.0 mg/l) was present at the bottom of the forebay water column during all seven months of the survey and from July through October at transition zone. A lens of low DO in the metalimnion occurred from July through October. Surface pH stayed around 9.0 from April through September, while bottom pH decreased from 7.5 in April to 7.0 in September and October. In April, conductivities were about 200 µmhos/cm throughout the water column. Surface conductivities steadily declined to a minimum of about 160 µmhos/cm in August while metalimnetic and bottom conductivities became slightly elevated during the survey with a maximum of 250 µmhos/cm.

South Holston had high concentrations of total nitrogen, with concentrations on occasion exceeding 1.0 mg/l. About 60 percent of the total nitrogen was nitrates plus nitrites in April, while nearly all was organic nitrogen in August. Total phosphorus (less than 0.02 mg/l) and chlorophyll-a concentrations (6 µg/l) were about average, for the ten "limited" monitoring reservoirs. TOC concentrations were the fourth highest concentrations of the ten "limited" monitoring reservoirs. DOC ranged from 80 to 96 percent of TOC, with the larger percentages occurring in August.

During the sampling period (April-October) low average flows resulted in an average residence time over one year. The long residence time promoted water clarity and hypolimnetic DO depletion. Water clarity on South Holston Reservoir was good with average Secchi depths of 2.7 meters at the forebay and 2.1 meters at transition zone.

Fish--Fish samples taken in the shoreline areas and offshore/deep areas of this reservoir produced a total of 2599 individuals represented by 26 species. Two-thirds of the total number were collected in the forebay but only 18 species, compared to 24 in the inflow. (There was no transition zone sampled in South Holston Reservoir.) The three dominant species were gizzard shad (35 percent), spotfin shiner (33 percent), and bluegill (13 percent). Other abundant species included smallmouth bass, rock bass, and black crappie (3 percent each), walleye, carp, quillback carpsucker, and white bass (2 percent each), and largemouth bass (1 percent). The health of largemouth bass in the inflow was fair (FHAI = 56), but could not be determined in the forebay due to low numbers sampled.

RIBI analysis of electrofishing data determined the quality of the littoral fish community in the inflow zone (RIBI = 39) to be good and ranked first among the five storage reservoirs with inflow sampling zones (i.e., Douglas, Cherokee, South Holston, Watauga, and Hiwassee). The forebay, however, rated poor with a RIBI value of 25 and compared poorly with the other 11 storage forebays. Five metrics were scored good in the inflow zone: sucker species (4), percent omnivores (4), percent invertivores (83), migratory spawning species (5), and lithophilic spawning species (6). There were two metrics scored poor, however, in the inflow zone: total species (18) and percent tolerant individuals (52). The remaining four metrics scored fair. The major difference in the inflow and forebay fish communities was species richness. Only ten species were present in a sample of 1040 fish that included only one sunfish species, no sucker species, one intolerant species, and no migratory or lithophilic spawning species. Percent omnivores (2) and percent invertivores (88) were in the good range of scoring criteria, however, so the problems in the forebay littoral fish community are in species richness and reproductive composition.

4.17 Watauga Reservoir

4.17.1 Physical Description

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the deepest reservoir sampled as part of TVA's 1991 Vital Signs Monitoring Program. With an annual average discharge of 700 cfs, Watauga Reservoir also has the longest hydraulic residence time of any of the Vital Signs reservoirs of 412 days. Large fluctuations of the water surface of Watauga Reservoir for flood protection are reflected in a useful controlled storage drawdown of 60 feet, from 1975 to 1915 (feet MSL), and an average annual drawdown of 26 feet.

4.17.2 Reservoir Health

The limited water quality and fish community information collected in 1991 gave evidence of an average or better than average aquatic ecosystem, with Watauga Reservoir having the best health of the three reservoirs (Boone, South Holston, and Watauga) monitored in the upper Holston River basin. Fish communities were about average compared with other tributary storage impoundments. Dissolved oxygen concentrations were adequate to good throughout the reservoir and nutrients concentrations and primary productivity were low but adequate to support a healthy aquatic community.

4.17.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Watauga Reservoir in 1991. Samples for analysis for pesticide, PCB, and metal contamination of fish tissue were not collected in 1990, and there are no fish consumption advisories for Watauga Reservoir.

4.17.4 Synopsis of 1991 Conditions

Water--Watauga Reservoir was thermally stratified throughout the reservoir with a maximum temperature difference of 20°C at the forebay in August and a maximum surface temperature of 27.5°C at transition zone in July. Bottom waters, around 7°C, in Watauga Reservoir were the second coldest of the tributary reservoirs. DO concentrations usually exceeded saturation from April to September in the photic zone with a maximum saturation of 119 percent in May at transition zone. Low DO (less than 2.0 mg/l) developed in the transition zone metalimnion in August and in the bottom waters at both forebay and transition zone locations in September.

From April through September there was a pH gradient in the water column with the highest values near the surface. The highest surface pH was 8.9, and the lowest bottom pH was 6.9. Conductivities were slightly less than 100 µmhos/cm with minor stratification.

Nutrient concentrations were low and water clarity high on Watauga Reservoir. Watauga Reservoir had lower organic carbon, total nitrogen, total phosphorus, and chlorophyll-a concentrations compared with South Holston Reservoir, resulting in a lower oxygen demand and higher dissolved oxygen concentrations than South Holston Reservoir. Nitrates plus nitrites were over two-thirds of the total nitrogen concentrations in April, whereas virtually all of the August total nitrogen concentrations were organic nitrogen.

The long residence time in 1991, approximately one year, and low nutrient and organic loading of Watauga Reservoir produce high water clarity while forming a limited area of late-summer low DO at the reservoir bottom and at the transition zone metalimnion. Average Secchi depths at the forebay and transition zone were 2.8 and 2.5 meters, respectively.

Fish--Combined fish samples in the shoreline (electrofishing) areas and offshore/deep (gill net) areas produced a total of 1922 fish of 15 species in the inflow zone and forebay of Watauga Reservoir. (There were no samples in a transition zone.) Fish were somewhat more abundant in the inflow zone (59 percent of total). Species diversity was low but evenly distributed: 13 species in the inflow zone and 14 in the forebay. The three dominant species by number were bluegill (57 percent), rock bass (10 percent), and spotfin shiner (10 percent).

Other common species were walleye (6 percent), gizzard shad (5 percent), smallmouth bass (4 percent), and largemouth bass (1 percent). Excellent health of largemouth bass was indicated by FHAI values of 13 and 20 in the inflow zone and forebay, respectively.

Fair littoral fish communities were identified by RIBI analysis of shoreline electrofishing data. The inflow zone (RIBI = 31) of Watauga Reservoir ranked third of five storage reservoir inflow zones sampled in 1991. The forebay (RIBI = 29) ranked about in the middle of the 11 forebays sampled in 1991. Low shoreline species diversity in both zones (12 in the inflow, 9 in the forebay) was the driving factor in the fair RIBI designations. In addition to poor scores for the total species metric, sunfish species (1), sucker species (1), intolerant species (1), and lithophilic spawning species (2) metrics were also scored poor.

Metrics for migratory spawning species (2 at each zone) and percent tolerant individuals (12 - 15) received fair scores in both zones. The trophic composition metrics for omnivores (0 percent, both zones) and invertivores (77 and 92 percent) scored good in both zones, as did FHAI (13 and 20). The inflow scored higher due to more fish in the sample (968 fish-inflow vs. 598 fish-forebay).

4.18 Hiwassee Reservoir

4.18.1 Physical Description

Five tributary storage impoundments in the Hiwassee River watershed (Hiwassee, Chatuge, Nottely, Blue Ridge, and Ocoee No. 1) were monitored as part of the 1991 "limited" Vital Signs program. Hiwassee Reservoir, in the southwestern corner of North Carolina, is the largest of these five and is impounded by Hiwassee Dam at Hiwassee River mile (HRM) 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet, (with a maximum depth of about 250 feet at the dam). It has an average annual discharge of about 2050 cfs and average residence time of about 100 days. Hiwassee Reservoir has a relatively large useful controlled storage drawdown for flood protection of about 76 feet, from 1526.5 to 1450 feet (MSL), and an average annual drawdown of 45 feet.

4.18.2 Reservoir Health

Vital Signs "Limited" Monitoring in Hiwassee Reservoir in 1991 indicated a relatively healthy reservoir. Hiwassee (along with Watauga and Blue Ridge) Reservoir was among the best small tributary reservoirs monitored in 1991. Dissolved oxygen concentrations were adequate or good throughout the reservoir, fish communities were fair to good, and nutrient levels were relatively low resulting in adequate levels of primary production.

4.18.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas in 1991. However, two canoe access sites (CAS) Grape

Creek CAS at Song Branch mile 0.4 and Mission Dam CAS at Hiwassee River mile 106.1 were sampled in 1990 and found to fully support water contact recreation. No samples for pesticide, PCB, and metal contamination of fish tissue were collected in 1990 in Hiwassee Reservoir, and no fish consumption advisories have been issued for Hiwassee Reservoir.

4.18.4 Synopsis of 1991 Conditions

Water--The Hiwassee Reservoir forebay develops two areas of steep thermoclines in the water column, one slightly below the surface and another about 50-meters deep. This configuration is caused by the location of the turbine intakes which draw water from the middle of the water column, allowing the colder bottom water and warmer surface waters to remain in place throughout the summer. The bottom water at the forebay stayed below 10°C throughout the sampling period, while surface water temperatures reached 27.5°C at the forebay in July. DO in the photic zone was above saturation from April through September with a maximum DO saturation of 112 percent at the inflow location.

Water in the Hiwassee River system is naturally low in pH and conductivity. In Hiwassee Reservoir in 1991, photic zone pH generally increased in the summer to a maximum of 8.7 in August while bottom pH declined to a minimum of 5.8 in September. Conductivities were generally quite low, between 20 and 30 uμmhos/cm in Hiwassee Reservoir, but as low DO hypolimnetic conditions developed, bottom conductivities rose to a maximum of 57 μmhos/cm in October.

The five Hiwassee River basin reservoirs, as a whole, had the lowest concentrations of organic carbon, total nitrogen, total phosphorus, and chlorophyll-a among the Vital Signs reservoirs monitored in 1991. Concentrations of these four parameters in Hiwassee Reservoir were higher than in Blue Ridge, Chatuge, or Ocoee No. 1 reservoirs, but lower than in Nottely Reservoir. Hiwassee Reservoir exhibited high water clarity, with an average Secchi depth of 3.9 meters in the forebay. Only Blue Ridge forebay had greater clarity.

Flows in 1991 were above average, creating a residence time of about 100 days during the sampling period. The relatively low organic and nutrient loading and high flows limited the area of DO depletion to the near-permanent pool of cold water at the forebay and along the bottom at transition zone.

Fish--Fish samples taken in nearshore and offshore/deep areas of Hiwassee Reservoir collected a total of 2024 fish of 26 species. Numbers of fish collected in the inflow (759), transition (749), and forebay (516) were roughly comparable; more species were found in the inflow (22) than the transition (20) or the forebay (18). Bluegill was the dominant species collected (53 percent), followed by gizzard shad (7 percent), smallmouth bass (6 percent), white bass, green sunfish (5 percent each), spotted bass, black crappie (4 percent each), largemouth bass (3 percent), and flathead catfish (2 percent). Health of largemouth bass was poor in the inflow zone (FHAI = 84) and fair in the transition zone (FHAI = 58). No FHAI was possible for the forebay due to an inadequate sample.

The quality of the littoral fish communities based on RIBI analysis of electrofishing results was fair at the inflow (RIBI = 35) which ranked second best of the five storage reservoir inflows sampled in 1991. The transition zone (RIBI = 41) rated good and ranked first among the seven storage reservoir transition zones sampled in 1991. The forebay (RIBI = 31) also ranked high among the 11 tributary storage forebays sampled in 1991. Very low percentages of tolerant individuals were found in all zones sampled (0-2 percent), resulting in good scores for that metric. All three zones were scored good for the percentage invertivores (80-85 percent) metric, also. On the other hand, poor scores were assigned for total species (13-17) in each zone. Species richness was especially low in the forebay, as no sucker species, intolerant species, migratory spawning species, or lithophilic spawning species were found. Overall abundance of fish was scored fair at each zone. Other metrics scored good in the transition zone were sunfish species (5), omnivores (1 percent), and migratory spawning species (3).

4.19 Chatuge Reservoir

4.19.1 Physical Description

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 450 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL), however, the annual drawdown averages only ten feet.

4.19.2 Reservoir Health

Vital Signs "Limited" Monitoring in the forebay of Chatuge Reservoir in 1991 indicated the overall health of the reservoir to be fair, with low dissolved oxygen concentrations at lower depths of Chatuge Reservoir being the primary problem. This problem was known prior to 1991 monitoring. The specific cause(s) of this condition are probably associated with the residence time and depth of the reservoir, but more detailed studies on reservoir inflows are underway to better understand and possibly correct this situation. In addition, TVA is evaluating various technologies to aerate releases from Chatuge Dam. Reservoir nutrient concentrations were low, primary productivity was fair to good, and the fish community was fair.

4.19.3 Reservoir Use Suitability

Use Suitability Monitoring--No information was collected for bacteriological contamination at recreation areas in 1991. However, three recreation locations (Jackrabbit Campground at Philadelphia Cove, Hiwassee Beach at HRM 126.6, and Clay County Park at HRM 121.8) were sampled in 1990 and found to fully support water contact recreation. No samples for analysis for pesticide, PCB, and metal contamination of fish tissue in Chatuge Reservoir were collected in 1990, and no fish consumption advisories have been issued for Chatuge Reservoir.

4.19.4 Synopsis of 1991 Conditions

Water--Chatuge Reservoir was stratified from April through September with a maximum temperature difference of 15°C and a maximum surface temperature of 27.7°C in July. Super-saturated DO conditions only occurred in the photic zone in May (104 percent) and September (106 percent), indicative of the low photosynthetic activity in Chatuge Reservoir. Low DO (below 2 mg/l) developed at the bottom of the water column in July and in the metalimnion in August. By October, DO concentrations had increased to at least 7 mg/l throughout the water column.

The pH in Chatuge Reservoir was low and averaged less than 7.0. Surface pH increased during the summer to a high of 8.7, and bottom pH decreased to a low of 5.8, both extremes occurring in September. Conductivities were also low, averaging less than 25 µmhos and varied from 18 to 34 µmhos/cm during the survey period. Only in September, a result of hypolimnetic anoxia, were bottom conductivities 50 percent higher than surface conductivities.

Chatuge along with Blue Ridge reservoirs were the two most oligotrophic lakes sampled in 1991. Concentrations of total nitrogen and total phosphorus were low, 0.15 mg/l and 0.006 mg/l, respectively. Concentrations of chlorophyll-a and total organic carbon were also low 3.2 µg/l, and 1.2 mg/l, respectively. Secchi depths varied from 2.1 meters in September and October to 3.9 meters in July.

Flows were above normal during the first month and a half and the last month of the survey and well below normal during the intervening time. The residence time based on the average flow during the survey was about 250 days.

Fish--A total of 597 fish, representing 15 species, were collected by shoreline electrofishing and offshore/deep gill netting in the singular sampling location in the forebay of Chatuge Reservoir. The two predominant species were bluegill (43 percent) and white bass (18 percent). Other common species included spotted bass (13 percent), largemouth bass (6 percent), warmouth (4 percent), redbreast sunfish (3 percent), and hybrid striped bass (3 percent).

RIBI analysis of shoreline electrofishing data indicated a fair fish community. The RIBI value of 31 ranked Chatuge reservoir forebay among the top four storage reservoir forebays. Good scores were assigned for four metrics: percent tolerant individuals (7 percent), percent omnivores (1 percent), percent invertivores (83 percent), and FHAI (37). But overall species diversity was below expectations, and poor scores were assigned for the species richness metrics for total species (11), sucker species (1), and intolerant species (1), and both of the reproductive composition metrics, as no migratory spawning species or lithophilic species were sampled. The other two metrics, sunfish species (3) and total fish sampled (379), were rated fair.

4.20 Nottely Reservoir

4.20.1 Physical Description

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 400 cfs which result in an average hydraulic retention time of about 213 days. The annual drawdown averages about 24 feet on Nottely Reservoir, however, 45 feet of controlled storage drawdown is available for flood protection (1780-1735 feet MSL).

4.20.2 Reservoir Health

Vital Signs "Limited" Monitoring data collected in 1991 showed the conditions in Nottely Reservoir were quite similar to Chatuge Reservoir. There are concerns about low DO at lower depths and investigations are underway to determine the causes. In addition, like Chatuge Dam, TVA is evaluating various technologies to aerate releases and improve the concentrations of DO in water released from Nottely Dam. In reservoir nutrient concentrations were moderately low, chlorophyll-a concentrations, being fairly low, were fair to poor, and fish community was fair.

4.20.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Nottely Reservoir in 1991. However, the recreation area at Poteet Creek was sampled in 1990 for fecal coliform bacteria and found to fully support water contact recreation. No samples for analysis for pesticide, PCB, and metal contamination of fish tissue in Nottely Reservoir were collected in 1990, and no fish consumption advisories have been issued for Nottely Reservoir.

4.20.4 Synopsis of 1991 Conditions

Water--Nottely Reservoir was thermally stratified from April through September, with a maximum temperature difference of 13°C and a maximum surface temperature of 27.9°C in July. Low DO appeared in July, beginning first in the metalimnion, then at the bottom of the water column. During August and September, about 80 percent of the water column had DO less than 2.0 mg/l. Only in May and June did the photic zone DO become super-saturated (maximum of 106 percent in May). The absence of DO super-saturation indicates the low photosynthetic activity in Nottely Reservoir.

Like Chatuge and Blue Ridge reservoirs, Nottely Reservoir is a lightly buffered system, with pH averaging about 6.7 and conductivity averaging less than 30 µmhos/cm. Photic zone pH reached a maximum of 8.1 (April through June), while bottom pH dropped as low as 5.9 (August). Conductivities were between 21 and 34 µmhos/cm throughout the survey, with the highest concentrations occurring near the bottom in July.

Secchi depths were 1.6 meters in April, increasing steadily to 4.1 meters in September, then dropping to 2.4 meters in October. As mentioned, all the Hiwassee River Basin reservoirs had low concentrations of TOC, total nitrogen, total phosphorus, and chlorophyll-a. In 1991, concentrations of nutrients and organics were slightly higher in Nottely Reservoir than in Chatuge and Blue Ridge reservoirs, while chlorophyll-a concentrations were slightly lower.

Flows were below normal during most of the sampling period resulting in a residence time of nearly 200 days. Nottely and Chatuge have similar temperature profiles, but metalimnetic DO depletion occurs earlier and is more extreme in Nottely, probably due to the higher organic and nutrient loading.

Fish--Shoreline electrofishing in the littoral zone and experimental gill netting in the profundal zone collected 778 fishes of 18 species in the forebay of Nottely Reservoir. By far, the most abundant species was bluegill (42 percent). It was followed by warmouth (8 percent), spotted bass (7 percent), gizzard shad (6 percent), redbreast sunfish (6 percent), white bass (3 percent), channel catfish (3 percent), green sunfish (2 percent), carp (2 percent), brown bullhead (2 percent), and walleye (2 percent). No other species accounted for more than 1 percent of the overall total of fish sampled.

A poor littoral fish community was indicated by RIBI analysis of shoreline electrofishing results. With an RIBI value of 27, Nottely Reservoir ranked slightly below average of the 11 storage reservoir forebays sampled in 1991. Metrics influencing the poor rating were associated with low species diversity, total species (13), sucker species (0), and intolerant species (0). The number of lithophilic spawning species (1) and FHAI (74) also scored poor. On the other hand, two metrics were rated good: percentage invertivores (86), and the total number of fish in the sample (629). The remaining four metrics received fair scores.

4.21 Blue Ridge Reservoir

4.21.1 Physical Description

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with a average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. Although Blue Ridge Reservoir is not operated for flood control (only peaking power production), it has a potential useful controlled storage of 101 feet (1691-1590 feet MSL), indicative of the large water level drawdowns which are possible, however, the annual drawdown averages only 36 feet.

4.21.2 Reservoir Health

Vital Signs "Limited" Monitoring in the forebay of Blue Ridge Reservoir in 1991 showed the water quality to be generally good, low in nutrients, high water clarity, and fair algal productivity (chlorophyll-a concentrations). Blue Ridge Reservoir had the highest quality littoral zone fish community of all TVA storage reservoir forebays. Comparatively, Blue Ridge Reservoir had the best water quality conditions of the five Hiwassee basin reservoirs sampled in 1991.

4.21.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Blue Ridge Reservoir in 1991. However, fecal coliform data collected in 1990 found the recreation area at Morgantown

Point to fully support water contact recreation. No fish tissue samples for analysis for pesticide, PCB, and metal contamination were collected in 1990, and no fish consumption advisories have been issued for Blue Ridge Reservoir.

4.21.4 Synopsis of 1991 Conditions

Water--Blue Ridge Reservoir was thermally stratified from April to September with a maximum temperature difference of about 12°C and a maximum surface temperature of 28.6°C in July. Photic zone DO was super-saturated only in April (107 percent) and September (101 percent), indicative of the low photosynthetic activity in Blue Ridge Reservoir.

The soft water of Blue Ridge Reservoir is characterized by low ph and low conductivity. In April, pH varied from 7.8 at the surface to 6.9 at the bottom. Surface pH never exceeded the April value, but bottom pH decreased throughout the summer to a minimum of 5.9 in September. Conductivities varied from 15 to 25 µmhos/cm during the year with little or no difference in the water column.

Blue Ridge Reservoir had among the lowest concentrations of TOC, total nitrogen, total phosphorus, and chlorophyll-a of the Vital Signs reservoirs. Over 90 percent of the TOC was DOC. The low organic and nutrient concentrations limit photosynthetic activity, which precludes low DO conditions from developing, and enhances water clarity. Water clarity was better in Blue Ridge Reservoir than any other Vital Signs reservoir, with Secchi depths ranging from 3.2 meters in June to 6.9 meters in September.

Fish--Electrofishing samples in the shoreline areas and experimental gill netting samples in the deeper, offshore areas of the Blue Ridge Reservoir forebay collected 855 individuals of 16 species. By far the predominant species captured was bluegill (72 percent). Other species frequently encountered were smallmouth bass (9 percent), spotted bass and redbreast sunfish (3 percent each), and white bass and largemouth bass (2 percent each). Many more fish were collected by electrofishing (89 percent) than gill netting, largely attributed to the large number of bluegill inhabiting shoreline areas.

Blue Ridge Reservoir had the highest quality littoral zone fish community of all TVA storage reservoir forebays, according to RIBI analysis of electrofishing data. Its RIBI value of 33 placed on the borderline of fair-to-good ratings for all the forebays (mainstream and storage) sampled during 1991. This reservoir received good scores for five of the 11 metrics: percent tolerant individuals (2), percent omnivores (1), percent invertivores (85), total number of fish sampled (408), and FHAI (39). Overall species diversity, however, was no better in Blue Ridge Reservoir than other storage reservoirs, and poor scores were assigned to the metrics for total species (10), sucker species (0), intolerant species (0), migratory spawning species (0), and lithophilic spawning species (0). The remaining metric, sunfish species (4), rated fair.

4.22 Ocoee Reservoir No. 1 (Parksville Lake)

4.22.1 Physical Description

Ocoee No. 1 Reservoir, also known as Parksville Lake, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has an approximate surface area of 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet and is about 100 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), it is designed with a useful controlled drawdown of 20 feet (838-818 feet MSL). Annual drawdown averages only seven feet on Ocoee No. 1 Reservoir.

4.22.2 Reservoir Health

The aquatic health of Ocoee No. 1 Reservoir is less than ideal. This reservoir is downstream of Copperhill, Tennessee, an area which was denuded of vegetation many years ago due to copper mining and smelting. Given the years of pollution problems in this basin, conditions found in 1991 were no surprise. Almost no primary production and a poor fish community were the primary indicators of problems. However, presence of a viable fish community is an improvement and should be viewed as a positive sign of recovery resulting from mitigative actions in the basin.

4.22.3 Reservoir Use Suitability

Use Suitability Monitoring--Bacteriological sampling at MacPoint recreation area in 1991 found low concentrations of fecal coliform bacteria, indicative that the area fully supports water contact recreation.

Analysis of composited fish fillets for metals, collected in 1990, from the forebay of Ocoee No. 1 Reservoir found selenium concentrations of 1.0 and 1.7 μg/g in catfish and rainbow trout, respectively. Analysis of these samples for pesticides and PCBs, found PCB concentrations of 1.0 and 0.4 μg/g, in the catfish and rainbow trout fillets, respectively. These 1990 results confirm similar results found in previous years. This history of elevated selenium and PCB concentrations, along with the history of water quality problems in Ocoee No.1 Reservoir, supports the need for more thorough examinations.

4.22.4 Synopsis of 1991 Conditions

Water--The high level turbine intake in Ocoee Dam allows cold water to remain in the hypolimnion of the reservoir during the summer, creating large surface to bottom temperature differences. In July, nearly a 19°C temperature difference was measured with a surface temperature of 27.2°C and a bottom temperatures of 8.3°C. Only South Holston and Watauga reservoirs have colder bottom water in the latter part of the summer. The absence of DO super-saturation indicates the low photosynthetic activity in Ocoee No. 1 Reservoir. DO saturation in the photic zone varied from a low of 93 percent in August to a high of 104 percent in September. The lowest DO was 5.1 mg/l at the reservoir bottom in October. Although the location of the turbine intake creates strong thermal stratification, this thermal stratification does not result in depletion of dissolved oxygen in the hypolimnion of Ocoee No. 1 Reservoir, as in most other tributary reservoirs. This is because years of erosion/sedimentation have minimized sediment oxygen demand and because biological productivity of Ocoee No. 1 is so low that there is little organic matter to settle and decay using up the oxygen.

The range in pH was 6.5 to 7.8. The only values below 7.0 were in September and October. Conductivities varied from 52 to 72 μmhos/cm with little difference in the water column.

Ocoee No. 1 Reservoir had comparatively low concentrations of total nitrogen and total phosphorus, and very low chlorophyll-a and total organic carbon concentrations, averaging 1.4 μg/l and 1.0 mg/l, respectively. These low chlorophyll-a and organic carbon concentrations are the lowest of the tributary storage reservoirs sampled in 1991.

Metallic toxicity is suspected as a contributing factor to the low algal productivity. Secchi depths varied from 2.1 meters in April to 4.6 meters in October.

Flows were above normal in April and May and normal for the rest of the year. Theoretical residence time during the study period (April-October) was about 35 days. However, the warmer summer inflows to Ocoee No. 1 Reservoir pass through the reservoir above the denser cold, bottom water and are discharged via the high level turbine intake. This creates a shorter residence time for summer inflows and a much longer residence time for cold water trapped in the hypolimnion.

Fish--Shoreline electrofishing and offshore/deep gill netting in the forebay of Ocoee No. 1 Reservoir produced a total of 271 fishes representing 12 species. Bluegill and largemouth bass were the most abundant species collected, amounting to 62 percent and 21 percent of the total sample, respectively. Spotted bass (4 percent), yellow perch (3 percent), and green sunfish (2 percent) were also frequently encountered.

RIBI analysis of the shoreline electrofishing data determined the quality of the littoral fish community was poor. Ocoee No. 1 Reservoir (RIBI = 25) was ranked near the bottom of the list of storage reservoir forebays. It received poor scores for seven of the eleven metrics used for the electrofishing RIBI, including total species (9), sucker species (0), intolerant species (0), migratory spawning species (0), lithophilic spawning species (0), total fish sampled (228), and FHAI (76). However, of the individuals that were sampled, the percentages of omnivores (2) and invertivores (82), as well as the percentage of tolerant individuals (1), were rated good for their respective metrics. The one remaining metric, sunfish species (4), scored fair.

4.23 Tims Ford Reservoir

4.23.1 Physical Description

Tims Ford Reservoir, in middle Tennessee, is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir at full pool is 34 miles long and has a surface area of 10,600 acres. The depth of the reservoir at the dam is 143 feet, and the reservoir has an average depth of about 50 feet. Average annual discharges from Tims Ford Dam average about 1400 cfs, resulting in a hydraulic resident time of water in the reservoir of about 273 days. Tims Ford Reservoir has a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection, however, annual drawdowns average about 12 feet.

4.23.2 Reservoir Health

Only water quality monitoring was conducted in Tims Ford Reservoir in 1991. No fish community studies were performed. The water quality information showed good levels of chlorophyll-a, indicative of adequate algal productivity to support the aquatic food web. However, high total nitrogen loading and low summertime DO concentrations in the hypolimnion of Tims Ford Reservoir are a significant concern. The low DOs most likely have a detrimental impact on bottom dwelling organisms and the higher forms of aquatic life. TVA is continuing to install and upgrade equipment at Tims Ford Dam to increase DO concentrations in the water released from the dam.

4.23.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Tims Ford Reservoir in 1991 (bacteriological studies are being conducted on Tims Ford Reservoir in 1992). No fish tissue samples for analysis for pesticide, PCB, and metal contamination were collected in 1990, and no fish consumption advisories have been issued for Tims Ford Reservoir.

4.23.4 Synopsis of 1991 Conditions

Water--Tims Ford Reservoir was thermally stratified throughout the monitoring period with a maximum temperature difference, surface to bottom, of about 20°C in July. At this time, maximum surface temperatures were 28.7°C in the forebay and 29.7 in the transition zone. Photic zone DO saturation averaged 118 percent at each sampling location from April through September. Low DO (<2 mg/l) first occurred in the hypolimnion in May and subsequently in the metalimnion in June. All of the hypolimnion had less than 2 mg/l DO in August and September at the forebay and from July through September at the transition zone.

In April, pH varied from 7.2 at the bottom to 7.8 at the surface. Surface pH reached a high of 9.4 in June, and bottom pH reached a minimum of 6.9 in September. Unlike other reservoirs, lowest conductivities were frequently measured near the bottom of Tims Ford Reservoir. For example, from May through September, forebay, near bottom conductivities ranged from about 80 to 100 µmhos/cm, gradually increasing as summer progressed. During this same period, conductivities in the top ten meters of the forebay ranged from about 100 to 165 µmhos/cm. A similar pattern was observed at the transition zone; however, conductivities at the transition zone were about 30 percent higher than conductivities observed at the forebay.

Total nitrogen concentrations at Tims Ford transition zone (0.35-1.6 mg/l) were among the highest measured in 1991 at any of the Vital Signs Monitoring locations and roughly comparable to the total nitrogen concentrations measured in the transition zone of Cherokee Reservoir. The forebay concentrations of total nitrogen in Tims Ford were lower (0.33-1.17 mg/l), but still higher than any of the other ten "limited" monitoring tributary reservoir forebays. Nitrate plus nitrite comprised about half of the April concentration of total nitrogen; organic nitrogen comprised most of the remainder. In August, organic nitrogen comprised virtually all of the total nitrogen. Of the ten "limited" monitoring tributary storage reservoirs, only Boone and Beech Reservoirs had higher concentrations of TOC, total phosphorus, and chlorophyll-a than Tims Ford Reservoir, indicative of its relatively high algal productivity. Forebay concentrations of chlorophyll-a and TOC averaged about 6.3 µg/l and 2.7 mg/l, respectively, with DOC comprising 80-95 percent of the TOC.

Secchi depths stayed about 2 meters from April through August, then increased in September and October to over 4 meters. Flows were above normal during the first half of the survey and below normal during the last half. Based on average flows during the survey, the residence time was over 250 days. The high spring flows probably contributed to the very high nitrogen concentrations in April. The very low summer flows, strong thermal stratification through October, and depletion of available nutrients by August resulted in very clear water in September and October.

4.24 Beech Reservoir

4.24.1 Physical Description

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir, which is only 5.3 miles long and 32 feet deep at the dam, has no hydropower generating facilities and is the primary source of water supply for the city of Lexington. The reservoir is an urban lake with considerable residential lake front development, and it receives a large amount of recreational use relative to its small size of approximately 900 acres. In 1991, daily discharge averaged only 20 cfs from Beech Dam, resulting in a comparatively long hydraulic residence time of approximately 280 days.

4.24.2 Reservoir Health

Only water quality monitoring was conducted in Beech Reservoir in 1991. No fish community studies were performed. The data collected indicate poor water quality, with Beech Reservoir exhibiting classic conditions of cultural eutrophication: i.e., low DOs, high chlorophyll-a concentrations, low water clarity, high nutrients, and high levels of organic carbon.

4.24.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Beech Reservoir in 1991; however, bacteriological studies conducted in 1990 showed that the swimming beach area of Beech Reservoir fully supports water contact recreation. No fish tissue samples for analysis for pesticide, PCB, and metal contamination were collected in 1990, and no fish consumption advisories have been issued for Beech Reservoir.

4.24.4 Synopsis of 1991 Conditions

Water--Beech Reservoir is the smallest of the Vital Signs reservoirs, with an average depth of only four meters. Being relatively shallow and with a long hydraulic residence time, it had the warmest average water temperature of any of the Vital Signs reservoirs in 1991. Beech Reservoir was the least thermally stratified of the tributary reservoirs, with a maximum temperature difference of about 8°C in June and July. However, by September, the entire water column had warmed to a water surface temperature of 26°C, and the reservoir was fully mixed. The maximum surface temperature was 30.9°C in July, which exceeded the Tennessee maximum water temperature criteria for fish and aquatic life of 30.5°C. Photic zone DO saturation varied from 105 to 114 percent from April through July, but averaged just 70 percent from August through October. In August, the surface DO concentration of 4.8 mg/l (at 1.5-meter depth) was the only photic zone DO measurement among the ten "limited" monitoring tributary storage reservoirs that was less than 5.0 mg/l, and was below the Tennessee criteria of 5.0 mg/l for fish and aquatic life. From mid-May through August, the lower half of the water column in Beech Reservoir consisted of low DO (<2 mg/l) water, including extensive areas of zero DO water from June until mid-August. The thermal mixing of the water column in September eliminated the low DO water condition.

In April, pH varied from 6.7 to 7.2. The very low DO conditions dropped hypolimnetic pH to 5.9 in June and July. Conductivities were about 40 µmhos/cm throughout the water column in April, increased at the bottom steadily to 129 µmhos in August, then returned to about 40 µmhos/cm after destratification in September.

Organic carbon concentrations were quite high in Beech Reservoir. TOC and DOC were 3.3 and 3.1 mg/l in April and 3.8 and 3.2 mg/l in August. These were among the highest average concentrations of any of the Vital Signs Monitoring reservoirs. Total nitrogen concentrations ranged from 0.45 to 0.61 mg/l, with organic nitrogen comprising over 90 percent of the total nitrogen concentration in both April and August. Only the transition zone locations on Boone Reservoir had higher concentrations of total phosphorus or chlorophyll-a concentrations than Beech Reservoir. The average chlorophyll-a concentration was 17.3 µg/l with a maximum concentration of 22 µg/l in April.

Beech Reservoir was the most turbid of the ten "limited" monitoring reservoirs. Secchi depth was 1.2 meters in April, 1.1 meters in May and June, and was below 1 meter for the rest of the sampling period. The small size of Beech Reservoir, especially the relatively shallow depth compared to other TVA reservoirs, and the primary discharge over the spillway means that much of the turbidity, even in late summer, is likely due to resuspension of material from the bottom of the reservoir.

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Tennessee Valley Authority
Water Management

Reservoir Monitoring – 1992
Summary of Vital Signs and Use Suitability Monitoring on Tennessee Valley Reservoirs

August 1993

Tennessee
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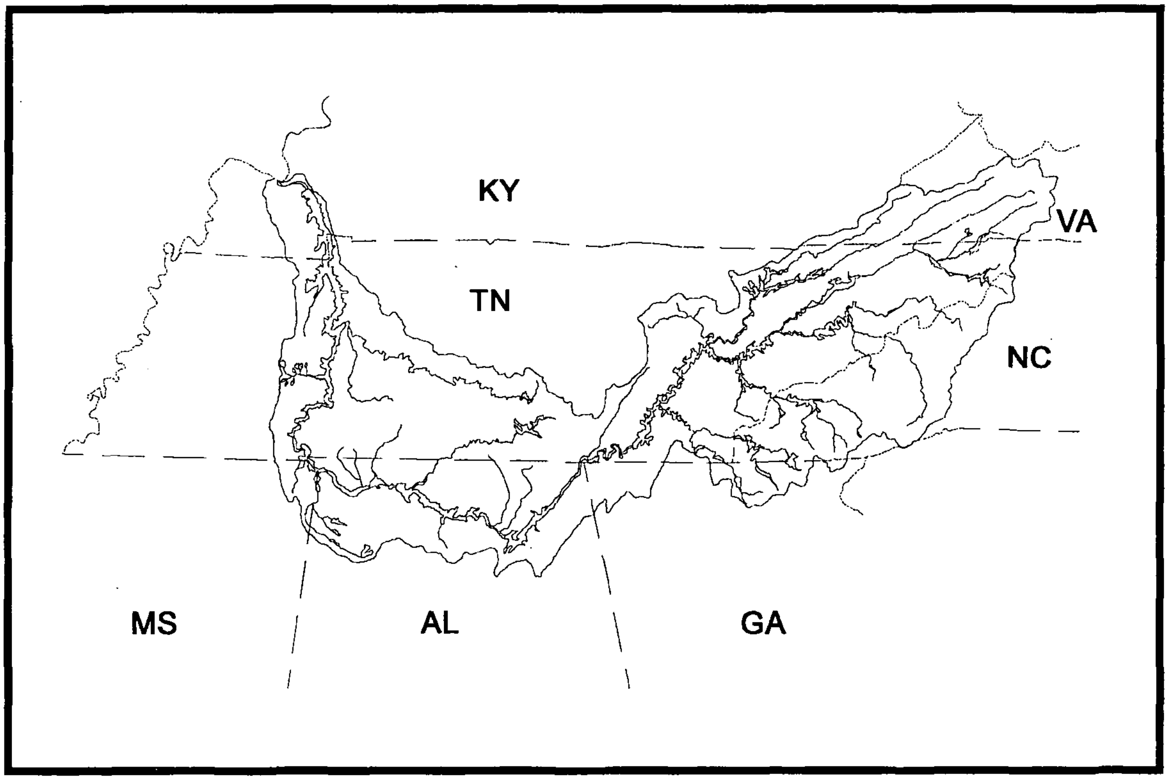
Chattanooga, Tennessee

August 1993

RESERVOIR MONITORING - 1992

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING ON TENNESSEE VALLEY RESERVOIRS



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Water Resources

RESERVOIR MONITORING - 1992
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING ON TENNESSEE VALLEY RESERVOIRS

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FIGURES

EXECUTIVE SUMMARY

The Tennessee Valley Authority (TVA) initiated a Reservoir Monitoring Program in 1990 as part of its Water Resources and Ecological Monitoring Programs. In these first three years (1990-1992), the Reservoir Monitoring Program has been improved and expanded. In 1990, only 12 TVA reservoirs were examined, the nine mainstream Tennessee River reservoirs (Kentucky through Fort Loudoun) and three major tributary storage reservoirs Cherokee, Douglas, and Norris (Dycus and Meinert, 1991). In 1991, the Reservoir Monitoring Program was expanded to 24 reservoirs, to include the system's only two tributary reservoirs with navigation locks (Tellico and Melton Hill) and ten other smaller tributary reservoirs (Dycus and Meinert, 1992).

This report describes TVA's Reservoir Monitoring Program for 1992. Twenty-four reservoirs were again monitored in 1992, however, several changes are of importance. Transition zone sampling locations on Kentucky, Wheeler, and Guntersville were relocated and midreservoir sampling locations on Chatuge and Nottely Reservoirs were added to better define ecological conditions on these reservoirs. Hydroacoustic estimates of fish abundance on all reservoirs were eliminated pending a more thorough evaluation of this technique and fish community sampling was added on Normandy Reservoir. Also, information collected from TVA's Stream Monitoring Program was used to supplement evaluations of specific reservoirs for the first time in 1992.

The two objectives of the Reservoir Monitoring Program are to provide basic information on the "health" or integrity of the aquatic ecosystem in TVA reservoirs (referred to as Vital Signs Monitoring) and to provide screening level information for describing how well each reservoir meets the "fishable" and "swimmable" goals of the Clean Water Act (referred to as Use Suitability Monitoring).

The basis of Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators at one or more strategic locations in each reservoir, i.e., the forebay immediately upstream of the dam; the transition zone (the midreservoir region where the water changes from free flowing to more quiescent, impounded water; and the inflow or headwater region of the reservoir. The monitoring tools comprised: physical/chemical water quality sampling; sediment quality and toxicity testing; benthic macroinvertebrate community evaluations; and fish community evaluations.

In general, all monitoring tools were employed at all three sampling locations on the 11 run-of-the-river reservoirs (Kentucky through Fort Loudoun and Melton Hill and Tellico) and on Norris, Cherokee, and Douglas Reservoirs. However, water and sediment quality and sediment toxicity sampling were not conducted at run-of-the-river inflow locations due to the effects of the upstream impoundment and the lack of suitable substrate for collection of sediment. On the remaining ten smaller tributary reservoirs, fewer locations were sampled (usually the forebay or the forebay and midreservoir), and generally only water quality and fish community data were collected.

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) and suitability of fish from TVA reservoirs for human consumption (fishable). Bacteriological samples are collected at over 200 sites in the Tennessee Valley: designated swimming areas, canoe access sites, highly used recreational areas, and selected nonrecreation sites that provide information on pollution sources or inflow stream water quality. Not all sites are sampled each year. Beginning in 1993, each recreation site will be revisited at least once every other year. In 1992, 65 sites on seven reservoirs and six tributary streams were sampled for fecal coliform bacteria.

Fish tissue studies examined fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data were provided to appropriate state agencies to determine need for further study and possibly fish consumption advisories. Fish tissue data reported here represent autumn 1991 and most 1992 collections. Some 1992 results were not available due to the time delay required for laboratory analysis.

Vital Signs Monitoring

The reservoirs monitored in 1992 were divided into two categories for comparative purposes - run-of-the-river reservoirs (the nine mainstream reservoirs plus the two navigable tributary reservoirs) and tributary storage reservoirs (the three large reservoirs including Norris, Cherokee, and Douglas plus the ten smaller tributary reservoirs). Primary differences between these two categories were retention time and drawdown depth.

Run-of-the-river reservoirs--With the exception of Tellico Reservoir, the aquatic health of all 11 run-of-the-river reservoirs was satisfactory or better in 1992. However, for most reservoirs, results of at least one monitoring tool (i.e., dissolved oxygen, chlorophyll, sediment quality, benthos, or fish) indicated areas for needed improvements. Among the run-of-the-river impoundments, Kentucky, Wheeler, Guntersville and Nickajack Reservoirs appeared to have the healthiest aquatic environments; while Fort Loudoun and Tellico Reservoirs appeared to have the most problems. As was the case in 1991, both of these reservoirs have documented or high potential for low dissolved oxygen (DO) in lower strata in their forebays, poor forebay sediment quality, and one or more atypical features of both the macroinvertebrate and fish communities. These low ecological health ratings are at least partly a result of the physical features of these reservoirs and the way water flows through them. Fort Loudoun and Tellico Reservoirs are connected by a relatively shallow, man-made canal. Water leaving Tellico flows through this canal and is discharged through the hydroelectric units in Fort Loudoun Dam. The surface discharge from Tellico creates a stagnant pool at the bottom of the lake, which contributes to the low DOs and poor benthic communities. This canal effectively "skims" only warm surface water off the top 20 feet of the pool. The water in lower strata becomes stagnant, and anoxia develops during summer. Significant physical alterations would be required to improve conditions in the Tellico forebay. The very soft water which naturally occurs in Tellico Reservoir may also contribute to the toxicity problems. The situation in Fort Loudoun Reservoir is expected to improve as the quality of water discharged from Cherokee and Douglas Dams upstream continues to improve and as improvements in the control of nonpoint source pollution are put in place in the Knoxville metropolitan area. The frequent occurrence of sediment toxicity in Tellico Reservoir continues to be a concern, and a special assessment study may need to be initiated to identify the cause and propose corrective action.

Tributary storage reservoirs--In 1992 satisfactory conditions were documented in seven of the 13 tributary storage reservoirs. A good ecological health rating was given to only one (Blue Ridge), and four had poor ecological conditions (Douglas, Cherokee, Chatuge, Parksville [Ocoee #1], and Beech Reservoirs). Douglas, Cherokee, and Chatuge stratified during the summer and had near-anoxic conditions in mid and lower portions of the water column much of the summer. The poor ecological health of Cherokee and Douglas Reservoirs noted in 1992 had been observed in 1991, and 1990 Vital Signs Monitoring, as well as in previous studies. These reservoirs have been the subject of several investigations, some of which are still underway. Although Chatuge received a poor rating in 1992, the actual rating was just below the level considered fair, which was the rating given in 1991. There actually was little difference in results between the two years. Parksville Reservoir is downstream of Copperhill, Tennessee, an area which was denuded of vegetation many years ago due to copper mining and smelting. Given the years of pollution problems in this basin, conditions found in 1992 (and 1991) were no surprise. Almost no primary production and a poor fish community were the primary indicators of problems. However, the mere presence of a viable fish community is an improvement and viewed as a sign of recovery resulting from continuing mitigative actions in the basin. Boone Reservoir experienced improvement from 1991 (poor) to 1992 (satisfactory). Over the years, problems in Boone have changed from floating sewage sludge with excessive algal growth and extreme oxygen deficits in the mid-1980s, to an enriched ecosystem with areas of high algal activity and low dissolved oxygen concentrations at specific depths in the 1990s. Completion of the reaeration and re-regulation weir in 1991, downstream from South Holston dam, has both stabilized flows and improved dissolved oxygen in the South Holston River arm of Boone Reservoir. Conditions in Boone Reservoir are expected to continue to improve as wastewater treatment plants are upgraded and as nonpoint source pollution is controlled.

Use Suitability Monitoring

Bacteriological Studies--During spring and summer of 1992, fecal coliform samples were collected at 65 recreation areas, of which 28 were designated swimming beaches and 11 were canoe access sites. All sites were sampled on at least ten occasions within a month. All designated swimming beaches sampled on Vital Signs reservoirs except two met EPA guidelines for water contact recreation. The exceptions were Smith Camp-on-the-Lake on Nickajack Reservoir and Dry Creek Recreation Area on Tims Ford Reservoir which did not meet water contact recreation guidelines, due to occasionally high fecal coliform bacteria, particularly after rainfall.

In addition, as part of Vital Signs Monitoring, fecal coliform samples were collected in the forebay and transition zone of the 11 run-of-the-river reservoirs and Norris, Cherokee, and Douglas. None of these sampling locations exhibited poor bacteriological water quality.

Fish Tissue Studies--Six TVA reservoirs--Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Parksville--were examined intensively in 1992. Intensive studies are conducted on reservoirs where a contaminant problem is known or suspected. PCBs was the contaminant of interest on all these reservoirs, except Wheeler where DDTr (total DDT) is the problem. Chlordane was also of interest in some of these reservoirs. Fish consumption advisories which recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all of these six reservoirs except Parksville. Advice provided by the Tennessee Department of Environment and Conservation and that provided by the Alabama Department of Public Health is based in part on the results of these studies.

Results of screening studies in 1991 and 1992 did not indicate any new reservoirs in need of intensive investigations. Several tributary reservoirs had somewhat elevated mercury concentrations.

Therefore, efforts in autumn 1993 will be directed at better evaluating this observation by analyzing both channel catfish, the species typically used as the indicator, and largemouth bass, a top predator which would be expected to have higher mercury concentrations than catfish.

1.0 INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) initiated a program in 1990 to systematically monitor its reservoirs. The Reservoir Monitoring Program was made possible by an increase in federal appropriations to fulfill TVA's stewardship and reservoir management responsibilities. Reservoir Monitoring consolidated several newly-developed activities along with several existing activities to form an integrated program. Reservoir Monitoring is now part of TVA's comprehensive Clean Water Initiative, which also includes stream monitoring, River Action Team watershed examinations, Vector and Plant Management, and public information/educational activities.

This report presents the results of TVA's reservoir monitoring activities conducted in 1992. In addition to this technical report, a nontechnical document was prepared based on 1992 monitoring results. This public information document, "RiverPulse 1992," (TVA, 1993) is being broadly distributed to Tennessee Valley residents and users of TVA reservoirs. Past results of 1990 and 1991 monitoring activities and reservoir health evaluations are provided in a series of technical and nontechnical reports (see references). Copies of all these documents are available from: TVA Water Management Library, 1101 Market Street, HB 2C-C, Chattanooga, TN 37402, Telephone: (615) 751-7338.

1.2 Objectives

Objectives of the Reservoir Monitoring Program are to provide basic information on the "health" or integrity of the aquatic ecosystem in each TVA reservoir and to provide screening level information for describing how well each reservoir meets the "fishable" and "swimmable" goals of the Clean Water Act. The ecological integrity of reservoir ecosystems is examined under a task called Vital Signs Monitoring. The basis of Vital Signs

Monitoring is examination of appropriate physical, chemical, and biological indicators in important areas of each reservoir. The information is used to evaluate the health of each reservoir and the overall health of the reservoir system, and to target detailed assessment studies in areas where significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions and monitoring water quality trends for TVA reservoirs.

Use Suitability Monitoring examines how well each reservoir meets the fishable and swimmable goals of the Clean Water Act. Examination of levels of toxic contaminants in fillets from important fish species is the basis for the fishable use evaluation. Swimmable or water contact uses are examined by conducting bacteriological sampling at designated swimming beaches and other highly used recreation areas.

1.3 Summary Report Description

This document summarizes and integrates results from TVA's Reservoir Monitoring Program activities in 1992. Chapter 1 provides an introduction and background for the Reservoir Monitoring Program and chapter 2 describes the methods and monitoring tools used in Vital Signs, Use Suitability, and Stream Monitoring activities to assess reservoir ecological conditions.

Chapter 3 provides an overview of 1992 hydrologic conditions. Physical conditions in a reservoir are mostly controlled by streamflow and water temperature, as well as by physical configuration of the reservoir basin and the dam. Given that streamflows and water temperatures vary from year to year, it is essential to consider these variables in evaluating ecological conditions within a reservoir.

Chapter 4, "Reservoir-by-Reservoir Summary and Conclusions," is the main part of the report. This chapter provides a physical description of each reservoir, an evaluation of the ecological health and use suitability of each reservoir, and a summary of results from all monitoring activities. The ecological health evaluation is based on an integration of results from the various monitoring tools in Vital Signs Monitoring. The detailed summaries are provided as a ready reference of 1992 results and are intended for the technical audience to see the basis for the evaluation of each reservoir.

It is important to note that these results are from only the third year of the Reservoir Monitoring Program. Conclusions and reservoir ecological health evaluations drawn from this newly implemented monitoring program must be considered tentative and subject to revision in future years as more data are acquired on each reservoir. Because of naturally occurring year-to-year variability (i.e., different hydrologic conditions-drought, floods, etc. and different environmental conditions-solar radiation, waste loads, etc.), several years of information will be needed to confidently make definitive statements about the ecological health of each reservoir.

2.0 MATERIALS AND METHODS

2.1 Vital Signs

The basis of the Vital Signs Monitoring is examination of appropriate physical, chemical, and biological indicators. Generally, three areas in each reservoir are monitored: the forebay immediately upstream of the dam; the transition zone (the midreservoir region where the water changes from free flowing to more quiescent, impounded water); and the inflow or headwater region of the reservoir. Sampling locations and specific monitoring activities for Vital Signs Monitoring during 1992 are shown in figure 2.1 and listed in tables 2.1 and 2.2.

The Vital Signs component of the Reservoir Monitoring Program includes four activities to examine reservoir health:

(1) physical/chemical characteristics of water (section 2.1.1, below);

(2) acute toxicity screening and physical/chemical characterization of sediment (section 2.1.2, below);

(3) benthic macroinvertebrate community sampling (section 2.1.3, below); and,

(4) fish community evaluations (section 2.1.4, below).

In addition a discussion of the aquatic macrophyte communities is included to provide a more comprehensive evaluation of each reservoir's ecological health (section 2.1.5, below).

2.1.1 Physical/Chemical Characteristics of Water

In 1992, physical/chemical water quality variables were measured at a total of 46 locations on 24 reservoirs. The Vital Signs water quality monitoring activities on these reservoirs followed a "basic" (27 locations-table 2.1) or "limited" (19 locations-table 2.2) sampling strategy.

Basic--The basic sampling strategy included monthly water quality surveys (January and April through September) at 27 locations, i.e., the forebays and transition zones (inflows not examined) on 14 TVA reservoirs--the 11 run-of-the-river reservoirs and the three largest tributary storage reservoirs (Norris, Cherokee, and Douglas). Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform tests; photic zone composite chlorophyll-a samples; and surface and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids.

Limited--The limited sampling strategy included monthly water quality sampling (April through October) for a smaller list of parameters at 19 locations, i.e., the forebays (and at midreservoir locations on larger impoundments) on the remaining ten tributary storage reservoirs (Boone, South Holston, Watauga, Hiwassee, Chatuge, Blue Ridge, Nottely, Ocoee No. 1, Tims Ford, and Beech). The limited water quality sampling strategy was similar to the basic water quality sampling, except that nutrients and total organic carbon samples were only collected from the water surface and only in April and August. In addition, no fecal coliform, color, and suspended solids samples were collected as part of the limited monitoring strategy.

The physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Reservoir health evaluations methods used to assess physical-chemical quality are described below in section 2.2.1 and 2.2.2.

2.1.2 Acute Toxicity Screening and Physical/Chemical Characterization of Sediment

Annual sediment samples and near bottom water were collected during summer 1992 from 27 locations, i.e., the forebays and transition zones of the 14 basic monitoring reservoirs as shown in table 2.1. Eckman dredge samplers were used to collect the top three centimeters of sediment, and Kemmerer or Isco water samplers were used to collect the near-bottom water. Sediment samples were a composite of at least three subsamples. The composite samples were subsequently split for both acute toxicity testing and for physical/chemical analyses.

Acute Toxicity Testing--All samples were screened for toxicity using acute time-frame Microtox® (light emitting bacteria) and Rotox® (rotifer, *Brachionus calyciflorus* survival) tests. Microtox® analysis evaluated the effective concentration in laboratory duplicate samples at which the light output was reduced relative to a control. The effective concentration used was the EC_{10}, which was the concentration at which light emission in the samples was reduced by 10 percent. Although Microtox® EC_{10} values have been shown to correspond with impairments to insect populations, use of Microtox® for the purpose of describing sediment toxicity in TVA reservoirs is considered experimental. For this reason, Microtox® results should not be interpreted as a definitive stand-alone analysis. Rotifer acute (24 hour) toxicity was reported if the average survival in three replicates was significantly reduced (95 percent probability) from a control. Rotifer and Microtox® results were used in conjunction to describe toxicity. Microtox® will be replaced by a 48-hour acute *Ceriodaphnia* test in 1993.

Physical/Chemical Characteristics--Sediment samples were analyzed for 12 metals, total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs).

Specific details and evaluations of the acute toxicity tests results and the physical/chemical characteristics of sediment are available in TVA technical report (Moses, Sesler, Wade, and Meinert, 1993). Reservoir health evaluations of sediment quality are described below in section 2.2.3.

2.1.3 Benthic Macroinvertebrate Community Sampling

Benthic macroinvertebrate community samples were collected in spring 1992 from 39 locations, i.e., the forebay, transition zone, and inflow of the 14 basic monitoring reservoirs (inflow samples were not collected on Douglas Reservoir), as shown in table 2.1. At each sample location, a line-of-sight transect was established across the width of the reservoir, and ten equally spaced samples were collected along this transect. A Ponar dredge was used to collect samples, except when rocky substrates necessitated the use of a Peterson dredge. Specimens were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Six metrics were chosen to evaluate reservoir health which could be acquired by either a rapid field assessment or a lab oriented assessment and are described below in section 2.2.4. Benthic macroinvertebrate data are available in computer readable form from TVA.

2.1.4 Fish Community Evaluations

In autumn 1992, electrofishing and gill netting were employed on 24 reservoirs, i.e., the 14 basic Vital Signs Monitoring reservoirs and ten limited monitoring reservoirs, as shown in tables 2.1 and 2.2. Ten electrofishing transects were sampled within each location, with all habitats sampled, and dominant habitats receiving the most effort. Habitat distinctions were based on major changes in substrate (e.g., bluff, rip-rap, or clay). Ten experimental gill nets were also set overnight at each location in all habitat types where conditions permitted. At some inflow locations, flow and/or lack of suitable sites limited the number of nets that could be set.

Largemouth bass collected as part of the electrofishing survey were transported to a mobile laboratory for immediate examination of external/internal abnormalities and blood chemistry characteristics. At each sampling location, 15 individuals greater than 250 mm total length were examined and a Fish Health Assessment Index (FHAI) was calculated.

A Reservoir Fish Assemblage Index (RFAI) was employed using data from the electrofishing samples. The RFAI uses 11 fish assemblage measurements (metrics) and is described below in 2.2.5.

2.1.5 Aquatic Macrophytes

Coverage of aquatic macrophytes was determined from large-scale (1 inch=600 feet or 1 inch=1000 feet) color aerial photography flown in the late summer or early fall of 1992, during maximum submerged macrophyte coverage. Boat surveys to determine species composition of the dominant macrophyte communities were conducted at selected sites at the approximate time of the aerial overflight. Aquatic macrophyte colonies were delineated on mylar overlays attached to photographic prints, labeled according to species, and areal coverage determined using an electronic planimeter. Reservoirs flown for aerial photography in 1992 included: Kentucky, Wheeler, Guntersville, Nickajack, Chickamauga, Tellico, Douglas, Boone, Tims Ford, and Normandy. For reservoirs where aerial photography was unavailable, standard field surveys and historical information were used to estimate community composition and coverage. Submersed aquatic plant populations generally are rare in tributary reservoirs because of the wide fluctuations of water surface elevations associated with their operation for floodwater storage. Known populations have been extremely small, short-lived, and of little significance.

A detailed summary of TVA's Aquatic Plant Management Program for 1992 and proposed work for 1993 is contained in a technical report (Burns, Bates, and Webb, 1993), which is updated and published annually.

2.1.6 Inter-Reservoir Comparisons of Data

In 1992, Vital Signs Monitoring was conducted on the 11 run-of-the-river reservoirs and Norris, Cherokee, and Douglas Reservoirs. Limited monitoring was also conducted on ten smaller tributary storage reservoirs to supplement the basic Vital Signs Monitoring (see tables 2.1 and 2.2, and section 2.1.1). In general, only water chemistry and fish community information were collected on this group of ten smaller tributary reservoirs (table 2.2). With the exception of Use Suitability Monitoring of fish tissue on Ocoee No. 1 and fecal coliform sampling on Tims Ford, no sediment toxicity, benthic macroinvertebrate, fish tissue, or bacteriological information were collected on these ten limited monitoring tributary storage reservoirs in 1992.

Comparisons of ecological health were made between these two groups of reservoirs, i.e., run-of-the-river reservoirs and tributary reservoirs. In chapter 4.0, "Reservoir-by-Reservoir Summary and Conclusions," because physical processes are different for run-of-the-river reservoirs and tributary reservoirs (viz., short vs. long detention times, shallow vs. deep annual drawdowns, weakly vs. strongly stratified, etc.), different ecological response conditions result.

Physical/chemical water quality characteristics of the run-of-the-river reservoirs are often different than the tributary reservoirs (e.g., thermal stratification, hypolimnetic anoxia, productivity, etc.). Likewise, inter-reservoir comparisons of fish communities were also categorized. Because of different fish community structures in run-of-the-river reservoirs versus tributary storage reservoirs, fish community comparisons were limited to either the run-of-the-river reservoirs or to the tributary storage reservoirs. Run-of-the-river reservoirs were Kentucky, Pickwick, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Watts Bar, Fort Loudoun, Melton Hill, and Tellico. Tributary storage reservoirs were Norris, Cherokee, Douglas, Boone, South Holston, Watauga, Hiwassee, Chatuge, Blue Ridge, Nottely, Ocoee No. 1, Tims Ford, Beech, and Normandy.

2.2 Reservoir Ecological Health Evaluation

An evaluation methodology was developed to assess the overall ecological health or condition of each of the 24 TVA reservoirs (11 run-of-the-river reservoirs and 13 tributary storage reservoirs), tables 2.1 and 2.2, monitored in 1992. The following presents an overview of TVA's reservoir ecological health evaluation methodology. Additional details are given in Dycus and Meinert, 1993. The reservoir health evaluations presented in chapter 4.0, "Reservoir-by-Reservoir Summary and Conclusions," are based on information gathered in 1992 on five aquatic health indicators--dissolved oxygen, chlorophyll-a, sediment quality, benthic community, and fish community.[1]

At sampling locations in each reservoir (i.e., forebay, transition zone or midreservoir, and inflow) each of the five aquatic health indicators were rated from 5 (i.e., "good") to 1 (i.e., "poor"). Potentially, 15 ratings were possible for each reservoir (i.e., three locations x five indicators). In practice, however, chlorophyll-a and sediment quality information were not collected at inflow locations, and dissolved oxygen data were available only at inflow locations on the mainstem run-of-the-river reservoirs of the Tennessee River.[2]

Consequently, in the 11 run-of-the-river reservoirs, 12 or 13 ratings were typically used to evaluate reservoir health. At most of the remaining 13 tributary reservoirs, because of their smaller size, only chlorophyll-a, dissolved oxygen, and fish

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[1] It should be noted that this reservoir health methodology, which was jointly developed by a TVA panel of aquatic biologists, environmental engineers, and water quality scientists, is undergoing continual refinement. The panel recognizes the difficulty in trying to evaluate the aquatic health of a complex reservoir ecosystem based solely on these indicators which are measured at only a small number of locations. The panel anticipates that as understanding and experience grow, these indicators and their evaluations will change. In fact, the panel solicits comments and criticisms of their choice of aquatic health indicators, their methods of rating each of the indicators, and their overall evaluations of the reservoirs.

[2] Chlorophyll-a and sediment toxicity/quality data were not collected at reservoir inflow locations because many of these inflow locations are in the tailrace of an upstream dam and are dominated by the effects of the upstream reservoir, rather than the processes that occur in the reservoir being sampled. Also, the lack of suitable substrate (i.e., sediment) at many inflow locations due to the wash out and the high velocities of the water released by the upstream dam, precluded the collection of samples for sediment analyses. DO data from the tailraces of dams on the mainstream portion of the Tennessee River were used (when available) to assess the inflow station in the downstream reservoir.

community information were collected at the forebay, midreservoir, and/or inflow locations. Consequently, three to nine ratings (one to three locations x three indicators) were typically used to evaluate the ecological health of the these smaller tributary reservoirs.

To arrive at a final overall ecological health evaluation for each reservoir, equal weights were given to each of the five ecological health ratings. Then the ratings at all sampling locations (forebay, transition zone or midreservoir, and inflow) were added and a percentage of the total possible rating was calculated. Reservoir evaluations could range from 20 percent (all 1-poor ratings) to 100 percent (all 5-good ratings) or any percentage (and combination of ratings) in between.

Run-of-the-river reservoirs were evaluated as "good" if the overall reservoir percentage was greater than 72 percent; "fair" if the overall reservoir percentage was between 52 percent and 72 percent; and "poor" if the overall reservoir percentage was less than 52 percent. Similarly, tributary storage reservoirs were evaluated as "good" if the overall reservoir percentage was greater than 72 percent; "fair" if the overall reservoir percentage was between 57 percent and 72 percent; and "poor" if the overall reservoir percentage was less than 57 percent.

To illustrate, two examples of the rating scheme are attached, table 2.3: Chickamauga Reservoir with five aquatic health indicators at three locations and South Holston Reservoir with three aquatic health indicators at two locations.

2.2.1 Dissolved Oxygen (DO)

The DO of a reservoir was evaluated by examining DO concentrations in the water column (WC_{DO}) and DO concentrations at the bottom of the reservoir (B_{DO}). The final DO evaluation (ranging from 1 to 5) was the average of these two ratings:

$$\textbf{DO Rating} = 0.5(WC_{DO} \text{ rating} + B_{DO} \text{ rating})$$

• Water Column DOs (WC_{DO}) - Isopleths of DO concentrations versus depth and time were plotted for each sampling location for a seven-month period. This seven-month period was March-September for the 14 basic Vital Signs reservoirs, and April-October for the ten Limited Vital Signs reservoirs (tables 2.1 and 2.2). For each sampling location (forebay or transition zone), the water column DO (WC_{DO}) rating was based on an estimate of the percent of the time and the depth [time x depth] that the concentration of DO was less than 2.0 mg/L. If the percent of the [time x depth] was:

<5% - WC_{DO} was rated a 5 (good);
>5% but <10% - WC_{DO} was rated a 3 (fair); and
>10% - WC_{DO} was rated a 1 (poor).

In addition, in consideration of state DO water quality criteria for fish and aquatic life, if the measured DO at the 1.5 meter depth at a sampling location (forebay, transition zone, or inflow) was at any time:

<5.0 mg/L - the WC_{DO} rating was decreased one unit; or
<4.0 mg/L - the WC_{DO} rating was decreased two units; or
<3.0 mg/L - the WC_{DO} rating was decreased three units; etc.

• Bottom DOs (B_{DO}) - The bottom DO rating was based on an estimate of the number of months near bottom concentrations of DO at each sampling location were less than 2 mg/L. If the number of months with bottom DOs less than 2 mg/L was:

Less than one month - B_{DO} was rated a 5 (good);
One to two months - B_{DO} was rated a 3 (fair); and
Two or more months - B_{DO} was rated a 1 (poor).

In addition, if conditions existed where there was no DO at the bottom of the reservoir (i.e., 0 mg/L), the bottom DO rating (B_{DO}) was lowered one unit, with the minimum B_{DO} rating being 1 (poor).

2.2.2 Chlorophyll-a

The chlorophyll-a rating at each reservoir sampling location was based on the average summer (April-September or October) photic zone concentration of chlorophyll-a (corrected). Chlorophyll-a concentrations were rated as follows:

<3 µg/L - rated a 3 (fair);
3 to 10 µg/L - rated a 5 (good);
10.1 to 15 µg/L - rated a 3 (fair); and,
>15 µg/L - rated a 1 (poor).

If any single chlorophyll-a sample exceeded 30 µg/L, the value was not included in the calculation of the average concentration, and the chlorophyll-a rating was decreased one unit. In addition, if detectable concentrations of nutrients (total nitrogen and total phosphorus) were present but average chlorophyll-a concentrations were less than 3 µg/L, indicating limiting conditions on primary productivity other than nutrients, the chlorophyll-a rating was rated 1 (poor).

2.2.3 Sediment Quality

Samples of sediment were split and used to rate sediment quality at each reservoir sampling location. One split was tested for toxicity (S_{TOX}) and one split was analyzed for heavy metals, un-ionized ammonia, and organochlorine pesticides (S_{CHM}). The final sediment quality evaluation (ranging from 1 to 5) was the average of these two ratings:

Sediment Quality Rating = 0.5(S_{TOX} rating + S_{CHM} rating).

• Sediment Toxicity (S_{TOX}) - These ratings were derived from Microtox® (light emitting bacteria) and Rotox® (rotifer) acute toxicity evaluations at the 14 basic Vital Signs reservoirs. Sampling locations were rated as follows:

No Significant Rotifer toxicity

and EC_{10} < 25%	-	S_{TOX} was rated a 5 (good);
and EC_{10} > 25%	-	S_{TOX} was rated a 3 (fair);
Significant Rotifer toxicity	-	S_{TOX} was rated a 1 (poor);

• Sediment Chemistry (S_{CEM}) - Ratings for chemical sediment quality were based on the following: (1) detectable amounts of any organochlorine pesticide or PCB, (2) un-ionized ammonia concentrations in sediment pore water above 200 μg NH_3/L, or (3) concentrations of Cd, Cr, Cu, Pb, Hg, Ni, and Zn that exceeded EPA Region V guidelines for heavily polluted sediment (EPA, 1977), where:

No exceedances of guidelines - S_{CEM} was rated a 5 (good);
One constituent exceeding guidelines - S_{CEM} was rated a 3 (fair);
Two or more exceeding guidelines - S_{CEM} was rated a 1 (poor).

2.2.4 Benthic Community

An evaluation methodology was developed to assess benthic communities in three distinct sampling zones in a reservoir (forebay, transition zone and inflow). Six benthic community metrics were selected for the evaluation:

(1) total taxa richness;
(2) long-lived species (Corbicula, Hexagenia, mussels, and snails);
(3) EPT (Ephemeroptera, Plecoptera, and Trichoptera);
(4) proportion of Chironomids;
(5) proportion of Tubificidae; and
(6) proportion as dominant taxa.

At each sample location, ten equally spaced samples were collected along a cross-sectional transect. For each of the first three metrics an average was calculated by dividing the sum of the number of appropriate taxa in each sample by the total number of samples, (i.e., ten samples). For the fourth and fifth metrics, an average of the proportions of the appropriate taxa found in each of the ten samples was calculated. This approach gives equal weighting to all samples regardless of sample size, which eliminates the problem of biasing introduced when one sample at a location has an exceptionally large or small density. The sixth metric was computed similar to the fourth and fifth metrics. The average of the proportion of the dominant taxon in each sample was calculated, even though the dominant taxon may have been different in each of the ten samples. This allowed more discretion to identify imbalances at a sampling location than developing an average for a single dominant taxon for all samples at the location.

For each metric, because of different habitat conditions, different evaluation criteria were used for each of the three distinct zones in a reservoir (forebay, transition zone, and inflow). The range of values for each of the six metrics, based on the 1991 and 1992 data, were trisected into good, fair, and poor ranges for forebays, transition zones, and inflow locations. Only run-of-the-river reservoirs were trisected and evaluated in 1992 because insufficient data exists for a similar analysis of the tributary storage reservoirs.[3]

Metrics which fell into the good range were scored a 5, metrics which fell into the fair range were scored a 3, and metrics which fell into the poor range were scored a 1. Scores of the six metrics were then summed to produce an overall benthic community evaluation for each location. The range of attainable scores (6 to 30) was divided into five equal groups as shown below:

<u>Benthic Community Evaluation</u>

Total Score	Rating	
6-10	1	Poor
11-15	2	
16-20	3	Fair
21-25	4	
26-30	5	Good

(Sum of scores for the six metrics at each location)

[3] Due to the distinct differences between run-of-the-river reservoirs and tributary storage reservoirs, different metric scoring criteria should be used for these two types of reservoirs. Currently, only three tributary storage reservoirs (Norris, Cherokee, and Douglas) are sampled. The addition of 16 tributary storage reservoirs in 1993 will increase the benthic data base allowing for a better idea of how they should be scored.

2.2.5 Fish Community

A Reservoir Fish Assemblage Index (RFAI) developed by Karr and Jennings,[4] was used to rate the fish community at each sampling location (forebay, transition zone, and inflow) based on autumn (1992) electrofishing (littoral zone) data. The RFAI used 11 metrics in 1992. The metrics addressed:

(a) species richness and composition - total numbers of species, sunfish species, sucker species, intolerant species, and percentage of tolerant individuals sampled, excluding shad;

(b) trophic composition - percentage of omnivorous individuals, and percentage of invertivorous individuals;

(c) reproductive composition - numbers of migratory spawning species, and numbers of lithophilic spawning species;

(d) overall fish abundance; and

(e) fish health assessment index (FHAI) of largemouth bass.

Each metric was assigned a score of 1, 3, or 5 with 5 representing a "good" condition, and scores of 3 and 1 indicating "fair" and "poor" conditions, respectively. (In cases where inadequate numbers of largemouth bass were sampled to calculate the FHAI, a score of 3 was arbitrarily assigned to the FHAI metric.) Due to the distinct differences between the fish populations they support, run-of-the-river reservoirs and tributary storage reservoirs used different scoring criteria for the metrics.

For each of three distinct sampling locations in each reservoir, scores of the 11 metrics were summed to produce RFAI

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[4] The RFAI used to evaluate the electrofishing results is in the developmental phase. Substantial efforts have been made to date on selecting and evaluating appropriate metrics. These efforts are continuing and further improvements are expected. Therefore, RFAI values reported are considered preliminary.

values. The range of "attainable" RFAI values (11 to 55) was divided into five equal groups for 1992 sampling results as follows:

Fish Community Evaluation

Total Score	Rating	
11-19	1	Poor
20-28	2	
29-37	3	Fair
38-45	4	
46-55	5	Good

(Sum of scores for the 11 metrics at each location)

A discussion of the ongoing development of the RFAI and results of the fish community evaluations and for the 1991 Vital Signs Monitoring data are available in TVA technical reports (Wilson, 1992; and Scott, Hickman, and Brown, 1992).

2.3 Use Suitability

The Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) and suitability of fish from TVA reservoirs for human consumption (fishable).

The Use Suitability component of the Reservoir Monitoring Program is based on two activities: (1) bacteriological sampling and (2) fish tissue analysis.

2.3.1 Bacteriological Sampling

In 1989, TVA began a program of periodically sampling recreation sites in the Tennessee Valley for fecal coliform bacteria to determine each site's suitability for water contact recreation. In addition to swimming beaches, many other recreation sites are also included in the program, such as canoe launch areas, picnic areas, boat ramps, marinas, etc. The bacteriological sampling program includes approximately 250-300 sites including several nonrecreation sites used for determining inflow stream water quality and identifying water pollution sources. The program is designed to sample all locations on a frequency of about once every other year.

In 1992, fecal coliform samples were collected in spring and summer to evaluate use suitability for whole body water contact recreation at 28 designated swimming beaches and 11 canoe access sites. Including informal recreation sites where incidental water contact may occur (e.g., boat launch ramps, picnic areas, parks, marinas, etc.), all together 65 locations were sampled in 1992. These recreational bacteriological samples were collected in a manner to conform with state criteria and federal guidelines, such that at each site, at least ten fecal coliform samples were collected within a 30-day sampling period. Recreation sites were classified as fully supporting, partially supporting, and not supporting water contact recreation based on EPA guidelines for fecal coliform bacteria. In addition, 27 forebay and transition zone locations were sampled monthly as part of the basic Vital Signs Reservoir Monitoring Program (table 2.1).

A technical report (Fehring, 1993) provides specific details and evaluations of TVA's 1992 bacteriological monitoring results.

2.3.2 Fish Tissue Analysis

In cooperation with Valley states, TVA analyzes tissues of Tennessee Valley fish as part of both "screening" and "intensive" evaluations. Screening studies are based on analysis of composited fillets of indicator fish species (primarily channel catfish) and are intended to identify possible problem areas where intensive investigation might be needed.

Intensive studies are conducted on reservoirs where contamination problems are known or suspected and involve analysis of individual fillets from important fish species. This information is used to document the geographical extent and the concentration level of the contamination, so state public health officials can determine whether fish consumption advisories are necessary to protect human health.

Fish collected for screening studies are usually analyzed for PCBs, pesticides, and selected metals on EPA's Priority Pollutant List. Fish for intensive studies are usually analyzed only for the contaminant of concern. During the preparation process, external and internal conditions are recorded as well as length, weight, sex, fillet weight, and liver weight.

Screening Studies--Channel catfish were collected from 15 reservoirs in autumn 1991 and 16 in autumn 1992. Fillets were removed, composited by location, and analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List.

Intensive Studies--Five TVA reservoirs were examined intensively in 1991: Wheeler, Nickajack, Watts Bar, Fort Loudoun, and Melton Hill. Ocoee Reservoir No. 1 (Parksville) was added to this list in 1992. The contaminant of concern was PCBs in each case. Chlordane was also of concern in some reservoirs. Fish consumption advisories that recommend limiting the quantity of fish eaten or avoiding any consumption are in effect for all these reservoirs except Ocoee.

Results of intensive and screening fish tissue studies conducted in autumn 1991 and 1992 are presented in Williams and Dycus, in preparation.

2.4 Stream (Fixed Station) Monitoring

TVA's ambient fixed-station stream monitoring program was established in 1986 to provide basic information necessary to evaluate the water quality of major tributaries to the Tennessee River. The fixed-stations are located in the downstream portions of 12 watersheds on major tributaries to the Tennessee River and are designed to allow trend detection and reflect overall upstream conditions within the basin hydrologic unit. Details in regard to TVA's fixed-station monitoring program are provided in TVA, 1992.

In 1992, the ambient fixed-station monitoring information was also used to supplement and enhance TVA's reservoir ecological health evaluations, given that these fixed-station locations are also upstream of TVA's Vital Signs reservoirs (figure 2.2). Water quality information collected at each location was used to assess the quality of water flowing into the downstream receiving reservoir, thus often providing additional insights to explain the conditions found in the receiving reservoir.

At each fixed-station location, four types of data were examined to supplement the 1992 reservoir ecological health assessments:

(1) physical/chemical characteristics of water, primarily nutrient concentrations (section 2.4.1, below);

(2) acute toxicity screening and chemical characterization of sediment (section 2.4.2, below);

(3) benthic macroinvertebrate community sampling (section 2.4.3, below); and,

(4) fish community evaluations (section 2.4.4, below).

2.4.1 Physical/Chemical Characteristics of Water

In 1992, physical/chemical water quality variables were measured bimonthly at 12 fixed-station locations. Variable selection included: 11 different field/physical measurements; six measures of nutrients; six major cations/anions; nine metals; and fecal coliform bacteria. Details are contained in TVA, 1992.

The physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Methods used to assess physical/chemical quality of each fixed-station in regard to the reservoir ecological health evaluations are described below in section 2.5.1.

2.4.2 Acute Toxicity Screening and Chemical Characterization of Sediment

Annual stream sediment and stream bottom water samples were collected at the 12 fixed-station monitoring locations during the summer of 1992. Each sediment sample was a composite of five undisturbed 3-inch deep samples collected on a transect across the stream. Sediment samples were split into two portions. One portion was analyzed for sediment chemistry analyses and the other for sediment pore water and bottom water toxicity testing.

Chemistry analyses--Sediment samples were analyzed for 13 metals and 26 selected trace organics (organochlorine pesticides and PCBs).

Toxicity testing--Both acute and chronic testing were conducted using both sediment pore water and stream bottom water. Chronic toxicity (survival, growth, and reproduction) tests were performed at seven fixed-stations, and acute toxicity tests were performed at five fixed-stations. Chronic tests evaluated seven-day response of Ceriodaphnia (daphnids) and Pimephales promelas (fathead minnow larvae). Acute testing evaluated the 24-hour survival response of Brachionus calyciflorus (rotifer) and the 5- and 15-minute responses of Photobacterium phosphoreum (Microtox® light emitting bacteria). Test endpoints consisted of the Lowest Observed Effect Concentration (LOEC) for chronic tests, the LC_{50} and EC_{50} concentrations for rotifers, and the EC_{10} concentrations for Microtox®.

Details and evaluations of the toxicity testing and the chemical analyses of sediment are provided in Moses, Sesler, and Wade, 1993. Methods used to assess the sediment quality of each fixed-station for the reservoir ecological health evaluations are described below in section 2.5.2.

2.4.3 Benthic Macroinvertebrate Community Sampling

Benthic macroinvertebrate community sampling was conducted annually (summer) at each fixed-station. Seven samples were collected per station including three Hess samples (for pool habitat), three Surber samples (for riffle habitat), and one qualitative sample. Qualitative samples consisted of one to two man-hours collecting with a D-net or handpicking in various habitats. Habitats targeted for qualitative sampling were leaf packs, woody debris, emergent aquatic vegetation, and boulders. Indicators examined to assess benthic community structure were number of intolerant species, species richness, and species equitableness.

Details and evaluations of the benthic community data are provided in Saylor and Ahlstedt, 1990. Methods used to assess the benthic community at each fixed-station in regard to the reservoir ecological health evaluations are described below in section 2.5.3.

2.4.4 Fish Community Evaluations

Fish community sampling was conducted annually (summer) at each fixed-station using a boat mounted electrofishing unit (for deep pool habitat) and a backpack electrofishing unit, dip net, and seine (for wadable habitat). Three general habitats were sampled until three consecutive units of sampling effort (seine haul or timed shocking run) produced no additional species. Twelve indicators were examined to assess fish community.

Details and evaluations of the fish community data are provided in Saylor and Ahlstedt, 1990. Methods used to assess the fish community at each fixed-station for the reservoir ecological health evaluations are described below in section 2.5.4.

2.5 Fixed-Station Ecological Health Evaluation

An evaluation methodology (similar to the Reservoir Ecological Health Evaluation, section 2.2) was developed to assess the overall ecological health or condition at each of the 12 fixed-station monitoring locations. Particular emphasis was given to the relationship between the conditions found at the fixed-station and the potential for impacts on conditions in the downstream reservoir. The following presents an overview of TVA's fixed-station ecological health evaluation methodology. The evaluations were based on four aquatic health indicators:

(1) total phosphorus (as a measure of nutrient enrichment and potential for excessive algal productivity); (2) sediment quality; (3) benthic community; and (4) fish community. At each fixed-station location the four aquatic health indicators were rated as "good," "fair," or "poor." Equal weights were given to each of the four indicator ratings and each rating was assigned a numeric value: "good"=5; "fair"=3; and "poor"=1. The four aquatic indicator scores were summed to produce an overall ecological health evaluation for the fixed-station ranging from 4 to 20. A fixed-station with an overall rating of 9 or less was rated "poor," 10 to 15 "fair," and 16 to 20 "good."

2.5.1 Total Phosphorus

Phosphorus is an essential nutrient required by aquatic plants for photosynthesis and growth. In freshwater ecosystems phosphorus is most often the nutrient least available to plants, relative to their needs, and thus can limit algal productivity. When present in excess of critical concentrations, phosphates in combination with sufficient nitrogen stimulate algae and other aquatic plant growth, sometimes to an undesirable level, which may interfere with the waters use or become a nuisance to man. To prevent the development of biological nuisances and to control accelerated phosphorus loading for the protection of downstream receiving waterways, EPA has indicated a guideline for maximum total phosphorus concentration of 0.10 mg/L for streams or flowing waters and 0.05 mg/L at the point where any stream enters a lake or reservoir (EPA, 1986). For each sampling location, the total phosphorus rating is based on the EPA guideline and the average of six samples/year: <0.05 mg/L = "good," 0.05-0.10 mg/L = "fair," and >0.10 mg/L = "poor." In addition, waters that receive high nitrogen concentrations in the presence of sufficient phosphorus often stimulate the growth of algae and other aquatic plants to an undesirable extent. High average (relative to the majority of Valley streams) nitrate+nitrite nitrogen concentrations greater than 0.65 mg/L resulted in lowering a rating from "good" to "fair" or from "fair" to "poor," as appropriate.

2.5.2 Sediment Quality

Ratings of "good," "fair," and "poor" for sediment quality were primarily based on sediment toxicity findings. These findings were derived from Microtox® (light emitting bacteria) and Rotox® (rotifers) acute toxicity testing at five fixed-station locations, and from fathead minnow embryo-larval survival and teratogenicity and daphnid (Ceriodaphnia) survival and reproduction chronic toxicity testing at seven fixed-station locations. Sampling locations were rated as follows:

Sediment Toxicity Evaluation	Rating
Microtox/Rotox:	
EC10 <25% and/or significant rotifer toxicity	-- 1 (Poor)
EC10 <25% and no significant rotifer toxicity	-- 3 (Fair)
EC10 >25% and no significant rotifer toxicity	-- 5 (Good)
or	
Fish/Daphnids:	
Acute Toxicity	-- 1 (Poor)
Chronic Toxicity	-- 3 (Fair)
No Toxicity	-- 5 (Good)

Secondarily, if toxicity ratings were "good" or "fair" then NH_3 and heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) concentrations were examined. Concentrations of un-ionized ammonia (>200 μg NH_3/L) or heavy metals exceeding EPA Region V guidelines for polluted sediments (EPA, 1977) would lower the sediment quality rating from "good" to "fair" or from "fair" to "poor," accordingly.

2.5.3 Benthic Community

A modified version of the benthic index of biotic integrity (BIBI) (Kerans et. al., 1992) was used to rate the condition of the benthic community. A sample of the macroinvertebrate community was assessed by the following 12 metrics that measure taxa richness and composition, balance in trophic structure, and relative abundance.

I. Taxa Richness and Community Composition

(1) Taxa richness
(2) Occurrence of intolerant snail and mussel species*
(3) Number of mayfly (Ephemeroptera) taxa
(4) Number of stonefly (Plecoptera) taxa
(5) Number of caddisfly (Trichoptera) taxa
(6) Total number of EPT taxa*
(7) Proportion of individuals as oligochaetes
(8) Proportion of individuals in the two most abundant taxa

II. Trophic and Functional-Feeding Group

(9) Proportion of individuals as omnivores and scavengers
(10) Proportion of individuals as collector-filterers
(11) Proportion of individuals as predators

III. Abundance

(12) Total abundance of individuals (in quantitative samples, lower score given for extremely low values and extremely high values)

*Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.

Values obtained for each of these metrics were scored (1-poor, 3-intermediate, or 5-expected) against best expected value based on data from reference sites supporting healthy fish communities and having good water quality. Metric scores are then summed to produce an index ranging from 12 to 60. The resultant benthic community index for each fixed-station was classified as "poor" (index <30), "fair" (index 34-44), or "good" (index >45).

2.5.4 Fish Community

A modified version of Karr's (1981) index of biotic integrity (IBI) was used to assess the condition of the resident fish community at 11 of the 12 fixed-station monitoring locations.

(Fish community sampling was not conducted at the Elk River fixed-station in 1992.) An index and rating were produced by applying the following 12 metrics.*

I. Species richness and composition

(1) Number of native species.
(2) Number of darter species.
(3) Number of native sunfish species (excluding <u>Micropterus</u> sp.).
(4) Number of sucker species.
(5) Number of intolerant species.
(6) Percentage of individuals as tolerant species.

II. Trophic structure

(7) Percentage of individuals as omnivores.
(8) Percentage of individuals as specialized insectivorous minnows and darters.
(9) Percentage of individuals as piscivores.

III. Fish abundance and condition

(10) Catch rate (average number per unit of sampling effort, seine hauls and shocking runs).
(11) Percentage of individuals as hybrids.
(12) Percentage of individuals with poor condition, injury, deformity, disease, or other anomaly.

*If fish community information was missing or not collected, a score of "fair" is arbitrarily given for the missing metric.

Actual values obtained for each of these metrics were scored (1-poor, 3-intermediate, or 5-expected) against values expected under pristine conditions (i.e., best expected value). The 12 metric scores were then summed to produce an index ranging from 12 to 60, and the fish community at the fixed-station was rated as "poor" (index <36), "fair" (index 40-44), or "good" (index >46). Professional judgment was involved when a fish community index fell between ratings; for example, when an index of 38 rated between "poor" and "fair." The resultant rating would be either "poor" or "fair" depending on the judgment of the biologist taking the sample. Judgment was usually influenced by which of the 12 metrics are affected, condition of the coexisting macroinvertebrate community, or previous IBI ratings obtained for the site.

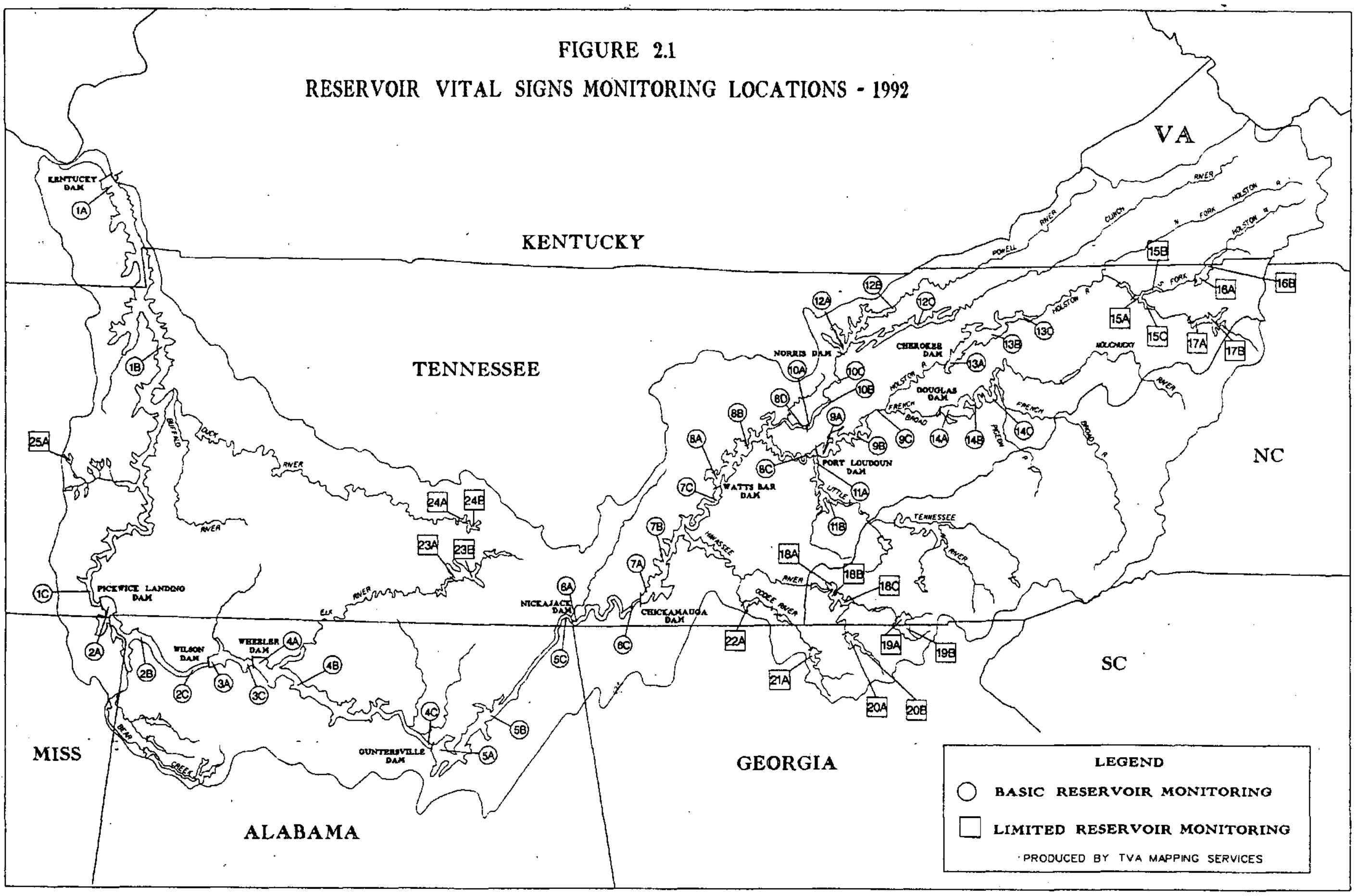

FIGURE 2.1
RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1992

FIGURE 2.2
FIXED-STATION MONITORING LOCATIONS - 1992

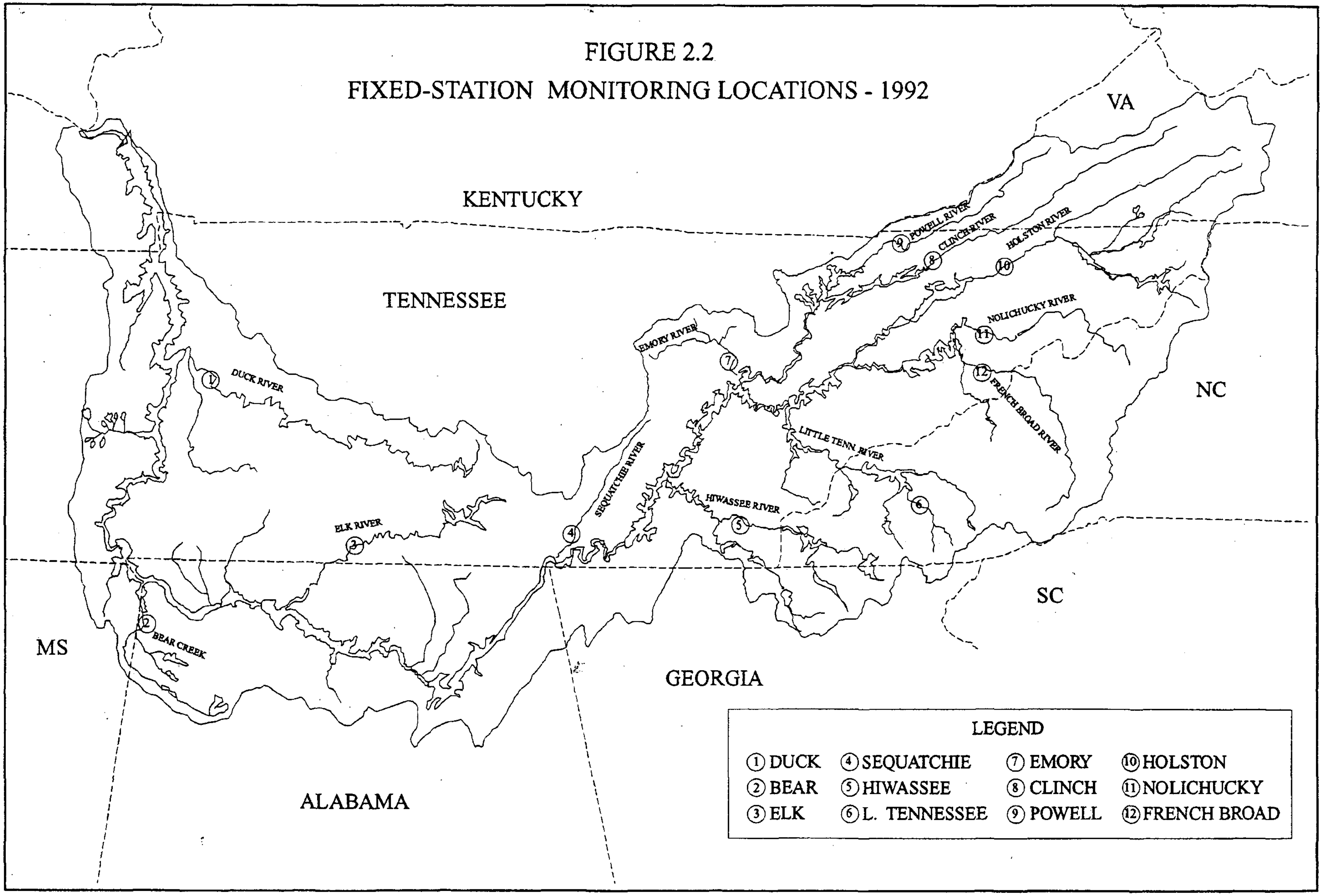

Table 2.1
SUMMARY OF RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1992
--Basic Monitoring Strategy--

			Reservoir Vital Signs Monitoring Tools				
				Sediment Quality[d]		Benthic	Fish Community[f]
Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Invertebrates[e]	Diversity/RIBI
		Run-of-the-river Reservoirs					
Kentucky	TRM 23	1A-FB	M	A	A	A	A
	TRM 85	1B-TZ	M	A	A	A	A
	TRM 200-206	1C-I	-	-	-	A	A
Pickwick	TRM 207	2A-FB	M	A	A	A	A
	TRM 230	2B-TZ	M	A	A	A	A
	TRM 256-259	2C-I	-	-	-	A	A
Wilson	TRM 261	3A-FB	M	A	A	A	A
	TRM 273-274	3C-I	-	-	-	A	A
Wheeler	TRM 277	4A-FB	M	A	A	A	A
	TRM 296	4B-TZ	M	A	A	A	A
	TRM 347-348	4C-I	-	-	-	A	A
Guntersville	TRM 350	5A-FB	M	A	A	A	A
	TRM 375	5B-TZ	M	A	A	A	A
	TRM 420-424	5C-I	-	-	-	A	A
Nickajack	TRM 425	6A-FB	M	A	A	A	A
	TRM 469-470	6C-I	-	-	-	A	A
Chickamauga	TRM 472	7A-FB	M	A	A	A	A
	TRM 490	7B-TZ	M	A	A	A	A
	TRM 518-529	7C-I	-	-	-	A	A
Watts Bar	TRM 531	8A-FB	M	A	A	A	A
	TRM 561	8B-TZ	M	A	A	A	A
	TRM 600-601	8C-I	-	-	-	A	A
	CRM 19-22	8D-I	-	-	-	A	A
Fort Loudoun	TRM 605	9A-FB	M	A	A	A	A
	TRM 625	9B-TZ	M	A	A	A	A
	TRM 652	9C-I	-	-	-	A	A

Table 2.1 (continued)
SUMMARY OF RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1992
--Basic Monitoring Strategy--

			Reservoir Vital Signs Monitoring Tools				
				Sediment Quality[d]		Benthic	Fish Community[f]
Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Invertebrates[e]	Diversity/RIBI
		Run-of-the-river Reservoirs					
Melton Hill	CRM 24	10A-FB	M	A	A	A	A
	CRM 45	10B-TZ	M	A	A	A	A
	CRM 59-66	10C-I	-	-	-	A	A
Tellico	LTRM 1	11A-FB	M	A	A	A	A
	LTRM 21	11B-TZ	M	A	A	A	A
		Tributary Storage Reservoirs					
Norris	CRM 80	12A-FB	M	A	A	A	A
	PRM 30	12B-MR	M	A	A	A	A
	CRM 125	12C-MR	M	A	A	A	A
Cherokee	HRM 53	13A-FB	M	A	A	A	A
	HRM 76	13B-MR	M	A	A	A	A
	HRM 91	13C-I	-	-	-	A	A
Douglas	FBRM 33	14A-FB	M	A	A	A	A
	FBRM 61	14B-MR	M	A	A	A	A
	FBRM 72	14C-I	-	-	-	-	A
		Totals	27	27	27	39	40

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a. TRM - Tennessee River Mile; CRM - Clinch River Mile; FBRM - French Broad River Mile; PRM - Powell River Mile; HRM - Holston River Mile; LTRM - Little Tennessee River Mile

b. FB - Forebay; TZ - Transition Zone; MR - Midreservoir; I - Inflow

c. M - monthly water quality surveys (January and April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near-bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for toxicity (Microtox® and Rotox®). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and 26 trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual autumn, electroshocking and gill-netting techniques are used to evaluate the near shore fish community.

Table 2.2
SUMMARY OF RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1992
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Reservoir Vital Signs Monitoring Tools: Fish Community[d] Diversity/RBI
		Tributary Storage Reservoirs		
Boone	SFHR 19	15A-FB	M	A
	SFHR 27	15B-MR	M	A
	WRM 8	15C-MR	M	A
South Holston	SFHR 51	16A-FB	M	A
	SFHR 62	16B-MR/I[e]	M	A
Watauga	WRM 37	17A-FB	M	A
	WRM 44	17B-MR/I[e]	M	A
Hiwassee	HiRM 77	18A-FB	M	A
	HiRM 85	18B-MR	M	A
	HiRM 90	18C-MR/I[e]	M	A
Chatuge	HiRM 122	19A-FB	M	A
	HiRM 126	19B-MR	M	-
Nottely	NRM 22	20A-FB	M	A
	NRM 31	20B-MR	M	-
Blue Ridge	ToRM 54	21A-FB	M	A
Ocoee No.1	ORM 12	22A-FB	M	A
Tims Ford	ERM 135	23A-FB	M	A
	ERM 150	23B-MR	M	A
Normandy	DRM 249.5	24A-FB	-	A
	DRM 255.0	24B-MR	-	A
Beech	BRM 36	25A-FB	M	-
		Totals	19	18

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a. SFHR - South Fork Holston River; WRM - Watauga River Mile; HiRM - Hiwassee River Mile; NRM - Nottely River Mile; ToRM - Toccoa River Mile; ORM - Ocoee River Mile; ERM - Elk River Mile; BRM - Beech River Mile; DRM - Duck River Mile

b. FB - Forebay; MR - Midreservoir; I - Inflow

c. M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone chlorophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved orthophosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual autumn electroshocking and gill-netting techniques are used to evaluate the near-shore fish community.

e. Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a midreservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

Table 2.3

Computational Method For Evaluation of Reservoir Health

Chickamauga Reservoir - 1992

Aquatic Health Indicator	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen: % of [time x depth] <2 mg/l less than 5mg/l at 1.5 meter # months <2mg/l at bottom	 0 (5) No 0 (5)	 0 (4) Yes 0 (5)	 0 (4) Yes 0 (5)	5	4	4
Chlorophyll-a, ug/l: average maximum	 6.2 (5) 12.0	 4.6 (5) 7.0	 NA	5	5	NA
Sediment Quality Rotifer Survival Microtox Metals/NH3/pesticides	 56% (1) EC10 13% Cu, Zn (1)	 87% (1) EC10 100% Zn (3)	 NA NA	1	2	NA
Benthic Community: Dominance Tubificidae Chironmidae EPT Long-lived Taxa richness Total	 5 5 5 5 5 5 30	 5 5 3 5 5 3 26	 1 1 5 1 3 1 12	5	5	2
Fish Community: RFCI score	 25	 NS	 35	3	NS	3
		Sampling Location Sum		19 of 25	16 of 20	9 of 15
		Reservoir Sum		44 of 60 [73%]		
		OVERALL RESERVOIR EVALUATION		"good" (green)		

Overall Reservoir Evaluation Key:
Less than 52% - poor (red)
>52% and <72% - fair (yellow)
Greater than 72% - good (green)

South Holston Reservoir - 1992

Aquatic Health Indicator	Observations			Ratings		
	Forebay	Mid-reservoir	Inflow	Forebay	Mid-reservoir	Inflow
Dissolved Oxygen: % of [time x depth] <2 mg/l less than 5mg/l at 1.5 meter # months <2mg/l at bottom	 13.2 (1) No 3 (1)*	 19.2 (1) No 4 (1)*	 NA NA	1 *DO was 0 mg/l at bottom	1	NA
Chlorophyll-a, ug/l: average maximum	 3.1 (5) 4.0	 8.6 (5) 16.0	 NA	5	5	NA
Fish Community: RFCI score	 33	 27	 NA	3	2	NA
		Sampling Location Sum		9 of 15	8 of 15	
		Reservoir Sum		17 of 30 [57%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
Less than 57% - poor (red)
>57% and <72% - fair (yellow)
Greater than 72% - good (green)

3.0 HYDROLOGIC OVERVIEW OF WATER YEAR 1992

Seasonal variations in atmospheric temperature and rainfall have a direct impact on water quality. Consequently, many water quality characteristics (temperature, dissolved oxygen, conductivity, water clarity, suspended solids, etc.) exhibit seasonal effects. During those times of the year when runoff is minimal (normally August-October) streamflow is derived principally from the base flow of groundwater. Groundwater contains greater concentrations of dissolved minerals than does surface drainage because of increased water/soil/rock contact and longer groundwater residence time. During those times of the year when runoff is higher (normally January-March) streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution. Consequently, lower concentrations of most dissolved constituents are added to a river during heavy rainfall and subsequent high flows. However, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams. This carries large loads of nonpoint source pollutants (nutrients, suspended solids, fecal bacteria, etc.) to streams and rivers. From a water quality perspective, low streamflows not only often result in higher water conductivity and higher water clarity, but also lakes and rivers are less able to dilute and assimilate the anthropogenic wastes discharged to them. Since low streamflows often occur during the warmer summer months, the problem of low streamflows can be critical. Warmer water temperatures combined with low streamflows enhance biological activity and thermal stratification, resulting in the potential for dissolved oxygen deficit problems and impacts on aquatic life. One of the important benefits of the TVA reservoir system is the ability to maintain adequate streamflow through the reservoir system during extended periods of low rainfall and low runoff by the controlled release of water. Such was the case in the summer of 1992 (June through October), when rainfall was below normal, but streamflow through the system was regulated at just slightly above average levels, thereby helping to maintain a healthy aquatic river system. Consequently, examining atmospheric temperature, rainfall, and runoff patterns during 1992 aids in interpretation of the Reservoir Vital Signs Monitoring data.

3.1 Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit,°F (15.6 degrees Celsius, °C) with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce climatic data, atmospheric temperatures in the TVA region averaged about 0.3°F (0.2°C) cooler than normal (USDOC, 1992). January and February were unusually warm with 2.6°F (1.4°C) and 4.9°F (2.7°C) above normal, respectively, figure 3.1-a. However, the rest of the months were near or below normal. May, June, August, and October had departures greater than -1.0°F (-0.6°C). This resulted in a cooler than normal growing season.

3.2 Rainfall

The Tennessee River basin averages about 51-52 inches (1295-1320 millimeters [mm]) of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches (2360 mm) in the mountains of southwestern North Carolina near Highlands to a low of about 37 inches (940 mm) in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches of the basin average. March is usually the wettest month and October the driest.

Rainfall in the Tennessee Valley in 1992 averaged 43.4 inches (1102 mm), about 8 inches (204 mm) less than the long-term 100-year average (a departure of about minus 15 percent) and about 12.7 inches (323 mm) less rainfall than 1991 (TVA, 1992). Following a wet October-December 1991, each of the first five months of 1992 was more than an inch (25 mm) below the long term average, with the greatest departure being -2.4 inches (-61 mm) in April, as shown in figure 3.1-b. Consequently, the period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. In spite of this rainfall deficit, all TVA reservoirs were at summer pool levels by the end of May. Rainfall during the summer (June through October) was slightly below normal (0.1 inches). Rainfall was rather evenly distributed in the Tennessee Valley in 1992 with that portion east of Chattanooga receiving about 43.5 inches (1105 mm) and that portion west of Chattanooga receiving about 43.3 inches (1100 mm).

Extreme precipitation events for 1992 were few. April 20-22 brought heavy rains along the Tennessee-North Carolina border resulting in seven inch plus (>180 mm) storm totals. A freakish snowstorm hit May 5-8 dropping as much as 60 inches (1524 mm) of snow at Mt. Pisgah, North Carolina. Hurricane Andrew remnants dropped over five inches (127 mm) of rain in a 24-hour period on August 27 in northwest Georgia.

3.3 Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation, transpiration, and infiltration reduce the amount of runoff. Watersheds that receive 50 to 60 inches of precipitation annually average about 20 to 30 inches of runoff. In a normal year, the discharge of the Tennessee River (approximately 64,000 cfs) corresponds to about 22 inches of runoff distributed over the 40,900 square mile drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and fall months. In 1992, runoff was about an inch (25 mm) below normal, with the first six months of the year having below normal runoff and the last six months having above average runoff, figure 3.1-c. The abnormally dry spring and low runoff (January-May) of 1992, combined with the spring filling of the tributary reservoirs (resulting in the release of little water from the tributary reservoirs) resulted in low flows in the mainstem Tennessee River reservoirs, particularly in April. Consequently, an unusual episode of early spring thermal stratification on the tributary and many of the mainstem reservoirs was observed in April 1992. Higher, more normal flows in May and June (after the filling of the tributary reservoirs and higher amounts of rain) resulted in the destratification of the mainstem reservoirs and a return to more normal reservoir conditions. The impacts of the early spring stratification on the water quality of several reservoirs is discussed in the following chapter.

The net result for the Tennessee Valley in 1992 was an annual 15 percent deficit in precipitation with resultant total runoff that was approximately 0.9 inches below the long-term mean of 22.5 inches. Mean streamflows during 1992 for each of the Vital Signs reservoirs reflect the lower than average annual runoff (table 3.1).

Table 3.1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Reservoir Flow 1960-92 (cfs)	Average Hydraulic Residence Time-1992[a] (Days)	CY 1992 Reservoir Flow (cfs)
Run-of-the-River Reservoirs								
Kentucky	40,200	184.0	160.3	88	2,839	63,182	28.6	49,960
Pickwick	32,820	53.0	43.1	84	924	56,505	9.3	50,057
Wilson	30,750	15.5	15.5	108	634	53,305	6.5	48,840
Wheeler	29,590	74.0	67.1	66	1,050	50,956	11.1	47,838
Guntersville	24,450	76.0	67.9	65	1,018	41,562	12.5	41,086
Nickajack	21,870	46.0	10.4	60	241	35,593	3.5	35,122
Chickamauga	20,790	59.0	35.4	83	628	34,174	9.4	33,608
Watts Bar	17,300	72.0/24.0[b]	39.0	105	1,010	27,788	19.7	25,846
Fort Loudoun	9,550	50.0	14.6	94	363	15,742	9.3	19,664
Tellico	2,627	33.2	16.5	80	415	6,365[c]	33[c]	6,301[c]
Melton Hill	3,343	44.0	5.7	69	120	4,424	16.5	3,670
Tributary River Reservoirs								
Norris	2,912	73.0/53.0[b]	34.2	202	2,040	4,070	325.7	3,158
Cherokee	3,428	54.0	30.3	163	1,481	4,529	177.1	4,215
Douglas	4,541	43.0	30.4	127	1,408	6,879	96.0	7,398
Boone	1,840	17.4/15.3[b]	4.3	129	189	2,510	37.3	2,555
South Holston	703	24.0	7.6	239	658	983	346.3	958
Watauga	468	16.0	6.4	274	569	700	351.6	816
Hiwassee	968	22.0	6.1	255	422	2,077	95.2	2,234
Chatuge	189	13.0	7.0	124	234	453	241.8	488
Nottely	214	20.0	4.2	167	170	405	180.4	478
Blue Ridge	232	11.0	3.3	156	193	614	155.4	626
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	1,415	30.6	1,400
Tims Ford	529	34.0	10.6	143	530	967	358.7	745
Normandy	195	17.0	3.2	83	110	343	161.7	--
Beech	16	5.3	0.9	32	11	14[d]	280[d]	--

a. Measurements based on normal maximum pool and average flows.

b. Major/minor arms of reservoir.

c. Estimated based on releases from Chilhowee Dam, and adjusted based on the additional drainage area between Tellico (2627 sq miles) and Chilhowee (1977 sq miles) dams.

d. Estimated

FIGURE 3.1 Temperature, Precipitation, and Runoff – Tennessee River Basin, 1992

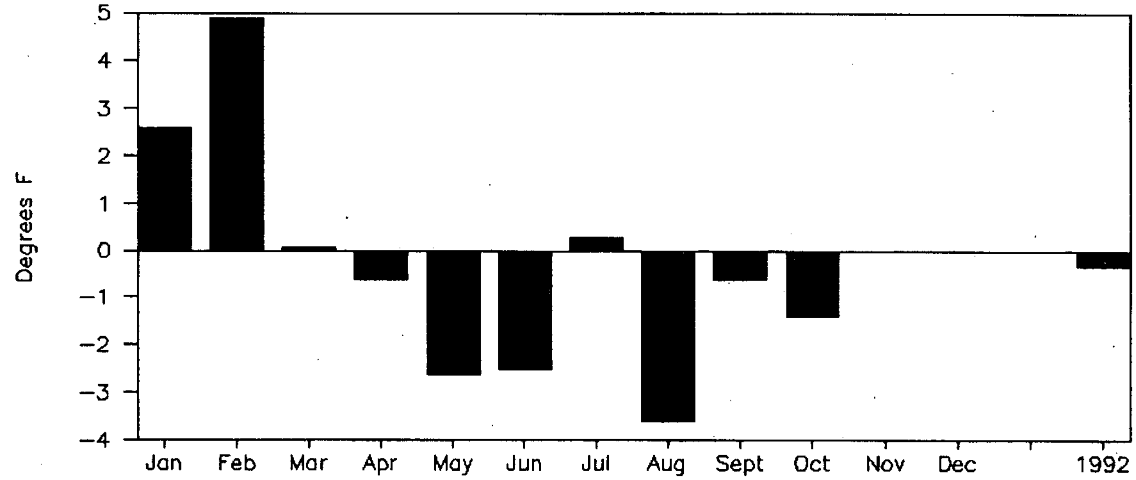

FIGURE 3.1a. Temperature Departures From 1951–1980 Normal (deg F) in the TVA Region.

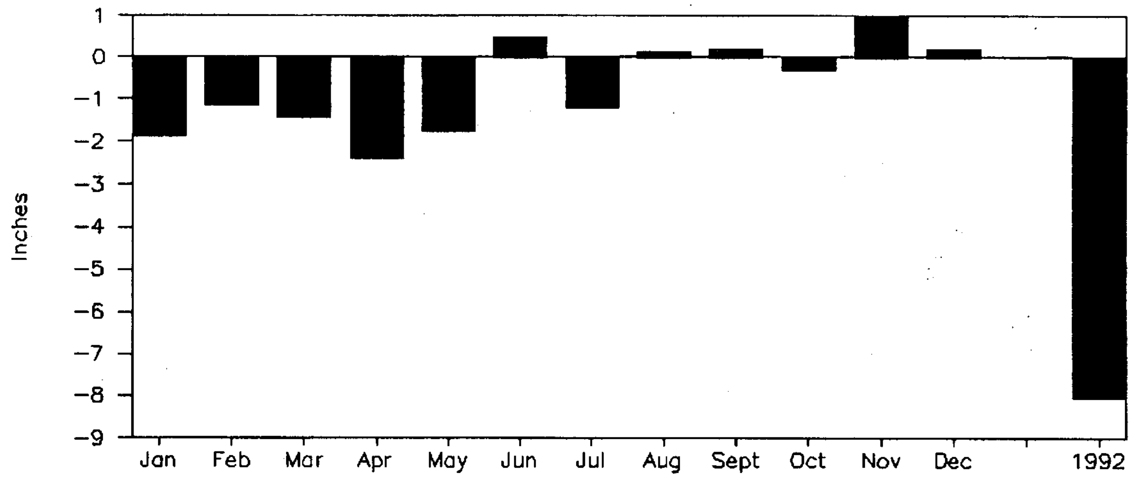

FIGURE 3.1b. Precipitation Departures From 1890–1990 Average (Inches) For The Tennessee River Basin.

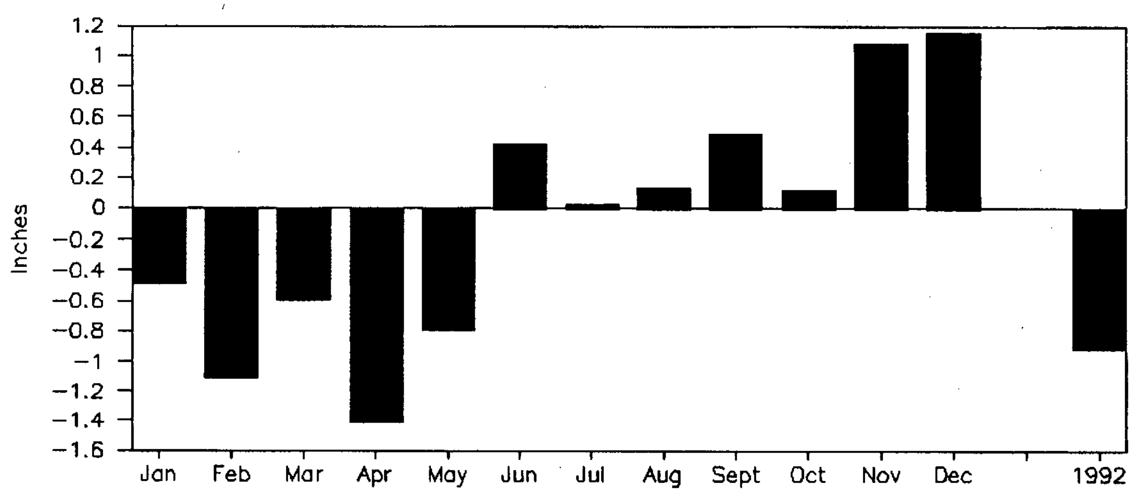

FIGURE 3.1c. Runoff Departures From 1890–1990 Average (Inches) For Tennessee River Basin, Above Kentucky Dam.

4.0 RESERVOIR-BY-RESERVOIR SUMMARY AND CONCLUSIONS

4.1 Kentucky Reservoir

4.1.1 Physical Description

Kentucky Reservoir is the first and largest reservoir on the Tennessee River. The dam is located at Tennessee River mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2280 miles. Average annual discharge is about 63,000 cfs which provides an average hydraulic retention time of about 23 days. Additional information about Kentucky is provided in table 3.1.

A major tributary to the Tennessee River (and Kentucky Reservoir) is the Duck River which provides on the average about 6.5 percent of the total flow through Kentucky Reservoir and joins the Tennessee River at about mile 110.

Information collected in 1990 and 1991 at TRM 112.0 indicated water quality conditions more representative of a riverine environment than a transition lacustrine environment. Consequently, the transition zone sampling location was relocated further downstream, from TRM 112.0 to TRM 85.0 in 1992.

4.1.2 Reservoir Health

Kentucky Reservoir had the best ecological health evaluation of all Vital Signs reservoirs monitored in 1992. All ecological health indicators (DO, chlorophyll-a, sediment quality, benthos, and fish) were good at the forebay. And four of the five ecological health indicators (all except fish community) were good at the other locations. Although the fish community was evaluated as fair at these locations, it was only slightly below the cut-off point to be rated good.

Aquatic plants covered about 2600 acres of Kentucky Reservoir in 1992 compared to about 2800 in 1991. Most plants were found around islands and shallow embayments downstream of the Duck River.

The stream monitoring site on the Duck River showed generally fair ecological health in 1992. This was driven by high phosphorus and high nitrogen concentrations and only fair conditions for sediment quality, benthos, and fish communities. Undesirable conditions at this site included extensive bank erosion and unstable bottom substrate conditions. Although the Duck River contributes only about 6.5 percent of the total flow of Kentucky Reservoir under average flow conditions, it can contribute significant amounts of nutrients and sediment to the reservoir.

4.1.3 Reservoir Use Suitability

Use Suitability Monitoring activities did not identify any impairments on Kentucky Reservoir in 1992. Sixteen of 19 swimming areas tested fully support water contact recreation. Hester's Spot-In-The-Sun, Cedar Knob, and Pirate's Cove partially support recreation because of the high fecal coliform concentrations after rain. Ten of the 19 were sampled in 1992, the other nine were sampled in 1989. Bacteriological sampling in midchannel collections in association with Vital Signs Monitoring activities did not detect any fecal coliform bacteria. Examination of channel catfish fillets in autumn 1991 and 1992 from six locations between Kentucky and Pickwick Dams found only low levels of heavy metals and pesticides at all locations. The only analyte high enough to be of interest was lead at 0.6 $\mu g/g$ at one location in 1992. Similar concentrations have been found sporadically in previous years but there has been no pattern in space or time.

4.1.4 Synopsis of 1992 Conditions

Water--Surface temperatures in Kentucky Reservoir ranged from a minimum of 4.8°C in January to a maximum of 28.6°C in July at the forebay sampling location and from 6.9°C to 29.6°C for the same months at the transition zone location. Dissolved oxygen concentrations at the 1.5-meter depth ranged from a low of 6.7 mg/L in September to a high of 11.3 mg/L in January at the forebay and from 6.4 mg/L to 9.4 mg/L for the same months at the transition zone. The minimum DO observed in Kentucky Reservoir in 1992 was 3.3 mg/L in June at the bottom of the reservoir at the forebay.

The temperature and DO data depict a seasonal warming and weak stratification of Kentucky Reservoir in 1992. The greatest temperature differential (surface-to-bottom) was 3.8°C in June at the forebay. During June and July, a weak, transient oxycline developed at Kentucky forebay. In June, dissolved oxygen ranged from 10.1 mg/L at the surface to 3.3 mg/L at the bottom, and in July, DOs ranged from 7.8 mg/L at the surface to 3.8 mg/L at the bottom. The transition zone DOs were much more uniform and well mixed with the minimum bottom DO being 3.7 mg/L in July.

Values of pH ranged from 6.9 to 8.9 on Kentucky Reservoir. Values of 8.5 and higher accompanied by DO saturation values exceeding 100 percent were observed in May and June indicating significant photosynthetic activity in the forebay of Kentucky Reservoir.

Average total phosphorus (0.061 mg/L) and total nitrogen (0.71 mg/L) concentrations at the transition zone were higher than at most other monitoring locations on the Tennessee River, an effect of the upstream inflows from the Duck River with naturally high concentrations of phosphorus and (to a lesser degree) nitrogen. Because of high ambient phosphorus concentrations, average TN/TP ratios for samples collected at both the forebay and transition zone were low, indicating a lack of nutrient limitation and conditions highly supportive of photosynthetic activity.

The highest chlorophyll-a concentrations were measured in May (22 μg/L) and June (23 μg/L) at the forebay. (Values of pH greater than 8.5 and dissolved oxygen concentrations above 100 percent saturation were also measured during these May and June algal blooms.) Chlorophyll-a concentrations averaged about 9 μg/L at the forebay and about 6 μg/L at the transition zone of Kentucky Reservoir in 1992.

Fecal Coliform Bacteria--Bacteriological studies were conducted at ten swimming beaches on Kentucky Reservoir in 1992. Fecal coliform bacteria concentrations at Moor's Resort, Big Bear Resort, Shawnee Bay Resort, Hickory Hill Resort, Paradise Cove, Irvin Cobb Resort, and Missing Hills Camp were low, allowing fully supports water contact recreation classifications. Occasionally high concentrations at Hester's Spot-In-The-Sun, Cedar Knob, and Pirate's Cove resulted in the three swimming areas receiving partially supports classifications. Monthly

Vital Signs sampling at the forebay and transition zone never found bacterial concentrations above the detection limit.

Sediment--Chemical analyses of sediments did not reveal any metal or organic analyte to be a concern, although free ammonia was measured (234 μg/L) in sediment pore water collected in the forebay; however, toxicity tests did not detect any acute toxicity. Particle size analysis showed forebay sediments were almost totally silt and clay (99 percent), whereas sediments at the transition zone, given the hydrologic conditions at the site, were different (sand 29 percent, silt and clay 71 percent).

Benthic Macroinvertebrates--The benthic communities at all three reservoir sampling locations were good. The forebay site had 16 taxa and a total of 790 organisms/m^2 with Coelotanyopus sp (31 percent) and Musculium sp (26 percent) as the most abundant organisms collected. The transition zone location at TRM 85.0, which was changed from TRM 112.0, represented a more diverse (29 taxa) and abundant (1247 organisms/m^2) community than previous location. Corbicula sp was the dominant organism (40 percent of the total) and Hexagenia sp was second (21 percent). The inflow site had 33 taxa and a total of 583 organisms/m^2. Corbicula sp was the dominant taxon making up 62 percent of the total collected. Although the forebay had only minor increases from 1991 in diversity and density, the transition and inflows had substantial increases.

Aquatic Macrophytes--Aquatic plants decreased from 2813 acres in 1991 to 2616 acres in 1992. Kentucky Reservoir has the third-largest amount of aquatic vegetation within the TVA system. Aquatic macrophytes peaked at about 7100 acres in 1987. Significant declines in spinyleaf and southern naiad populations have occurred in recent years. Eurasian watermilfoil was the dominant macrophyte on Kentucky Reservoir and generally occurred in monospecific stands. However, it was sometimes mixed with coontail and naiads. Aquatic vegetation on Kentucky Reservoir was primarily found from TRM 110 downstream to near the vicinity of Kentucky Dam.

Fish Community--Fish data collection at near shore (30 electrofishing transects) and offshore bottom areas (25 net-nights) showed a diverse fish assemblage of 45 species dominated in numbers by gizzard shad (93 percent). Emerald shiners (1.5 percent), bluegill (1 percent), and largemouth bass (.5 percent) followed gizzard shad in abundance. Total numbers of fish were greatest in the forebay zone, due to the presence of large numbers of gizzard shad. If numbers of gizzard shad are disregarded, electrofishing results indicate similar fish abundance in forebay (555) and transition (500) areas with fewer individuals in the inflow zone (152). Gill netting catch rates of all species combined were two times greater in the forebay

(34.7 per net-night) than the transition area and three times greater than the inflow. Fish Health Assessment indices indicated a fair condition of largemouth bass in the transition zone and poor conditions at the inflow and forebay zones.

The Reservoir Fish Assemblage Index (RFAI) showed the littoral fish community (based on results of electrofishing samples) of the forebay (RFAI=41) to be the best found in TVA mainstream forebays during 1992. Fish communities in the transition (RFAI=37) and inflow (RFAI=35) zones ranked in the upper and middle 30 percentile, respectively, when compared to other mainstream transition and inflow areas. The inflow zone had the highest total number of species (24) with the forebay and transition zones having 23 species each. High numbers of lithophilic spawners (4-8), low percentages of omnivores (2-3 percent) and tolerants (2-3 percent), and high percentages of invertivores (58-89 percent) resulted in good scores for those metrics. The only apparent problems detected were a low abundance of fish in the inflow, low numbers of suckers in the transition zone, and poor health of largemouth bass in forebay and inflow areas.

Fish Tissue--Five channel catfish for screening purposes were collected in autumn 1991 from each of five locations (TRMs 23, 60, 100, 173, and 206). Fillets were composited by location, and analyzed for metals, PCBs and pesticides on EPA's Priority Pollutant List. Concentrations of all analytes were relatively low. In 1990 the PCB concentration of 0.9 $\mu g/g$ from TRM 173 was considered high enough to be of interest when resampled in autumn 1991. The concentration in 1992 at that location was 0.4 $\mu g/g$, similar to concentrations observed from this location in 1987, 1988, and 1989.

In 1992 a comparable set of catfish were sampled from these same locations (except TRM 85 was sampled instead of TRM 100 to coinside with the transition zone location). Again, concentrations of all analytes were low. One analyte of interest was lead with a concentration of 0.6 $\mu g/g$ at TRM 85. Similar levels have occurred sporadically with no pattern in locations over the five years screening samples have been collected from Kentucky Reservoir.

4.2 Pickwick Reservoir

4.2.1 Physical Description

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream, run-of-the-river reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is about 56,000 cfs which provides an average hydraulic retention time of about eight days. Additional information about reservoir characteristics is in table 3.1.

A major tributary, Bear Creek, joins the Tennessee River in Pickwick Reservoir at about mile 225. Bear Creek provides, on the average, about 2.5 percent of the flow through Pickwick Reservoir.

4.2.2 Reservoir Health

The ecological health of Pickwick Reservoir was generally good in 1992, similar to the conditions in 1991. DO was good at all locations in 1992. Sediment quality at the forebay was slightly improved in 1992; however, mercury in sediment was again found in 1992 (historical problem). Algal conditions were poor in 1992 at the transition zone due to high average summer concentrations and a major algal bloom which occurred in May on both Pickwick Reservoir and Wilson Reservoir. The benthos community at the inflow location downstream of Wilson Dam was improved in 1992 compared with 1991. This was due to a combination of using an improved evaluation system and actual improvements in the health of the community of bottom animals. The fish community evaluation at the forebay significantly decreased from good in 1991 to poor in 1992. For some reason, very few fish were collected in the forebay area in 1992. This location will be examined closely in 1993 fish sampling to see whether the 1992 results really represent conditions there.

There were only about 100 acres of aquatic plants on Pickwick Reservoir in 1992.

The monitoring location on Bear Creek showed fair ecological health in 1992. The fish community was good in 1992 and much improved over past years. Some impaired conditions in the sediment quality probably also adversely affect the bottom-dwelling animals. Given that Bear Creek contributes only about 2 percent of the flow to Pickwick Reservoir under average conditions, water entering the Pickwick Reservoir from Bear Creek will have some influence on the Bear Creek embayment but almost no effect on the main body of the reservoir.

4.2.3 Reservoir Use Suitability

Use Suitability Monitoring did not identify bacteriological or fish tissue contamination problems. There are no fish consumption advisories on Pickwick Reservoir based on fish collected from 1988 through 1991. Concentrations of metals, PCBs, and pesticides in composited catfish fillets were relatively low. Slightly elevated levels of chlordane seen in 1990 were not found in 1991. Monthly Vital Signs sampling at the forebay and transition zone in 1992 found only one bacteria sample above the detection limit, 27 colonies per 100 milliliters at the transition zone in January. Swimming areas at Pickwick Landing State Park and McFarland Park fully support water contact recreation as does the Goat Island Recreation Area based on 1989 survey results. Bacteriological sampling at recreation areas on Pickwick Reservoir is planned for 1993.

4.2.4 Synopsis of 1992 Conditions

Water--Surface temperatures ranged from 6.8°C in January to 30.1°C in July at the forebay and from 7.1°C to 29.2°C for the same months at the transition zone. The 30.1°C in July at the forebay was the highest temperature observed in the Tennessee River in 1992. Temperatures above 30.0°C exceed state of Alabama water quality criteria for fish and aquatic life. Values for DO at the 1.5-meter depth ranged from a high of 10.6 mg/L in January to a low of 7.0 mg/L in August at the forebay and from 10.6 mg/L in January to 5.9 mg/L in June at the transition zone. The minimum DO observed in Pickwick Reservoir in 1992 was 3.2 mg/L in July near the bottom at the forebay.

Temperature and DO data depict a seasonal warming and transient stratification of Pickwick Reservoir. Lower than normal winter and spring streamflows resulted in the early onset of thermal stratification. A maximum temperature differential (surface to bottom) of 6.1°C was measured at the forebay in April rather than later in the summer as is normally the case. In addition, DOs ranged from 9.6 to 6.2 mg/L (from the surface to the bottom) in April at the forebay. Flows increased in May, and throughout the summer were near or above normal levels, resulting in greater destratification of the reservoir. In July, an oxycline was observed at the forebay with DO ranging from 10.6 at the surface to 3.2 near the bottom. Throughout the year, the transition zone was well generally mixed and lacked any appreciable stratification.

Values of pH ranged from 7.0 to 9.1 on Pickwick Reservoir. Near surface pH values of 8.5 and higher (and DO saturation values exceeding 100 percent) were observed during periods of high photosynthetic activity in May and July at both the forebay and at the transition zone.

Average concentrations of total nitrogen (0.70 mg/L-forebay and transition zone) in Pickwick Reservoir were among the higher averages observed in the Tennessee River reservoirs in 1992.

High concentrations of chlorophyll-a were measured in May at the transition zone in Pickwick Reservoir (46 μg/L), coincident with DOs greater than 12 mg/L, pHs greater than 9.0, and oxygen saturations greater than 125 percent, all indicative of the occurrence of a major algal bloom (see discussion of chlorophyll-a concentrations and major algal bloom on Wilson Reservoir in May). Summer chlorophyll-a concentrations averaged about 11 μg/L at both Pickwick Reservoir sampling locations in 1992.

<u>Fecal Coliform Bacteria</u>--No bacteriological studies were conducted at swimming beaches on Pickwick Reservoir in 1992. Monthly Vital Signs sampling at the forebay and transition zone found only one bacteria sample above the detection limit, 27 colonies per 100 milliliters at the transition zone in January.

<u>Sediment</u>--The presence of mercury in sediments of Pickwick Reservoir was documented many years ago and remains of interest today. Concentrations of mercury in sediment were measured in Pickwick Reservoir at both the forebay and transition zone, 0.60 and 1.20 μg/g, respectively. The transition zone concentration was the highest mercury in sediment measured in 1992 at Vital

Signs reservoirs. Chemical analyses of sediments revealed no other metal or organic analyte to be a concern.

Experimental acute toxicity screening Microtox® tests indicated a potential for toxicity in test pore water (but not water column) from the forebay. Test results indicated an EC_{10} (the concentration indicated by literature to correlate with instream effects to invertebrates) of 24 percent after 15 minutes exposure. However, there was no confirmation of toxicity using rotifer testing. These results generally agree with 1990 and 1991 results when "an indication" of toxicity was found. Results from 1993 tests will continue to be closely scrutinized for confirmation of these results.

Particle size analyses showed sediments at the forebay were 99 percent silt and clay. Sediment composition at the transition zone was silt-65 percent and sand-36 percent.

Benthic Macroinvertebrates--The benthic communities at the forebay and transition zone were good, while the inflow rated as fair. The forebay site had 24 taxa and a total of 577 organisms/m^2. Coelotanyopus sp was the most numerous taxon present (32 percent of the total) followed by Hexagenia sp (22 percent) and Corbicula sp (17 percent). A total of 591 organisms/m^2 were collected in the transition zone and 26 taxa. The most dominant species were Corbicula sp with 32 percent of the total and Hexagenia sp with 20 percent. The inflow location was represented by mostly Corbicula (84 percent). There were 17 taxa and 760 organisms/m^2 collected, which was a substantial increase in density. Overall, Pickwick Reservoir collections increased in diversity and density in 1992.

Aquatic Macrophytes--There was an estimated 105 acres of submersed plants on Pickwick Reservoir in 1992, primarily in the upstream portion of Yellow Creek embayment. Historically, most of the aquatic vegetation on Pickwick Reservoir has been in Yellow Creek embayment, and spinyleaf naiad has been the most abundant macrophyte.

Fish Community--Fish collections at near shore areas (30 electrofishing transects) and offshore bottom areas (25 net-nights) from the three sampling areas on Pickwick Reservoir resulted in the collection of 1633 fish including 39 species. Clupeids were the dominant taxa present, accounting for 46 percent of the total sample. Other dominant taxa included bluegill (5 percent), largemouth bass (3 percent), and carp (3 percent). Fish abundance was greatest in the inflow zone (157), followed by the forebay (141), and transition zone (116). Health of largemouth bass was fair in the transition zone (FHAI=64) and poor in forebay (FHAI=69) and inflow zones (FHAI=77).

The quality of the littoral fish community in the inflow (RFAI=31) and transition (RFAI=29) zones rated fair while the forebay (RFAI=25) rated poor. Factors having the most negative influence on RFAI scores were low total numbers of fish, over-abundance of omnivorous individuals, and poor largemouth bass health. However, the inflow and transition zones scored good for lithophilic spawners, and the inflow exhibited high numbers of migratory and intolerant species. Compared to the other mainstream reservoirs, the forebay ranked in the lower third, and the transition and inflow zones ranked in the middle 30 percentile.

Fish Tissue--One composite sample of five channel catfish was collected at the forebay, transition zone, and inflow during both 1991 and 1992. Concentrations of all metals were low. Mercury was detected in most samples both years, but at relatively low concentrations (maximum of 0.24 μg/g at two locations in 1992). Pesticides and PCBs were generally low in 1991. In 1992 DDTr was relatively high at the inflow (2.4 μg/g) yet not detected at the other two locations. This is not thought to represent a problem because concentrations of this magnitude have not been observed in previous years of screening. It is possible that one of the catfish in the composite was from Wheeler Reservoir where there is a problem with DDT contamination in one area resulting in high concentrations in fish. Relatively high concentrations of chlordane in 1990 were not found in 1991 or 1992. PCBs were detected in all samples both years (range 0.2 to 0.7 μg/g) with concentrations tending to be higher at the inflow. Samples will be re-collected at the inflow site in autumn 1993 to ensure that a possible problem with DDTr, chlordane, or PCBs is not overlooked.

4.3 Wilson Reservoir

4.3.1 Physical Description

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 53,000 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

4.3.2 Reservoir Health

Ecological health of Wilson Reservoir was improved in 1992 compared to 1991 but still generally fair conditions exist. Low concentrations of DO (>1 mg/L) in the forebay of Wilson Reservoir were again observed during the summer months. A massive algal bloom occurred in May 1992, with very high chlorophyll-a concentrations. This, plus high summertime average chlorophyll-a concentrations, is indicative of an excessive algal activity and eutrophic conditions. A poor benthos community was found at the forebay, probably related to the low concentrations of dissolved oxygen near bottom during summer. Sediment quality at the forebay was good in 1992 indicating no impairment due to bottom substrates. This was an improvement over 1991 when fair sediment quality conditions were found. All ecological health indicators measured at the inflow location (DO, fish, and benthos) were good. There were only five acres of aquatic plants on Wilson Reservoir in 1992.

4.3.3 Reservoir Use Suitability

Use Suitability Monitoring found low or nondetectable levels of fecal coliform bacteria at the forebay during monthly sampling. There has been no recent sampling of recreation sites on Wilson Reservoir. PCBs were the subject of intensive investigations in Wilson Reservoir during the 1980s due to high levels observed then. Concentrations were highest when the study began in 1984 and decreased to nonproblematic levels in 1987. Concentrations increased slightly in 1989 and 1990, possibly due to heavy rainfall with resulting high runoff and reservoir flows. Relatively high concentrations of PCBs in 1991 may have been a carry-over from those two years. However, PCBs were below detection limits in the most recent set of samples in 1992.

4.3.4 Synopsis of 1992 Conditions

Water--Surface temperatures ranged from 7.2°C in January to 29.2°C in July at the forebay sampling location. Values for DO at the 1.5-meter depth ranged from a high of 13.1 mg/L in May (during a major algal bloom) to a low of 5.5 mg/L in August.

Temperature and DO data show seasonal warming and a weak springtime thermal stratification in 1992, due at least in part to the low streamflows from January through May. The greatest degree of thermal stratification was observed in April, when temperature ranged from 19.3°C (surface) to 13.0°C (bottom). Periods of DO stratification were observed in May, June, and July with DO differentials of greater than 5 mg/L observed during these three months. Dissolved oxygen concentrations near the bottom of Wilson Reservoir were measured at or below 1 mg/L during July. For the year, average DO concentrations in Wilson forebay (6.8 mg/L) were lower than at any other Vital Signs monitoring location on the Tennessee River.

Values of pH ranged from 6.9 to 9.8. In April, May, and July near-surface values of pH were greater than 8.5. These coincided with high photosynthetic activity, high temperatures, and high dissolved oxygen measurements.

In May, a major algal bloom was observed throughout the lower end of Wilson Reservoir. Chlorophyll-a was measured up to 146 μg/L, coincident with pHs greater than 9.5, DOs greater than 15 mg/L, and oxygen saturations greater than 150 percent. This chlorophyll-a concentration (146 μg/L) is the highest documented chlorophyll-a concentration ever measured in the main river portion of the Tennessee River, and was at least due in part to the low releases from Wilson Dam (i.e., high detention times) in the months of April and May. The predominant algae during this May bloom were Crytomonas, Stephanodiscus (diatom), and a variety of green algae. With the exception of Boone Reservoir in northeastern Tennessee and Beech Reservoir in west Tennessee, average chlorophyll-a concentrations on Wilson Reservoir were among the highest among the Vital Signs reservoirs in 1992. Summer chlorophyll-a averaged about 33 μg/L at the forebay of Wilson in 1992; however, excluding the extremely high chlorophyll-a concentration observed in May, the summer chlorophyll-a concentrations in Wilson forebay averaged about 11 μg/L.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches on Wilson Reservoir in 1992. Monthly Vital Signs sampling at the forebay found four of seven bacteria samples above the detection limit, the maximum was 20 colonies per 100 milliliters.

Sediment--Chemical analyses of sediments did not reveal any metal or organic analyte to be a concern. Particle size analysis showed forebay sediments were almost totally silt and clay (99 percent). In 1991, acute toxicity screening of the sediment pore water at the forebay found substantially reduced survival of rotifers (57 percent survival). In 1992, no acute toxicity was found in forebay sediment of Wilson Reservoir. Further sediment sampling and refinements in toxicity testing will help to more clearly define existing conditions in the forebay of Wilson Reservoir.

Benthic Macroinvertebrates--Compared to other mainstem reservoirs, the benthic community at the forebay of Wilson Reservoir was poor, while the community at the inflow was good. The forebay location had 12 taxa and 682 organisms/m^2 composed of mostly Chironomus (57 percent of the total) and Tubificidae (30 percent). The inflow location had 31 taxa and 1028 organisms/m^2. The Asiatic clam Corbicula sp was most dominant at the inflow comprising 48 percent of the total and Tubificidae was second (23 percent). Densities and diversity in the forebay were similar to 1991, however, the inflow diversity increased from 16 to 31 while densities remained the same.

Aquatic Macrophytes--An estimated five acres of spinyleaf naiad occurred on Wilson Reservoir in 1992. Other macrophytes such as Eurasian watermilfoil and muskgrass have historically occurred in small and localized populations.

Fish Community--Shoreline electrofishing (20 transects) and offshore gill netting (20 net-nights) at the forebay and inflow of Wilson Reservoir produced 2468 individuals of 35 species, and showed fish were most abundant in the inflow (83 percent of the total fish collected). Species representing the largest portion of the Wilson fish community included emerald shiner (35 percent), gizzard shad (30 percent), bluegill (10 percent), and largemouth bass (4 percent). Each of these species were at least twice as abundant in the inflow zone. Health of largemouth bass was poor in both forebay (FHAI=81) and inflow (FHAI=92) zones.

The 11 electrofishing RFAI metrics described the littoral fish community of the inflow zone (RFAI=41) to be good and the forebay (RFAI=33) fair. These ranked in the upper and middle 30 percentiles, respectively, when compared to the other ten run-of-the-river reservoir inflow and transition zones. Metrics that resulted in the better rating of the inflow over the forebay, despite the relatively short distance between these zones, included total abundance of individuals, higher percentage of invertivores, and more sucker and migratory spawning species. Both zones scored high for number of lithophilic spawning species and percent tolerant individuals.

Fish Tissue--Composited channel catfish samples were collected from the forebay and inflow areas in autumn 1991 and 1992. All analytes but PCBs in the 1991 samples were low or not detected. PCB concentrations in 1991 samples were 1.2 and 0.7 $\mu g/g$ at the forebay and inflow, respectively. The 1992 samples from both of these locations had PCB concentrations below the detection limit. Other analytes had low concentrations or were not detected.

A relatively high concentration of lead (0.75 $\mu g/g$) was found in one of the 1990 screening samples. High concentrations of lead were not seen in any of the 1991 or 1992 samples (maximum of 0.06 $\mu g/g$).

4.4 Wheeler Reservoir

4.4.1 Physical Description

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is about 51,000 cfs which provides an average hydraulic retention time of about 10-11 days. Information collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 307.5. Consequently, in 1992 the transition zone sampling location was relocated further downstream from TRM 307.5 to TRM 295.9.

The Elk River joins the Tennessee River in the downstream portion of Wheeler Reservoir at about mile 284 and provides, on the average, about 6 percent of the flow through Wheeler Reservoir.

4.4.2 Reservoir Health

The overall ecological health of Wheeler Reservoir was again evaluated as good in 1992, as it was in 1991. Despite fair evaluations for several ecological health indicators, particularly in the forebay area of Wheeler Reservoir, the absence of any poor ratings (plus the fact that most of the fair ratings were borderline to good) resulted in an overall good ecological health rating for Wheeler Reservoir in 1992. DOs were measured less than 2 mg/L near the bottom in the forebay in July. An large algal bloom also occurred in July, in the forebay, which resulted in a fair algal rating. The fish community evaluation was slightly lower at both the forebay and inflow in 1992 than in 1991. (Because of bad weather conditions on the scheduled sampling date, a representative fish community sample could not be collected at the transition zone.)

Aquatic macrophytes colonized about 4400 acres on Wheeler Reservoir in 1992, compared to about 3500 acres in 1991.

The monitoring site on the Elk River was ecologically poor in 1992. Nutrient concentrations were quite high, resulting from phosphorous-rich soils in the watershed, and these high nutrient inflows to Wheeler Reservoir from the Elk River can stimulate algal blooms. The Elk River benthic community at the fixed station sampling location was rated poor, probably due to a combination of only fair bottom conditions and regulated, cold water released from Tims Ford Dam. TVA is working to improve the releases from Tims Ford Dam. No fish samples were collected from the Elk River in 1992. The Elk River contributes about 6 percent of the flow to Wheeler Reservoir.

4.4.3 Reservoir Use Suitability

Use Suitability Monitoring did not identify concerns about bacterial levels at the forebay or transition zone. Monthly Vital Signs sampling at the forebay and transition zone found two of seven bacteria samples at or above the detection limit at each station. The maximum concentration was 109 colonies per 100 mL at the transition zone in June. No swimming beaches were sampled in 1992. The four swimming areas on Wheeler Reservoir fully support water contact recreation based on results from surveys in 1990.

The Alabama Department of Public Health advises that most fish species from within the Indian Creek embayment on Wheeler Reservoir should not be eaten due to DDT contamination. An intensive study was conducted in autumn 1991 to determine if high concentrations existed in fish from the Tennessee River in an area 15 miles downstream to five miles upstream of the Indian Creek embayment. Based on the 1991 results the public was further advised not to eat largemouth bass, channel catfish, and smallmouth buffalo from within one mile either side of the area where Indian Creek and the Tennessee River join. Other bottom feeding fish species (such as carp and suckers) from the area should also be avoided. Furthermore, channel catfish caught from the Tennessee River between Indian Creek and the Interstate 65 bridge should not be eaten. Fish were again collected from these areas in the Tennessee River in 1992 to continue examining DDT concentrations. The 1992 fish had much lower concentrations than those in 1991. A comparable study will be conducted in autumn 1993, and results will be available in 1994.

4.4.4 Synopsis of 1992 Conditions

Water--Wheeler Reservoir was generally well mixed and lacked persistent thermal stratification in 1992. Surface temperatures ranged from 6.5°C in January to 29.7°C in July at the forebay sampling location and from 6.4°C to 28.6°C for the same months at the transition zone. DO at the 1.5-meter depth ranged from 11.1 mg/L in January to 6.4 mg/L in September at the forebay and from 11.1 mg/L in January to 6.0 mg/L in June at the transition zone.

Temperature data for the period January through the end of September for both the forebay and the transition zone show seasonal warming and rather weak stratification of Wheeler Reservoir in 1992. Greatest temperature differentials of 3.5 and 3.3°C were measured in May and June at the forebay. An oxycline developed in May, June, and July at the forebay, with DO differentials of about 5.8, 6.9, and 8.2 mg/L and with minimum near-bottom DOs of 1.4 mg/L in July. The transition zone was well mixed and lacked any DO stratification with a minimum DO of 5.9 mg/L.

Values of pH ranged from 6.9 to 8.9 during 1992. Values of pH equal to or greater than 8.5 were observed in May, June, and July at the forebay, but no pHs exceeded 7.9 at the transition zone. During these same months (May, June, and July), DO concentrations measured at the forebay at the 1.5-meter depth exceeded saturation concentrations (>125 percent).

Ammonia nitrogen concentrations measured in Wheeler Reservoir, at both the forebay and the transition zone, were relatively high--higher than at any other Vital Signs Monitoring location on the Tennessee River in 1992. Ammonia nitrogen concentrations averaged approximately 0.10 mg/L at the forebay and 0.09 mg/L at the transition zone. These ammonia concentrations are consistent with the high ammonia concentrations also observed in 1990 and 1991. Given the volume of flow of the Tennessee River and the lack of any appreciable anoxia in Wheeler Reservoir, they are indicative of large point source waste discharge(s).

The highest chlorophyll-a concentrations were measured in June at the forebay (33 μg/L) and averaged about 11 mg/L at the forebay in 1992. However, very low chlorophyll-a concentrations were measured at the transition zone, with summer chlorophyll-a concentrations averaging only about 2-3 μg/L. At the present, the low chlorophyll-a concentrations measured at the transition zone on Wheeler Reservoir in 1992 are unexplained, given apparent adequate light and nutrients. TN/TP ratios varied between 6 and 20 and averaged about 12, and Secchi depths averaged over 1.3 meters, evidencing a lack of nutrient and/or light limitations and conditions that should be conducive to much higher algal activity. Future information will be closely studied to help understand this apparent unusual condition in the transition zone of Wheeler Reservoir.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches on Wheeler Reservoir in 1992. Bacteriological sampling at recreation areas on Pickwick Reservoir are scheduled in 1993. Monthly Vital Signs sampling at the forebay and transition zone found two of seven bacteria samples at or above the detection limit at each station. The maximum concentration was 109 colonies per 100 mL at the transition zone in June.

Sediment--Chemical analysis of sediments did not detect concentrations of any organic or metal analyte of concern. Toxicity tests revealed no indications of toxicity at either test location. Sediments were 98 percent silt and clay at the forebay and 61 percent silt and clay and 39 percent sand at the transition zone location.

Benthic Macroinvertebrates--On Wheeler Reservoir in 1992, the forebay and transition locations rated fair, while the inflow rated good. The forebay location had 14 taxa and 440 organisms/m^2, dominated by the chironomid Coelotanyopus sp (43 percent) and Tubificidae (24 percent). The transition zone had 23 taxa and 740 organisms/m^2. The dominant taxa were Corbicula sp which comprised 32 percent of the total followed by Hexagenia sp (18 percent) and Coelotanyopus sp (18 percent). The inflow had 26 taxa and 638 organisms/m^2, dominated by Corbicula (55 percent of the total). The forebay was similar in density and diversity to 1991, while the transition zone and inflow increased.

Aquatic Macrophytes--Aquatic plants increased from 3462 acres in 1991 to 4412 acres in 1992. Wheeler Reservoir had the second-largest amount of aquatic vegetation within the TVA system. Dominant submersed species were Eurasian watermilfoil and spinyleaf naiad. These were most abundant in shallow overbank habitats from TRM 297 upstream to TRM 309. Wheeler Reservoir also had large populations (1009 acres) of American lotus concentrated in Flint Creek embayment, overbank sloughs upstream of Flint Creek, and in Swan Creek embayment.

Fish Community--Fish data collected in near shore and offshore bottom areas showed that 998 individuals of 36 species were recorded in both electrofishing (20 transects) and gill netting (18 net-nights) samples. No fish community samples could be collected from the transition zone of Wheeler Reservoir in fall 1992, due to adverse weather conditions. Species distribution included 28 in the forebay and 29 in the inflow zone of the reservoir. Gizzard shad (38 percent) comprised the majority of the total individuals collected, followed by bluegill (9 percent), emerald shiners (6 percent), spotted bass (3 percent) and largemouth bass (2 percent). Health of largemouth bass as described by the FHAI was rated poor at both inflow (87) and forebay (69) sites.

RFAI analysis revealed the quality of the littoral fish community in the forebay (RFAI=37) to be fair, ranking in the upper one-third among other TVA mainstream forebays. However, the inflow (RFAI=27) was poor, ranking among the lowest scores when compared to other TVA mainstream reservoir inflows. Metrics contributing to the fair designation in the forebay were low percentage of omnivores, high percentage of invertivores, and a high number of lithophilic spawning species. The poor RFAI in the inflow was driven by fair ratings for most metrics and poor ratings for percentage of tolerant individuals, poor largemouth bass health, and low density of fish. The forebay also exhibited low numbers of individuals.

Fish Tissue--Composite catfish samples for screening purposes were collected from the forebay, transition zone, and inflow in autumn 1991 and 1992. Intensive studies were also conducted during this same time period to examine DDTr concentrations in a 20-mile stretch of Wheeler Reservoir near the Indian Creek embayment, located between the inflow and the transition zone. Three five-fish composites of channel catfish, largemouth bass, and smallmouth buffalo were collected from four locations for the intensive study.

Samples for screening purposes indicated all metals were relatively low during both 1991 and 1992. Most pesticides except DDTr were not detected. DDTr levels were low in 1991 (maximum 0.29 μg/g), contrary to high levels from those sites in 1990 (maximum 3.3 μg/g), with concentrations between these in 1992 (maximum 1.6 μg/g). High chlordane concentrations observed in 1990 were not found in either 1991 or 1992. Relatively high PCB concentrations reported for 1990 (maximum 1.4 μg/g) were again found in 1991 (maximum 1.3 μg/g), but generally lower levels were found in 1992 (maximum 0.8 μg/g). PCB concentrations during all years were higher at upstream locations.

Samples from the intensive study in 1991 found quite high concentrations of DDTr. At least one sample of one test species exceeded 5 μg/g at all four sites. Highest concentrations were in smallmouth buffalo (maximum 43 μg/g) from near the mouth of Indian Creek with lower concentrations at the upstream location and the location at the downstream end of the study reach. Largemouth bass tended to have lower concentrations than the other two species. Samples for the intensive study in autumn 1992 (samples actually collected in January 1993) had substantially reduced concentrations. Only two samples exceed 5 μg/g whereas 15 from 1991 exceeded that concentration. Also, the geographical pattern was not distinct in these samples. Because of the discrepancy between the two years, the intensive study will be repeated in autumn 1993.

4.5 Guntersville Reservoir

4.5.1 Physical Description

Guntersville Dam, located at TRM 349.0, creates a 76-mile-long reservoir which has a surface area of 67,900 acres and shoreline of 949 miles at full pool. Average annual discharge is about 41,500 cfs which corresponds to an average hydraulic retention time of about 12 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics; however, it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. Because of large areas of shallow water that preclude water level drawdowns for flood protection and aquatic plant control, drawdown on Guntersville Reservoir during winter months is nominal and is manifested in an abundance of aquatic macrophytes in the expansive, shallow overbank and embayment areas. Guntersville has the greatest areal coverage of aquatic plants of any TVA reservoir.

A large tributary joins the Tennessee River at about TRM 423, in the upstream portion of Guntersville Reservoir, and just downstream from Nickajack Dam. On the average the Sequatchie River contributes less than 2 percent to the total flow of the Tennessee River through Guntersville Reservoir.

(Data collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 396.8. Consequently, in 1992 the transition zone sampling location was relocated further downstream from TRM 396.8 to TRM 375.2.)

4.5.2 Reservoir Health

Ecological health conditions were good in Guntersville Reservoir in 1992. Addition of transition zone sampling information in 1992 with good health ratings for four of the five ecological health indicators (algae, oxygen, benthos, and sediment) plus improvements in several health indicators at the other locations, helped raise the overall ecological health evaluation from fair in 1991 to good in 1992. There were no poor ratings for any of the ecological health indicators either within the reservoir or on the Sequatchie River in 1992. DO was rated fair at the inflow to Guntersville Reservoir due to the release of water with DOs less than 5 mg/L from Nickajack Dam in July and August 1992. Benthos community evaluations were higher at both the forebay and the inflow in 1992, than in 1991. Although the fish community rated fair at all locations, the fish community score was only slightly lower than the level considered good.

Aquatic macrophytes increased from 5165 acres in 1991 to 5993 acres in 1992, with Guntersville Reservoir having greater macrophyte coverage than any other reservoir in the TVA system.

The ecological health of the Sequatchie River monitoring site was good in 1992. All ecological health indicators were either good or fair. Coal mining activities may be hindering the fish community and bottom dwelling animals as indicated by deposits of coal fines and other sediments.

4.5.3 Reservoir Use Suitability

There are no fish consumption advisories on Guntersville Reservoir. Channel catfish composites collected from Guntersville Reservoir in autumn 1990 had sufficiently high PCB concentrations to warrant further examination but were not high enough for the state to issue an advisory. Catfish collected from the same locations in 1991 and 1992 had progressively lower concentrations than those from 1990 with the 1992 concentrations generally indicative of "background" levels found in channel catfish throughout the Tennessee River. The six swimming areas on Guntersville Reservoir and the casual recreation area at Marshall County Park Number 1 all fully support water contact recreation, based on results from surveys conducted in 1992. In addition, the lower put-in and upper take-out access areas on the Sequatchie River fully support water contact recreation, based on 1992 survey results. In 1990 and 1992, Vital Signs Monitoring

1992 survey results. In 1990 and 1992, Vital Signs Monitoring identified the presence of fecal coliform bacteria at the forebay in excess of a water-contact recreation guideline of 200/100 mL on several sample dates. However, in all but one sample collected from both the forebay and transition zone locations in 1992, no fecal coliform bacteria were detected, giving evidence of improved conditions.

4.5.4 Synopsis of 1992 Conditions

Water--Guntersville Reservoir was well mixed and lacked any strong thermal stratification during 1992. Surface water temperatures ranged from 7.1°C in January to 28.2°C in July in the forebay and from 7.4°C to 28.5°C for the same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 10.7 mg/L in January to 6.4 mg/L in September at the forebay and from 10.7 mg/L in January to 5.6 mg/L in July at the transition zone.

Temperature data for the period January through the end of September for both the forebay and the transition zone depict the intermittent thermal stratification of Guntersville Reservoir in 1992. As with other mainstem reservoirs, low spring flows in 1992 encouraged maximum surface to bottom temperature differentials and stratification in April, evidenced in the forebay, where water temperatures ranged from 19.3°C at the surface to 14.0°C at the bottom. April through August showed the development of a persistent oxycline in the forebay, with surface DOs being 3.7, 4.5, 4.5, 3.9, and 2.8 mg/L (April through August, respectively) greater than bottom DOs. The minimum DO measured in Guntersville Reservoir in 1992 was 2.9 mg/L at the bottom in July in the forebay. The transition zone was well mixed throughout the year with a minimum DO of 5.4 mg/L measured in July at the bottom. Releases of water from Nickajack Dam were consistently below 5.0 mg/L in July, ranging from 4.2-4.9 mg/L, impacting the ecological health of the inflow site on Guntersville Reservoir. In addition, DOs of 3.2 and 4.0 mg/L were measured in August and September, respectively, in the releases from Nickajack Dam.

Values of pH ranged from 6.8 to 8.4. Surface water pH values in excess of 8.0 were observed in May and June at the forebay, but pHs did not exceed 7.8 at the transition zone. There was about a 23 percent decrease in average nitrite plus nitrate concentrations from 0.31 mg/L at the transition zone to 0.24 mg/L at the forebay (along with corresponding increases in organic nitrogen and organic carbon) suggesting the photosynthetic uptake of nutrients and primary production processes occurring in the lower end of Guntersville Reservoir.

At the forebay, the highest chlorophyll-a concentration of 12 μg/L was measured in August (average summer chlorophyll-a concentration was 6-7 μg/L in 1992). At the transition zone chlorophyll-a concentrations were lower, averaging about 4 μg/L. TN/TP ratios frequently exceeded 20 at both the forebay and transition zone, indicating conditions when phosphorus concentrations may have limited photosynthesis. Water clarity on Guntersville Reservoir in 1992 was the highest among the mainstem Tennessee River reservoirs, with average Secchi depths of 1.8 and 1.6 meters at the forebay and transition zone, respectively.

<u>Fecal Coliform Bacteria</u>--Bacteriological studies were conducted at six swimming beaches and three other locations on Guntersville Reservoir in 1992. Fecal coliform bacteria concentrations at the swimming beaches at Guntersville State Park, Honeycomb Campground, Jaycette Park, Carlisle Park, Siebold Creek, and Goosepond Creek and at the other three sites sampled were low, allowing fully supports water contact recreation classifications. Monthly Vital Signs sampling at the forebay and transition zone found one bacterial concentration at the detection limit (10 fecal coliform organisms/100 mL) but none above.

<u>Sediment</u>--Chemical analysis of sediments did not detect concentrations of any organic analyte of concern; however, zinc was detected in the forebay at a slightly elevated concentration of 280 mg/kg (dry weight). Toxicity tests revealed no indications of toxicity at either test location. Sediments were 93 percent silt and clay and 7 percent sand at the forebay, and 51 percent silt and clay and 49 percent sand at the transition zone location.

<u>Aquatic Macrophytes</u>--Aquatic macrophytes on Guntersville Reservoir increased from 5165 acres in 1991 to 5993 acres in 1992. The reservoir had the largest acreage of aquatic plants in the TVA system. In 1990 the reservoir was stocked with 100,000 triploid grass carp for aquatic vegetation control. About 93 percent of the total amount of vegetation was upstream of TRM 373 and primarily confined to shallow embayments and overbank areas adjacent to the river channel. Eurasian watermilfoil was the dominant submersed macrophyte species and colonized about 5400 acres in 1992. Only one acre of "topped out" hydrilla occurred on Guntersville Reservoir in 1992 compared to about 2900 acres in 1988 when aquatic vegetation peaked at about 20,200 acres.

<u>Benthic Macroinvertebrates</u>--The forebay and transition zone sampling locations had good benthic macroinvertebrate communities while the inflow benthic communities were fair. The

forebay had 748 organisms/m^2 and 15 taxa. The chironomid Coelotanyopus sp composed 38 percent of the total and Corbicula sp 26 percent. The transition zone had 1182 organisms/m^2 and 21 taxa. The dominant taxa were Corbicula sp (30 percent of the total), Musculium sp (23 percent) and Hexagenia sp (21 percent). The inflow zone was comprised of 41 taxa and 1719 organisms/m^2. The dominant species were Corbicula sp (56 percent of the total) and Tubificidae (20 percent). Compared with 1991, the forebay had a slight decrease in density in 1992; however, the transition zone and inflow both had a substantial increases in density and diversity.

Fish Community--Shoreline electrofishing (30 transects) and offshore gill netting (28 net-nights) produced 8441 fish representing 39 species in Guntersville Reservoir in 1992. Both sampling techniques showed fish abundances were lowest in the inflow zone (520) and highest in the forebay (6174). Emerald shiners were the dominant species, comprising 80 percent of the total collection, however, they were only recorded in the forebay and transition zone. When emerald shiners are discarded from the samples, fish abundance in the forebay and inflow zone are reversed resulting in the highest numbers in the inflow and lowest in the forebay. Other dominant species included 7 percent gizzard shad, 3 percent bluegill, and 1 percent each of largemouth and spotted bass, redear sunfish, yellow bass, and channel catfish. Curiously, largemouth bass were five times more abundant in the transition zone than the inflow zone or forebay. FHAI showed the health of largemouth bass in the transition zone (FHAI=76) was poor. Insufficient sample sizes in the inflow and forebay precluded determination of FHAIs.

Electrofishing RFAI analysis determined that fish communities in both the forebay (RFAI=39) and transition zone (RFAI=39) rated good while that present in the inflow zone (RFAI=27) scored poor. Compared to other mainstream reservoirs, the Guntersville forebay and transition zone were in the upper third and the inflow zone the lower third. Metrics contributing to the good designation for the forebay and transition areas were abundance of individuals, sunfish species (5-6), and percent omnivores (1-4 percent), invertivores (94-99 percent), and tolerants (0-1 percent). The poor designation for the inflow zone was attributed to high percentage omnivores (16 percent), and tolerants (24 percent), and low percentage invertivores (42 percent).

Fish Tissue--Composite catfish samples were collected from the forebay, transition zone, and near the inflow in autumn 1991 and again in autumn 1992. One reason for resampling was that relatively high PCB concentrations of chlordane and PCBs had been found in 1990 (chlordane levels at the forebay were 0.10 $\mu g/g$ and those from near the inflow were 0.11 $\mu g/g$; whereas, PCB concentrations at these two locations were 1.2 and 1.3 $\mu g/g$, respectively). Chlordane was not detected in any of the 1991 or 1992 samples and PCB concentrations decreased progressively from year to year (maximum 0.9 $\mu g/g$ in 1991 and 0.4 $\mu g/g$ in 1992). Metals were relatively low during all years at all locations.

4.6 Nickajack Reservoir

4.6.1 Physical Description

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is approximately 35,500 cfs which provides average hydraulic retention time of only about three-four days, the shortest retention time among the reservoirs monitored in this program.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sampling sites exhibited quite similar water quality conditions. This is not unexpected, given that the two sites are relatively close together (separated by only 7.5 river miles), and Nickajack is a very well-mixed, run-of-the-river reservoir (average hydraulic retention times of three-four days). Therefore, sampling at the transition zone in Nickajack Reservoir was discontinued for 1992 monitoring.

4.6.2 Reservoir Health

Nickajack Reservoir had a good ecological health rating in 1992, the same as in 1991. The only poor rating was for DO at the inflow site on the upper end of Nickajack Reservoir. This was due to low DOs in the releases from Chickamauga Dam in July and August, 1992. DOs of 2.7, 3.8, and 4.5 mg/L were measured during these months - not low enough to cause mortality, but low enough to diminish the ecological health of the reservoir. An improvement in sediment quality was found in 1992 compared to 1991 when sediment quality rated fair. Survival of test organisms was 100 percent in forebay sediment in 1992. The fish community at the forebay showed a low number of species and a low number of fish.

Aquatic macrophytes on Nickajack Reservoir declined from 832 acres in 1991 to 583 acres in 1992.

4.6.3 Reservoir Use Suitability

The Tennessee Department of Environment and Conservation has issued an advisory that catfish should not be eaten by children, pregnant women, and nursing mothers because of PCB levels, other individuals should limit consumption to no more than 1.2 pounds per month. Fish tissue studies in autumn 1991 found PCB concentrations comparable to previous years (generally about 1 $\mu g/g$). Fillets from catfish collected autumn 1992 had PCB concentrations about half those previously found in the five years of fish tissue studies on Nickajack Reservoir. The study will be repeated in autumn 1993 to determine if lower PCB concentrations are found again. Monthly Vital Signs sampling at the forebay in 1992, found very low bacterial concentrations, all at or below the detection limit. Based on 1992 recreation survey results, three of the four swimming areas on Nickajack Reservoir fully support water contact recreation. Smith's Camp-On-The-Lake partially supports water contact recreation due to periodically high fecal coliform concentrations attributed to high populations of ducks and geese. The informal swimming areas on North Chickamauga Creek at Bethel Bible Village and Hixson Greenway partially support recreation due to high fecal coliform bacteria concentrations after rain. This reach of the creek is also a popular canoeing stream. This evaluation is based on surveys conducted in 1992. Based on 1992 survey results for South Chickamauga Creek, the canoeing area near Graysville partially supports recreation after rain. This creek does not support water contact recreation at Ringgold.

4.6.4 Synopsis of 1992 Conditions

Water--Surface water temperatures ranged from 6.8°C in January to 27.6°C in July in the forebay; and values for DO at the 1.5-meter depth ranged from 11.4 mg/L in January to 5.5 mg/L in September at the forebay.

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only three to four days (table 3.1), results in it being the best mixed of any of the

Vital Signs reservoirs. Temperature and DO data reflect a lack of stratification in Nickajack Reservoir in 1992, with the exception that in April, during low flow conditions on the Tennessee River, a maximum temperature differential (surface to bottom) of 3.8°C was measured at the forebay. During the same month, the maximum DO differential was 2.8 mg/L. In all other months the reservoir was well mixed. The minimum DO measured in Nickajack Reservoir in 1992 was 5.0 mg/L, at the bottom of the forebay, in July. DOs of 2.7, 3.8, and 4.5 mg/L were measured in the releases of water from Chickamauga Dam in July and August.

Values of pH and conductivity varied over a rather narrow range, from 7.1-8.2 and from about 160-190 µmhos/cm, respectively. At the forebay, the highest chlorophyll-a concentration of 9 µg/L was measured in April and averaged about 4 µg/L in 1992. Values of pH of 8.2 and DO saturation of 105-110 percent (which were the highest pH and DO saturations observed in Nickajack Reservoir in 1992) were measured in April coincident with the high chlorophyll-a observation at the forebay.

<u>Fecal Coliform Bacteria</u>--Bacteriological studies were conducted at four swimming beaches and three other locations on Nickajack Reservoir in 1992. Fecal coliform bacteria concentrations at the swimming beaches at Shellmound Recreation Area, Marion County Park, and Maple View Public Use Area, and at the three nonswimming areas were low, allowing fully supports classifications. Fecal coliform bacteria concentrations were high at Smith's Camp-On-The-Lake during and after rain, creating a does not support water contact recreation classification. Monthly Vital Signs sampling at the forebay found two bacterial concentrations at the detection limit but none above.

<u>Sediment</u>--In 1992 sediment samples collected from Nickajack forebay were tested for toxicity but not analyzed for heavy metal concentrations. (Elevated concentrations of lead, copper and zinc were found in the forebay sediment of Nickajack Reservoir in 1990 and 1991. Future sampling and analyses of sediment in Nickajack forebay for heavy metals is planned in 1993.) No sediment toxicity was found in 1992 for Microtox® nor Rotifer survival tests, which is an improvement over previous years' results. In 1990 results from the Microtox® acute screening test identified a toxic response to sediment pore water from the forebay. This appeared to be related to metal toxicity. Results from the 1991 acute toxicity tests did not find toxicity in the Microtox® test but did in the Rotox® test. Refinements in these indicator tests in future years will continue to be made, and the results will be closely examined in association with sediment chemistry and benthic macroinvertebrate results to better evaluate the quality of Nickajack Reservoir sediment.

Benthic Macroinvertebrates--The benthic macroinvertebrate community in the forebay of Nickajack Reservoir was rated good, represented by 18 taxa and 785 organisms/m^2. The dominant species in the forebay were Hexagenia sp (40 percent) and Corbicula sp (19 percent). The benthos community at the inflow rated fair. Corbicula sp dominated the inflow (56 percent), which had 26 taxa and 904 organisms/m^2. The number of taxa did not significantly change at either location between 1991 and 1992, however, density (number of organisms per square meter) was substantially higher in the inflow in 1992 compared with 1991.

Aquatic Macrophytes--Aquatic plants on Nickajack Reservoir declined from 832 acres in 1991 to 583 acres in 1992. Eurasian watermilfoil was the dominant macrophyte with other species such as American pondweed, naiads, and coontail occurring in mixed colonies with watermilfoil. Aquatic macrophytes were most abundant from TRM 425 upstream to TRM 440. The 1992 macrophyte coverage on Nickajack Reservoir was at its lowest level in more than a decade.

Fish Community--Fish collections in the littoral (20 electrofishing transects) and offshore/benthic areas (16 net-nights) of Nickajack Reservoir found fish to be more concentrated in the inflow zone (719) than the forebay (598). Brook silverside was the most abundant species (comprising 28 percent of the overall sample), followed by gizzard shad (18 percent), bluegill (15 percent), freshwater drum (8 percent), spotted bass (8 percent) and largemouth bass (4 percent). Health of largemouth bass was good in both the forebay (FHAI=23) and inflow areas (FHAI=24).

The quality of the littoral fish communities of Nickajack Reservoir was fair in the forebay and good in the inflow zone, based on the electrofishing RFAI. The inflow zone scored a 45, the highest value recorded in all TVA reservoirs. The forebay RFAI score of 33 was in the middle 30 percentile when compared to other mainstream forebays. Three metrics were considered good in both the forebay and inflow zones; low percentage omnivores, high percentage invertivores, and FHAI indices rated as good. The inflow had six metrics rated good, five rated fair, and no poor ratings. The forebay exhibited a relatively even distribution between the 11 metrics with four good, three fair, and four poor designations. Metrics contributing poor values for RFAI in the forebay were low diversity and abundance, and inadequate numbers of suckers and migratory spawning species.

Fish Tissue--The PCB concentration in channel catfish has averaged about 1.0 $\mu g/g$ over the last three years. The Tennessee Department of Environment and Conservation (TDEC) has issued a precautionary advisory due to PCB contamination in catfish from Nickajack Reservoir. This means that children, pregnant women, and nursing mothers should not consume catfish, and all others should limit consumption to 1.2 pounds per month.

Fish tissue studies conducted in autumn 1991 were aimed at examining the long-term trend of PCB concentrations in channel catfish and developing a data base for carp and smallmouth buffalo. Ten individuals of all three species were collected at two sites, one near the forebay, and the other in the upper end of the reservoir about 13 miles downstream of the inflow. PCB concentrations in channel catfish were similar to those found in previous years - the average at the forebay was 1.5 $\mu g/g$ and the range was 0.3 to 3.6 $\mu g/g$, and the average at the upper reservoir location was 0.9 $\mu g/g$ and range 0.2 to 1.9 $\mu g/g$. PCB concentrations in carp were relatively low at the forebay (average 0.3 $\mu g/g$ and maximum 0.8 $\mu g/g$) but elevated at the upper location (average 1.2 $\mu g/g$ and maximum 2.7 $\mu g/g$). Concentrations in smallmouth buffalo were relatively low at both locations (average 0.2 and 0.4 $\mu g/g$ at both locations).

Channel catfish and carp were sampled at the same locations in autumn 1992. The 1992 study also included collection of striped bass (including hybrid striped bass x white bass) from just downstream of Chickamauga Dam. PCB concentrations in the catfish and carp were substantially reduced (about half) from those previously found. The average for channel catfish was 0.4 and 0.5 $\mu g/g$ (maximum 0.8 $\mu g/g$) at the forebay and upper location, respectively. Concentrations in carp were similar to those in catfish. Highest concentrations were found in striped bass (average 0.8 $\mu g/g$ and maximum 1.1 $\mu g/g$). The reduced concentrations in catfish and carp need to be verified, so these species, along with striped bass, will be resampled in autumn 1993.

Chlordane concentrations in catfish have also been generally elevated in previous studies. Concentrations in the above fish were lower in 1991 than in previous studies and even lower in 1992 than 1991. Fish to be collected in autumn 1993 will be analyzed for chlordane in addition to PCBs.

4.7 Chickamauga Reservoir

4.7.1 Physical Description

Chickamauga Reservoir can be described as an "average" mainstream Tennessee River reservoir. Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is approximately 34,000 cfs which provides an average hydraulic retention of nine to ten days (table 3.1).

A major tributary to the Tennessee River, the Hiwassee River, flows into the middle portion of Chickamauga Reservoir at about TRM 499. The flow from the entire Hiwassee River watershed contributes approximately 16.5 percent of the flow through Chickamauga Reservoir. The Hiwassee River just below Appalachia Dam (which does not include any flow from the Ocoee River or any other downstream tributaries) contributes about 6.5 percent of the flow of the Tennessee River through Chickamauga Reservoir.

4.7.2 Reservoir Health

The overall ecological health rating for Chickamauga Reservoir was good in 1992, although only marginally so. Several health indicators scored lower in 1992 than in 1991. Sediment quality ratings changed from good in 1991 to poor in 1992 at the forebay and transition zone. Both of the tests used to evaluate sediment quality: chemical examination for heavy metals; and survival of test organisms in water extracted from the sediments (Microtox® and Rotox®), indicated poor conditions at both locations tested in 1992. Elevated concentrations of copper and zinc were found in the sediment in Chickamauga Reservoir. Both Microtox® and Rotox® tests showed low survival for the test organisms at the forebay, indicating potential sediment toxicity. Rotox® tests also indicated potential sediment toxicity at the transition zone.

DO was rated fair at the transition zone because DO was measured less than the state standard of 5 mg/L at the five-foot depth in September. DO was rated fair at the inflow to Chickamauga Reservoir due to the release of water with DOs less than 5 mg/L from Watts Bar Dam in July 1992. A poor benthic community was also found in the inflow, with a small number of benthic macroinvertebrate taxa. A representative fish community sample could not be collected at the transition zone in 1992 because of particularly adverse weather conditions during the field survey.

Aquatic macrophytes on Chickamauga Reservoir covered 387 acres in 1992 compared to 680 acres in 1991. Aquatic macrophytes peaked at about 7500 acres in 1988 and have continuously declined since then.

The ecological health of the fixed station monitoring site on the Hiwassee River was good in 1992. All ecological health indicators (nutrients, sediment quality, benthic community, and fish community) rated either good or fair.

4.7.3 Reservoir Use Suitability

There are no fish consumption advisories for Chickamauga Reservoir. Fillets from Chickamauga Reservoir catfish have been examined for several years as part of a variety of studies. Study results have indicated no consistent or reservoir-wide problems. Results from most of these studies have usually found higher concentrations of PCBs in catfish from the inflow area than from other sites in the reservoir. An intensive study was conducted in autumn 1990 because of the PCB problems upstream in Watts Bar Reservoir and downstream in Nickajack Reservoir. Ten catfish were collected from five locations and examined individually. Average PCB concentrations were relatively low in all samples with many samples having less than detectable concentrations. Channel catfish were collected for screening purposes in autumn 1991 and autumn 1992 from the inflow, transition zone, and forebay. In 1991 concentrations of all analytes from all locations were low, except PCBs at the inflow (1.2 μg/g). This was also the case in 1992, except even the PCB concentration at the inflow was low (0.7 μg/g) relative to most previous studies. No bacteriological studies were conducted at swimming beaches on Chickamauga Reservoir in 1992. However, the most recent data show that swimming areas previously tested on Chickamauga Reservoir fully support water contact recreation. The public use area near the dam and Lake Junior were surveyed in 1989 and seven swimming areas were surveyed in 1990, and all were found safe for water contact recreation at that time. Monthly Vital Signs sampling in 1992, at the forebay and transition zone in the open water portion of Chickamauga Reservoir, found all samples at or below the detection limit.

4.7.4 Synopsis of 1992 Conditions

Water--Surface temperatures ranged from 6.8°C in January to 28.0°C in July in the forebay and from 6.1°C to 26.1°C for the same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 11.4 mg/L in January to 5.4 mg/L in September at the forebay and from 11.5 mg/L to 4.6 mg/L for these same months at the transition zone. The 4.6 mg/L concentration of DO at the 1.5-meter depth is the lowest in-reservoir DO measured at the 1.5-meter depth on any of the Vital Signs reservoirs in 1992, and is less than the state of Tennessee minimum water quality criteria for fish and aquatic life of 5.0 mg/L. The lowest measured DO in Chickamauga Reservoir in 1992 was 2.8 mg/L, found at the bottom of the forebay in July.

Like many other mainstem Tennessee River reservoirs, Chickamauga is generally well mixed and lacks any strong thermal stratification. However, the low flows of the Tennessee River system in April and early May facilitated the development of a weak thermocline and oxycline in these months at both the forebay and transition zone sampling locations, in 1992. Maximum temperature differentials (surface to bottom) of 4.5°C and 3.0°C were observed at the forebay, in April and May, respectively. At the transition zone, in April and May, maximum temperature differentials of 2.4°C and 3.0°C, respectively, were measured. During these same two months, oxygen differentials of 3.2 mg/L and 5.8 mg/L, respectively, were measured at the forebay; and, 3.3 mg/L and 4.7 mg/L, respectively, were measured at the transition zone. (The larger oxygen differentials measured in May were a result of high DOs at the water surface during a period of high photosynthetic activity.) Minimum DOs measured in

Chickamauga Reservoir in 1992 were 2.8 mg/L and 3.5 mg/L, at the bottom of the forebay and the transition zone, respectively, in July.

Values of pH ranged from 7.0 to 8.6. Conductivity ranged from about 155 to 195 μmhos/cm, and averaged about 170 μmhos/cm. Comparison of pH and conductivity at the transition zone with upstream pH and conductivity at Watts Bar Dam forebay indicates these are lowered by the soft water inflows of the Hiwassee River to Chickamauga Reservoir, about nine miles upstream of the transition zone.

Average total nitrogen concentrations in Chickamauga Reservoir were among the lowest measured at Vital Signs Monitoring locations on the Tennessee River in 1992. In addition, both total phosphorus and dissolved orthophosphorus concentrations were also among the lowest observed at any of the Vital Signs Monitoring locations on the Tennessee River.

The highest chlorophyll-a concentrations were measured in May, 12 μg/L and 7 μg/L, respectively, at the forebay and transition zones. Concentrations of chlorophyll-a averaged 6-7 μg/L at the forebay and 4-5 μg/L at the transition zone in 1992.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches on Chickamauga Reservoir in 1992. Monthly Vital Signs sampling at the forebay and transition zone found the June bacteria samples at the detection limit at each station. All other samples were below the detection limit.

Sediment--As in 1991, sediment samples collected in Chickamauga Reservoir in 1992 had slightly elevated concentrations of copper and zinc. In 1991, screening tests did not identify any potential toxic conditions. However in 1992, sediment collected from the forebay showed toxic effects on test organisms for both the Microtox® test (EC_{10}=13 percent) and the Rotox® test (rotifer survival=56 percent); and sediment collected from the transition zone also showed toxic effects on test organisms for the Rotox® test (rotifer survival=87 percent).

Particle size analysis showed sediments were 97 percent silt and clay at the forebay; and transition zone sediments were mostly silt and clay (80 percent) and sand (20 percent).

Benthic Macroinvertebrates--The forebay and transition zone benthic macroinvertebrate communities rated good, while the inflow communities rated poor. The forebay had 13 taxa and 900 organisms/m^2. The most numerous taxa collected were the mayfly Hexagenia sp (36 percent of the total), the chironomid Coelotanyopus sp (23 percent), and the asiatic clam Corbicula sp

(17 percent). The transition zone which had an average number of taxa (14) and had the greatest number of organisms collected (1312 per square meter) among all the Vital Signs transition zones sampled in 1992. Hexagenia sp accounted for 32 percent of the total while Sphaeriidae and Corbicula sp accounted for an additional 19 and 18 percent, respectively. The Chickamauga Reservoir inflow site had the fewest taxa (12) from among the Vital Signs inflow sites sampled in 1992; however, this is an increase at this site over the 1990 and 1991 collections. The number of organisms (933 per square meter) also increased substantially from previous years with 80 percent of the species collected being Corbicula sp. The forebay and transition zone densities slightly increased while the number of taxa remained similar.

Fish Community--Fish data collected in littoral (20 electrofishing transects) and offshore zones (15 net-nights) of Chickamauga forebay resulted in the collection of 37 species (1737 individuals). Emerald shiner was the most abundant species (collected at the rate of 43 per 300 meter transect), accounting for 25 percent of the total number of fish collected. Bluegill comprised 23 percent of the samples, gizzard shad (17 percent), largemouth bass (7 percent), smallmouth bass (6 percent) and spotted bass (4 percent). Due to large numbers of emerald shiners, fish abundance was twice as great in the forebay as the inflow. If emerald shiners are disregarded, the forebay still contained one-third more individuals than the inflow. A representative sample could not be collected in the transition zone of Chickamauga Reservoir in fall 1992 due to adverse weather conditions on the day of the survey. Electrofishing RFAI analysis showed a fair quality littoral fish community in both the inflow zone (RFAI=35) and forebay (RFAI=35). Both areas of Chickamauga Reservoir ranked in the middle 30 percentile when compared to mainstream reservoirs. Metrics receiving good rankings for both included percent omnivores, invertivores, and tolerant individuals. Few number of sucker species were present at either location resulting in poor scores for that metric. The health of largemouth bass was fair at both the inflow zone (FHAI=52) and forebay (FHAI=54).

Fish Tissue--There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA Priority Pollutant List). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 $\mu g/g$ at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 $\mu g/g$ at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

4.8 Watts Bar Reservoir

4.8.1 Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are Watts Bar Dam (located at TRM 529.9), Fort Loudoun Dam (located at TRM 602.3), and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,800 cfs providing an average hydraulic retention time of about 18 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone sampling location in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the inflow on the Tennessee River and the inflow on the Clinch River. Water entering from the Clinch River arm from Melton Hill Reservoir is quite cool due to the hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

A major tributary to the Clinch River arm of Watts Bar Reservoir is the Emory River which supplies on the average about 5 percent of the total flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

4.8.2 Reservoir Health

The ecological health of Watts Bar was fair in 1992, same as in 1991. During both years this fair rating was only slightly below the level considered good. Algae was rated good at both the forebay and transition zone locations sampled in 1992. The sediment quality testing at the forebay and the transition zone in 1992 found low survival of test organisms and high concentrations of either ammonia or zinc. In August, concentrations of dissolved oxygen were less than 5 mg/L in the Tennessee River inflow to Watts Bar Reservoir due to the release of water with low DOs from Fort Loudoun Dam. Bottom-dwelling animals rated poor in both 1992 and 1991 at the Tennessee River inflow to Watts Bar Reservoir, possibly related to the low DOs from Fort Loudoun Dam.

Aquatic plants have declined from about 700 acres in the late 1980s to about 10 acres in 1992.

The overall ecological health of the Emory River at the fixed station monitoring site was fair in 1992. The primary problem was with poor sediment quality, evidenced by poor survival of test organisms, suggesting that toxicity may be emanating from active and abandoned coal mines in the watershed.

4.8.3 Reservoir Use Suitability

Use Suitability Monitoring activities have not identified any bacteriological problems on Watts Bar Reservoir. The swimming areas at Roane County Park and Riley Creek campground fully support recreation. The informal recreation area near the upper end of Caney Creek embayment partially supports recreation. These evaluations are based on 1990 survey results. Bacteriological sampling in 1992 on Watts Bar Reservoir was limited to midchannel collections in association with Vital Signs Monitoring activities. Fecal coliform bacteria were below levels of detection in all samples.

As a result of PCB contamination, the Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of several fish species from Watts Bar Reservoir. In the Tennessee River portion catfish, striped bass, and striped bass/white bass hybrids should not be eaten. Also a precautionary advisory (children and pregnant or lactating women do not eat fish; all others limit fish consumption to 1.2 pounds per month) is in effect for largemouth bass, white bass, sauger, carp and smallmouth buffalo. In the Clinch River arm striped bass should not be eaten and a precautionary advisory is in effect for catfish and sauger.

Also, TDEC has issued a do not eat advisory for fish taken from the East Fork of Popular Creek due to mercury, metals, and organic chemical contamination.

4.8.4 Synopsis of 1992 Conditions

Water--Surface water temperatures ranged from 6.0°C in January to 27.3°C in July in the forebay and from 6.2°C to 26.3°C for these same months at the transition zone. Values for DO at the 1.5-meter depth ranged from 11.6 mg/L in January (as well as 11.6 mg/L in April due to high photosynthetic activity) to 6.3 mg/L in September at the forebay; and, from 11.4 mg/L in January to 5.8 mg/L in September at the transition zone. The minimum observed DO concentration in Watts Bar Reservoir in 1992 was 0.6 mg/L at the bottom of the forebay in July.

Temperature and dissolved oxygen data show that during the summer of 1992, Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification in the forebay. Surface to bottom temperature differentials (ΔTs) were 7.0°C in April (during the period of low flows) and exceeded 6°C in May and June. DO versus depth data showed a rather strong oxycline to develop in the forebay of Watts Bar Reservoir from May through August. During these four months surface to bottom differences in DO were consistently greater than 7.0 mg/L, and near bottom DO concentrations in the hypolimnion were less than 1 mg/L in July. The transition zone was much more well mixed during the summer of 1992. Maximum ΔTs were 4.1°C (in April) and the minimum bottom DO measured was 5.5 mg/L (in September).

Values of pH ranged from 6.7 to 9.1 on Watts Bar Reservoir. Throughout the summer (April-August) near surface values of pH in the forebay were often high, exceeding 8.5, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/L at the forebay and 0.033 mg/L at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations. In addition, the average dissolved orthophosphorus concentrations of 0.008 mg/L and 0.010 mg/L, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1992.

The highest chlorophyll-a concentrations were measured in June at the forebay (14 μg/L) and in May at the transition zone (14 μg/L). Surface concentrations of chlorophyll-a averaged about 7 μg/L at the forebay and about 8 μg/L at the transition zone in 1992. The high TN/TP ratios observed at the transition zone indicate the possibility of phosphorus limitation on primary productivity.

Forebay Secchi depth and suspended solids measurements averaged 1.4 meters and 4.9 mg/L, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1992.

Fecal Coliform Bacteria--These were no swimming beaches on Watts Bar Reservoir examined as part of this monitoring program in 1992. (The swimming areas at Roane County Park and Riley Creek campground were sampled in 1990, at which time they fully supported water contact recreation. The informal recreation area near the upper end of Caney Creek embayment partially supports recreation, based on 1990 survey results.) Monthly samples collected in midchannel of Watts Bar Reservoir, at the forebay and transition zone as part of the 1992 Vital Signs Monitoring activities, all had concentrations at or less than the detection limit (10 fecal coliform colonies per 100 mL).

Sediment--Slightly elevated concentrations of mercury were detected in the sediment of Watts Bar Reservoir in 1992. Concentrations of 0.50 and 0.60 mg/kg were measured in the forebay and transition zone, respectively. The most likely source of this contamination is past operations at Oak Ridge National Laboratory where major environmental cleanup activities are now underway. In addition, elevated sediment zinc concentrations (220 mg/kg) were found in the transition zone, and high concentrations of un-ionized ammonia (470 μg NH_3/L) in sediment pore water were found in the forebay of Watts Bar Reservoir. Sediments were almost entirely silt and clay (97-98 percent) at both the forebay and transition zone.

The toxicological screening of sediment using rotifers (Rotox®) and light emitting bacteria (Microtox®) in Watts Bar Reservoir in 1992 found indications of toxicity at both locations. Low survival of rotifers (50 percent survival) was found using sediment pore water collected in the forebay of Watts Bar Reservoir, and Microtox® tests provided an indication of toxicity in sediment pore water collected at the transition zone.

Benthic Macroinvertebrates--In 1992, the forebay area of Watts Bar Reservoir and the Clinch River inflow had fair benthic communities. The transition zone had a good benthic community, while the Tennessee River inflow had a poor benthic community.

The forebay had 19 taxa and 693 organisms/m^2 which is an increase from 1991. Tubificidae comprised 41 percent of the organisms collected and Chironomus sp 27 percent. The transition zone density (868 organisms/m^2) and number of taxa (16) were similar to 1991 with the most numerous taxa being Musculium sp (34 percent) and Hexagenia sp (27 percent). The Tennessee River inflow location had 23 taxa and 547 organisms/m^2, which was an increase in number of taxa compared to 1991, but similar densities. The dominant taxon was Corbicula sp (62 percent). The Clinch River had 20 taxa and 335 organisms/m^2 dominated by Corbicula sp (43 percent) and the chironomid Dicrotendipes sp (28 percent).

Aquatic Macrophytes--Aquatic plants have declined from about 700 acres in the late 1980s to an estimated 10 acres in 1992. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community--Shoreline electrofishing (40 transects) and offshore gill netting (46 net-nights) sampled a total of 4081 fish represented by 41 species. Two species made up the majority of the overall sample: gizzard shad (54 percent) and bluegill (13 percent). These species were followed in abundance by emerald shiners (4 percent), brook silversides (2 percent), and largemouth bass (1 percent). Fish were most abundant in the Clinch River inflow zone (1565) followed by the Tennessee River inflow zone (1316), transition zone (769), and forebay (521). Number of taxa present ranged from 23 in the Clinch River inflow zone to 38 in the Tennessee River inflow zone. FHAI analysis found largemouth bass health to be fair in the forebay (FHAI=53) and transition zone (FHAI=67) and poor in the Tennessee River inflow zone (FHAI=73). No FHAI was possible in the Clinch River inflow zone due to low numbers of largemouth bass collected.

RFAI analysis of shoreline electrofishing data indicated fair littoral fish communities in the two inflow zones (Clinch River Arm RFAI=37, Tennessee River Arm RFAI=37) and the transition (RFAI=31). The forebay fish community was poor (RFAI=27). Compared to respective zones of other mainstream reservoirs, both inflow zones ranked in the upper third, while the forebay and transition zone ranked in the middle 30 percentile. Conditions exhibited in the two inflow stations indicated more species and more diversity in sucker, intolerant, migratory spawning, and lithophilic spawning species than either the transition zone or forebay. Sunfish diversity was rated good in the transition zone, forebay, and Tennessee River inflow. Metrics contributing to the poor forebay designation were a high percentage of tolerant individuals, low fish abundance, and low numbers of sucker, migratory spawning, intolerant, and lithophilic spawning species.

Fish Tissue--Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public not to eat certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and largemouth bass) were reexamined in autumn 1991 as part of the continuing study to remain abreast of conditions in this reservoir. These fish were examined individually for PCBs. Average PCB concentrations among sample sites ranged 1.1 to 2.6 $\mu g/g$ for channel catfish (eight locations), 0.6 to 2.4 $\mu g/g$ for striped bass (three locations), 0.1 to 0.8 $\mu g/g$ for sauger (three locations), and 0.3 to 0.5 $\mu g/g$ for largemouth bass (four locations). (Note: some of the above channel catfish data and all largemouth bass data are part of a Department of Energy study on Watts Bar Reservoir and are still considered preliminary.) In 1992 three of the above four species were reexamined. White bass were examined in 1992, and largemouth bass were not. Average PCB concentrations among sample sites were 0.4 to 1.9 $\mu g/g$ for channel catfish (five sites), 1.0 to 1.1 $\mu g/g$ for striped bass (two sites), 0.2 to 0.6 $\mu g/g$ for sauger (three sites), and the average for white bass at the single location was 0.7 $\mu g/g$. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from the above referenced DOE study.

4.9 Fort Loudoun Reservoir

4.9.1 Physical Description

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 15,700 cfs which provides an average hydraulic retention time of about 12 days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments with each having long retention times. Both of these deep storage impoundments become strongly stratified during summer months resulting in the release of cool, low DO, hypolimnetic water during operation of the hydroelectric units. Although some warming and reaeration of the water occurs downstream from Cherokee and Douglas dams, both the temperature and DO levels are still low when the water reaches Fort Loudoun Reservoir. This cooler, lower DO inflow water, coupled with the deep turbine withdrawals from Fort Loudoun Dam, creates an underflow through Fort Loudoun Reservoir during the summer, and results in thermally stratified conditions. The discontinuous operations of the hydroelectric units at the upstream dams create pulses of flow through Fort Loudoun, and the degree of thermal and DO stratification can vary depending on these pulses.

Fort Loudoun Reservoir also receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. (Since Tellico Dam has no outlet, under most normal conditions, water flows into Fort Loudoun Reservoir from Tellico Reservoir.) Water from Tellico Reservoir (Little Tennessee River) is often cooler and higher in

DO, and has a much lower conductivity than water in Fort Loudoun Reservoir (Tennessee River). In 1992, the forebay sampling location on Fort Loudoun Reservoir (originally located at Tennessee River Mile (TRM) 603.2) was moved upstream to TRM 605.5. This resulted in a better assessment of the water quality conditions of the Tennessee River in the forebay portion of Fort Loudoun Reservoir by minimizing the effects of the Little Tennessee River and Tellico Reservoir on the data gathered in the forebay of Fort Loudoun Reservoir.

Although Fort Loudoun Reservoir is a mainstream reservoir, its complex set of hydrologic conditions (cool water inflows from the Holston, French Broad, and Little Tennessee rivers) causes it to often exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than that in other mainstream reservoirs.

4.9.2 Reservoir Health

Vital Signs monitoring information showed that the ecological health of Fort Loudoun Lake was between fair and poor in 1992, and just slightly lower than in 1991. Good conditions were observed for DO and chlorophyll at the transition zone in Fort Loudoun Reservoir; however, all other ecological health indicators at all other sampling locations were poor or fair. Fish community evaluations were poor at all three sampling locations (forebay, transition zone, and inflow) in 1992. The fish community evaluation (IBI=15) at the inflow to Fort Loudoun Lake was the lowest of all the Vital Signs reservoir monitoring locations in 1992. Bottom-dwelling animals and sediment quality both rated poor at the forebay in 1992.

Aquatic macrophytes only covered 25 acres on Fort Loudoun Lake in 1992. Coverage over the past decade has ranged 25 to 140 acres.

4.9.3 Reservoir Use Suitability

The Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of two fish species from Fort Loudoun Reservoir. The state of Tennessee advises people not to eat catfish taken from Fort Loudoun Reservoir because of high levels of PCBs. Also, largemouth bass should not be eaten if they weigh over two pounds or are caught in the Little River embayment due to PCB contamination.

Fort Loudoun Reservoir has had a PCB problem for more than 20 years. Initially, TVA and state agencies examined a variety of species from throughout the reservoir to document the geographical and species variation. The study now continues as a trend study in which there is an annual collection of catfish from one location. PCB concentrations in catfish have varied over the years with no distinct trend.

The three swimming areas at the Dam Day Use Area, Yarberry Peninsula, and Louisville Point Park fully support recreation. Louisville Point Park was surveyed in 1992; the other sites were surveyed in 1989. Based on 1990 information, the water quality in downtown Knoxville, along the north shore of Fort Loudoun Reservoir does not support recreation. Use Suitability Monitoring did not find any bacteriological problems at the forebay or transition zone during monthly Vital Signs Monitoring in 1992.

4.9.4 Synopsis of 1992 Conditions

Water--Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in the forebay portion of the reservoir which persisted throughout most of the summer (April through August) of 1992. Surface water temperatures ranged from 6.6°C in January to 28.7°C in July at the forebay and from 6.1°C to 29.6°C for the same months at the transition zone. Maximum thermal stratification occurred in the forebay in June when surface to bottom temperature differentials (ΔTs) were 8.2°C, and in the transition zone in April when ΔTs of 9.9°C were observed.

In Fort Loudoun Reservoir in 1992, DO at the 1.5-meter depth ranged from 11.5 mg/L in August (algal bloom) to 5.3 mg/L in September at the forebay; and from 14.0 mg/L in January to

5.4 mg/L in September at the transition zone. The minimum DO observed in Fort Loudoun Reservoir in 1992 was 1.8 mg/L at the bottom of the forebay during August. Maximum surface to bottom dissolved oxygen differentials (ΔDOs) exceeded 7 mg/L each month, May through August, at the forebay. The transition zone was better mixed with ΔDOs exceeding 3 mg/L observed only in July, and a minimum bottom DO of 5.1 in August.

Values of pH ranged from 6.5 to 9.1. At the forebay, pH values exceeding 8.5, and DO saturation values exceeding 110 percent were measured from April through August giving evidence of substantial photosynthetic activity. During April, May, and July, a similar pattern of high pHs and high DO saturations was observed, although to a lesser extent, at the transition zone.

Conductivity ranged from 90 to 255 μmhos/cm, averaging about 195 μmhos/cm at the forebay and 215 μmhos/cm at the transition zone. The slightly lower conductivities measured at the forebay area were caused by the mixing of the inflows from the Little Tennessee River, via the Tellico Reservoir canal with the higher conductivity water of the Tennessee River. For example, during summer, water from Tellico Reservoir is usually colder than the surface water of Fort Loudoun Reservoir causing it to flow under the warmer water of Fort Loudoun Reservoir. This was the case in September 1992, when water surface conductivity was greater than 200 μmhos/cm and near-bottom conductivity was about 110 μmhos/cm in the forebay of Fort Loudoun Reservoir. In the spring, the water from Tellico Reservoir may be warmer than the water of Fort Loudoun Reservoir and often flows across the top and "floats" on the surface of the Fort Loudoun Reservoir. Such was the case in April 1992, when the Fort Loudoun forebay had surface conductivity less than 100 μmhos/cm and near-bottom conductivity near 200 μmhos/cm. Other months (e.g., May, June, July, etc.) give evidence of partially mixed "lenses" of low conductivity water from Tellico Reservoir merging with the higher conductivity water from Fort Loudoun Reservoir forebay at one or more depths.

Nutrient concentrations (total nitrogen and total phosphorus) were high at both the forebay and the transition zone. The average nitrite plus nitrate nitrogen concentrations of 0.55 mg/L (forebay) and 0.41 mg/L (transition zone) were the highest average concentrations of this nutrient measured in 1992 at any of the Tennessee River Vital Signs Monitoring locations. These high concentrations of nitrogen are due to a combined effect of the wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad Rivers, which also have relatively high nitrogen concentrations.

The highest chlorophyll-a concentrations in the forebay occurred in May (17 μg/L) and June (18 μg/L) and in the transition zone in April (18 μg/L). Surface concentrations of chlorophyll-a averaged about 11 μg/L and 8 μg/L, at the forebay and transition zone, respectively.

Fecal Coliform Bacteria--Bacteriological studies were conducted at one swimming beach on Fort Loudoun Reservoir in 1992. Fecal coliform bacteria concentrations at the swimming beach at Louisville Point Park were low, allowing a fully supports water contact recreation classification. Monthly Vital Signs sampling at the forebay and transition zone found all bacterial concentrations below the detection limit.

Sediment--Chemical analyses of sediments revealed relatively high concentrations of zinc at both the forebay and transition zone in 1992, similar to the concentrations measured in 1991. In addition, interstitial sediment pore water had high concentrations of un-ionized ammonia at the transition zone. Particle size analysis showed forebay sediments and transition zone sediments were primarily totally silt and clay (>80 percent).

The toxicological screening of sediment using rotifers (Rotox®) in Fort Loudoun Reservoir in 1992 found indications of toxicity at the forebay, based on the low survival of rotifers (50 percent survival) using forebay sediment pore water.

Benthic Macroinvertebrates--In 1992, benthic macroinvertebrate sampling showed poor communities in the forebay and inflow locations of Fort Loudoun Reservoir, while the transition zone had a fair benthic community. Two forebay locations (TRM 603.2 and 605.5) were sampled in 1992. Both locations were similar, rating "poor," with 11 taxa, 125 organisms/m^2 collected at TRM 603.2 and 9 taxa, 121 organisms/m^2 collected at TRM 605.5. The number of taxa was similar in the forebay to the previous year, but the density was much lower. Chironomus sp dominated both TRM 605.5 (80 percent) and TRM 603.2 (45 percent) with Tubificidae contributing an additional 23 percent at TRM 603.2. At the transition zone, the number of taxa (13) and density of organisms (478 organisms/m^2) were similar to the previous year. The dominant species were Chironomus sp (28 percent) and Tubificidae (28 percent). The inflow was dominated by Polypedilum sp (58 percent), Tubificidae (19 percent), and Corbicula sp (18 percent). The number of taxa (17) and density (2433 organisms/m^2) was a substantial increase from the previous year.

Aquatic Macrophytes--Aquatic plants on Fort Loudoun Reservoir were primarily upstream of TRM 635. An estimated 25 acres of aquatic plants were present in 1992. Coverage over the past decade has ranged from 25 to 140 acres, and Eurasian watermilfoil has been the dominant species.

Fish Community--Fish samples from the littoral (30 electrofishing transects) and profundal areas (28 net-nights) of Fort Loudoun Reservoir produced 5171 individuals, representing 38 species in 1992. The most abundant taxa was gizzard shad which accounted for 79 percent of the total number collected. Other abundant species included bluegill (7 percent), carp (3 percent), largemouth bass (1 percent), and channel catfish (1 percent). The number of species found in the forebay, transition zone, and inflow zone were 29, 26, and 15, respectively. Fish health analysis showed largemouth bass from Fort Loudoun Reservoir forebay (FHAI=41) were scored as fair. FHAI analysis in the inflow and transition zones was not possible due to an insufficient number of largemouth bass collected.

RFAI analysis of shoreline electrofishing data showed the littoral fish communities were poor in both the transition zone (RFAI=23) and forebay (RFAI=23). The inflow zone RFAI score of 15 represented the lowest designation of all samples conducted in TVA reservoirs in fall 1992. The transition zone and forebay ranked in the middle and lower 30 percentile, respectively, in comparison with other TVA mainstream reservoirs. Nine of the 11 metrics analyzed for the inflow received poor scores. Problems associated with all three zones included low fish abundance, low numbers of intolerant species, and high percentages of both omnivores and tolerant individuals. The high relative abundance of carp, a tolerant, omnivorous species, in Fort Loudoun Reservoir had a major influence on several metrics.

Fish Tissue--The sample site for the PCB trend study is near the transition zone at TRM 625. Ten channel catfish were collected from there in autumn 1991 and 1992. Concentrations in catfish from both 1991 and 1992 were higher than had been found in catfish collected in 1990 (average of 1.0 $\mu g/g$ and range of 0.3 to 1.9 $\mu g/g$). The 1991 samples had an average of 2.5 $\mu g/g$ (range 1.4 to 4.6 $\mu g/g$), and the 1992 samples had an average 1.8 $\mu g/g$ (range <0.1 to 4.2 $\mu g/g$).

4.10 Tellico Reservoir

4.10.1 Physical Description

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It was the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of about 16,000 acres at full pool. The average estimated flow through Tellico Reservoir in 1992 was approximately 6300 cfs which provided an average retention time of about 33 days. Very little of this water is discharged from Tellico Dam. Rather, it is diverted through a navigation canal to adjacent Fort Loudoun Dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably as discussed in section 4.9, Fort Loudoun Reservoir. The hydrodynamics and exchange of water via the inter-connecting canal significantly affect water quality within Tellico Reservoir (and Fort Loudoun Reservoir). The canal is only 20-25 feet deep, but the depth of the reservoir at the forebay of Tellico Dam is about 80 feet. Thus water at strata below about 25 feet is essentially trapped and becomes anoxic during much of the summer in the forebay of Tellico Reservoir.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico Rivers. The transition zone site selected for sample collection in 1992 was in the Little Tennessee River, just upstream of the confluence with the Tellico River at Little Tennessee River Mile (LTRM) 21.0. Water conditions at that site are largely controlled by discharges from Chilhowee Dam at LTRM 33.6. This water is cold, nutrient poor, and has a low mineral content, conditions that are not particularly conducive to establishing a diverse, abundant aquatic community. In 1993, the transition zone sampling location in Tellico Reservoir was moved downstream to just below the confluence of the Tellico River, to LTRM 15.0, a site more characteristic of lacustrine rather than riverine conditions.

4.10.2 Reservoir Health

The ecological health of Tellico Reservoir was poor and among the lowest of the 23 Vital Signs reservoirs monitored in 1992, with conditions being similar to those found in 1991. Near-bottom concentrations of dissolved oxygen in the forebay of Tellico Reservoir were again low in 1992. Approximately three months during the summer (July, August, and September) concentrations of oxygen near the bottom of the forebay were at or below approximately 1.0 mg/L. Also, at the forebay, sediment quality was considered poor due to a high rotifer mortality in tests conducted using sediment pore water collected from Tellico forebay and due to high ammonia concentrations in the sediment. Given the above two conditions, it is not surprising that the benthic community in the forebay was also poor. At the transition zone location poor benthos and poor fish communities were found, as well as an indication of sediment toxicity due to low survival of test animals (rotifers). The low water hardness in the Little Tennessee River and Tellico Reservoir may have exacerbated the sediment toxicity results.

Most of the 228 acres of aquatic macrophytes on Tellico Lake in 1992 were in the Tellico River arm of the Reservoir.

A fixed station sampling site on the Little Tennessee River, well upstream of Tellico Reservoir (at about LTRM 94.5) had very good ecological health in 1992 with all indicators (nutrients, sediment quality, benthos, and fish) being rated good.

4.10.3 Reservoir Use Suitability

Bacteriological studies were conducted at four swimming beaches and five other sites on Tellico Reservoir in 1992. Fecal coliform bacteria concentrations at the swimming beaches at Notchy Creek, Toqua, Vonore, and Lotterdale Cove Recreation Areas and at the other four nonswimming sites were low, allowing fully supports water contact recreation classifications. Monthly Vital Signs sampling at the forebay and transition zone location found all but one sample at each site below the detection limit of 10 colonies per 100 mL. In August the samples at each site exceeded the detection limit, the highest concentration being 33 colonies per 100 mL at the transition zone.

The state has advised that catfish from Tellico Reservoir should not be eaten because of PCB contamination. Fish were collected in autumn 1991 and 1992 for tissue analysis. Channel catfish were collected during both years as part of a continuing effort to examine the trend in PCB concentrations. Samples from both years indicated the PCB problem continues to exist with no downward trend.

4.10.4 Synopsis of 1992 Conditions

Water--Temperature data in Tellico Reservoir in 1992 show fairly strong thermal stratification beginning in April and persisting through September at both the forebay and transition zone. From June through August, temperature differentials between the water surface and bottom (ΔTs) equaled or exceeded 12°C at the forebay and 10°C at the transition zone. These differentials were due to a combination of atmospheric warming of surface water-intensified by the low streamflows in April and May and the intrusion of surface waters from Fort Loudoun forebay-contrasted with the inflow of cool bottom water from the releases of Chilhowee Dam upstream. Seasonally, surface water temperatures ranged from 7.3°C in January to 26.7°C in June at the forebay and from 7.5°C to 26.5°C for the same months at the transition zone. Water in Tellico Reservoir in 1992 was relatively cool compared with other Vital Signs reservoirs, particularly at the transition zone which is influenced by the releases from Chilhowee Dam. The forebay and transition zone temperatures averaged 14.6°C and 15.9°C, respectively, the lowest among the run-of-the-river Vital Signs sampling locations in 1992.

DO at the 1.5-meter depth ranged from 11.1 mg/L in January to 6.3 mg/L in September at the forebay and from 14.0 mg/L in January to 8.3 mg/L in June at the transition zone. From June through September a persistent oxycline was present in the forebay. Differences between surface and bottom DOs (ΔDOs) were 5 to 9 mg/L, and near bottom concentrations were less than 1 mg/L in August and September. This near bottom, cool, low DO water was very low in conductivity, indicating that it was water released from Chilhowee Dam. At the transition zone the minimum DO was 4.6 mg/L, in June. In 1992, the average dissolved oxygen concentrations at the forebay (6.5 mg/L) and the transition zone (9.3 mg/L) were, respectively, lower and higher than any of the other run-of-the-river Vital Signs Monitoring locations.

Tellico Reservoir pH values were low and ranged from 5.9 to 8.6. Surface water pH exceeded 8.5 at the forebay only in July coincident with DO super-saturation values indicative of photosynthetic activity. Values of pH were the lowest of any of the run-of-the-river Vital Signs reservoirs, averaging 7.0 at both the forebay and transition zone. Values of pH below the state of Tennessee minimum criterion of 6.5 were observed in the hypolimnion of Tellico Reservoir at both the forebay and transition zone in August and September in 1992.

The conductivity of water in Tellico Reservoir was also quite low, averaging about 30 μmhos/cm at the transition zone and 70 μmhos/cm at the forebay. Mixing of forebay surface waters between Fort Loudoun and Tellico Reservoirs via the inter-reservoir canal influences water quality and causes the higher measured conductivity at Tellico forebay compared with Tellico transition zone.

Total nitrogen concentrations were low and averaged only 0.35 mg/L at the forebay and 0.27 mg/L at the transition zone. Dissolved orthophosphorus concentrations (the only form of phosphorus assimilated by algal cells) were also quite low, averaging only 0.006 and 0.004 mg/L at the forebay and transition zone, respectively. Together, these nutrient concentrations were among the lowest measured concentrations at Vital Signs Monitoring locations in 1992; and consequently, primary productivity could be expected to be limited much of the time. Average summer chlorophyll-a concentrations of 5 μg/L at the forebay and 3 μg/L at the transition zone were among the lowest observed in 1992 on Vital Signs reservoirs. The highest single sample chlorophyll-a concentrations measured in 1992 were 7 μg/L at the forebay and only 5 μg/L at the transition zone.

Water clarity data (Secchi depth, suspended solids, color, etc.) were comparatively high with little relative variation throughout the year. This is because inflows to Tellico Reservoir are primarily a result of Chilhowee Dam discharges which are of high clarity and low color, rather than rainfall runoff events.

<u>Fecal Coliform Bacteria</u>--Bacteriological studies were conducted at four swimming beaches and five other sites on Tellico Reservoir in 1992. Fecal coliform bacteria concentrations at the swimming beaches at Notchy Creek, Toqua, Vonore, and Lotterdale Cove Recreation Areas and at the other four nonswimming sites were low, allowing fully supports classifications. Monthly Vital Signs sampling at the forebay and midreservoir location found all but one bacterial concentration at each site below the detection limit. The August samples at each site exceeded the detection limit. The larger concentration was 33 colonies per 100 milliliters at midreservoir.

Sediment--In 1992, in sediment samples collected in Tellico Reservoir, there were no organic analytes (PCBs and pesticides) detected, and metal analytes approximated background concentrations; however, un-ionized ammonia concentrations in sediment pore water collected in the forebay were high (531 ug NH_3/L).

As in 1991, testing again revealed rather toxic conditions to test organisms exposed to interstitial pore water extracted from sediment collected at the forebay and transition zone. A high morality of rotifers (93 percent mortality at the forebay and 53 percent mortality at the transition zone), and Microtox® EC_{10} values less than 25 percent at both locations indicate sediment toxicity in Tellico Reservoir. Further studies are being conducted to try to determine the cause of the toxicity; however, the low water hardness and low concentrations of calcium in sediment may be an exacerbating condition.

Particle size analysis showed sediments at the forebay were comprised almost entirely of silt and clay (>99 percent). Sediments at the transition zone were 77 percent sand and 23 percent silt and clay.

Benthic Macroinvertebrates--The benthic community in Tellico Reservoir in 1992 had a poor community structure at the forebay and a fair community structure at the transition zone. The forebay location had 15 taxa and 191 organisms/m^2 dominated by Tubificidae (81 percent of the total). The transition zone had greater number of taxa (15) and number of organisms/m^2 (297) in 1992 than were found in 1991. Tubificidae was the dominant taxon (34 percent) and the chironomid Zalutschia zalutschicoia was the second most abundant (25 percent).

Aquatic Macrophytes--The 228 acres of aquatic macrophytes on Tellico Reservoir were most abundant in the Tellico River portion (TRM 1 to TRM 13) of the reservoir and along the Little Tennessee River portion from LTRM 9 to 15. Eurasian watermilfoil was the dominant submersed macrophyte on Tellico Reservoir. As has been the case with most other reservoirs within the TVA system, aquatic plants have declined on Tellico Reservoir since the late 1980s.

Fish Community--Electrofishing (20 transects) and gill netting samples (24 net-nights) in the transition zone and forebay produced 1986 individuals of 29 species on Tellico Reservoir in 1992. More fish (74 percent) as well as more species (26 compared to 22) were found in the forebay than in the transition zone. Gizzard shad, spotfin shiners, and bluegill were the dominant species, comprising 31, 26, and 20 percent of the total sample, respectively. Other frequently occurring species included carp (4 percent), largemouth bass (2 percent), walleye (1 percent) and smallmouth bass (1 percent). All of these species were more abundant in the forebay except for carp and walleye. FHAI analysis indicated poor health of largemouth bass in both the transition (FHAI=70) and forebay (FHAI=105) which represents the poorest condition observed in TVA mainstream reservoirs.

The littoral fish community at the transition zone (RFAI=19) was poor, and the forebay (RFAI=35) community was fair, based on electrofishing data. The Tellico transition zone ranked last, while the forebay rated in the middle 30 percentile, compared to respective zones of other run-of-the-river reservoirs. (Note: Results from biomonitoring on Tellico Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs in storage impoundments and the presence of a navigation lock allowing recruitment of fish species.) Both zones received poor scores for intolerant species, percentage of tolerant individuals, and poor FHAI. The forebay was better than the transition in fish abundance, and percent omnivores and invertivores.

Fish Tissue--An advisory not to eat catfish from Tellico Reservoir has been in effect for several years. Documentation of the PCB problem in what was thought to be a background study in 1985 came as a surprise because there was basically no industrial development in the watershed. Subsequently, more intensive studies supported the initial results and showed very little change in concentrations during the late 1980s. Several attempts at locating potential sources were fruitless and the source remains unknown. A less intensive sampling effort was begun in autumn 1990. Since then one composite of five channel catfish has been collected annually from the forebay and one from an area about 10 miles upstream of there (several miles downstream of the transition zone) to continue examination of the temporal trend in PCB concentrations.

This effort was repeated in 1991 and 1992. The composite catfish samples collected in autumn 1991 from the forebay and midreservoir locations had PCB concentrations of 1.4 and 1.1 $\mu g/g$, respectively. Chlordane, typically found in previous samples, was not detected in 1991 samples. Other organics and metals were either not detected or detected in low concentrations. In 1991 largemouth bass were also collected and analyzed for mercury because the 1990 catfish samples had somewhat elevated mercury levels. Mercury concentrations were not high in the 1991 largemouth bass samples (maximum 0.14 $\mu g/g$).

Channel catfish samples collected in autumn 1992 had relatively high PCB concentrations - 2.7 $\mu g/g$ at the forebay and 1.9 $\mu g/g$ at the midreservoir location. Chlordane concentrations were also relatively high - 0.22 and 0.20 $\mu g/g$, respectively. Other organics were either not detected or found in very low concentrations. Arsenic, cadmium, lead, and selenium were not detected in either sample. Mercury concentrations were relatively high - 0.65 and 0.36 $\mu g/g$ at the forebay and midreservoir locations. Due to these high concentrations of mercury, largemouth bass will be examined again along with channel catfish in 1993.

4.11 Melton Hill Reservoir

4.11.1 Physical Description

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream from Melton Hill Dam about 44 miles. Melton Hill Reservoir has about 170 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is about 4400 cfs which results in an average retention time of approximately 14 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant factor influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and midreservoir areas, is the cold water entering from Norris Dam discharges. During summer, water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a re-regulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

4.11.2 Reservoir Health

Overall, the ecological health of Melton Hill Reservoir falls in the fair range and is about the same in 1992 as in 1991. Chlorophyll and DO were both good at both the forebay and the transition zone. However, a poor fish community was found at all three locations (forebay, transition zone, and inflow) in 1992. This was also the case at the transition zone and inflow in 1991. Cool water flowing in from the bottom layer of Norris Lake causes problems for fish in Melton Hill, especially in the middle and upper sections. The water is too cold to support fish that like warm water, but too warm to support fish that thrive in cold water. Sediment quality was rated fair in 1992 compared to good in 1991 at both the forebay and the transition zone due to a negative response of test organisms to sediment found in the forebay and an elevated copper concentration found in sediment collected from the transition zone. These conditions were not observed in 1991.

Aquatic macrophyte coverage on Melton Hill Lake in 1992 was about 240 acres. During the past decade, coverage has ranged from about 100 to 250 acres.

4.11.3 Reservoir Use Suitability

In 1992, Use Suitability Monitoring for water contact recreation was limited to just monthly samples collected at midchannel at the forebay and transition zone as part of the Vital Signs Monitoring. All but two samples, collected at the transition zone, were less than 10 colonies per 100 mL. August and September samples at the transition zone had concentrations of 13 and 23 colonies per 100 mL, well below the maximum recommended for water contact recreation. Based on information collected in 1990, the swimming at Carbide Park fully supports water contact recreation. The swimming area at the Dam Day Use Area and the informal recreation at Solway Bridge partially support recreation, due to relatively high concentrations of bacteria after rain. Recreation areas on Melton Hill Reservoir are being resampled in 1993.

TDEC has advised the public to avoid consumption of catfish from Melton Hill Reservoir because of PCB contamination. Samples are collected annually from the transition zone and near the inflow by TVA and from the forebay by the Oak Ridge National Laboratory as part of ongoing, cooperative studies. PCB concentrations collected in autumn 1991 and 1992 generally fell within the range found in previous years.

4.11.4 Synopsis of 1992 Conditions

Water--In 1992, thermal stratification began in April and persisted through September at both the forebay and the transition zone in Melton Hill Reservoir. Temperature differentials (ΔTs) exceeding 10°C between the water surface and the bottom were found at the forebay in June, July, and August; and at the transition zone in May, June, and July. Seasonal surface water temperatures ranged from 7.7°C in January to 27.9°C in July at the forebay and from 8.8°C to 27.2°C for the same months at the transition zone. Due to the upstream cool water discharges from Norris Reservoir, the water in Melton Hill Reservoir is relatively cool, particularly at the transition zone. In the late summer (August-September), water surface temperatures are often 5-7°C cooler at the transition zone than at the forebay. In 1992, the average temperature of the transition zone (16.5°C) on Melton Hill Reservoir was lower than all other run-of-the-river transition zone locations except Tellico's.

DOs at the 1.5-meter depth in Melton Hill Reservoir in 1992, ranged from 13.7 mg/L in June (large algal bloom) to 9.3 mg/L in September at the forebay, and from 11.7 mg/L in January to 7.8 mg/L in September at the transition zone. Unusual for a run-of-the-river reservoir, the lowest DOs measured in Melton Hill were found in the metalimnion instead of at or near the bottom. The lower metalimnetic DO concentrations (1.4 mg/L at the forebay and 6.8 mg/L at the transition zone) in Melton Hill Reservoir occurred in June and may have been due to the decay of settled autochthonous material being produced near the surface during photosynthesis. At both locations, low flows, high pHs (≥8.5), and high oxygen saturations (>125 percent) were measured in June.

Overall, values of pH ranged from 7.4 to 9.0 in Melton Hill Reservoir in 1992. Surface water pHs exceeded 8.5 at the forebay from April through August, coincident with DO super-saturation values (>120 percent), and indicative of photosynthetic activity.

Average nitrite plus nitrate nitrogen concentrations were high in Melton Hill Reservoir. The average concentration at the transition zone (0.60 mg/L) was the highest nitrite plus nitrate nitrogen among all Vital Signs locations sampled in 1992.

TN/TP ratios were often high (>50) indicating a potential for phosphorus limitation to algal productivity in Melton Hill Reservoir. Further, dissolved orthophosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only 0.006 mg/L at the forebay and transition zone, respectively, among the lowest measured concentrations at Vital Signs Monitoring locations in 1992. Consequently, summer chlorophyll-a concentrations of 6 μg/L at the forebay and 7 μg/L at the transition zone, may reflect a limiting nutrient effect. The highest chlorophyll-a concentrations were measured in May at the transition zone (16 μg/L) and in June in the forebay (8 μg/L).

Water clarity (Secchi depth, suspended solids, color, etc.) of Melton Hill Reservoir was comparatively high and measurements were generally stable throughout the year, being influenced to a relatively small degree by reservoir flows. This is due in large part because flows in Melton Hill Reservoir are largely controlled by discharges from Norris Dam rather than rainfall runoff events.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches on Melton Hill Reservoir in 1992. Monthly Vital Signs sampling at the forebay and transition zone found all but two bacterial concentrations, both at the transition zone, below the detection limit. The larger of these two concentrations was 23 colonies per 100 milliliters in September, well below water contact recreation criteria.

Sediment--There were no metal or organic analytes of serious concern and neither Microtox® nor Rotox® tests identified toxicity in 1992 and 1991. However, in 1992, a slightly high copper concentration (150 mg/kg) was found in one sample collected at the transition zone, and a Microtox® EC_{10} value of <25 percent was found in sediment pore water collected in the forebay. Additional sampling in 1993 will provide further sediment quality information.

Benthic Macroinvertebrates--All three reservoir locations (forebay, transition zone, and inflow) were found to have fair benthic communities in 1992. The number of taxa was relatively high in the forebay (21), transition zone (22), and inflow locations (28), each having increased substantially from 1991. There was a slight increase in the density of organisms collected in the forebay (689 organisms/m^2) and a decrease in the transition zone (277 organisms/m^2) compared to 1991. There was a substantial increase in density in the inflow (824 organisms/m^2) compared to the previous year. Tubificidae was the most common organism with 28 percent in the forebay, 51 percent in the transition zone and 53 percent in the inflow. Additionally, the chironomid Procladius sp represented 15 percent of the total organisms in the forebay and Paratendipes sp 24 percent in the inflow.

Aquatic Macrophytes--Eurasian watermilfoil was the dominant aquatic plant and was most abundant from CRM 24 to 51. Coverage over the past decade has generally ranged from about 100 to 250 acres.

Fish Community--Electrofishing (30 transects) and gill netting efforts (33 net-nights) on Melton Hill Reservoir produced a total of 1401 fish representing 31 species in 1992. Gizzard shad was the most numerous species (70 percent of the total number of fish sampled), followed in abundance by bluegill (4 percent), brook silverside (4 percent), carp (4 percent), and largemouth bass (3 percent). Fish were least abundant in the inflow zone and most abundant in the transition zone. Fewer species were also collected from the inflow zone (11) than the forebay (21) or transition zone (22). The health of the largemouth bass was fair based on FHAI values of 48 and 40 at the transition zone and forebay, respectively. No FHAI was calculated for the inflow sample due to low numbers of largemouth bass collected.

Littoral zone fish communities rated poor in all three zones based on RFAI analysis of shoreline electrofishing samples. RFAI values of 19 in the inflow zone, and 23 in the forebay were in the lower third when compared to other TVA mainstream reservoirs. The RFAI value of 23 in the transition zone ranked in the middle 30 percentile. (Note: Results from biomonitoring on Melton Hill Reservoir like Tellico, were compared to results from mainstream reservoirs due to similar operational characteristics. These reservoirs lack deep drawdown which occurs in storage impoundments and have a navigation lock.) Problems common to all three zones include low fish abundance, low numbers of sunfish species, and a high percentage of omnivores. The only good metric rating in all zones was a high number of lithophilic spawning species in the forebay.

<u>Fish Tissue</u>--PCB contamination in catfish from Melton Hill Reservoir has been under study for the past few years. Because of this contamination, the TDEC has advised the public not to eat these catfish. TVA participates on a study team with TDEC, TWRA, and ORNL to investigate PCBs and other contaminants in fish from east Tennessee reservoirs. In 1991 and 1992 ORNL collected and analyzed channel catfish from the forebay, while channel catfish from near the transition zone and inflow were collected and analyzed by TVA. In 1991 average PCB concentrations were 0.3, 1.4, and 1.9 $\mu g/g$ at the forebay, transition zone, and inflow, respectively. Chlordane was not detected at these locations. In 1992 average PCB concentrations from these same locations were 0.8, 1.0, and 0.5 $\mu g/g$, respectively, and average chlordane concentrations were 0.07, 0.10, and 0.05 $\mu g/g$, respectively.

4.12 Norris Reservoir

4.12.1 Physical Description

Norris Reservoir is formed by Norris Dam at Clinch River mile (CRM) 79.8. It is a large, dendritic tributary storage impoundment of the Clinch and Powell Rivers which flow together about nine miles upstream of the dam. Norris Reservoir is one of the deeper TVA tributary reservoirs with depths over 200 feet. It has a potential controlled storage drawdown of 74 feet, from 1034 to 960 (feet MSL) for flood control; however, annual drawdowns average only about 32 feet, given that full pool levels are not usually reached before annual drawdown begins. At full pool, the surface area of the reservoir is 34,200 acres, the shoreline is about 800 miles in length, and water is impounded 73 miles upstream on the Clinch River and 53 miles upstream on the Powell River. Norris Reservoir has a long average retention time (about 250 days) with an average annual discharge from Norris Dam of approximately 4100 cfs. However, in 1992, annual flows were significantly lower, averaging about 3158 cfs, due to releases from Norris Dam which were much below the long-term average from February through June. The low flows in 1992 resulted in an average retention time in Norris Reservoir of 325 days (and during the summer, 383 days). Due to the great depth and long retention time of Norris Reservoir, significant vertical stratification is expected. Additional information about the physical and hydrologic characteristics of Norris Reservoir are given in table 3.1.

Because of the confluence of the Clinch and Powell Rivers relatively close to the dam, three reservoir sampling locations were established: one forebay site; and two midreservoir sites--one on the Clinch River and one on the Powell River. In addition, fixed station sampling sites are also located on the Clinch and Powell Rivers, which together provide about 80 percent of the flow to Norris Reservoir.

4.12.2 Reservoir Health

Norris is an oligotrophic reservoir with very high water clarity, which is in great part due to phosphorus limitations to primary production. The ecological health of Norris Reservoir in 1992 was fair, with conditions about the same as in 1991. Norris Reservoir has low nutrient concentrations resulting in low levels of primary productivity, which in turn poorly supports higher forms of aquatic life. Dissolved oxygen concentrations in the deeper portions of Norris Reservoir, particularly at the midreservoir locations on the Clinch and Powell Rivers, have historically been low. A condition which, although undesirable, is often observed in deep, highly stratified, tributary reservoirs with long detention times. However, compared with other years, oxygen concentrations in the hypolimnion of the forebay of Norris Reservoir were slightly improved in 1992. Low concentrations of nutrients in the forebay resulted in low algal levels, a diminished food chain and, consequently, a low overall abundance of fish in the reservoir. This along with the low oxygen in the hypolimnion of the forebay contributes to the poor fish community. However, the low levels of algae make the water clear, blue, and aesthetically pleasing. The forebay of Norris Reservoir has the highest water clarity of any TVA reservoir.

The stream monitoring site on the Clinch River indicated overall good ecological health in 1992; the site on the Powell River indicated fair conditions. Water in the Powell and Clinch Rivers flowing into Norris Reservoir is cool, clear, and low in nutrients with good fish communities. On the Powell River, excessive sedimentation of sand and coal fines from active and abandoned coal mines in the watershed stresses biological communities, resulting in moderately impaired conditions for bottom-dwelling organisms in that stream. The Powell and Clinch Rivers together contribute about 80 percent of the flow to Norris Reservoir.

4.12.3 Reservoir Use Suitability

There are no fish consumption advisories on Norris Reservoir. Channel catfish for screening purposes were collected in 1991 and 1992. All analytes except PCBs were low or not detected during both years. Highest PCB concentrations were 0.5 μg/g in 1991 and 0.9 μg/g in 1992. Areas will be resampled in autumn 1993 to further examine PCB concentrations. Bacteriological quality on Norris Reservoir is good. In 1992, monthly Vital Signs sampling for bacteria found no concentrations at the forebay and midreservoir above detection limits. Based on information collected in 1991, the swimming area at Loyston Point partially supports water contact recreation, and the swimming area on Big Ridge Lake fully supports water contact recreation. (Big Ridge Lake is a small lake adjacent to Norris Reservoir.) The canoe access area downstream of Norris Dam and the flow re-regulation dam partially supports recreation.

4.12.4 Synopsis of 1992 Conditions

Water--Surface water temperatures ranged from 8.0°C in January to 27.3°C in July in the forebay, from 4.9°C to 28.1°C for the same months at the Clinch midreservoir sampling location, and from 6.7°C to 29.2°C for the same months at the Powell midreservoir sampling location. Strong thermal stratification was evident in Norris Reservoir in 1992. Solar heating and low streamflows initiated thermal stratification by April, and it was well established by June. Maximum water column temperature differentials (ΔTs) occurred in July, when the temperatures decreased almost 20°C from the water surface to the bottom at the forebay, and 18-19°C at the midreservoir sampling locations. The strong thermal stratification in Norris Reservoir persisted through September. Bottom water temperatures in Norris forebay (6 to 10°C in 1992) are among the lowest of any of the Vital Signs monitoring locations.

Dissolved oxygen at the 1.5-meter depth ranged from 12.6 mg/L in January to 8.0 mg/L in July at the forebay, from 11.8 mg/L in January to 7.4 mg/L in August at the Clinch midreservoir sampling location, and from 11.7 mg/L in January to 8.3 mg/L in August at the Powell midreservoir sampling location. Dissolved oxygens less than 1 mg/L developed in July near the bottom at the midreservoir sampling locations and persisted through September; however, dissolved oxygens less than 1 mg/L were only observed in the forebay in September. In August, the anoxia development in the Clinch and Powell midreservoir sampling locations resulted in hypolimnetic dissolved oxygen concentrations being less than 1 mg/L over approximately two-thirds of the water column depths.

In 1992, values of pH in Norris Reservoir ranged from 7.1 to 8.7 at the three monitoring locations. However, surface pHs did not exceed 8.5 at the forebay. Surface water pH values exceeding 8.5 were observed at the midreservoir locations during summer when dissolved oxygen saturation concentrations were high (>100 percent) indicating substantial photosynthetic activity.

The conductivity of the water is among the highest of the Vital Signs reservoirs. Reservoir-wide, conductivities ranged from about 200 to 400 μmhos/cm. They averaged about 250 μmhos/cm at the forebay, about 280 μmhos/cm at the Clinch midreservoir sampling location, and about 295 μmhos/cm at the Powell midreservoir sampling location.

As expected, concentrations of nutrients were quite low. The average total phosphorus and dissolved orthophosphorus concentrations of 0.008 and 0.006 mg/L, respectively, measured at the forebay were among the lowest average total phosphorus concentrations measured in 1992. TN/TP ratios exceeding 100 were frequently measured in individual samples on Norris Reservoir, indicating severely limiting phosphorus conditions in Norris Reservoir.

Summer concentrations of chlorophyll-a averaged less than 2 μg/L at the Norris Reservoir forebay. At both the Powell and Clinch midreservoir sampling locations, chlorophyll-a concentrations averaged 4-5 μg/L. Further evidence of the low productivity of Norris Reservoir were the low total organic carbon concentrations measured in 1992.

Norris Reservoir was quite clear at both the forebay and the midreservoir sampling locations. Forebay Secchi depth measurements averaged over 5.0 meters, the highest of all Vital Signs monitoring locations. Midreservoir sampling location Secchi depths averaged 1.8 meters on the Clinch and 2.4 meters on the Powell.

<u>Fecal Coliform Bacteria</u>--No bacteriological studies were conducted at swimming beaches on Norris Reservoir in 1992. Monthly Vital Signs sampling at the forebay and the two midreservoir stations found all bacterial concentrations below the detection limit.

<u>Sediment</u>--Among the 28 Vital Signs locations sampled for sediment quality in 1992, Norris forebay had the highest lead

concentration (90 mg/kg). (The 1990 and 1991, sediment samples collected at Norris forebay also had high lead concentrations, 88 and 110 mg/kg, respectively.) No other heavy metals were detected at concentrations of concern. The presence of DDT detected in the forebay sediment in 1991 was not found in 1992. There was no toxicity in either the Microtox® or Rotox® tests.

Particle size analysis showed the substrates at the forebay and Powell River midreservoir sampling location were mostly silt and clay (>98 percent), whereas silt and clay comprised about 74 percent of the substrate at the Clinch River midreservoir sampling location.

Benthic Macroinvertebrates--Among the three reservoir monitoring locations on Norris Reservoir, the forebay had the highest number of benthic taxa (23), but the lowest density (680 organisms/m^2) dominated by *Corbicula* sp (52 percent) and Tubificidae (26 percent). Compared with data collected in 1991, the midreservoir sampling locations on Norris Reservoir had higher numbers of taxa and total organisms. The number of taxa found in 1992 at the Clinch and Powell midreservoir sampling locations were 14 and 23, respectively; and, the density of organisms were 701 per square meter and 1102 per square meter, respectively. Both midreservoir sampling locations were dominated by Tubificidae (Clinch 46 percent, and Powell 63 percent). Additionally, the chironomid *Chironomus* sp represented 21 percent of the Clinch midreservoir sampling location population and *Procladius* sp 17 percent of the Powell midreservoir sampling location population.

Fish Community--Fish collections from the littoral (30 electrofishing transects) and profundal areas (36 net-nights) of Norris Reservoir produced a total of 1102 individuals representing 28 species. Dominant species reservoir-wide were bluegill (39 percent), gizzard shad (14 percent), walleye (11 percent), quillback (5 percent), and largemouth and spotted bass (4 percent, each). Highest concentrations of fish were found in the forebay (43 percent of total fish sampled) due to the abundance of bluegill in the electrofishing samples (30 fish per 300 meter transect), but only eight species were found.

Abundances of fish in the Clinch and Powell midreservoir sampling locations were nearly identical (30 and 28 percent of total fish sampled, respectively). Additionally, species diversity between both sampling locations was similar with 22 species being collected at the Clinch River midreservoir sampling location and 23 at the Powell River midreservoir sampling location.

The quality of the littoral fish communities of Norris Reservoir was determined to be fair in both the Powell (RFAI=33) and Clinch (RFAI=29) midreservoir sampling locations, and poor in the forebay (RFAI=25), based on shoreline electrofishing results. The Powell and Clinch River midreservoir sampling locations, ranked in the upper and middle thirds, respectively, when compared to these sections of other TVA tributary reservoirs. The forebay ranked in the lower third. All three Norris sampling locations scored poor in metrics for fish abundance, numbers of sunfish, and intolerant species; conversely, all scored good for percent omnivores. The Powell transition, and the forebay also scored good for low percentage of tolerant individuals (0-2 percent). Fish health was rated good in the Clinch River midreservoir (FHAI=29). No FHAI was conducted in the Powell River midreservoir sampling location or forebay due to inadequate numbers of largemouth bass collected.

Fish Tissue--Fish tissue samples for screening studies were collected on Norris Reservoir in autumn 1991 and 1992. In 1991 all metals and pesticides were either not detected or found in very low concentrations. However, PCB concentrations were about 0.5 $\mu g/g$ at both of the sample locations. All analytes were again low in 1992 except for PCBs, which were highest at the forebay where the concentration was 0.9 $\mu g/g$. Concentrations at the other two locations were low. Screening samples will be collected again in autumn 1993 to further evaluate PCB concentrations.

4.13 Cherokee Reservoir

4.13.1 Physical Description

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile (HRM) 52.3. Like Norris and Douglas Reservoirs, it is a large, deep, tributary storage impoundment with a substantial drawdown which begins in late summer. When the water surface is at full pool, winter drawdown is 53 feet. However, full pool is not reached most years, and the long-term average drawdown is about 28 feet. At full pool, Cherokee Reservoir is 54 miles long, has a surface area of 30,300 acres, and a shoreline of 393 miles. Average annual discharge is about 4500 cfs which provides an average hydraulic retention time (at full pool) of approximately 165 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit is greater on Cherokee than any of the other Vital Signs Monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

4.13.2 Reservoir Health

The ecological health of Cherokee Reservoir in 1992 was generally poor, with little change in conditions from 1991. In 1992, good algal populations were found at the forebay; however, all other ecological indicators (fish, benthos, dissolved oxygen, sediment) at both the forebay and midreservoir were fair or poor. Near-bottom dissolved oxygen concentrations were low at the forebay and midreservoir. This near-bottom, low dissolved oxygen condition, often observed in deep tributary reservoirs with long detention times, is especially severe in Cherokee Reservoir, resulting in high concentrations of un-ionized ammonia in sediment and poor benthos communities. The fair fish community observed at the forebay and inflow and poor fish community observed at the midreservoir sampling location were probably also impacted by the low oxygen concentrations in Cherokee Reservoir.

The overall ecological health at the stream monitoring site on the Holston River, which provides over 80 percent of the flow to Cherokee Reservoir, was fair in 1992. A poor algal rating was due to the effect high nutrient concentrations have on aquatic plant productivity. Large communities of aquatic macrophytes grow in the Holston River upstream of Cherokee Reservoir. Growth of these plants is stimulated by the clear water and high nutrient concentrations in the Holston River. When these plants die and break loose they are carried downstream into Cherokee Reservoir where they consume oxygen as they decompose, further adding to the oxygen deficit problems of Cherokee Reservoir.

4.13.3 Reservoir Use Suitability

There are no fish consumption advisories on Cherokee Reservoir. Channel catfish for screening tissue analysis were collected in 1991 and 1992. All analytes were not detected or found in low concentrations except PCBs. Maximum PCB concentrations were 0.9 $\mu g/g$ at the inflow in 1991 and 0.8 $\mu g/g$ at the forebay in 1992. Screening samples will be collected again in 1993 to further examine PCB concentrations. Swimming areas are scheduled to be sampled in 1993. Monthly Vital Signs bacteriological monitoring at the forebay and midreservoir found all bacterial concentrations below the detection limit.

4.13.4 Synopsis of 1992 Conditions

Water--Surface water temperatures ranged from 6.8°C in January to 27.6°C in July at the forebay and from 5.5°C to 30.0°C for the same months at the midreservoir sampling location. Dissolved oxygen at the 1.5-meter depth ranged from 14.0 mg/L in April (algal bloom) to 8.1 mg/L in August at the forebay and from 12.4 mg/L in June (algal bloom) to 8.8 mg/L in May at the midreservoir sampling location.

Thermal stratification in Cherokee Reservoir began in April and was well established by June. At the forebay, from June through August, temperature differences (ΔTs) between the surface and the bottom of the reservoir ranged from about 13 to 16°C. The development of hypolimnetic anoxia near the bottom of the reservoir and the occurrence of epilimnetic photosynthesis near the water surface resulted in dissolved oxygen gradients (ΔDOs) from about 7-9 mg/L during these same months. Similar conditions existed at the midreservoir sampling location, from May through July, with ΔTs ranging from 11 to 15°C and ΔDOs ranging from 6 to 13 mg/L. In July, hypolimnetic dissolved oxygen concentrations less than 1 mg/L were measured from the bottom of the reservoir (40 meters) to within 10 meters of the surface at the forebay, i.e., three-fourths of the water column. At the midreservoir sampling location, anoxic hypolimnetic effects were also observed in July. Hypolimnetic dissolved oxygen concentrations less than 1 mg/L were measured from the bottom of the reservoir to within nine meters of the surface, greater than one-half the depth of the reservoir at the midreservoir sampling location. (The depth of the water in July at the midreservoir sampling location was about 22 meters.) At both the forebay and the midreservoir sampling location, highly reducing conditions were evident during this period of anoxia, characterized by the high, near-bottom, concentrations of ammonia nitrogen and dissolved orthophosphorus being released from the sediment.

Values of pH ranged from 6.6 to 9.2 in Cherokee Reservoir. At both the forebay and the midreservoir sampling location, pH values equal to or exceeding 8.5 and/or dissolved oxygen saturation values exceeding 100 percent were measured monthly, April through September, giving evidence of a great deal of photosynthetic activity.

The average nutrient concentrations (total nitrogen concentrations of 0.91 mg/L and total phosphorus concentrations of 0.07 mg/L) measured at the midreservoir sampling location of Cherokee Reservoir are higher than any other Vital Signs Monitoring location, indicating large waste discharges to the Holston River upstream of the reservoir. TN/TP ratios indicate a higher productivity potential at the midreservoir sampling location and occasional phosphorus limiting conditions at the forebay. The midreservoir sampling location is much more supportive of photosynthetic activity than the forebay, evidenced by the higher near-surface chlorophyll-a, and the high pHs and DOs discussed above. The highest chlorophyll-a concentrations were measured in June at the midreservoir sampling location (18 μg/L) and in April at the forebay (15 μg/L). Summer, photic zone concentrations of chlorophyll-a averaged about 9 μg/L at the forebay and 11 μg/L at the midreservoir sampling location.

<u>Fecal Coliform Bacteria</u>--No bacteriological studies were conducted at swimming beaches on Cherokee Reservoir in 1992. (Studies are planned for 1993 at one water contact recreation area on Cherokee Reservoir.) Monthly Vital Signs sampling at the

forebay and midreservoir found all bacterial concentrations below the ten colonies per 100 mL, in 1992.

Sediment--Chemical analyses of sediments revealed no metal or organic analyte to be a serious concern and there was no toxicity of sediment pore water to test organisms. However, copper concentrations in sediment from the midreservoir sampling location (64 mg/kg) were higher than those measured in most Vital Signs reservoirs in 1992. In addition, high concentrations of un-ionized ammonia were measured in sediment pore water.

Particle size analysis showed both forebay and midreservoir sampling location sediments were almost totally silt and clay (>97 percent).

Benthic Macroinvertebrates--In 1992, the benthic macroinvertebrate community in the forebay of Cherokee Reservoir showed an improvement over conditions found in 1991. This was represented by an increase in taxa (12) and density (551 organisms/m^2) at the forebay that dominated by Tubificidae (61 percent) and Chironomus sp (19 percent). Similar to last year, the midreservoir sampling location had relatively few taxa (9) and low densities (214 organisms/m^2). Tubificidae dominated the midreservoir sampling location (34 percent) with Polypedilum sp (25 percent) and Chironomus sp (20 percent) being the next most abundant organisms collected. The taxa number (16) and density (265 organisms/m^2) in the inflow were similar to 1991. Tubificidae dominated in the inflow (37 percent) with Chironomus sp (28 percent) being second-most abundant.

Fish Community--Fish sampling in shoreline (30 electrofishing transects) and offshore/deep areas (35 net-nights) of Cherokee Reservoir produced a total of 3222 individuals including 28 species. The most numerous species was gizzard shad (44 percent), followed by bluegill (18 percent), striped bass (8 percent), largemouth bass (7 percent), and walleye (5 percent). Species richness ranged from 21 in the forebay to 23 in the midreservoir and 25 in the inflow zone. FHAI analysis found fair health of largemouth bass in the forebay (FHAI=42) and midreservoir (FHAI=65) with poor health in the inflow zone (FHAI=68).

RFAI analysis of shoreline electrofishing data determined the quality of the littoral fish communities of the inflow (RFAI=27) and midreservoir (RFAI=25) zones to be poor and the forebay (RFAI=29) to be fair. Only two metrics (omnivorous and tolerant individuals) were analyzed as good in all samples of Cherokee Reservoir. Both occurred in the forebay. Both the forebay and inflow ranked in the middle 30 percentile compared to other storage forebays and inflow zones. However, the midreservoir sampling location was classified in the lower

30 percentile. At the midreservoir location, low incidence of sucker, intolerant, migratory, and lithophilic spawning species were key metrics in the poor RFAI designation of this zone. Major metric contributors to the low RFAI in the inflow were largemouth bass health, percent invertivores, and low sunfish diversity. The forebay also received low scores for total fish abundance and low diversity of sunfish, sucker, and intolerant species; however, good scores for percent omnivores and tolerant individuals somewhat offset these lower scores.

Fish Tissue--Channel catfish were collected from Cherokee Reservoir as part of screening studies in autumn 1991 and 1992. Results from 1991 indicated low or nondetectable concentrations of metals. Mercury, known to be a problem in the North Fork Holston, was 0.41 $\mu g/g$ at the forebay with lower concentrations at the other two locations. None of the pesticides examined were detected and PCB concentrations were 0.5, 0.3, and 0.9 at the forebay, transition zone, and inflow, respectively. Results for 1992 were similar. Most metals were not detected (mercury was lower in 1992 at a maximum of 0.29 $\mu g/g$ at the inflow), and the only organics found were PCBs and chlordane. Chlordane concentrations were low (maximum 0.7 $\mu g/g$) and PCB concentrations were generally similar to those in 1991 - 0.8, 0.5, and 0.5 $\mu g/g$ at the forebay, transition zone, and inflow, respectively.

4.14 Douglas Reservoir

4.14.1 Physical Description

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston rivers which form the origin of the Tennessee River. Reservoir drawdown during late summer and autumn in preparation for winter and spring floods is rather large, with up to a 60-feet decrease in elevation (assuming full pool when drawdown begins). Given that full pool elevations are not reached every year, the annual drawdown averages about 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is approximately 6900 cfs which provides an average hydraulic retention time of about 105 days.

Due to depths and lengthy retention times, storage impoundments typically have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extends from the forebay to the midreservoir sampling location.

4.14.2 Reservoir Health

The ecological health of Douglas Reservoir can be described as fair to poor, with little change between 1991 and 1992. Factors adversely affecting the ecological health of Douglas Reservoir are strong thermal stratification and high nutrient loadings, resulting in hypolimnetic anoxia and release of reduced chemical species from the sediment and excessive eutrophication of the reservoir. All ecological health indicators (algae, dissolved oxygen, sediment, benthos, and fish) scored either fair or poor at all reservoir monitoring locations in 1992. Algae rated fair in 1992 because of relatively high concentrations of chlorophyll-a, indicative of high nutrients and high primary productivity. Near-bottom dissolved oxygen was low at the forebay and midreservoir, although slightly improved compared with 1991. This hypolimnetic anoxia promoted the release of ammonia (and sulfide) from the sediment and along with the low dissolved oxygen conditions negatively impacted the benthic community. Overall, the fish community was fair. Comparing 1992 with 1991, the fish community was slightly improved at both the forebay and midreservoir but poorer at the inflow.

In 1992, there were two fixed station, stream monitoring sites on the two major tributaries to Douglas Reservoir, one on the French Broad River and one on the Nolichucky River. The overall health of the stream monitoring sites on the Nolichucky and French Broad Rivers was poor in 1992. Both rivers have high nutrient concentrations which promote the excessive algal productivity in Douglas Reservoir. Chronic sedimentation due to mica and feldspar mining and extensive agriculture in the Nolichucky River watershed results in a poor rating for the sediment quality in that stream. The fish community on the French Broad River was poor in 1992. Given the poor water quality of the Nolichucky and French Broad Rivers flowing into Douglas Reservoir, the impaired ecological health of the reservoir is not unexpected. Together the Nolichucky and French Broad rivers provide about 75 percent of the total inflow to Douglas Reservoir.

4.14.3 Reservoir Use Suitability

There are no fish consumption advisories on Douglas Reservoir. However, fish from the Pigeon River upstream of Douglas Reservoir should not be eaten because of dioxin contamination. Swimming areas were not sampled in 1992 but are scheduled to be sampled in 1993. However, monthly Vital Signs sampling at the forebay and the midreservoir found all bacterial concentrations at or below detection limits, indicative of good conditions for open water recreation.

4.14.4 Synopsis of 1992 Conditions

Water--Surface water temperatures in Douglas Reservoir in 1992 ranged from a low of 6.9°C in January to a high of 28.6°C in July in the forebay and from 4.4°C to 29.6°C for the same months at the midreservoir sampling location. Dissolved oxygen concentrations at the 1.5-meter depth ranged from a low of 5.3 mg/L in September to a high of 11.9 mg/L in April (algal bloom) at the forebay and from 7.3 mg/L in August to 13.3 mg/L in January at the midreservoir sampling location. In September, the highest measured dissolved oxygen concentrations made at Douglas forebay were 5.4 mg/L at the water surface.

Thermal stratification was established in April. From April through July, there was a 9-12°C difference in temperature from the surface to the bottom of the reservoir occurring both in the forebay and in midreservoir. This strongly stratified condition was followed by strong hypolimnetic anoxia in July, August, and September, particularity in the forebay. In August and September, hypolimnetic dissolved oxygen concentrations less than approximately 1 mg/L were measured from the bottom of the reservoir (30 meters) to within about ten meters of the surface at the forebay, i.e., two-thirds of the water column. Further, as mentioned above, dissolved oxygen concentrations never exceeded 5.3 mg/L at the forebay location in September. During this period of summer anoxia, hypolimnetic ammonia nitrogen concentrations were high, giving evidence of the highly reducing conditions and the release of ammonia from the sediments.

Values of pH ranged from 6.1 to 9.3 in Douglas Reservoir in 1992. Throughout the summer, April through September, values of pH equal to or exceeding 8.5 and dissolved oxygen saturation values usually exceeding 100 percent were measured at the water surface at both the forebay and midreservoir sampling locations, indicative of high levels of photosynthesis and primary productivity.

Concentrations of total nitrogen, total phosphorus, and total organic carbon are quite high in Douglas Reservoir, particularity at the midreservoir location where total nitrogen averaged 0.82 mg/L, total phosphorus averaged 0.06 mg/L, and total organic carbon averaged 3.1 mg/L in 1992. Higher near surface chlorophyll-a concentrations and higher pHs and DOs show that the midreservoir region of Douglas Reservoir, like the midreservoir area in Cherokee Reservoir, is more productive than the forebay region. Summer surface concentrations of chlorophyll-a averaged about 11 µg/L at the forebay, and about 13 µg/L at the midreservoir sampling location. The chlorophyll-a levels found in Douglas Reservoir are among the highest of the Vital Signs reservoirs.

Comparisons of water clarity data between the midreservoir sampling location and the forebay of Douglas Reservoir show a decrease in suspended loads and an increase in water clarity as the velocity of the water slows and suspended matter settles out. True color measurements show the water in Douglas to be very highly-colored when compared with other TVA reservoirs. True color values, averaged 19 and 15 PCUs at the forebay and midreservoir sampling locations, respectively, in 1992. These color values were the highest among the Vital Signs Monitoring locations.

Fecal Coliform Bacteria--No bacteriological studies were conducted at swimming beaches on Douglas Reservoir in 1992. Monthly Vital Signs sampling at the forebay and midreservoir found all bacterial concentrations below the detection limit.

Sediment--Chemical analysis of sediments revealed no metal or organic analyte to be a concern. Also, toxicity tests did not indicate toxicity. However, analysis of pore water and water overlying bottom substrates had high concentrations of ammonia, probably due to the anoxic conditions. Concentrations of un-ionized ammonia in sediment pore water collected at the midreservoir sampling location were 825 $\mu g\ NH_3/L$. Particle size analysis showed the substrate to be essentially all silt and clay (>99 percent) at the forebay and to be 78 percent silt and clay, 22 percent sand at the midreservoir sampling location.

Benthic Macroinvertebrates--Indicative of low near-bottom dissolved oxygen concentrations, low numbers of benthic taxa were collected at both the forebay (7) and midreservoir sampling locations (7) of Douglas Reservoir in 1992, although this was a small increase from 1991 collections. The organism density, similar to 1991, was relatively low in the forebay (282 organisms/m^2) and midreservoir sampling locations (113 organisms/m^2). The dominant species in the forebay was *Chironomus* sp which represented 44 percent of the total organisms, followed by Tubificidae with 40 percent. The midreservoir sampling location was dominated by Tubificidae (57 percent) and the chironomid *Phaenopsectra* sp (37 percent).

Fish Community--Shoreline electrofishing (30 transects) and offshore/deep netting (36 net-nights) samples collected 3096 fish of 28 species. Uniquely, two piscivorous species, largemouth bass (22 percent of total fish sampled) and sauger (20 percent), were the most abundant in Douglas Reservoir samples. Gizzard shad (19 percent), bluegill (16 percent), white bass (9 percent) and carp (3 percent) followed in order of density. The largemouth bass electrofishing catch rate (23 per 300 m transect) was among the highest recorded in all TVA reservoirs sampled in fall 1992. The health of largemouth bass was consistent, with all three zones receiving a fair designation (46, 54, and 54 in the forebay, midreservoir, and inflow, respectively).

The RFAI analysis of shoreline electrofishing data showed both forebay (RFAI=33) and midreservoir areas (RFAI=37) were fair and ranked in the upper 30 percentile compared to other TVA storage forebays and midreservoirs. The inflow RFAI of 21 ranked poor and was the lowest score recorded for all storage reservoir inflows. There were no intolerant species sampled in Douglas Reservoir which lowered RFAI scores in all three zones. Other metrics which lowered the inflow zone RFAI were low diversity, abundance, numbers of sunfish and sucker species, and percentage invertivores. Low percentage omnivores in the forebay and midreservoir; high total abundance, diversity, and low percent tolerant individuals in the midreservoir; and high diversity of lithophilic spawning species in the forebay contributed to the fair RFAI rating.

Fish Tissue--There were no fish tissue studies conducted on Douglas Reservoir in 1991 or 1992.

4.15 Boone Reservoir

4.15.1 Physical Description

There were three tributary storage impoundments in the South Fork Holston River basin (Boone, South Holston, and Watauga) included in the 1992 Vital Signs "limited monitoring" program. Boone Reservoir, the smallest of these three tributary impoundments, is located in northeastern Tennessee and is formed by Boone Dam at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, and an average depth of 44 feet. (Boone Reservoir is over 100-feet deep near the dam.) Annual average discharge from Boone Dam is about 2500 cfs which results in an average hydraulic residence time of about 38 days. Large fluctuations of the water surface of Boone Reservoir for flood protection are reflected in the useful controlled storage drawdown on Boone Reservoir of 55 feet, from 1385 to 1330 (feet MSL); however, annual drawdowns are usually much less and average about 25 feet.

Three locations were selected for ecological health monitoring in Boone Reservoir, one at the forebay and two midreservoir sampling locations, one on the Watauga River arm and one on the South Fork Holston River arm.

4.15.2 Reservoir Health

The ecological health of Boone Reservoir improved in 1992, compared with conditions which existed in 1991. Completion of a water re-regulation and reaeration weir below South Holston Dam in 1992 improved both summer flows and concentrations of dissolved oxygen in the South Fork Holston River arm of Boone Reservoir.

The 1992 data showed lower algae populations (chlorophyll-a) at the South Holston River midreservoir sampling location as well as higher concentrations of dissolved oxygen at the South Holston midreservoir location and at the forebay location near the dam. The fish community was better in the Watauga arm of the reservoir and in the forebay than in 1991.

4.15.3 Reservoir Use Suitability

No samples were collected for analysis for pesticide, PCB, and metal contamination of fish tissue in Boone Reservoir in 1991 or 1992. However earlier studies found PCBs and chlordane in fish tissue, resulting in a state issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. The swimming area at Boone Dam is scheduled for bacteriological monitoring in 1993. However, fecal coliform bacteria collected in 1989 (the most recent data) found that the Boone Dam Day Use Area fully supported water contact recreation.

4.15.4 Synopsis of 1992 Conditions

Water--Boone Reservoir was thermally stratified throughout the summer with a maximum temperature difference of 14°C at the forebay and a maximum surface temperature of 26.8°C at the South Fork Holston River midreservoir station in August. Dissolved oxygen in the photic zone exceeded saturation from April through September, with a maximum percent saturation of 149 percent at the forebay, 152 percent at the Watauga River midreservoir station, and 150 percent at the South Holston River midreservoir station. In October, dissolved oxygen dropped below saturation at all three locations. Low dissolved oxygen was more pronounced in the metalimnion than at the bottom of the reservoir at the forebay and in the South Fork Holston River arm. In the South Holston River metalimnion, dissolved oxygen was below 1 mg/L from July through September. Bottom dissolved oxygen dropped below 1 mg/L in September in the Watauga River arm.

Photic zone pH exceeded 9.0 SU at each of the three stations at least once during the survey. The highest pH was 9.2 SU at the forebay in April and in the Watauga River arm in May.

The minimum pH was 6.9 SU in the Watauga River arm in September at the bottom of the water column.

Conductivity in the Watauga River was generally between 150 and 200 μmhos/cm early in the year, but decreased during the summer in the hypolimnion to a minimum of 87 μmhos/cm in August. Conductivity in the South Fork Holston River was between 200 and 250 μmhos/cm in April, increased in the metalimnion to between 275 and 283 from June through September, and decreased in the epilimnion to a minimum of 150 μmhos/cm in October and in the hypolimnion to 171 μmhos/cm in September. Conductivity at the forebay reflected the mixing of the two rivers with a range of 98 to 249 μmhos/cm.

Average secchi depths for the three stations were 1.4 meters at the forebay, and 1.1 meters at the two midreservoir stations. Average TOC concentrations were 2.75 mg/L at the forebay, 3.15 mg/L in the South Fork Holston River, and 2.65 mg/L in the Watauga River. Total nitrogen varied from 0.45 mg/L at the forebay in August to 1.01 mg/L at both midreservoir stations in April. Nitrate plus nitrite concentrations represented most of the total nitrogen in the Watauga River and about half the total nitrogen at the forebay and in the South Fork Holston River in April. Organic nitrogen comprised most of the total nitrogen in August. Ammonia concentrations were at or below the detection limit of 0.01 mg/L for each measurement. Average total phosphorus concentrations were 0.015 mg/L at the forebay, 0.025 mg/L in the Watauga River, and 0.035 mg/L in the South Fork Holston River. Chlorophyll-a concentrations averaged 10.3 μg/L at the forebay to 13.7 μg/L in the South Fork Holston River.

Of the eight midreservoir stations in the limited monitoring program, the South Holston arm of Boone Reservoir had the highest concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll-a. The Watauga arm of Boone Reservoir had the second-highest concentration of each of these parameters. The high organic and nutrient loading of Boone Reservoir results in high productivity, low water clarity, and greater dissolved oxygen depletion just below the photic zone than in most TVA reservoirs. Boone Reservoir has less than half of the average residence time of the other seven larger limited monitoring reservoirs (excluding Beech and Parksville Reservoirs). Consequently, bottom dissolved oxygen depletion is less than at most of these other seven reservoirs.

<u>Fish Community</u>--Electrofishing (30 transects) and gill netting (34 net-nights) results from Boone Reservoir yielded 20,963 individuals of 22 species. By far, spotfin shiners were the most abundant species, comprising 82 percent of the total number of fish sampled. Other species comprising a significant portion of the reservoir sample included bluegill (11 percent), gizzard shad (3 percent), carp (1 percent), and largemouth bass

(1 percent). Health of largemouth bass was fair in the forebay (FHAI=62) and South Fork Holston midreservoir area (FHAI=43) and poor in the Watauga River midreservoir area (FHAI=77).

RFAI analysis of the shoreline electrofishing samples found that both the forebay (RFAI=33) and the Watauga River midreservoir sampling location (RFAI=29) were fair, and the South Fork Holston River midreservoir sampling location (RFAI=27) rated poor. The forebay ranked in the upper 30 percentile and both the Watauga and South Fork Holston River midreservoir sampling locations ranked in the middle 30 percentile, compared to similar areas in other TVA storage reservoirs. All three reservoir zones exhibited similar metric characteristics: scores rated good for fish abundance and percent omnivores and invertivores, and scores rated poor for numbers of sunfish and intolerant species and percent tolerant individuals, and taxa metric scores were fair in all three sample areas. Additional metrics which contributed to the lower rating of the South Fork Holston River midreservoir sampling location were number of migratory and lithophilic spawning species.

4.16 South Holston Reservoir

4.16.1 Physical Description

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles in length, over 230 feet deep near the dam, an average depth of 86.5 feet, and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, this results in an average hydraulic residence time of almost one year (337 days)--one of the longest residence times of any TVA reservoir. Large fluctuations of the water surface of South Holston Reservoir for flood protection are reflected in the useful controlled storage drawdown on South Holston Reservoir of 67 feet, from 1742 to 1675 (feet MSL), although average annual drawdown is about 33 feet.

4.16.2 Reservoir Health

The ecological health evaluation of South Holston Reservoir was fair in 1992, about the same as in 1991. Although South Holston Reservoir still experienced low DOs near bottom during 1992 summer (as is the case with most deep storage impoundments), the low DOs were present for a shorter duration than in 1991. The low DOs, combined with rather modest levels of algae, contribute to the fair fish community on South Holston.

4.16.3 Reservoir Use Suitability

There are no fish consumption advisories on South Holston Reservoir. No swimming areas were tested in 1992. The most recent fish collected for tissue analysis were collected in autumn 1991. The single composite of channel catfish from the forebay had low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury). The mercury concentration was

0.42 μg/g, below the level used to issue an advisory but high enough to be of interest.

4.16.4 Synopsis of 1992 Conditions

Water--South Holston Reservoir was thermally stratified throughout the summer with a maximum temperature difference of 18°C and a maximum surface temperature of 25.3°C at the forebay in August. The bottom temperatures at the forebay warmed slightly from 5.8°C in April to 8.4°C in October. The bottom waters are the coldest of any of the reservoirs. Photic zone dissolved oxygen was super-saturated from April through September except for August at midreservoir. Maximum saturation was 129 percent in July at the forebay and 134 percent in June at midreservoir. Low dissolved oxygen (less than 2.0 mg/L) was present at the bottom of the water column at both stations from July through October. A lens of low dissolved oxygen in the metalimnion occurred in August and September at midreservoir and in October at the forebay.

Surface pH ranged from 8.6 to 9.0 SU from April through September at midreservoir and from June through September at the forebay. The minimum pH was from 7.0 at each station at the bottom of the water column in October.

Conductivity varied from 166 to 211 μmhos/cm with the highest values at the bottom of the water column. Average Secchi depths were 3.4 meters at the forebay and 1.8 meters at midreservoir. TOC concentrations averaged about 2.1 mg/L at both stations. Average total nitrogen concentrations were 0.51 mg/L at the forebay and 0.63 mg/L at midreservoir. Most of the total nitrogen was nitrates plus nitrites in April and organic nitrogen in August. Average chlorophyll-a concentrations were 3.1 μg/L at the forebay and 8.6 μg/L at midreservoir.

The South Holston midreservoir station had the fourth or fifth highest concentrations of total nitrogen, total phosphorus, and total organic carbon of the eight midreservoir stations under the limited monitoring program. South Holston Reservoir's long residence time, along with the relatively high organic and nutrient loads, allows sufficient depletion of the dissolved oxygen in the depths and below the photic zone to affect other water quality parameters, such as pH and conductivity.

Fish Community--Fish samples taken in the shoreline areas (20 electrofishing transects) and offshore/deep areas (24 net-nights) of South Holston Reservoir produced a total of 510 individuals represented by 20 species. Fish density and diversity was evenly distributed between the forebay (257 individuals of 15 taxa) and midreservoir sampling location (253 individuals of 18 taxa). No inflow zone sample was collected from South Holston Reservoir. The three most abundant species were spotfin shiner

(24 percent), walleye (13 percent) and gizzard shad (11 percent). Other abundant species included white bass (10 percent), smallmouth bass (10 percent), bluegill (7 percent), carp (6 percent), channel catfish (5 percent), and largemouth bass (4 percent). The health of largemouth bass in the midreservoir sampling location was fair (FHAI=64) but could not be determined in the forebay due to insufficient numbers of individuals collected.

RFAI analysis of electrofishing data determined the quality of the littoral fish community in the midreservoir sampling location (RFAI=27) to be poor, however, ranked in the middle 30 percentile compared to the other 11 storage reservoir midreservoir sampling locations. The forebay (RFAI=33) rated fair and was classed in the upper third of all storage reservoir forebays. Four metrics (diversity, abundance, percent tolerant individuals, and number of sunfish species) were rated poor in both midreservoir sampling location and forebay of South Holston Reservoir. The forebay exhibited good ratings for intolerant and lithophilic spawning species and percentages of invertivores and omnivores, while the midreservoir sampling location scored high for only one metric (number of sucker species).

4.17 Watauga Reservoir

4.17.1 Physical Description

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the deepest reservoir sampled as part of TVA's 1992 Vital Signs Monitoring Program. With an annual average discharge of 700 cfs, Watauga Reservoir also has the longest hydraulic residence time (412 days) of any of the Vital Signs reservoirs. Large fluctuations of the water surface of Watauga Reservoir for flood protection are reflected in a useful, controlled storage drawdown of 60 feet, from 1975 to 1915 (feet MSL), and an average annual drawdown of 26 feet.

4.17.2 Reservoir Health

The overall ecological health condition for Watauga Reservoir was slightly lower in 1992 than in 1991, although both years rated fair. The fish community was poor at both the forebay and midreservoir locations in 1992. Dissolved oxygen at the midreservoir location decreased slightly in 1992, compared with 1991, but this was not a significant change in conditions.

4.17.3 Reservoir Use Suitability

There are no fish consumption advisories on Watauga Reservoir. No swimming areas were tested in 1992. Channel catfish for tissue analysis were last collected in 1991. All pesticides, PCBs, and metals (except mercury) were low or not detected. The mercury concentration in the single composite from the forebay was 0.53 $\mu g/g$. Additional fish tissue screening efforts will be conducted in autumn 1993.

4.17.4 Synopsis of 1992 Conditions

Water--Watauga Reservoir was thermally stratified throughout the sampling period with a maximum temperature difference of 18°C at both stations and a maximum surface temperature of 25.8°C at midreservoir in August. Bottom waters in Watauga Reservoir were the second-coldest of the tributary reservoirs. Dissolved oxygen concentrations were near or slightly over saturation from April to September in the photic zone with a maximum saturation of 110 percent in May at midreservoir. Low dissolved oxygen (less than 2.0 mg/L) occurred in the metalimnion and bottom waters at both stations in September and at the forebay in October. Low dissolved oxygen occurred in the bottom waters at midreservoir in October.

There was a pH gradient in the water column with the largest values near the surface and minimum values in the metalimnion and near the bottom throughout the year. Forebay pH values ranged from 8.9 to 6.4 SU, and midreservoir varied from 9.2 SU in August to 6.5 SU in October.

Conductivities were generally between 60 and 90 μmhos/cm with minor stratification. Average Secchi depths at the forebay and midreservoir were 1.7 and 1.8 meters, respectively. Average TOC concentrations were 1.9 mg/L at the forebay and 2.05 mg/L at midreservoir. Total nitrogen concentrations averaged 0.34 mg/L at the forebay and 0.45 mg/L at midreservoir. Nitrates plus nitrites comprised most of the April total nitrogen, and organic nitrogen was most of the total nitrogen in August. All ammonia concentrations were at or below the detection limit on 0.01 mg/L. Total phosphorus and dissolved orthophosphorus averaged 0.007 mg/L and 0.003 mg/L at the forebay, and 0.006 mg/L and 0.003 mg/L at midreservoir, respectively. Chlorophyll-a concentrations averaged 4.6 μg/L at the forebay and 5.6 μg/L at midreservoir. The maximum concentration was 9 μg/L at the forebay in August.

The Watauga midreservoir station had the fifth- or sixth-highest concentrations of total nitrogen, total organic carbon, and chlorophyll-a, and the lowest total phosphorus concentration of the eight midreservoir stations under the limited monitoring program. The long residence time and relatively low nutrient and organic loading of Watauga Reservoir produce high water clarity while forming a limited area of late-summer low dissolved oxygen at the reservoir bottom and at the midreservoir metalimnion.

Fish Community--Combined fish samples in the shoreline electrofishing (20 transects) and offshore gill netting (21 net-nights) produced a total of 843 individuals including 16 species in the midreservoir sampling location and forebay of Watauga Reservoir. No sample was conducted in the inflow zone. Fish were more abundant in the midreservoir sampling location (85 percent of total) but diversity was evenly distributed between both sample areas (13 taxa in the forebay and 15 in the midreservoir). The three dominant species by number were spotfin shiner (53 percent), walleye (16 percent), and bluegill (10 percent). Other common species were gizzard shad (4 percent), smallmouth bass (4 percent), and largemouth bass (3 percent). Health of largemouth bass as determined by FHAI analysis indicated a poor condition in the forebay (FHAI=94). Insufficient numbers were collected in the midreservoir to calculate the FHAI.

Poor littoral fish communities were identified by RFAI analysis of shoreline electrofishing data. In fact, both the midreservoir sampling location score of 23 and the forebay score of 19 were the lowest observed in comparable areas of other tributary reservoirs that were sampled. Metrics contributing to low RFAI evaluations in the two zones were very dissimilar with only species diversity and numbers of sunfish and sucker species being common to both. Poor forebay metric scoring was driven by low abundance, low percentage invertivores, low FHAI, and high percentage omnivores, where as, low midreservoir sampling location values resulted from low numbers of migratory spawning, intolerant, and lithophilic spawning species, and a high percentage of tolerant individuals.

4.18 Hiwassee Reservoir

4.18.1 Physical Description

Five tributary storage impoundments in the Hiwassee River watershed (Hiwassee, Chatuge, Nottely, Blue Ridge, and Ocoee No. 1) were monitored as part of the 1992 "limited" Vital Signs program. Hiwassee Reservoir, in the southwestern corner of North Carolina, is the largest of these five and is impounded by Hiwassee Dam at Hiwassee River mile (HRM) 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet (with a maximum depth of about 250 feet at the dam). It has an average annual discharge of about 2050 cfs and average residence time of about 100 days. Hiwassee Reservoir has a relatively large, useful, controlled storage drawdown for flood protection of about 76 feet, from 1526.5 to 1450 feet (MSL), and an average annual drawdown of 45 feet.

4.18.2 Reservoir Health

Ecological health of Hiwassee Reservoir was fair, about the same in 1992 as in 1991. Like most deep, tributary storage reservoirs, with long detention times, thermal stratification occurs during the summer in Hiwassee Reservoir. During periods of extended thermal stratification, this results in low concentrations of dissolved oxygen near the bottom of the reservoir when oxygen is consumed by biochemical processes in the reservoir and in the sediment at a faster rate than it is replenished from the atmosphere. The upper Hiwassee River watershed is largely forested with few sources of waste to the river. Consequently, concentrations of nutrients are generally low and primary productivity in the Hiwassee River reservoirs is also generally low, resulting in lower standing stocks of fish, due to the diminished food base.

4.18.3 Reservoir Use Suitability

There are no fish consumption advisories on Hiwassee Reservoir. One channel catfish composite from the forebay was screened for pesticides, PCBs, and metals in 1991. None of the pesticide for PCB analytes was detected. Most metals other than mercury were not detected or found in low or expected concentrations. The mercury concentration (0.69 $\mu g/g$) was relatively high and will be further investigated in fall 1993 when both channel catfish and largemouth bass composites will be examined from the forebay and transition zone. No swimming areas were tested on Hiwassee Reservoir in 1992. Bacteriological information collected in 1991 at the canoe access areas between Apalachia Dam and Chickamauga Reservoir show that these sites fully support water contact recreation, and based on 1990 information, the canoe access locations above Hiwassee Reservoir at Mission Dam and Grape Creek also fully support water contact recreation.

4.18.4 Synopsis of 1992 Conditions

Water--The Hiwassee Reservoir forebay develops two areas of steep thermoclines in the water column, one slightly below the surface and another about 50 meters deep. This configuration is caused by the location of the turbine intakes which draws water from the middle of the water column, allowing the colder bottom water and warmer surface waters to remain in place throughout the summer. The bottom water at the forebay stayed below 10°C throughout the summer, while surface water temperatures reached 28°C at the forebay in July. The temperature profiles at midreservoir and the inflow were similar to the upper 40 and 21 meters of the forebay profile, respectively. Dissolved oxygen in the forebay photic zone was above saturation from April through September, with a maximum dissolved oxygen saturation of 131 percent in August. The maximum dissolved oxygen saturation was 139 percent at midreservoir and 119 percent at the inflow. Low dissolved oxygen (less than 2 mg/L) occurred in the cold bottom waters of the forebay from June through October and extended into the warmer waters to about the 48 meter depth in September. Low dissolved oxygen occurred at the midreservoir bottom in August and September.

The maximum photic zone pH was 9.5 SU at the forebay in May, each of the other two stations had a maximum pH of over

9.0 SU. The minimum pH was 6.0 SU at the forebay bottom in July. Conductivities varied from 19 to 34 μmhos/cm in Hiwassee Reservoir, with the lowest values in the forebay photic zone during the first half of the sampling season, and the highest values at the bottom of the reservoir in July and August at the inflow and midreservoir stations, respectively. Average secchi depths were 3.7 meters at the forebay, 3.9 meters at midreservoir, and 3.6 meters at the inflow station. The maximum secchi depth was 5.4 meters at the forebay in October. TOC varied from 1.1 to 1.8 mg/L at the three stations. Total nitrogen concentrations averaged 0.23 mg/L at the forebay, 0.22 mg/L at midreservoir, and 0.20 mg/L at the inflow. Organic nitrogen comprised most of the total nitrogen for all samples except at the inflow in April, when nitrates plus nitrites comprised most of the total nitrogen. All ammonia concentrations were 0.02 mg/L or less. Total phosphorus and dissolved orthophosphorus concentrations both decreased moving downstream from 0.012 mg/L and 0.006 mg/L, respectively, at the inflow to 0.006 mg/L and 0.003 mg/L, respectively, at the forebay. Average chlorophyll-a concentrations were 3.3 μg/L at the forebay, 3.7 μg/L at midreservoir, and 2.6 μg/L at the inflow. The maximum concentration was 5 μg/L at both the forebay in September and at midreservoir in August and September.

The Hiwassee midreservoir station had the lowest or second-lowest average concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll-a of the eight midreservoir stations under the limited monitoring program. The low organic and nutrient loading resulted in the second-greatest water clarity of the ten reservoirs in the limited monitoring program and limited the area of low dissolved oxygen to the near-permanent pool of cold water at the forebay and along the bottom at midreservoir.

Fish Community--Shoreline electrofishing (30 transects) and offshore gill netting (32 net-nights) from the three zones of Hiwassee Reservoir resulted in the collection of 673 fish including 30 species. When gizzard shad were disregarded, the dominant taxa by number were bluegill (17 percent), largemouth bass (16 percent), smallmouth bass (11 percent), and green sunfish (3 percent). Health of largemouth bass, as determined by the FHAI analysis, was fair in both the inflow (FHAI=43) and midreservoir (FHAI=38) zones. No FHAI was attempted in the forebay, due to an insufficient number of largemouth bass collected in the electrofishing samples.

The Reservoir Fish Assemblage Index (RFAI) showed the littoral fish community (based on results of electrofishing samples) of the inflow zone (RFAI=39) to be the best found in TVA storage inflow zones. Fish communities in the midreservoir sampling location (RFAI=31) and forebay (RFAI=27) scored fair and poor, respectively, and were ranked in the middle 30 percentile compared to like zones in TVA tributary reservoirs. Metrics contributing to the good designation in the inflow zone included number of taxa, and number of sucker, migratory spawning, intolerant, and lithophilic spawning species. The poor RFAI in the forebay was driven by low total number of fish, low number of taxa, and low numbers of sucker and intolerant species.

4.19 Chatuge Reservoir

4.19.1 Physical Description

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 450 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL); however, the annual drawdown averages only ten feet.

4.19.2 Reservoir Health

The ecological health of Chatuge Reservoir in 1992 was evaluated just slightly lower than in 1992, poor to fair. The small difference is not considered a true change in the overall ecological health of the reservoir. Additional information was also available in 1992 because a midreservoir location was added for dissolved oxygen and algae sampling. Conditions at the midreservoir location were very similar to those near the dam, i.e., low near-bottom DOs and low algae levels, conditions similar to other Hiwassee River reservoirs, as discussed above in 4.18.2.

4.19.3 Reservoir Use Suitability

There are no fish consumption advisories on Chatuge Reservoir. One channel catfish composite from the forebay was screened for pesticides, PCBs, and metals in 1991. None of the pesticide for PCB analytes was detected. Although several metals were detected they occurred at low or expected concentrations. Based on 1990 bacteriological information, the swimming areas at Jackrabbit Campground, Hiwassee Beech, and Clay County Park all fully support water contact recreation. Swimming areas on Chatuge Reservoir are planned to be again sampled in 1993.

4.19.4 Synopsis of 1992 Conditions

Water--Chatuge Reservoir was stratified from April through September with a maximum temperature difference of 17°C and a maximum surface temperature of 27.1°C in July. Destratification of the reservoir occurs as the cold water at the bottom of the reservoir, 9.2°C in April, is replaced by warmer inflows and surface temperatures begin to cool in August. Supersaturated dissolved oxygen conditions occurred in the photic zone from May through July at both stations and in August at the forebay. The maximum saturation was 100 percent at midreservoir in July. Low dissolved oxygen (below 2 mg/L) occurred at the bottom of the water column in August and September at both stations, and extended to within eight meters of the surface at midreservoir.

Surface pH reached a high of 8.4 SU in June at midreservoir, and bottom pH decreased to a low of 5.9 SU in August at the forebay and in September at both locations. Conductivities varied from 16 μmhos/cm at both locations to 3 μmhos/cm at the forebay and 41 μmhos/cm at midreservoir. All values over 30 μmhos/cm occurred either in August or September at the bottom of the reservoir. Secchi depths averaged 3.5 meters at the forebay and 2.9 meters at midreservoir. The maximum Secchi depth was 4.4 meters at the forebay in July, and the lowest was 1.8 meters at midreservoir in June. Average TOC concentrations were 1.25 mg/L at both stations.

Average total nitrogen concentrations were 0.21 mg/L at the forebay and 0.29 mg/L at midreservoir. Organic nitrogen comprises over 80 percent of the total nitrogen at both stations during both surveys. Ammonia concentrations were all at or below the detection limit of 0.01 mg/L. Total phosphorus averaged 0.007 mg/L at the forebay and 0.008 mg/L at midreservoir. Dissolved orthophosphorus averaged 0.003 mg/L at both locations. Chlorophyll-a concentrations averaged 3.1 μg/L at the forebay and 3.6 μg/L at midreservoir, with a maximum concentration of 5 μg/L at the forebay in September.

The Chatuge midreservoir station had between the lowest and third-lowest average concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll-a of the eight midreservoir stations under the limited monitoring program. This results in relatively high water clarity and limiting low dissolved oxygen conditions to the late summer.

Fish Community--Only the forebay of Chatuge Reservoir was sampled in fall 1992. Electrofishing samples (ten transects) in shoreline areas and experimental gill netting samples (ten net-nights) offshore collected 532 individuals with 18 species represented. Uniquely, white bass (a piscivorous species) was the most abundant taxa in Chatuge Reservoir (56 percent of total fish sampled). Bluegill (14 percent), spotted bass (7 percent), and largemouth bass (6 percent) followed in order of density. There were twice as many fish collected in gill netting samples compared to electrofishing (also a unique situation) resulting from high catch rates of white bass. Health of largemouth bass in the forebay as analyzed by the FHAI was the best (FHAI=20) recorded in all storage forebays sampled during fall 1992.

RFAI analysis, based on littoral electrofishing results, revealed the quality of the fish community in the forebay (RFAI=27) to be poor; however, ranking in the middle 30 percentile compared to similar areas of TVA storage reservoirs. Metrics which lowered the forebay RFAI were low total abundance, and low numbers of sucker, intolerant, migratory, and lithophilic spawning species. Only two of the 11 metrics were rated as good (largemouth bass health [FHAI] and percent omnivorous individuals).

4.20 Nottely Reservoir

4.20.1 Physical Description

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 400 cfs which result in an average hydraulic retention time of about 213 days. The annual drawdown averages about 24 feet on Nottely Reservoir; however, 45 feet of controlled storage drawdown is available for flood protection (1780-1735 feet MSL).

4.20.2 Reservoir Health

The ecological health of Nottely Reservoir in 1992 was essentially the same as in 1991, fair. An additional midreservoir location was added in 1992 for dissolved oxygen and chlorophyll sampling; conditions there were similar to those found in the forebay, i.e., low near-bottom dissolved oxygen and low algae populations, conditions similar to other Hiwassee River reservoirs.

Nottely Reservoir's ecological health may not be as good as these monitoring results suggest, however. For example, there was a fish kill near the dam in the fall of 1992 which was probably related to low dissolved oxygen. Also, the water in Nottely Reservoir is frequently turbid due to excessive erosion on the lands surrounding the reservoir.

4.20.3 Reservoir Use Suitability

No fish consumption advisories have been issued for Nottely Reservoir. One channel catfish composite from the forebay was examined for pesticides, PCBs, and metals in 1991. The only organic analyte detected was PCBs, at a concentration (0.2 $\mu g/g$) just above the detection limit. A few metals were detected, but only mercury (0.47 $\mu g/g$) was sufficiently high to be of interest.

Similar concentrations have been found, although not consistently, in previous screening studies on reservoirs in the Hiwassee basin. Both channel catfish and largemouth bass composites will be collected from the forebay in autumn 1993 and examined for mercury to further examine this situation. No information was collected for bacteriological contamination at recreation areas on Nottely Reservoir in 1992. Fecal coliform sampling is planned for swimming areas in 1993. However, the recreation area at Poteet Creek was sampled in 1990 for fecal coliform bacteria and found to fully support water contact recreation.

4.20.4 Synopsis of 1992 Conditions

Water--Nottely Reservoir was thermally stratified from April through September, with a maximum temperature difference of 17°C and a maximum surface temperature of 27.1°C in July. Low dissolved oxygen (less than 2 mg/L) appeared at the bottom of the water column at both stations in July and expanded upward through September when low dissolved oxygen was within eight meters of the surface. A lens of low dissolved oxygen at about the eight meter depth appeared at midreservoir in July. Photic zone dissolved oxygen was supersaturated from May through August at both stations, with a maximum saturation of 126 percent at the forebay in July.

Photic zone pH was at least 8.5 SU at both stations in June and July with a maximum of 8.8 SU at the forebay both months. The minimum pH was 5.9 SU once at each station at the bottom of the water column. Conductivities were between 21 and 39 μmhos/cm at the forebay and 21 through 61 μmhos/cm at midreservoir. All conductivities greater than 30 μmhos/cm occurred at the bottom of the water column in July and August. Secchi depths averaged 2.4 meters at the forebay and 2.2 meters at midreservoir. The maximum Secchi depth was 3.1 meters at both stations, in September. Average TOC concentrations were about 1.8 mg/L at both stations.

In April, total nitrogen concentrations were 0.34 mg/L at the forebay, mostly as organic nitrogen, and 0.29 mg/L at midreservoir, slightly more than one-half as organic nitrogen. In August, the total nitrogen concentration at both stations had dropped to 0.04 mg/L. Ammonia concentrations were at or below the detection limit of 0.01 mg/L in all samples. Total phosphorus and dissolved orthophosphorus concentrations averaged 0.008 and 0.005 mg/L, respectively, at the forebay, and 0.015 and 0.006 mg/L, respectively, at midreservoir. Average chlorophyll-a concentrations were 4.1 μg/L at the forebay and 6.0 μg/L at midreservoir. The maximum chlorophyll-a concentration was 10 μg/L at midreservoir in April.

The Nottely midreservoir station had the lowest total nitrogen concentration, the third-lowest total organic carbon concentration, the third-highest total phosphorus concentration, and the fourth-highest chlorophyll-a concentration of the eight midreservoir stations under the limited monitoring program. Its water clarity is much less than the other Hiwassee River Basin Reservoirs but generally greater than the other TVA reservoirs.

Fish Community--Only the forebay of Nottely Reservoir was sampled in fall 1992. Shoreline electrofishing (ten transects) in the littoral zone and experimental gill netting (ten net-nights) in the offshore/deeper areas collected 820 individuals with 19 species represented. The two most abundant species represented in samples from the forebay were largemouth bass (54 percent) and bluegill (27 percent). Other common species included white bass (4 percent), spotted bass (3 percent), and white crappie (3 percent). The largemouth bass catch rate (44 per 300 m transect) was the highest recorded in all TVA reservoirs sampled. A FHAI of 54 indicated largemouth bass to be in fair condition in the littoral area of Nottely forebay.

A poor littoral fish community was indicated by RFAI analysis of forebay shoreline electrofishing results. With a RFAI value of 27, Nottely Reservoir was in the middle 30 percentile, compared to the other 13 tributary forebays sampled in fall 1992. The absence of any sucker, migratory spawning, intolerant, and lithophilic spawning species, and a low percentage of invertivorous individuals contributed to the poor RFAI value.

4.21 Blue Ridge Reservoir

4.21.1 Physical Description

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with an average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. Although Blue Ridge Reservoir is not operated for flood control (only peaking power production), it has a potential useful controlled storage of 101 feet (1691-1590 feet MSL), indicative of the large water level drawdowns which are possible; however, the annual drawdown averages only 36 feet.

4.21.2 Reservoir Health

The ecological health of Blue Ridge Reservoir was good in 1992, similar to that found in 1991. One minor difference was that the low algae levels observed in 1991 were even lower in 1992. This change lowered the algal rating to fair in 1992.

4.21.3 Reservoir Use Suitability

There are no fish consumption advisories on Blue Ridge Reservoir. One channel catfish composite from the forebay was collected in autumn 1991 and examined for pesticides, PCBs, and metals. Most organic analytes were not detected; those that were occurred in low concentrations. Likewise, all metal analytes were either not detected or were found in low or expected concentrations. Bacteriological sampling at recreation areas on Blue Ridge is being conducted in 1993. No bacteriological information was collected at recreation areas on Blue Ridge Reservoir in 1992. Based on 1990 information, the swimming area at Morgantown Point and the access location at Shallow Ford on the Toccoa River both fully support water contact recreation.

4.21.4 Synopsis of 1992 Conditions

Water--Blue Ridge Reservoir was thermally stratified from April to September with a maximum surface to bottom temperature difference (ΔT) of about 16°C and a maximum surface temperature of 27.1°C in July. In September, ΔTs dropped to 4°C as bottom temperatures reached 19.2°C from a low of 8.7°C in April. Photic zone dissolved oxygen was only slightly supersaturated with a maximum of 117 percent in July and less than 105 percent during the rest of the summer. Dissolved oxygen concentrations less than 2 mg/L were observed only once, at the bottom in August. Otherwise all dissolved oxygen measurements were above 3 mg/L.

The highest pH was 8.4 SU in the photic zone in July, the lowest was 5.8 SU at the bottom in August. Most pH measurements were between 6.0 and 7.5 SU. Conductivities varied from 14 to 24 µmhos/cm during the year, only near the bottom in August did conductivity reach 20 µmhos/cm. The average Secchi depth was 4.8 meters, with a maximum 6.1 meters in July.

TOC averaged 3.65 mg/L, and total nitrogen averaged 0.17 mg/L, with most of the total nitrogen as organic nitrogen. Both ammonia concentrations were at or below the detection limit of 0.01 mg/L. Total phosphorus and dissolved orthophosphorus averaged 0.007 mg/L and 0.004 mg/L, respectively. The average chlorophyll-a concentration was 2 µg/L.

The low nutrient loading limits photosynthetic activity and limits low dissolved oxygen occurrences. Blue Ridge has the greatest water clarity of all of the monitored TVA reservoirs. Its very low conductivity indicates it also has the softest water with the least buffering capacity. Consequently, pH can occasionally become very low (less than six standard units).

Fish Community--Only the forebay of Blue Ridge Reservoir was sampled in fall 1992. Electrofishing samples (10 transects) in shoreline areas and experimental gill netting samples (10 net-nights) offshore collected 541 individuals with 15 species represented. By far the predominant species captured was bluegill (70 percent) followed distantly by smallmouth bass (9 percent), white bass (7 percent), and largemouth bass (4 percent). There were four times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of bluegill inhabiting shoreline areas. Health of largemouth bass in the forebay as analyzed by the FHAI was the second-best (FHAI=27) recorded in all storage forebays sampled during fall 1992.

The RFAI score of 31 (based on littoral zone electrofishing results) rated fair and fell in to the middle 30 percentile when compared to other TVA storage forebays. This reservoir received good scores for four of the 11 metrics: percent omnivores, invertivores, and tolerant individuals, and FHAI. Depressed species diversity (seven taxa) accounted for low metric scoring in numbers of sucker, migratory spawning, and intolerant species.

4.22 Ocoee Reservoir No. 1 (Parksville Reservoir)

4.22.1 Physical Description

Ocoee No. 1 Reservoir, also known as Parksville Reservoir, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has an approximate surface area of 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin, and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet, and is about 100 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), it is designed with a useful controlled drawdown of 20 feet (838-818 feet MSL). Annual drawdown averages only about seven feet on Ocoee No. 1 Reservoir.

4.22.2 Reservoir Health

The ecological health of Parksville Reservoir is poor with little change in the two years Vital Signs monitoring activities have been conducted on the reservoir. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. In spite of the availability of nutrients, algal productivity (the base of the aquatic food chain) is very low and the reservoir does not support a balanced fish community. The fish populations in Parksville Reservoir are very low. The high dissolved oxygens found in Parksville Reservoir are largely due to a lack of oxygen consuming (i.e., decaying) matter. This adds evidence that little biological activity is occurring within the reservoir.

4.22.3 Reservoir Use Suitability

There are no fish consumption advisories in effect for Parksville Reservoir. However, screening studies over the past several years have found PCB concentrations near the level used to issue a "Limit Consumption" advisory. Analysis of a channel catfish composite sample from the forebay in 1991 followed this trend with a PCB concentration of 1.4 $\mu g/g$. As a result, TVA and the state designed and conducted a more detailed sampling of fish from there in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish--average of 10 was 1.5 $\mu g/g$ at the forebay and 1.0 $\mu g/g$ at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish--averages at the two sites were 0.6 and 0.7 $\mu g/g$, respectively. Bluegill sunfish and rainbow trout composites from these areas had low concentrations. There had been no action taken on these results at the time this report was prepared.

No bacteriological information was collected in 1992 on Parksville Lake; however, based on 1991 bacteriological information, the swimming area at Mac Point fully supports water contact recreation, as well as the white water rafting put-in and take-out locations on the Ocoee River upstream of Parksville Lake. Additional bacteriological sampling is planned in 1993.

4.22.4 Synopsis of 1992 Conditions

Water--The maximum surface temperature was 26.9°C in July, with a maximum temperature difference in the water column of 18°C. Maximum dissolved oxygen saturation in the photic zone was 105 percent in September. The lowest dissolved oxygen was 4.4 mg/L in October. The range in pH was 6.1 to 7.6 SU. Conductivities varied from 48 to 59 μmhos/cm. Secchi depths varied from 2.1 meters in April to 3.6 meters in July, with an average of 3.0 meters. The average TOC concentration was 1.05 mg/L. Total nitrogen concentrations averaged 1.6 mg/L, with about 60 percent as organic nitrogen. Ammonia concentrations were at or below the detection limit of 0.01 mg/L. Total phosphorus and dissolved orthophosphorus concentrations averaged 0.005 and 0.004 mg/L, respectively. Chlorophyll-a concentrations averaged 1.1 $\mu g/L$, with a maximum concentration of 2 $\mu g/L$.

Summer inflows flow over the hypolimnion and out the high level turbine intake, creating a short residence time for summer inflows, a long residence time in the hypolimnion, and strong thermal stratification. The lack of algal productivity severely limits dissolved oxygen depletion in the hypolimnion. Parksville Reservoir has the lowest or second-lowest concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll-a, but the third-highest concentration of dissolved orthophosphorus at the forebay of the ten tributary reservoirs under the limited monitoring program. The Ocoee River entering Parksville Reservoir carries a high sediment load which may be causing the phosphorus to precipitate. Metallic toxicity may also be a contributing factor in the low algal productivity.

Fish Community--Only the forebay of Parksville Reservoir was sampled in fall 1992. Shoreline electrofishing (ten transects) and offshore netting (ten net-nights) produced a total of 183 individuals including 16 species. Largemouth bass and bluegill were the most abundant species collected, amounting to 56 percent and 21 percent of the total sample, respectively. Channel catfish (4 percent) and yellow perch (3 percent) were also frequently encountered. A FHAI score of 67 indicated largemouth bass to be in fair condition in the forebay of Parksville Reservoir.

RFAI analysis of the shoreline electrofishing data determined the quality of the littoral fish community was poor. Parksville Reservoir (RFAI=25) was among the worst of the storage reservoir forebays. It received poor scores for seven of the 11 metrics used for the electrofishing RFAI, including low species diversity (11) and abundance (104), low percent invertivores (50 percent), and total absence of sucker, intolerant, and migratory and lithophilic spawning species.

Fish Tissue--There are no fish consumption advisories on Parksville Reservoir. However, previous screening studies conducted 1987 through 1990 have consistently found relatively high PCB concentrations (about 1.0 µg/g) and higher than expected selenium concentrations (about 1.0 µg/g) at the forebay. The channel catfish composite from the forebay in 1991 agreed with these results--PCB concentration was 1.4 µg/g and the selenium concentration was 0.6 µg/g. These selenium levels are not high enough to have implications for human health but are higher than anywhere else in the Tennessee Valley and might have environmental implications. Because of the consistently elevated PCB concentrations, TVA, TDCE, and TWRA designed and conducted a more intensive effort on Parksville Reservoir for autumn 1992. The study included individual analysis on channel catfish and largemouth from the forebay and upper reservoir area and composite analysis of bluegill sunfish from both areas and rainbow trout from the lower portion of the reservoir. PCBs, chlordane, selenium, and mercury were the analytes of interest. Results generally fell along expected line. PCB concentrations in channel catfish were relatively high (averages 1.5 and 1.0 µg/g and maxima 3.0 and 1.9 µg/g at the forebay and upper locations, respectively). PCB concentrations in largemouth bass were not as high (averages 0.6 and 0.7 μg/g and maxima 1.7 and 2.0 μg/g at the forebay and upper location, respectively). PCB concentrations in the bluegill and trout composites were only slightly above detection limits. Chlordane and mercury concentrations were low or not detected in all samples. Selenium concentrations fell generally as expected (around 1.0 μg/g). At the time this report was prepared, no action had been taken on these results.

4.23 Tims Ford Reservoir

4.23.1 Physical Description

Tims Ford Reservoir, in middle Tennessee, is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir at full pool is 34 miles long and has a surface area of 10,600 acres. The depth of the reservoir at the dam is 143 feet, and the reservoir has an average depth of about 50 feet. Average annual discharges from Tims Ford Dam average about 970 cfs, resulting in a hydraulic resident time of water in the reservoir of about 275 days. Tims Ford Reservoir has a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection, however, annual drawdowns average about 12 feet.

4.23.2 Reservoir Health

The ecological health of Tims Ford Reservoir in 1992, based on monitoring of water chemistry (temperature, pH, dissolved oxygen, and nutrients), chlorophyll-a, and fish was fair. This reservoir was monitored only for water chemistry and chlorophyll-a in 1991. The most obvious ecological health problem was the low concentrations of dissolved oxygen near bottom, which is often found in deep, tributary storage reservoirs with long detention times like Tims Ford. In spite of these low dissolved oxygen conditions, Tims Ford Reservoir has a fair to good fish community, helped by the availability of naturally occurring nutrients in the Elk River watershed which support adequate algal productivity.

4.23.3 Reservoir Use Suitability

There are no fish consumption advisories for Tims Ford Reservoir. Channel catfish composites collected from the forebay and transition zone in autumn 1992 were screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations. One point of interest was absence of PCBs in these samples because previous screening studies had typically found PCBs, sometimes at slightly elevated levels. Bacteriological data collected in 1992 show that the swimming area at Dry Creek Recreation Area partially supports water contact recreation because of high fecal coliform concentrations after rain. In addition, although there is no designated swimming area at Estill Springs Park, the data show that this location would fully support water contact recreation.

4.23.4 Synopsis of 1992 Conditions

Water--Tims Ford Reservoir was thermally stratified throughout the monitoring period with a maximum temperature difference of about 18°C and a maximum surface temperature of 28.4°C in July. Photic zone dissolved oxygen saturation averaged 167 percent at the forebay and 144 percent at midreservoir. Low dissolved oxygen (<2 mg/L) occurred at both stations from August through October. At the forebay there were two areas of low dissolved oxygen, at the bottom of the water column and in the metalimnion. At midreservoir there was only one area of low dissolved oxygen which extended from the bottom to within less than ten meters of the surface in August and September.

Photic zone pH was over 8.5 SU from April through September at the forebay and from May through July at midreservoir. The maximum pH was 9.1 SU at the forebay in May and July, and the minimum was 7.0 SU at midreservoir in the metalimnion in September. Conductivities at the forebay were generally between 100 and 150 μmhos/cm, with higher values occurring during periods of very low dissolved oxygen concentrations. The highest conductivity at the forebay was 176 μmhos/cm in September in the metalimnion. At midreservoir, conductivities were generally about 30 μmhos/cm higher than at the forebay with the highest value of 214 μmhos/cm again occurring in the metalimnion in September.

TOC concentrations averaged 2.8 mg/L at the forebay and 2.5 mg/L at midreservoir. Total nitrogen concentrations averaged 0.49 mg/L at the forebay and 0.69 mg/L at midreservoir. April concentrations were three- to four-times higher than August concentrations, and more than half consisted of nitrates plus nitrites. In August, most of the total nitrogen was in the form of organic nitrogen. The maximum photic zone ammonia was 0.02 mg/L. Total phosphorus and dissolved orthophosphorus averaged 0.01 mg/L and 0.003 mg/L at the forebay and 0.015 mg/L and 0.005 mg/L at midreservoir, respectively. Secchi depths averaged 2.3 meters at the forebay and 2.2 meters at midreservoir with a maximum depth of 3.0 meters at both stations, in July at midreservoir and in October at both stations. Chlorophyll-a concentrations averaged 6.9 μg/L at the forebay and 6.0 μg/L at midreservoir, with a maximum concentration of 14 μg/L at the forebay in May.

Tims Ford Reservoir has the third highest organic and nutrient loading of the ten limited monitoring tributary reservoirs. This results in high primary productivity, relatively low water clarity, and extensive areas of low dissolved oxygen.

Fecal Coliform Bacteria--Bacteriological studies were conducted at one swimming beach and three other sites on Tims Ford Reservoir in 1992. Fecal coliform bacteria concentrations were high during a period of high rainfall at the Dry Creek Recreation Area resulting in a does not support water contact recreational use classification. Bacteria concentrations at the other three sites (Estill Springs Park, Red Mill Bridge-Boiling Fork, and Lee Ford Bridge-Elk River) were low, allowing fully supports water contact use classifications. There were no monthly Vital Signs bacteriological samples collected at Normandy Reservoir in 1992.

Fish Community--Shoreline electrofishing (30 transects) and offshore experimental gill netting (36 net-nights) yielded 14,824 individuals with 31 species represented in Tims Ford Reservoir in 1992. However, spotfin shiners comprised 89 percent (13,192 individuals) of the total numbers collected. Disregarding spotfin shiners, the dominant species by number included bluegill (23 percent), channel catfish (22 percent), largemouth bass (7 percent), gizzard shad (6 percent), striped bass (5 percent), and smallmouth bass (5 percent). All three zones (forebay FHAI=71, midreservoir sampling location FHAI=76, and inflow zone FHAI=81) sampled in Tims Ford Reservoir revealed poor health of largemouth bass, as determined by FHAI analysis.

RFAI analysis of the shoreline electrofishing samples found a wide variation in the quality of the littoral fish community among sampling zones. The Tims Ford Reservoir inflow zone maintained the highest quality fish community (RFAI=39) found in all TVA storage inflows. The forebay (RFAI=35) fish community scored somewhat lower than the inflow zone but ranked in the upper-third of all tributary forebays sampled. The midreservoir sampling location fish community (RFAI=27) ranked in the middle 30 percentile compared to other tributary midreservoir sampling locations. All three sample zones received good metric scores for fish abundance and percent invertivores, fair designations for number of species, and poor ratings for percent tolerant individuals and FHAI. The midreservoir sampling location, forebay, and inflow zone received metric rankings of poor, fair, and good respectively, for numbers of sucker, migratory spawning, and intolerant species.

4.24 Normandy Reservoir

4.24.1 Physical Description

Normandy Reservoir, a tributary impoundment of the Duck River in middle Tennessee, is formed by Normandy Dam at Duck River mile (DRM) 248.6. Normandy Reservoir, constructed primarily for flood control and for water supply, has a drainage area of 195 square miles and no electric power generation capacity. Normandy Reservoir, one of TVA's smaller reservoirs, has at full pool elevation about 3200 surface acres, 73 miles of shoreline, and about 17 miles of impounded backwater. The reservoir has an average depth of about 35 feet and an average annual drawdown of about 11 feet.

4.24.2 Reservoir Health

Only fisheries and bacteriological monitoring were conducted in Normandy Reservoir in 1992. All ecological health indicator sampling (algae, dissolved oxygen, sediment quality, benthos, and fisheries) will be conducted on Beech Reservoir in 1993. However, based on past studies, Normandy Reservoir is considered to be one of the most eutrophic reservoirs in the Valley due to high nutrient concentrations (particularity phosphorus) which naturally occur in the Duck River basin. Low flows in the Duck River (ca. 350 cfs) at the dam site relative to the depth and storage volume of the reservoir, resulting in average annual hydraulic detention times or about 160 days, facilitate strong thermal stratification. Historically, dissolved oxygen concentrations have been very low in the hypolimnion during summer months, causing high concentrations of reduced species of sulfur, iron, and manganese. In addition, past studies have shown high concentrations of algae, dominated by nuisance blue-green algae. Vital Signs water quality monitoring will be initiated on Normandy Reservoir in 1993.

4.24.3 Reservoir Use Suitability

In 1992, fecal coliform bacteria concentrations at the Barton Springs swimming beach allow a fully supports water contact recreation classification. Fecal coliform bacteria concentrations at the Cedar Point Public Use Area were occasionally high, resulting in a partially supports water contact classification. There are no fish consumption advisories on Normandy Reservoir. A channel catfish composite collected from the forebay in autumn 1992 was screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations.

4.24.4 Synopsis of 1992 Conditions

Fecal Coliform Bacteria--Bacteriological studies were conducted at two swimming beaches and three boat docks on Normandy Reservoir in 1992. Fecal coliform bacteria concentrations at the Barton Springs swimming beach and three boat ramps (Boyd Branch boat ramp, Ward Chapel boat ramp, and Anthony Bridge boat ramp) allow a fully supports water contact recreation classification. Fecal coliform bacteria concentrations at the Cedar Point Public Use Area were occasionally high, resulting in a partially supports water contact classification. There were no monthly Vital Signs bacteriological samples collected at midreservoir locations on Normandy Reservoir in 1992.

Fish Community--Shoreline electrofishing (20 transects) and offshore experimental gill netting (24 net-nights) yielded 11,468 individuals with 25 species represented in Normandy Reservoir in 1992. However, gizzard shad comprised 90 percent (10,265 individuals) of the total number collected. Disregarding gizzard shad, the dominant species by number included bluegill (32 percent), spotfin shiner (14 percent), longear sunfish (11 percent), carp (9 percent), and largemouth bass (7 percent). Health of largemouth bass was fair in the forebay (FHAI=64) and poor in the midreservoir sampling location (FHAI=84).

RFAI analysis of the shoreline electrofishing samples resulted in the midreservoir sampling location and forebay to rate as fair with identical scores of 33. Both were in the upper-third each being second overall, when compared to other respective storage reservoir sample areas. Other similarities shared by these two sample zones included a good metric rating for percent invertivores, fair metric ratings for number of species, number of sucker, migratory spawning, and intolerant species, and a poor metric rating for percent tolerant individuals.

4.25 Beech Reservoir

4.25.1 Physical Description

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir, which is only 5.3 miles long and averages only about 12 feet deep, has no hydropower generating facilities and is the primary source of water supply for the city of Lexington. The reservoir is an urban lake with considerable residential lake front development, and it receives a large amount of recreational use relative to its small size of approximately 900 acres. Discharge from Beech Dam is estimated to average only about 14 cfs per day, resulting in very long estimated hydraulic residence times of 300 to 400 days.

4.25.2 Reservoir Health

As in 1991, only water quality monitoring was conducted in Beech Reservoir in 1992. All ecological health indicator sampling (algae, dissolved oxygen, sediment quality, benthos, and fisheries) will be conducted on Beech Reservoir in 1993. The 1992 water quality data continue to indicate poor ecological health in Beech Reservoir, evidenced by very low concentrations of dissolved oxygen and high chlorophyll-a concentrations.

4.25.3 Reservoir Use Suitability

No information was collected for bacteriological contamination at recreation areas on Beech Reservoir in 1992; however, bacteriological studies conducted in 1990 showed that the swimming beach area of Beech Reservoir fully supports water contact recreation. There are no fish consumption advisories on Beech Reservoir. Fish tissue samples were not collected in 1991 or 1992.

4.25.4 Synopsis of 1992 Conditions

Water--Beech Reservoir is the smallest and least thermally stratified of the monitored tributary reservoirs, with a maximum temperature difference of about 8°C in July. This is largely due to the shallow depth of the reservoir and the small amount of cool bottom water in Beech Reservoir. The average depth of Beech Reservoir is only about 12 feet. The maximum surface temperature was 30.7°C and the maximum photic zone dissolved oxygen saturation was 113 percent, both in July. At the forebay, low dissolved oxygen (less than 2 mg/L) occurred at the bottom of the water column from June through September, and was within 3.2 meters of the surface in July. The very low dissolved oxygen conditions dropped hypolimnetic pH to 5.8 SU in July, while maximum photic zone pH was 8.2 SU in April. Conductivities were generally between 30 and 50 μmhos/cm except at the bottom of the water column from June through August when values much higher were reached due to the extreme low dissolved oxygen conditions. The maximum conductivity of 118 μmhos/cm occurred in July. Secchi depth averaged 1.0 meters with a maximum of 1.3 meters in July.

TOC averaged 1.25 mg/L. Total nitrogen concentrations averaged 0.39 mg/L, over 90 percent of which was organic nitrogen. The maximum ammonia concentration was 0.03 mg/L. The average total phosphorus and dissolved orthophosphorus concentrations were 0.02 and 0.002 mg/L, respectively. Chlorophyll-a concentrations averaged 12.8 μg/L with a maximum concentration of 18 μg/L in April.

Beech Reservoir has very high organic and nutrient loadings, very high algal growth (compared to other TVA reservoirs), and very low water clarity. The small size of Beech Reservoir, especially the relatively shallow depth compared to other TVA reservoirs, and the primary discharge over the spillway means that inorganic turbidity also contributes to the low water clarity.

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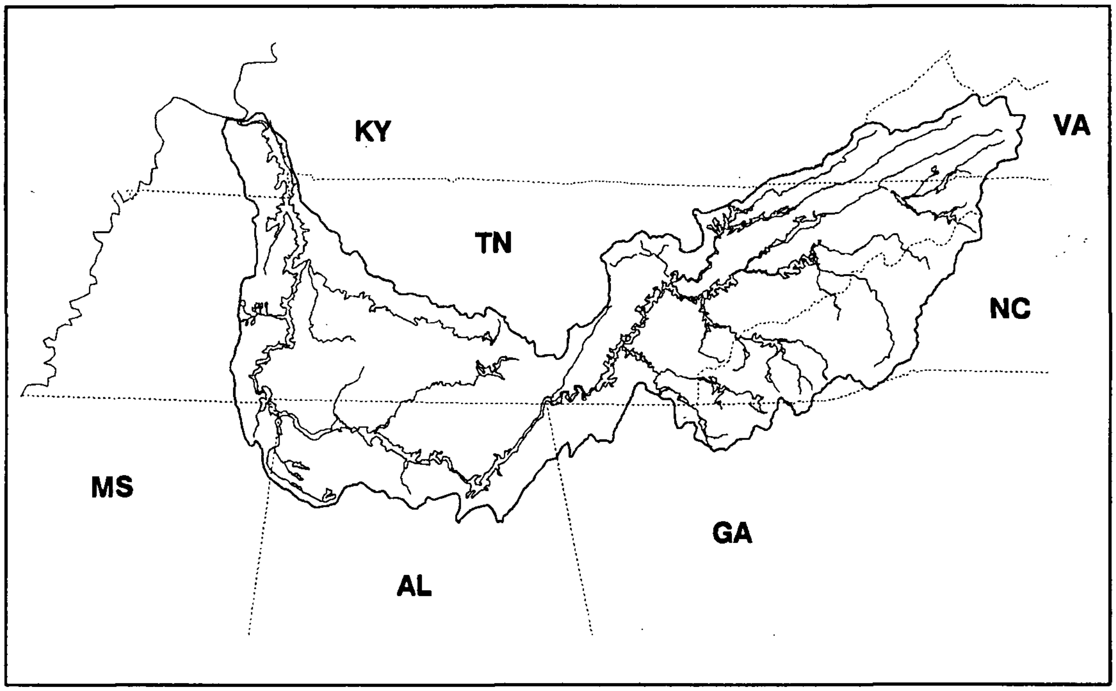
TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

VOLUME I



CLEAN WATER INITIATIVE

TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND
USE SUITABILITY MONITORING

Volume I

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EXECUTIVE SUMMARY

TVA initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component, and a reservoir monitoring component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary organized by sample locations within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-of-evidence approach was used--a stream or reservoir was deemed healthy if most of the physical, chemical, and biological monitoring components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used--dissolved oxygen, chlorophyll, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging from 1 to 5 representing very poor to excellent conditions, respectively. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year, the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these received perfect scores), three streams rated fair to good, and one stream rated poor. Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993. The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of-river reservoirs and deep storage reservoirs. Separate scoring criteria were used for the two categories. Overall ratings for the 11 run-of-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (75 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent). Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), 14 rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Most streams and reservoirs had ratings comparable to those observed in 1991 and 1992. Tributary reservoirs had generally poorer ratings, primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is partly due to the strong thermal stratification that occurs in deep reservoirs with relatively long retention times.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies.

Bacteriological Studies--Bacteriological samples are collected at over 260 sites in the Tennessee Valley. These include designated swimming areas, canoe access sites, highly used recreational areas, and selected nonrecreation sites that provide information on pollution sources or inflow stream water quality. Recreation sites are sampled at least once every two years.

In 1993, 71 swimming areas and 14 canoe access points were sampled for bacteriological conditions. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points on the Duck River exceeded the criterion, both in dry and wet weather.

Bacteriological sampling at nonrecreational areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

These results are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies--Fish tissue studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data are provided to appropriate state agencies to determine whether further study is needed or fish consumption advisories should be issued. Fish tissue data reported here represent autumn 1992 collections. Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time delay required for laboratory analysis.

Results of fish tissue screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies on waterbodies where there are known or suspected problems) did not indicate substantial changes from previous years.

1.0 INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) started a Stream Monitoring Program in 1986 to evaluate the major tributaries of the Tennessee Valley at fixed locations. A parallel program, Reservoir Monitoring, was begun in 1990 when funds were appropriated by Congress for TVA to strengthen its stewardship responsibilities. The combined Stream and Reservoir Monitoring efforts consolidated several newly-developed activities along with several existing activities to form an integrated program. These monitoring efforts, in addition to River Action Team watershed examinations and public information/educational activities, are now part of TVA's comprehensive Clean Water Initiative.

1.2 Objectives

Objectives of these monitoring efforts are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee River tributaries and reservoirs and to provide screening level information for describing how well these water resources meet the "fishable" and "swimmable" goals of the Clean Water Act.

The ecological integrity of stream and reservoir ecosystems is examined as part of an activity called Vital Signs monitoring. The basis of Vital Signs monitoring is examination of key physical, chemical, and biological indicators to evaluate the health of each stream or reservoir and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions as watershed improvements are made.

Another activity, Use Suitability monitoring, examines how well streams and reservoirs meet the fishable and swimmable goals of the Clean Water Act. Examination of levels of toxic contaminants in fillets from important fish species is the basis for the fishable use evaluation. Swimmable or water contact uses are examined by conducting bacteriological sampling at designated swimming beaches and other highly used recreation areas.

Using a quantitative approach to evaluate ecological health of water resources is relatively new, especially for reservoirs. This is only the third year TVA has used this approach, and we continue to make improvements based on experience gained each year. Ecological health evaluations drawn from this newly implemented monitoring program are subject to revision in future years as more data and experience are acquired on each reservoir. We welcome comments and suggestions for improvements in these ecological health evaluation methodologies. Please send comments/suggestions to the address above or contact appropriate individuals listed under key contacts on page ii.

1.3 Summary Report Description

Volume I of this report summarizes and integrates results from TVA's stream and reservoir monitoring activities in 1993. Chapter 1 provides background and objectives for the monitoring program. Chapter 2 describes the basis for study design and specific methods for sample collection. Chapter 3 describes the philosophical approach and data evaluation methods used for each indicator to determine stream and reservoir ecological health.

Chapter 4 provides an overview of hydrologic and meteorologic conditions for 1993. Conditions in streams and reservoirs are greatly affected by streamflow, rainfall, and temperature, as well as by physical and geologic characteristics of the watershed. Dams, and resulting reservoirs' dynamics, are important factors in the ecological health of regulated river systems. It is important to consider all these variables and their effects in evaluating ecological conditions of the Tennessee River system in any given year.

Chapter 5 discusses the 1993 monitoring results from a Valley-wide perspective. Discussion topics include an overview of ecological conditions, ecological indicators which "drove" the health ratings, changes from previous years, embayment monitoring (initiated in 1993), and swimmable and fishable conditions.

Chapters 6-17 provide a watershed-by-watershed summary and conclusions for each of the 12 watershed drainage areas in the Tennessee Valley. Each chapter provides a physical description of the watershed followed by a description of the physical characteristics, ecological health, and use suitability of each reservoir and stream monitoring site within the watershed. The ecological health evaluation is based on an integration of physical, chemical, and biological information gathered using the different Vital Signs monitoring tools.

Detailed summaries of 1993 results on each reservoir and stream are provided in Volume II of this report. Volume II is for technical audiences who prefer to form their own evaluation of conditions. It also serves as a detailed technical summary of conditions at TVA monitoring sites in 1993.

In addition to this technical summary report, a nontechnical document, *RiverPulse*, is available. *RiverPulse* (TVA, 1994) is broadly distributed to Tennessee Valley residents and users of TVA reservoirs. Annual issues of the technical report have been prepared since 1990, and annual issues of *Riverpulse* are available for 1991, 1992, and 1993. There also is a series of annual activity reports providing detailed results for each monitoring tool (e.g., water, sediment, benthos, fish, etc.). These detailed reports provide the basis for the summary report. Specific citations for summary and detailed reports are in the list of references. Copies of any of these documents are available from: TVA Water Management Library, 1101 Market Street, HB 2C-C, Chattanooga, TN 37402, Telephone: (615) 751-7338, FAX: (615) 751-7479.

2.0 DATA COLLECTION METHODS

2.1 Vital Signs Monitoring

2.1.1 Introduction

The study design for Vital Signs Monitoring is based on meeting the objectives outlined in Section 1.2. Several assumptions are fundamental to the study design:

1. Ecological health evaluations must be based on information on physical, chemical, and biological components of the ecosystem;
2. Vital Signs monitoring is a long-term effort to document the status of the river/reservoir system and track results of water quality improvement efforts;
3. Monitoring methods must be responsive by providing current information to resource managers;
4. The basic design must be considered dynamic and flexible, rather than rigid and static, and must allow adoption of new environmental monitoring techniques as they develop to meet specific needs; and
5. This is a monitoring program; it does not address specific cause/effect mechanisms. (The step beyond monitoring is assessment in which cause/effect investigations would target specific, identified concerns.)

Three important aspects were considered in establishing the study design: representative sampling locations; important ecological indicators; and frequency of sampling. The program that emerged balances these considerations as follows.

Sampling Locations--For reservoirs, the following three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam, Figure 2.1. Overbanks, basically the floodplain which was inundated when the dam was built, were included in transition zone and forebay areas. Another important reservoir area, embayments, also was considered. However, monitoring all embayments is beyond the scope of this program. Previous studies have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with relatively little influence from the main body of the reservoir. As a result, only four, large embayments, all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres, are included in the Vital Signs Monitoring Program. These were added in 1993 and are reported on here for the first time.

The stream monitoring sampling locations were located to sample the cumulative water quality for as large a percentage of a tributary watershed as possible, with sampling locations located in the free-flowing reaches of the river near the downstream end of the watershed, but upstream of any impounded water.

Ecological Indicators--Selection of appropriate ecological indicators for monitoring was tailored to the specific objective and type of monitoring location. Physical, chemical, and biological indicators were selected to provide information from various habitats or ecological compartments on the health of that particular habitat or compartment. In reservoirs (Figure 2.1) the open water or pelagic area was represented by physical and chemical characteristics of water (including chlorophyll) in midchannel. The shoreline or littoral area was evaluated by sampling the fish community. The bottom or benthic compartment was evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments and acute toxicity testing of pore water); and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

In streams, all available habitats were included to truly characterize the sample site. This is more easily accomplished in streams than in reservoirs because most habitats are visible. The same basic indicators used for reservoirs were also used in streams.

For both reservoirs and streams, information from each indicator was evaluated separately and results were then combined (without weighing) to arrive at an overall evaluation of reservoir ecological health. (See Chapter 3 for more details on the ecological health evaluation and scoring process.)

Sampling Frequency--Sampling frequencies were selected to take into consideration the expected temporal variation for each indicator. Physical and chemical components vary significantly in the short term, whereas biological components are more representative of long-term conditions. As a result, sampling for physical and chemical indicators is needed more frequently than biological indicators. In reservoirs, physical and chemical indicators were examined monthly from spring to fall and in streams every other month throughout the year. Biological indicators were sampled once each year for reservoir and stream sites. In reservoirs, benthic macroinvertebrate sampling was conducted in early spring (February-April), and fish assemblage sampling was conducted in autumn

(September-November). In streams, benthic and fish community sampling is conducted in late spring-early summer (May-June).

2.1.2 Reservoir Vital Signs Monitoring

The Vital Signs component of reservoir monitoring includes four main activities to examine and evaluate reservoir health:

(1) physical/chemical characteristics of water;

(2) acute toxicity and physical/chemical characteristics of sediment;

(3) benthic macroinvertebrate community sampling; and,

(4) fish assemblage sampling.

(In addition, aquatic macrophyte community information is included to provide a more comprehensive evaluation of each reservoir's ecological health.)

Data collection methods for each of these activities are given below. Sampling locations and specific monitoring activities for each reservoir are listed in Table 2.1 and shown in Figure 2.2.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality variables were measured at a total of 57 sampling locations on 30 reservoirs. Three specific QA/QC measures were incorporated in the reservoir physical/chemical water sampling activities. These included: (1) collection and analysis of triplicate sets of water samples once during the year at all forebay sampling locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling.

The water quality monitoring activities on the Vital Signs reservoirs followed a "basic" (11 run-of-the-river reservoirs) or a "limited" (19 tributary reservoirs) sampling strategy (Table 2.1).

Basic--Monitoring on the run-of-the-river reservoirs included monthly water quality surveys (April through September) at forebays and transition zones. Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone (defined as twice the Secchi depth) composite chlorophyll-a samples; and photic zone composite and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids. Physical/chemical water quality sampling was not conducted at most run-of-the-river reservoir inflows because most of these locations are tailwater areas of upstream dams; water quality characteristics there are more representative of processes in the upstream reservoir.

Limited--Tributary storage reservoirs were sampled monthly (April through October) for a smaller list of parameters. The approach was the same as for the run-of-the-river reservoirs, except that no fecal coliform, color, or suspended solids samples were collected, and only photic zone composites for nutrients and organic carbon samples were collected and only in April and August. The April and August nutrient samplings were designed to provide information on nutrient concentrations available at the beginning of the growing season, then near the end of the growing season. Forebays were sampled on all these reservoirs, and mid-reservoir locations were sampled on all but the smaller reservoirs.

Physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Reservoir health evaluation methods used to assess physical/chemical quality are described below (Section 3.1.2).

Acute Toxicity and Physical/Chemical Characteristics of Sediment--Annual sediment samples and near-bottom water samples were collected during the summer of 1993 from 59 locations, i.e., the forebays and transition zones (or mid-reservoir) of the 11 mainstream reservoirs and 19 tributary reservoirs as shown in Table 2.1. In addition, ten of the 59 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the ten sites. Replicate samples were handled and processed independently. Results from these ten sets of replicates were used to assess field methods consistency, variations in laboratory toxicity and physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment and Kemmerer or Isco water samplers were used to collect the near-bottom water. Each sediment sample was a composite of at least three subsamples independently collected at each sampling location from the original stream channel bed. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency, and split into two fractions: one fraction for acute toxicity testing, and one fraction for physical/chemical analyses. Samples were placed on ice immediately after collection, compositing, and splitting, and were shipped or carried to the appropriate laboratory. One split from each sampling location and the sample of near-bottom water were shipped to the Toxicity Testing Laboratory (TTL) for toxicity testing; the other split at each sampling location was shipped or carried to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute Toxicity Testing--Within 36 hours of collection, all sediment samples were screened for toxicity using Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. Organisms were exposed to undiluted interstitial (pore) water from the sediment and near bottom water. Interstitial water was obtained by refrigerated centrifugation of sediment. Control water consisted of Moderately Hard Reconstituted Water, MHRW (TVA, 1992b), (hardness of 80-100 mg/L as $CaCO_3$) enriched with 10 percent Tennessee River water from TTL's experimental channels for the daphnid test and MHRW adjusted to pH=7.5 using HCl for the rotifer test. All samples were aerated to bring dissolved oxygen levels to near saturation (8.4 mg/L at 25°C) before testing. Water chemistry (temperature, DO, pH, conductivity, alkalinity, and hardness) was measured for all samples and controls. After centrifugation of the sediment, pore water samples were collected and preserved and sent to the Environmental Chemistry Laboratory for un-ionized ammonia analysis. Four replicates of five individuals each were used in both tests. Rotifer (24-hr) and daphnid (48-hr) acute toxicity was reported if average survival in the four replicates was significantly reduced (95 percent probability) from the control.

Physical/Chemical Characteristics--Splits of the same sediment samples used in the toxicity testing were analyzed for 13 metals, un-ionized ammonia (in pore water), total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs, Table 2.3).

Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in TVA technical report (Moses, Simbeck, and Wade, 1994). How this sediment quality information was used in the reservoir health evaluations is described below in Section 3.1.2, Reservoir Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrate community samples were collected in the spring (March and April) of 1993 at 69 locations on the 30 Vital Signs reservoirs, Table 2.1. At each sample location, a line-of-sight transect was established across the width of the reservoir, and Ponar grab samples were collected at ten equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Only those samples which were collected from the permanently wetted bottom portion of the reservoir (i.e., those Ponar or Peterson samples collected below the elevation of the minimum winter pool level) were used to evaluate the condition of the benthic community. Samples were washed in the field, transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution. Specimens were sent to the laboratory where they were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Six metrics (Table 3.1) were chosen to evaluate the benthic macroinvertebrate community as it relates to the overall ecological health of the reservoir. These metrics and the rating scheme are described in Section 3.1.2, Reservoir Benthic Community Rating Scheme.

To assess the reproducibility of benthic macroinvertebrate sampling results, replicate samples were collected at nine of the 69 sampling locations in 1993, with all types of reservoir locations (i.e., forebay, transition zone, and inflow) included. At each of the replicate sampling locations, the sampling protocol involved collection of a first set of ten samples, leaving the sampling location, and then returning as near as possible to the original transect site (on the same day) and repeating the collection of a second (replicate) set of ten samples. The results from the nine sets of replicate samples were then evaluated for reproducibility. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request.

Fish Assemblage Sampling--In the autumn of 1993, electrofishing and/or gill netting data were collected from 69 locations on the 30 Vital Signs reservoirs to evaluate the fish assemblage, Table 2.1. Fifteen electrofishing runs (300 meters in length) were made at each location (forebay, transition or mid-reservoir, and inflow) with all habitats sampled in approximate proportion to their occurrence at the sampling location. Habitat distinctions were based on major changes in substrate (e.g., bluff, rip-rap, mud, etc.) and/or presence of cover such as brush or boat docks. Twelve experimental gill nets were also set overnight at each location covering all habitat types where conditions permitted. At some inflow locations, flow and/or lack of suitable sites limited the number of nets that could be set. All fish collected from either electrofishing or gill netting were enumerated, with length and weight measurements taken on important sport species. Estimated numbers were used when high densities of fish were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies. Twelve metrics (Table 3.3) were chosen to evaluate the fish assemblage as it relates to the overall ecological health of the reservoir and are described in Section 3.1.2, Reservoir Fish Assemblage Rating Scheme.

If the fish assemblage at a particular sampling location appeared to have changed substantially (up or down) from the previous year, the site was resampled (within one to two weeks) to assure that sampling conditions were not causing anomalous results. Resample results were used for two sampling locations (Cherokee Reservoir forebay and Guntersville Reservoir transition zone) during 1993 fish assemblage evaluations.

All data were recorded on a portable field data logger and downloaded to a personal computer before being added to the TVA mainframe fisheries data base. Fish assemblage data are available in computer-readable form from TVA upon request.

Aquatic Macrophytes--Coverage of aquatic macrophytes was determined from large-scale (1 inch=600 feet or 1 inch=1000 feet) color aerial photography flown during maximum submerged macrophyte coverage (late summer or early fall of 1993). Boat surveys to determine species composition of the dominant macrophyte communities were conducted at selected sites at the approximate time of the aerial overflight. Aquatic macrophyte colonies were delineated on mylar overlays attached to photographic prints, labeled according to species, and areal coverage determined using an electronic planimeter. Reservoirs flown for aerial photography in 1993 included Kentucky, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Tellico, South Holston, and lakes in the Beech River project. For reservoirs where aerial photography was unavailable, standard field surveys and historical information were used to estimate community composition and coverage. Submersed aquatic plant populations generally are rare in tributary reservoirs because of the wide fluctuations of water surface elevations associated with their operation for floodwater storage. Known populations have been extremely small, short-lived, and of little significance.

A detailed summary of TVA's Aquatic Plant Management Program for 1993 and planned work for 1994 is available in a technical report (Burns, Bates, and Webb, 1994) that is updated and published annually.

2.1.3 Stream Vital Signs Monitoring

In 1993, Vital Signs stream sampling locations were located on 12 major tributaries to the Tennessee River (Figure 2.3 and Table 2.2). At each stream sampling location, four types of information were collected and examined to assess the ecological health of the stream and to provide information for evaluating the conditions found in the downstream receiving reservoir. These four components of stream monitoring (which complement the same four components for reservoir monitoring) were:

(1) physical/chemical characteristics of water;

(2) acute toxicity and physical/chemical characteristics of sediment;

(3) benthic macroinvertebrate community sampling; and

(4) fish community sampling.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality characteristics were measured bimonthly (odd numbered months) at 12 stream locations (Table 2.2). QA/QC methods for the stream water quality sampling activities included: (1) collection and analysis of duplicate sets of water samples at five stream locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks (for metals and nutrient analyses) each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks (dissolved nutrients and dissolved metals) with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling. Physical/chemical water quality characteristics measured in 1993 included:

On-Site Measurements--flow, temperature, dissolved oxygen, pH, conductivity, alkalinity, and fecal coliform bacteria; and

Laboratory Measurements--physical analyses (hardness, color, turbidity, total suspended solids, total dissolved solids, and chemical oxygen demand), nutrient analyses (organic nitrogen, ammonia nitrogen, nitrite+nitrate nitrogen, total phosphorus, dissolved orthophosphorus, and total organic carbon), major cations/anions analyses (calcium, magnesium, sodium, potassium, chloride, and sulfate), and metal analyses (total and dissolved aluminum, dissolved cadmium, total and dissolved copper, total and dissolved iron, dissolved lead, total and dissolved manganese, dissolved nickel, dissolved silver, and total and dissolved zinc).

The physical/chemical water quality data are stored on EPA's water quality data storage and retrieval (STORET) system. Methods used to assess physical/chemical quality of each stream sampling location in regard to the ecological health evaluations are described in Section 3.1.3.

Acute Toxicity and Physical/Chemical Characteristics of Sediment--During the summer of 1993, an annual sediment and bottom water sample was collected at each of the 12 Vital Signs stream sampling locations, Table 2.2. Each sediment sample was a composite of at least five surficial sediment subsamples. At stream sampling locations with shallow and wadable water, subsamples were collected using clean stainless steel spoons. At sampling locations with deeper water, divers collected subsamples using one-liter glass jars. The subsamples were composited and thoroughly mixed to ensure uniform color and texture. At each sampling location the composited sample was then split for acute toxicity and for physical/chemical analyses. The split samples were placed on ice immediately and shipped to the Toxicity Testing Laboratory (TTL) at Browns Ferry Nuclear Plant for toxicity testing and to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute toxicity testing and physical/chemical analyses of the split samples were performed in exactly the same manner as described in Section 2.1.2, Reservoir Acute Toxicity and Physical/Chemical Characteristics of Sediment. Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in a TVA technical report (Moses, Simbeck, and Wade, 1994b). How this sediment quality information was used in the stream health evaluations is described in Section 3.1.3, Stream Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrates were sampled at the 12 stream sites between mid-May and early July (streamflow conditions permitting) in order to maximize collection before hatching of winged adults. The benthic sampling sites were located as close as possible to the corresponding water quality sampling location (Table 2.2), with exact site selection depending upon the presence of suitable habitat types. Stream habitat in Tennessee Valley rivers and streams can generally be classified as riffle, run, or pool.

Both quantitative (Hess and Surber) and qualitative (D-net and handpicking) samples were collected to define relative abundance and species occurrence at each site. Quantitative sampling was completed in substrate types ranging from rubble to gravel in both riffle and pool habitats. Qualitative sampling was limited to a maximum of two man-hours per site, or was discontinued when redundancy in organisms being collected was observed. In total, seven samples were collected per station. These include: (a) three Hess samples in pools at the head of a riffle in substrate that contained a light covering of silt; (b) three Surber samples collected in shallow riffle habitat and along the borders of emergent vegetation (limited to areas where the water did not exceed the depth of the sampling frame); and (c) a single qualitative sample of bottom fauna organisms using D-nets and handpicking from all habitats present. Habitats targeted for qualitative sampling were leaf packs, woody debris, emergent aquatic vegetation, and boulders.

All specimens were preserved in 10 percent formalin solution and returned to the laboratory for sorting, enumeration, and identification. Specimens were identified to the lowest practical taxon, typically genus or species. Twelve metrics, based on a classification system developed by Kerans et.al (1992), were used to evaluate the stream benthic ecological health (Table 3.4). Methods used to assess the ecological health of the benthic community at each stream sampling location are described below (Section 3.1.3, Stream Benthic Community Rating Scheme). Benthic macroinvertebrate data are available in computer-compatible form from TVA, upon request.

Fish Community Sampling--Fish community sampling was conducted in summer (May-July) at 11 of the 12 stream sampling locations in 1993, Table 2.2. (The Elk River site was not sampled.) A boat-mounted electrofishing unit was used for deep pool habitats, and a backpack electrofishing unit, dip nets, and seine were used for wadable habitats. At each stream site, at least four general habitats (run, riffle, shallow pool, and deep pool) were sampled until three consecutive units of sampling effort (seine haul or timed shocking run) produced no additional species per habitat. Additional habitats were sampled as determined by the field crew leader. Fish specimens that were difficult to identify were preserved and their identity later confirmed. All fish collected were enumerated. Numbers were estimated if high densities were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies.

A modified version of Karr's (1981) index of biotic integrity (IBI) was used to assess the condition of the resident fish community, Table 3.5. This evaluation scheme is described in Section 3.1.3, Stream Fish Community Rating Scheme. Fish community data are available in computer-readable form from TVA upon request.

2.2 Use Suitability Monitoring

Use Suitability monitoring provides screening level information on the suitability of selected reservoir areas and stream reaches in the Tennessee Valley for water contact recreation (swimmable) and suitability of fish for human consumption (fishable). The use suitability evaluation is based on results of: (1) bacteriological sampling at recreation areas, and (2) collection and analysis of fish tissue.

2.2.1 Bacteriological Sampling

In 1989, TVA began periodically sampling recreation sites in the Tennessee Valley for fecal coliform bacteria to determine each site's suitability for water contact recreation. In addition to swimming beaches, many other recreation sites were also included in the program, such as canoe launch areas, picnic areas, boat ramps, and marinas. This bacteriological sampling program now includes approximately 260 sites and is designed to sample all locations on a frequency of about once every other year. Prior to 1993, the sampling frequency was approximately once every five years.

Samples are collected in a manner to conform with state criteria and federal guidelines; at each site at least ten fecal coliform samples are collected within a 30-day sampling period during the summer recreation season. QA/QC procedures include running at least one duplicate sample at each site and preparation and analyses of sample container blanks each collection day to assess degree of contamination associated with sample containers, handling process, and analytical equipment. The suitability of a recreation site for water contact recreation is based on EPA guidelines for fecal coliform bacteria (EPA, 1991).

In 1993, fecal coliform samples were collected in spring and summer at 59 designated swimming beaches and 14 canoe access sites to evaluate use suitability for whole body water contact recreation. In addition, 53 informal recreation sites where incidental water contact may occur (e.g., boat launch ramps, picnic areas, parks, marinas, etc.), were sampled.

Monthly (April through September) bacteriological samples were collected at 20 forebay and transition zone locations and four major tributary embayments on the run-of-the-river reservoirs as part of the basic Vital Signs Reservoir Monitoring (Table 2.1).

All TVA bacteriological sampling data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Fehring, 1994) provides specific details and evaluations of TVA's 1993 bacteriological monitoring results, and is available upon request.

2.2.2 Fish Tissue Sampling

In cooperation with Valley states, since 1987 TVA has collected and analyzed fish from over 80 Tennessee Valley reservoir and stream locations as part of both "screening" and "intensive" evaluations. In screening studies, composited fillets of indicator fish species (primarily channel catfish) are analyzed for a wide range of potential contaminants to identify possible problem areas where intensive investigation may be needed. Intensive studies are conducted on reservoirs or streams where contamination problems are known or suspected, based on the screening study information. For intensive studies, individual fillets from several important fish species are analyzed for specific contaminants to better document the number of species contaminated and level of contamination in each species. Intensive studies also include a higher density of sampling locations in the reservoir or stream of interest to better define the spatial extent of the contamination. The intent is to provide information that state public health officials can use to determine whether fish consumption advisories should be issued to protect human health.

Screening Studies--Channel catfish were collected from 16 reservoirs in autumn of 1992. Fillets were removed, composited by location, and analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List (Table 2.3). During the preparation process, observations of external and internal conditions of each fish were recorded along with length, weight, sex, fillet weight, and liver weight.

Intensive Studies--The following six TVA reservoirs were examined intensively in 1992: Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Ocoee No. 1 (Parksville Reservoir). In each case, the contaminant of concern was PCBs, except for Wheeler, where DDT is the problem. Chlordane was also of concern in some reservoirs. Fish consumption advisories that recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all these reservoirs except Ocoee No. 1.

All fish tissue data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Williams and Dycus, 1993) provides specific details and evaluations of TVA's 1991 and 1992 fish tissue studies and is available on request.

Figure 2.1

Schematic of Key Reservoir Sampling Areas

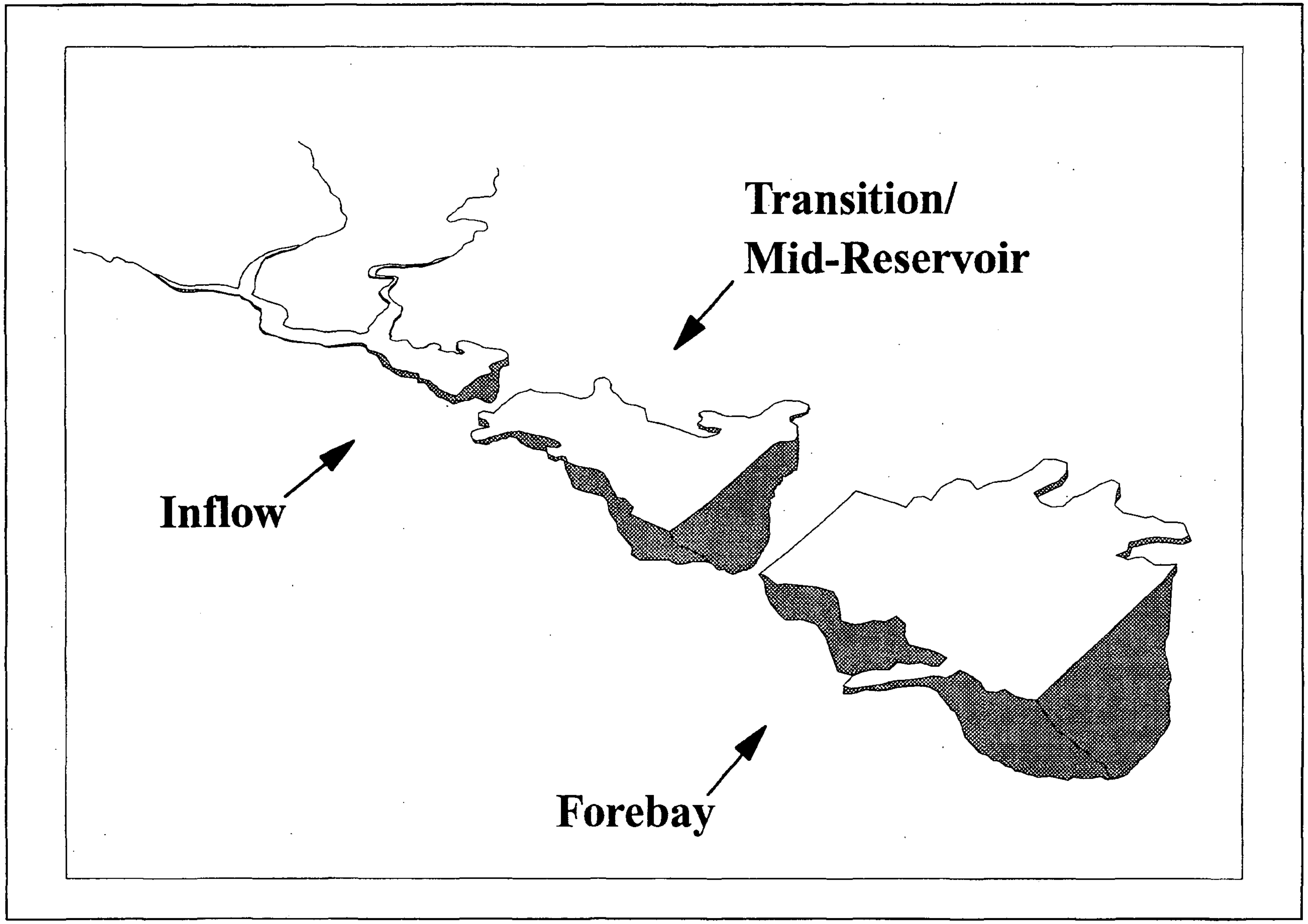
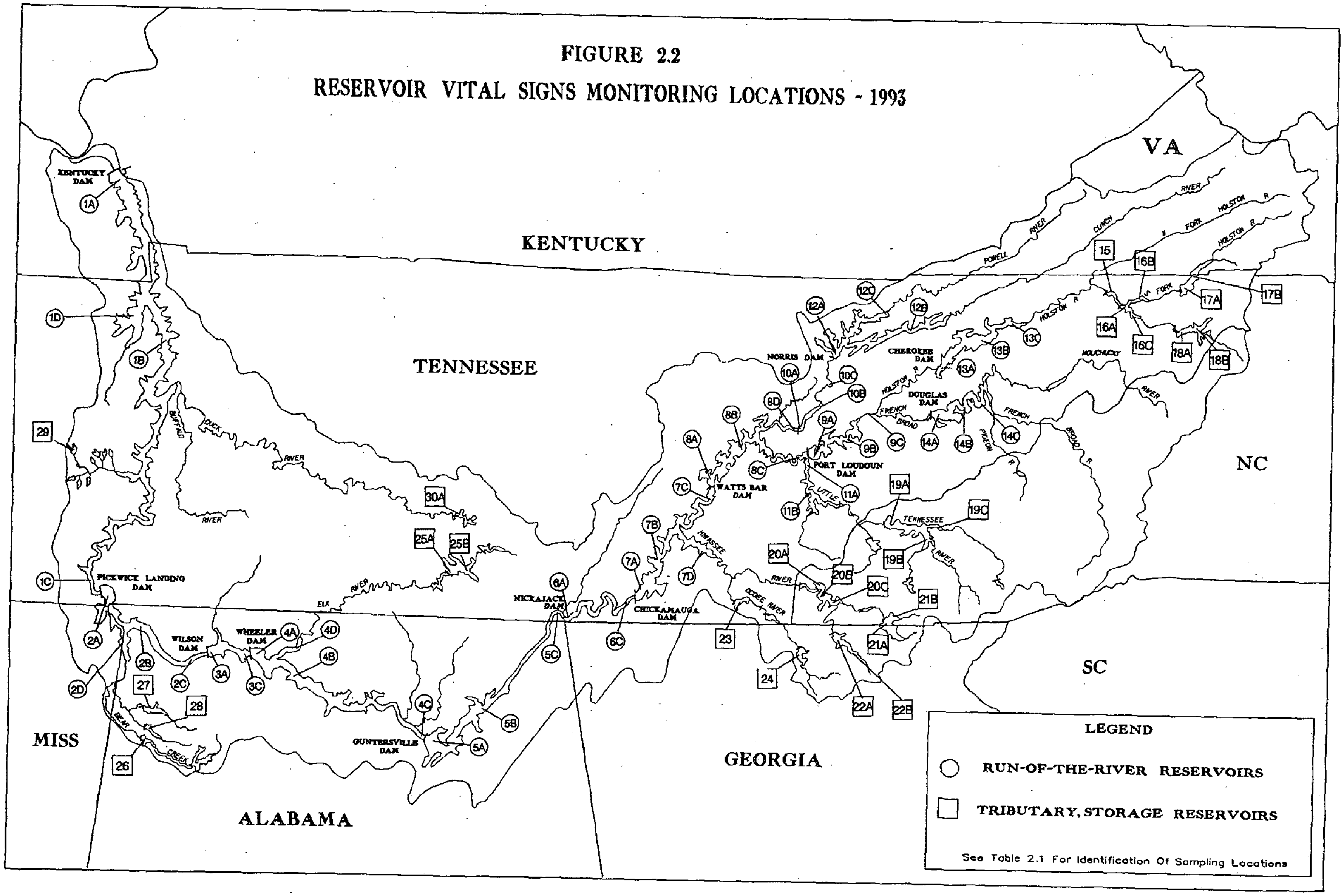


FIGURE 2.2
RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1993



PRODUCED BY TVA MAPPING SERVICES

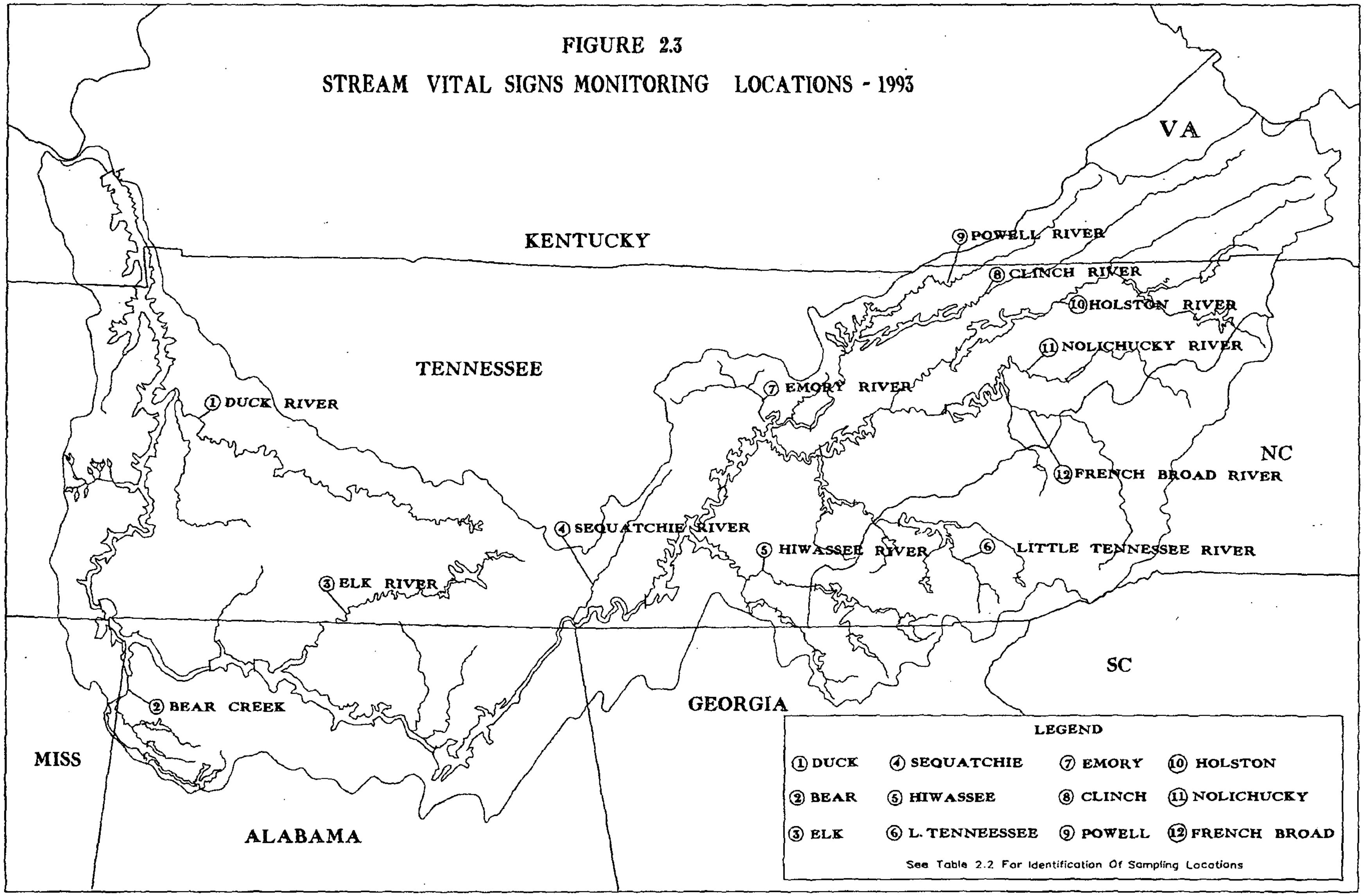


FIGURE 2.3
STREAM VITAL SIGNS MONITORING LOCATIONS - 1993

PRODUCED BY TVA MAPPING SERVICES

Table 2.1
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	202832	1A-FB	M	A	A	A	A
	TRM 85.0	477403	1B-TZ	M	A	A	A	A
	TRM 200-206	--	1C-I	-	-	-	A	A
	Big Sandy 7.4	477210	1D-E	M	A	A	A	A
Pickwick	TRM 207.3	476799	2A-FB	M	A	A	A	A
	TRM 230.0	016923	2B-TZ	M	A	A	A	A
	TRM 253-259	--	2C-I	-	-	-	A	A
	Bear Cr 8.4	017849	2D-E	M	A	A	A	A
Wilson	TRM 260.8	016912	3A-FB	M	A	A	A	A
	TRM 273-274	--	3C-I	-	-	-	A	A
Wheeler	TRM 277.0	016900	4A-FB	M	A	A	A	A
	TRM 295.9	017009	4B-TZ	M	A	A	A	A
	TRM 347-348	--	4C-I	-	-	-	A	A
	Elk River 6.0	017850	4D-E	M	A	A	A	A
Guntersville	TRM 350.0	017261	5A-FB	M	A	A	A	A
	TRM 375.2	017522	5B-TZ	M	A	A	A	A
	TRM 420-424	--	5C-I	-	-	-	A	A
Nickajack	TRM 425.5	476344	6A-FB	M	A	A	A	A
	TRM 469-470	--	6C-I	-	-	-	A	A
Chickamuaga	TRM 472.3	475358	7A-FB	M	A	A	A	A
	TRM 490.5	475265	7B-TZ	M	A	A	A	A
	TRM 518-529	--	7C-I	-	-	-	A	A
	Hiwassee 8.5	477512	7D-E	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

				Reservoir Vital Signs Monitoring Tools				
					Sediment Quality[d]			
Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	475317	8A-FB	M	A	A	A	A
	TRM 560.8	476041	8B-TZ	M	A	A	A	A
	TRM 600-601	--	8C-I	-	-	-	A	A
	CRM 19-22	--	8D-I	-	-	-	A	A
Fort Loudoun	TRM 605.5	477404	9A-FB	M	A	A	A	A
	TRM 624.6	475603	9B-TZ	M	A	A	A	A
	TRM 652	--	9C-I	-	-	-	A	A
Melton Hill	CRM 24.0	477064	10A-FB	M	A	A	A	A
	CRM 45.0	476194	10B-TZ	M	A	A	A	A
	CRM 59-66	--	10C-I	-	-	-	A	A
Tellico	LTRM 1.0	476260	11A-FB	M	A	A	A	A
	LTRM 15.0	476456	11B-TZ	M	A	A	A	A
	LTRM 21.0	476295	-	-	A	A	-	-
			Totals	24	25	25	35	35

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	476009	12A-FB	M	A	A	A	A
	CRM 125.0	477186	12B-MR	M	A	A	A	A
	PRM 30.0	477187	12C-MR	M	A	A	A	A
Cherokee	HRM 53.0	475025	13A-FB	M	A	A	A	A
	HRM 76.0	475028	13B-MR	M	A	A	-	A
	HRM 91	--	13C-I	-	-	-	A	A
Douglas	FBRM 33.0	475081	14A-FB	M	A	A	A	A
	FBRM 51.0	477510	14B-MR	M	A	A	-	A
	FBRM 61	--	14C-I	-	-	-	A	-
Ft.Pat Henry	SFHR 8.7	477509	15-FB	M	A	A	A	A
Boone	SFHR 19.0	475858	16A-FB	M	A	A	A	A
	SFHR 27.0	476221	16B-MR	M	A	A	A	A
	WRM 6.5	477511	16C-MR	M	A	A	A	A
South Holston	SFHR 51.0	475859	17A-FB	M	A	A	A	A
	SFHR 62.5	475573	17B-MR/I	M	A	A	A	A
Watauga	WRM 37.4	475576	18A-FB	M	A	A	A	A
	WRM 45.5	477513	18B-MR	M	A	A	A	A
Fontana	LTRM 62.0	370004	19A-FB	M	A	A	A	A
	LTRM 81.5	370177	19B-MR	M	A	A	A	A
	TkRM 3.0	370162	19C-MR	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	370001	20A-FB	M	A	A	A	A
	HiRM 85.0	370154	20B-MR	M	A	A	A	A
	HiRM 90	--	20C-I	-	-	-	A	A
Chatuge	HiRM 122.0	370003	21A-FB	M	A	A	A	A
	Shooting Cr 1.5	370178	21B-FB	M	A	A	A	A
Nottely	NRM 23.5	120883	22A-FB	M	A	A	A	A
	NRM 31.0	120806	22B-MR	M	A	A	A	A
Ocoee No.1	ORM 12.5	475684	23-FB	M	A	A	A	A
	ORM 16.5	--	-	-	A	-	-	-
Blue Ridge	ToRM 54.1	130032	24-FB	M	A	A	A	A
Tims Ford	ERM 135.0	477072	25A-FB	M	A	A	A	A
	ERM 150.0	475768	25B-MR	M	A	A	A	A
Bear Creek	BCM 75.0	017041	26-FB	M	A	A	A	A
Cedar Creek	CCM 25.2	017233	27-FB	M	A	A	A	A
L.Bear Creek	LBCM 12.5	017474	28-FB	M	A	A	A	A
Beech	BRM 36.0	475876	29-FB	M	A	A	A	-
Normandy	DRM 249.5	477453	30-FB	M	A	A	A	A
			Totals	33	34	33	34	34

Footnotes

a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. Numbers are keyed to Figure 2.2. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near-bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone chlorophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. Once a year (August) bottom water samples are collected for ammonia nitrogen. No samples are collected for fecal coliform, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near-shore fish community, during autumn.

Table 2.2
1993 Vital Signs Monitoring

STREAM VITAL SIGNS MONITORING LOCATIONS, 1993

Tributary Stream	River Mile	STORET ID #	Description
Duck River	26.0	475793	USGS stream gage above Hurricane Mills, TN
Bear Creek	27.3	017019	TVA stream gage near Bishop, AL
Elk River	36.5	477330	USGS stream gage at Veto Road bridge near Prospect, TN
Sequatchie River	6.3	477177	Valley Road bridge near Jasper, TN
Hiwassee River	36.9	477369	East Patty Road bridge near Benton, TN
Little Tennessee River	94.7	370158	USGS stream gage near Needmore, NC
Emory River	18.3	475838	USGS stream gage at Oakdale, TN
Clinch River	159.8	475846	USGS stream gage near Tazewell, TN
Powell River	65.4	475098	TVA stream gage near Arthur, TN
Holston River	118.7	475945	TVA stream gage near Surgoinsville, TN
Nolichucky River	10.3	477150	TVA stream gage at David Thomas bridge near Lowland, TN
French Broad River	77.5	475086	US Hwy 411 bridge at Oldtown, TN

Table 2.3
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Metals and Ammonia		
Aluminum, mg/g	1 mg/g	--
Arsenic, mg/kg	1 mg/kg	8 mg/kg[b]
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/g	0.5 mg/g	--
Chromium, mg/kg	10 mg/kg	75 mg/kg[b]
Copper, mg/kg	2 mg/kg	50 mg/kg[b]
Iron, mg/g	1 mg/g	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/g	0.5 mg/g	--
Manganese, mg/g	0.1 mg/g	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	10 mg/kg	300 mg/kg
Un-ionized Ammonia (in pore water), μg NH_3/l	10 $\mu g/l$	200 $\mu g/l$
Solids		
Total solids, %	0.1%	--
Total volatile solids, %	0.1%	--
Particle size, <0.062 mm diameter, %	0.1%	--
Particle size, <0.125 mm diameter, %	0.1%	--
Particle size, <0.50 mm diameter, %	0.1%	--
Particle size, <2.0 mm diameter, %	0.1%	--
Organochlorine Pesticides and PCB's		
Aldrin, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
α-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
β-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
γ-Benzene Hexachloride (Lindane), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
δ-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
Chlordane, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
Dieldrin, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
ρ,ρ DDT, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
ρ,ρ DDD, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
ρ,ρ DDE, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$

Table 2.3 (continued)
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Organochlorine Pesticides and PCB's (continued)		
α-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
ß-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
Endosulfan Sulfate, μg/kg	10 μg/kg	10 μg/kg
Endrin, μg/kg	10 μg/kg	10 μg/kg
Endrin Aldehyde, μg/kg	10 μg/kg	10 μg/kg
Heptachlor, μg/kg	10 μg/kg	10 μg/kg
Heptachlor Epoxide, μg/kg	10 μg/kg	10 μg/kg
Methoxychlor, μg/kg	10 μg/kg	10 μg/kg
PCB-1221, μg/kg	100 μg/kg	100 μg/kg
PCB-1232, μg/kg	100 μg/kg	100 μg/kg
PCB-1242, μg/kg	100 μg/kg	100 μg/kg
PCB-1248, μg/kg	100 μg/kg	100 μg/kg
PCB-1254, μg/kg	100 μg/kg	100 μg/kg
PCB-1260, μg/kg	100 μg/kg	100 μg/kg
PCB-1016, μg/kg	100 μg/kg	100 μg/kg
PCBs, Total, μg/kg	100 μg/kg	100 μg/kg
Toxaphene, μg/kg	500 μg/kg	500 μg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

3.0 ECOLOGICAL HEALTH AND USE SUITABILITY DETERMINATION METHODS

3.1 Vital Signs Monitoring

3.1.1 Introduction

The objective of Vital Signs monitoring is to determine the health or integrity of the aquatic ecosystem within each reservoir or at each stream sampling location. There are no official or universally accepted guidelines or criteria upon which to base such an evaluation. Consequently, an evaluation methodology was developed to assess the overall ecological health or condition of each of the 30 TVA Vital Signs reservoirs and 12 Vital Signs stream monitoring locations. The ecological health evaluation system combines both biological and physical/chemical information to examine reservoir and stream health. Five aquatic ecosystem indicators are used for reservoirs: dissolved oxygen, chlorophyll-a, sediment quality, benthic macroinvertebrates, and fish community; and four aquatic ecosystem indicators are used for streams: nutrient concentration, sediment quality, benthic macroinvertebrates, and fish community.

A critical step in developing an ecological health evaluation is deciding for each indicator what represents good conditions and what indicates poor conditions. This is more easily done for evaluation of streams because there usually are essentially unaltered reference sites that can be examined to define "good" conditions for each indicator, for example the various indices of biotic integrity for fish and benthic stream communities. Because reservoirs are man-made alterations of natural streams, there are no "reference reservoirs." An alternative approach to "reference conditions" is required.

3.1.2 Reservoir Ecological Health

Scoring criteria for the reservoir dissolved oxygen and chlorophyll-a indicators were based on what could be considered a conceptual model. This simply means that the criteria were developed subjectively, based on several years experience in evaluating biological systems in reservoirs. This experience has shown that below a threshold level of chlorophyll, primary production is not sufficient to support an active, biologically healthy food chain. In addition, chlorophyll concentrations above a higher threshold levels result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment. The conceptual model for dissolved oxygen criteria for a reservoir is quite complicated due to the combined effects of flow regulation and the potential for oxygen depletion in the hypolimnion. The scoring criteria described below attempt a multidimensional approach that includes considering dissolved oxygen levels both in the water column and near the bottom of the reservoir.

For the benthic macroinvertebrate and fish community indicators, scoring criteria are developed based on statistical examination of two or more years of data from TVA reservoirs. For these indicators, all previously collected TVA reservoir data for a selected community characteristic (e.g., number of taxa, total abundance, etc.) were ranked and divided into good, fair, and poor groupings. (Specific procedures used to determine scoring criteria for each grouping are given in Section 3.1.2, Benthic Community Rating Scheme and Fish Assemblage Rating Scheme.) Data for the current year of monitoring (e.g., 1993) are then compared to these criteria and scored accordingly. This approach is valid if the data base is sufficiently large and if it can be safely assumed that the data base covers the full spectrum of good to poor conditions.

The sediment quality indicator scoring criteria uses a combination of two characteristics: sediment toxicity to test organisms; and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs (using published guidelines for many of these analytes).

Dissolved Oxygen (DO) Rating Scheme--Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about the nature of a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are low in the metalimnion and hypolimnion. Hypolimnetic and metalimnetic oxygen depletion are common, but undesirable, occurrences in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia also promotes the biochemical release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, these chemicals can cause chronic or acute toxicity to bottom-dwelling animals.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions exist. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish growth and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

The ecological health evaluation considers oxygen concentrations in both the water column (WC_{DO}) and near the bottom of the reservoir (B_{DO}). The DO rating at each sampling location (ranging from 1 "poor" to 5 "good") is based on monthly summer water column and bottom water DO concentrations. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.) The final DO rating is the average of the water column DO rating and the bottom DO rating:

$$\text{DO Rating} = 0.5\ (WC_{DO}\ \text{rating} + B_{DO}\ \text{rating}),\ \text{where:}$$

WC_{DO} (Water Column DO) Rating--a six-month average of the percent of the reservoir cross-sectional area (at the location where the sampling was conducted--see Figure 3.1) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L.

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location
$<5\%$	5 (good);
$\geq 5\%$ but $\leq 10\%$	3 (fair);
$>10\%$	1 (poor).

Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows:

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted, Figure 3.1) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Chlorophyll Rating Scheme--Algae are the base of the aquatic food chain. Consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977). Too little primary productivity in reservoirs (mean summer chlorophyll-a concentrations less than 3 μg/L) indicates an inability to sustain a well-fed, growing, balanced, and healthy aquatic community. This eventually results in low standing stocks of fish. Too much primary productivity (mean summer concentrations greater than 15 μg/L) often is evidenced by occasional dense algal blooms, poor water clarity, and the predominance of noxious blue-green algae, and indicates poor ecological health. The large amounts of algal plant material produced under these conditions also deplete oxygen concentrations as the algae die and decompose. This can cause or aggravate problems of low DO in bottom waters.

Chlorophyll ratings at each sampling location are based on the average summer concentration of monthly, photic zone chlorophyll-a samples (corrected) collected from April through September (or October), as shown below. If triplicate samples are collected at a sampling location, the median value of the triplicate is used in calculating the summer average and the maximum.

Average Chlorophyll-a Concentration*	Sampling Location Chlorophyll Rating
Less than 3 μg/L	3 (fair);**
3 to 10 μg/L	5 (good);
10.1 to 15 μg/L	3 (fair);
Greater than 15 μg/L	1 (poor).

* If any single chlorophyll-a sample exceeds 30 μg/L, the value is not included in calculating the average, but the rating is decreased one unit, (i.e., 5 to 4, or 4 to 3, etc.) for each sample that exceeded 30 μg/L.

** If nutrients are present (e.g., nitrate+nitrite greater than 0.05 mg/L and total phosphorus greater than 0.01 mg/L) but chlorophyll-a concentrations are generally low (e.g., $\leq$ 2 μg/L), another/other limiting or inhibiting factors such as toxicity is likely. When these conditions exist, chlorophyll is rated 2 (poor).

Sediment Quality Rating Scheme--Contaminated bottom sediments can have direct adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. There are many sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). TVA's approach combines two sediment assessment methods--one biological, the other chemical--to evaluate sediment quality. TVA's scoring criterion is based on ratings for the toxicity of sediment pore water (S_{TOX}) to test organisms, and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia (Table 2.3). The final sediment quality score or rating is the average of these two ratings:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating), where:

S_{TOX} (Sediment Toxicity) Rating--Sediment toxicity is evaluated using both Rotox® (rotifer Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. The acute toxicity evaluations entail the exposure of these organisms (zooplankton) to interstitial pore water from sediment. The survival rates of the organisms are based on the average survival in four replicates of five individuals each, compared to a control. If average survival is significantly reduced (95 percent probability) from the control, the sample is considered to be toxic. Sampling locations are rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good)	Survival not significantly different than control and greater than or equal to 80 percent for both species, (i.e., no significant toxicity);
3 (fair)	Survival not significantly different from control, but less than 80 percent survival for either species; or
1 (poor)	Survival of either organism significantly less than control, (i.e., significant toxicity).

***S_{CHM}* (Sediment Chemistry) Rating**--Splits of the same sediment used in the sediment toxicity testing are analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings are based on: (a) concentrations of heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (EPA, 1977); (b) detectable amounts of PCBs or pesticides; and (c) concentrations of un-ionized ammonia in pore water above 200 μg NH_3/L. Each sampling location is rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

* Analytes (i.e., heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in Table 2.3.

Benthic Community Rating Scheme--Six community characteristics (or metrics), with scoring criteria specific to either run-of-the-river or storage reservoirs, are used to evaluate the ecological health of the benthic macroinvertebrate community (Table 3.1). These characteristics are:

1. **Taxa Richness**--The number of different taxa present. An increase in total taxa or taxa richness is used to indicate better conditions than low taxa richness.

2. **Longed-Lived species**--The number of taxa (<u>Corbicula</u>, <u>Hexagenia</u>, mussels, and snails) present. These organisms are long-lived and their presence indicate conditions which allow long-term survival.

3. **EPT**--The number of different taxa within these orders (Ephemeroptera-mayflies, Plecoptera-stoneflies, and Tricoptera-caddisflies). Higher numbers of this metric indicate good water quality conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.

4. **Proportion as Chironomidae**--The percent of the total organisms in the sample that are chironomids. A higher proportion indicates poor conditions.

5. **Proportion as Tubificidae**--The percent of the total organisms present that are tubificids. A higher proportion indicates poor quality.

6. **Proportion as Dominant Taxa**--The percent of total organisms present that are members of the dominant taxon. This metric is used as an evenness indicator. A large proportion comprised by one or two taxa indicates poor conditions.

Specific scoring criteria were developed for each of the six metrics for both run-of-the-river reservoirs and tributary reservoirs. And given the substantial habitat differences among forebays, transition zones/mid-reservoirs, and inflows, specific scoring criteria were also developed for each of these areas (Table 3.1). Data handling also differed among the metrics. Metric 1, taxa richness, is the average total number of taxa per sample at each site. Metrics 2 and 3 are handled similarly. For Metric 4 the proportion of chironomids in each sample is calculated, then these proportions are averaged for a location. An alternative that was considered was to sum the number of chironomids in all samples and divide by the sum of the total individuals for all samples. The approach selected gives equal weight to all samples regardless of sample size or sampling gear (Ponar or Peterson dredge). This eliminates the bias introduced in the alternate approach when one sample at a site has an exceptionally large or small density. Metric 5 is calculated in the same way. Metric 6, proportion as dominant taxa, is calculated as proportion for each sample, similar to computations for Metrics 4 and 5. The proportion is calculated for the dominant taxon in each sample even if the dominant taxon differed among the samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples at the site.

A quantitative approach is used to evaluate the benthic macroinvertebrate community information. The range of values for each of the six metrics found in the available data base (in this case, all the 1991, 1992, and 1993 Vital Signs benthic monitoring data) serves as the basis for evaluation criteria. For each metric at each of the three reservoir sampling zones (forebay, transition zone/mid-reservoir, and inflow) and two reservoir types (run-of-the-river and tributary) the data base values are divided into three groups using Ward's minimum variance analysis (SAS, 1989). This procedure places observations into three homogenous groups of approximate equal size. The groups are sorted and categorized as poor, fair, or good. Scoring criteria represent values between the highest and the lowest value in each group (Table 3.1). Results for each metric for the current year are then compared with these criteria and assigned quantitative values of 1 (poor), 3 (fair), or 5 (good) if they fall within the bottom-, middle-, or top-group, respectively. This results in a minimum score of 6 if all metrics at a site are poor, and a maximum score of 30 if all metrics are good. Detailed scoring criteria for each metric are provided in Table 3.1.

Metrics are summed for each reservoir sampling site to yield a final benthic score and are evaluated as follows:

Sum of Benthic Community Metric Scores	Sampling Location Benthic Rating
6-10	1 (poor)
11-15	2
16-20	3 (fair)
21-25	4
26-30	5 (good)

Fish Assemblage Rating Scheme--In 1993, a Reservoir Fish Assemblage Index (RFAI) (Hickman et.al, 1994) was used to rate fish assemblages as they relate to the overall ecological health of the reservoir. The RFAI is based on 12 metrics with scoring criteria specific to either run-of-the-river or storage reservoirs. Scoring criteria also are specific for the type of sample location within reservoirs--forebay, transition zone/mid-reservoir, or inflow; and for the type of sampling gear used (i.e., electrofishing for littoral fish communities and gill netting for pelagic fish communities). The metrics address the following 12 reservoir fish assemblage characteristics. Table 3.2 lists the trophic, reproductive, and tolerance designations of fish species collected as part of Vital Signs Reservoir Monitoring activities.

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.

2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.

3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and high sediment quality in littoral areas.

4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs. This metric closely parallels the lithophilic spawning species metric (Metric 10) and may be deleted from future RFAI calculations.

5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.

6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.

7. **Percent dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.

9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners are selected due to their sensitivity to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance and Fish Health

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

12. **Percent individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Each metric is assigned a score of 5, 3, or 1 -- representing "good," "fair," or "poor," conditions, respectively. Due to the distinct habitat differences among reservoirs and sampling locations--and the differences in fish assemblages they support--different scoring criteria are used for each of the 12 metrics for: (a) each reservoir type (i.e., run-of-the-river and tributary storage reservoirs); (b) each sampling location (forebay, transition/mid-reservoir, and inflow); and (c) each type of sampling gear used to collect the fish data (electrofishing and gill netting). Scoring criteria by reservoir type, by sampling location, and by sampling gear type are listed for each of the 12 fish community metrics in Table 3.3. There is not yet enough information for inflow sampling locations on tributary reservoirs to establish criteria for the fish community metrics at these particular sites.

The average of the sum of the electrofishing scores and the sum of the gill netting scores results in the Reservoir Fish Assemblage Index (RFAI) for each sampling location. The range of "attainable" RFAI values could be from 12 (if all metrics scored 1) to 60 (if all metrics scored 5). This range of RFAI values, from 12 to 60, is divided into five equal groupings to evaluate the overall health of the fish assemblage at each sampling location, as follows:

RFAI Score	Sampling Location Rating
12-21	1 (poor)
21-31	2
32-41	3 (fair)
42-51	4
52-60	5 (good)

A discussion of the development of the RFAI and results of the fish evaluations for the 1991-1993 Vital Signs Monitoring data are available in TVA technical reports (Scott, et. al, 1992; Brown, et. al, 1993; and Hickman et. al, 1994).

Overall Reservoir Health Determination--The overall ecological evaluation methodology combines the five previously discussed aquatic ecosystem indicators (DO, chlorophyll, sediment quality, benthic macroinvertebrates, and fish assemblage) into a single numeric value. This facilitates spatial comparisons among reservoirs and temporal comparisons for a reservoir through time.

The first step in determining an overall reservoir health score is to sum the ratings for all indicators (ranging from 1-poor to 5-excellent) at a sample site. The number of indicators monitored at each site varies. Generally, all five indicators are included; however, this is not always the case. For example, chlorophyll and sediment quality are not monitored at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. The number of sites per reservoir also varies from one (the forebay) in small tributary reservoirs to four (forebay, transition zone, inflow, and embayment) in selected run-of-the-river reservoirs. As a result, the number of ratings vary from five to 18 for the 30 reservoirs monitored in 1993. Specific information on what indicators were sampled in each reservoir is in Table 2.1.

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum potential ratings for that reservoir, and expressed as a percentage. For example, a small reservoir with only one sample site, the minimum health evaluation would be 20 percent (all five indicators rated poor-1 for a total score of 5 divided by the maximum possible total of 25) and the maximum would be 100 percent (all five indicators rated good-5). This same range of 20 to 100 percent applies to all reservoirs regardless of the number of sample sites, and the same calculation process is used.

The next step is to divide the 20-100 percent scoring range into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results are plotted and examined for apparent groupings.
2. Groupings are compared to known, a priori conditions (focusing on reservoirs with known poor conditions), and good-fair and fair-poor boundaries were established subjectively.
3. The groupings are compared to a trisection of the overall scoring range. A scoring range is adjusted up or down a few percentage points to ensure a reservoir with known conditions falls within the appropriate category. This is done only in circumstances where a nominal adjustment is necessary.

Based on these considerations, during the first two years of development (1991-1992), scoring ranges were as follows:

	Poor	Fair	Good
Run-of-the-river reservoirs	≤52%	>52-72%	>72%
Tributary, storage reservoirs	≤56%	>56-72%	>72%

The difference in the poor scoring range between the two types of reservoirs is due to the fact that two storage reservoirs with known poor conditions rated slightly higher than the boundary for the lower (poor) grouping on the run-of-the-river reservoirs. Hence, the high end of the lower scoring range for storage reservoirs was shifted upward from 52 to 56 percent to accommodate these reservoirs with known poor conditions.

Based on the experience gained in developing this evaluation process, review of the evaluation scheme by other state and federal professionals, and results of another year of monitoring, slight modifications were made in the original evaluation process and the numerical scoring criteria for each of the five ecological health indicators. In 1993, run-of-the-river reservoirs with overall scores greater than 72 percent were evaluated as "good"; those between 52 percent and 72 percent were rated "fair"; and those whose overall scores were less than 52 percent were rated "poor." Similarly, in 1993, tributary storage reservoirs were evaluated as "good" if their overall reservoir percentage was greater than or equal to 72 percent; "fair" if its overall reservoir percentage was between 57 percent and 72 percent; and "poor" if its overall reservoir percentage was less than 57 percent. The 1993 scoring ranges were:

	Poor	Fair	Good
Run-of-the-river reservoirs	<52%	52-72%	>72%
Tributary, storage reservoirs	<57%	57-72%	≥72%

Two examples that illustrate the overall reservoir health evaluation methodology are presented in Tables 3.6 and 3.7. Wilson Reservoir (Table 3.6) has five aquatic health indicators at one location and three indicators at another location. Cherokee Reservoir (Table 3.7) has five aquatic health indicators at one location and four indicators at another location.

3.1.3 Stream Ecological Health

An evaluation methodology similar to the Reservoir Ecological Health Evaluation (Section 3.1.2) is used to assess the overall ecological health at each of the 12 stream monitoring locations. Particular emphasis is given to the relationship between the conditions found at the stream sampling site and the potential for impacts on conditions in the downstream reservoir. The following overview summarizes TVA's stream ecological health evaluation methodology. The evaluations are based on four aquatic health indicators: (1) total phosphorus (as a measure of nutrient enrichment and potential for excessive algal productivity); (2) sediment quality; (3) benthic community; and (4) fish community.

At each stream sampling location the four aquatic health indicators are rated as "good," "fair," or "poor." Equal weights are given to each indicator, and each rating is assigned a numeric value of 1, 3, or 5 corresponding to "poor," "fair," or "good." The four scores are summed to produce an overall stream health evaluation at the sampling location ranging from 4 to 20. A stream sampling location with an overall rating of 9 or less ($\leq$45 percent) was rated "poor"; 10 to 15 (50 percent to 75 percent) "fair"; and 16 to 20 (80 percent to 100 percent) "good."

Nutrient Concentration Rating Scheme--Phosphorus is an essential nutrient required by aquatic plants for photosynthesis and growth. In freshwater ecosystems phosphorus is most often the nutrient least available to plants relative to their needs, and thus can limit algal productivity. When present in excess of critical concentrations, in combination with sufficient nitrogen phosphates, it can stimulate algae and other aquatic plant growth, sometimes to an undesirable level that interferes with water uses. To prevent the development of biological nuisances and to control accelerated phosphorus loading for the protection of downstream receiving waterways, EPA recommends a guideline for maximum total phosphorus concentration of 0.10 mg/L for streams or flowing waters and 0.05 mg/L at the point where any stream enters a lake or reservoir (EPA, 1986). These guidelines are used as the basis to evaluate total phosphorus concentrations in Tennessee Valley streams (average of 6 samples per year):

Average Total Phosphorus Concentration*	Sampling Location Nutrient Enrichment Rating
Less than 0.05 mg/L	5 (good);
0.05 to 0.10 mg/L	3 (fair);
Greater than 0.10 mg/L	1 (poor).

* In addition, waters that receive high nitrogen concentrations in the presence of sufficient phosphorus often stimulate the growth of algae and other aquatic plants to an undesirable extent. High average (relative to the majority of Valley streams) nitrate+nitrite nitrogen concentrations greater than 0.65 mg/L resulted in lowering a rating from "good" to "fair" or from "fair" to "poor," as appropriate.

Sediment Quality Rating Scheme--The stream sediment quality evaluation methodology is the same as for reservoir sediment quality. The scoring criterion is based on ratings for the acute toxicity of sediment pore water (S_{TOX}) to both Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia), and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia. The final sediment quality score or rating is the average of these two ratings. (Details are given in Section 2.1.2, Reservoir Sediment Quality Rating Scheme.)

$$\text{Sediment Quality Rating} = 0.5\ (S_{TOX}\ \text{rating} + S_{CHM}\ \text{rating}).$$

Benthic Community Rating Scheme--A modified version of the benthic index of biotic integrity (BIBI) (Kerans et. al, 1992) is used to rate the condition of the benthic community. Twelve benthic community attributes such as total taxa richness and richness of specific taxa, relative abundance of functional and trophic groups and certain tolerant organisms, and total abundance are used. Each of the 12 metrics is scored based on best expected conditions at reference sites supporting healthy benthic communities and good water quality. At each site three Surber (riffle), three Hess (pool), and one qualitative sample were taken. EPT, intolerant snail and mussel species metrics were computed pooling all qualitative and quantitative samples. Total abundance was computed pooling all quantitative samples. The remaining metrics were computed separately for each quantitative sample at a site.

Taxa Richness and Community Composition

1. Taxa richness
2. Occurrence of intolerant snail and mussel species*
3. Number of mayfly (Ephemeroptera) taxa
4. Number of stonefly (Plecoptera) taxa
5. Number of caddisfly (Trichoptera) taxa
6. Total number of EPT taxa*
7. Percentage as oligochaetes
8. Percentage in the two most dominant taxa

Trophic and Functional-Feeding Group

9. Percent as omnivores and scavengers
10. Percent as collector-filterers
11. Percent as predators

Abundance

12. Total abundance of individuals (combined quantitative samples, lower score given for extremely low values or extremely high values)

* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.

Values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against best expected value based on data from reference sites supporting healthy fish communities and having good water quality (Table 3.4). Metric scores are then summed to produce an index ranging from 12 to 60. The resultant benthic community index for each stream location is classified as "poor" (<30), "fair" (34-44), or "good" (>45). If the index score falls between 30-33, professional judgment is used to categorize the benthic community as either poor or fair.

Fish Community--A modified version of Karr's (1981) index of biotic integrity (IBI) is used to assess the condition of the resident fish community at 11 of the 12 stream monitoring locations. (Fish community sampling was not conducted on the Elk River in 1993.) An index and rating are produced for each site by applying the following 12 metrics.

Species richness and composition

1. Number of native species
2. Number of darter species
3. Number of native sunfish species (excluding *Micropterus* sp.)
4. Number of sucker species
5. Number of intolerant species
6. Percentage of individuals as tolerant species

Trophic structure

7. Percentage of individuals as omnivores
8. Percentage of individuals as specialized insectivorous minnows and darters
9. Percentage of individuals as piscivores

Fish abundance and condition

10. Catch rate (average number per unit of sampling effort, seine hauls and shocking runs)
11. Percentage of individuals as hybrids
12. Percentage of individuals with poor condition, injury, deformity, disease, or other anomaly

Actual values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against values expected under pristine conditions (i.e., best expected value, Table 3.5). The 12 metric scores are then summed to produce an index ranging from 12 to 60, and the fish community at the stream sampling location is rated as "poor" (index <36), "fair" (index 40-44), or "good" (index >46). Professional judgment is involved when a fish community index falls between ratings. For example, an index of 38 falls between "poor" and "fair" and would be either "poor" or "fair" depending on the judgment of the biologist taking the sample. Judgment usually is influenced by which of the 12 metrics rates poorest, condition of the coexisting macroinvertebrate community, or previous IBI ratings obtained for the site.

3.2 Use Suitability

3.2.1 Bacteriological Quality Evaluation

Each of the seven Valley states follows the EPA guideline of using a geometric mean fecal coliform concentration of 200 colonies per 100 milliliters (200/100 mL) of water to determine use suitability for whole body water contact recreation (EPA, 1991). Six of the states use an additional fecal coliform criterion to determine if a site is unsuitable for water contact recreation; either a percentage of samples exceeds 400/100 mL, or a maximum concentration of 1000/100 mL for any one sample.

TVA reports on the bacteriological condition of stream and reservoirs throughout the Valley in its publication *RiverPulse* using the following three categories:

Posted by the State:

+ The state has issued a public advisory against water contact and has posted signs near the body of water with the advisory.

+ Each area presently posted exceeds the geometric mean criterion due to a known human source of contamination.

Exceeds Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September exceeds 200/100 mL.

+ Each site identified is believed to exceed criterion due to animal waste.

Meets Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September is less than 200/100 mL.

TVA recommends no water contact recreation for at least two days following rain events at locations which only partially support water contact because of the bacteria which are washed into the water. In addition, TVA recommends no water contact recreation in the immediate vicinity of wastewater discharges regardless of what fecal bacteria data show, because of the possibility of mechanical breakdowns and sewage bypasses or overflows.

3.2.2 Fish Tissue Consumption Advisories

TVA and state agencies coordinate with one another in conducting fish tissue studies in the Tennessee Valley. There is a shared interest in the status of TVA reservoirs as important and valuable resources. As the government organizations responsible for regulatory and public health decisions related to lakes and streams, state agencies are interested in knowing both the ecological health of Valley reservoirs and whether the fish are safe to eat.

Prior to initiating sample collections each autumn, TVA and involved Valley state agencies meet to discuss the previous year's results and decide appropriate direction for further study. The group reaches agreement on species to collect, locations to sample, and the agencies responsible for conducting each part of the work. TVA provides its results to the appropriate states, then the states take action to protect public health. This usually involves deciding whether to issue an advisory against consuming selected species or age classes of fish. TVA's role in this process is to provide accurate results, to provide consultation to the state(s) as appropriate, and support the state's decisions.

Figure 3.1

Cross-section of Tellico Reservoir Forebay Showing Areas where Summer DO Concentrations averaged less than or equal to 2 mg/l.

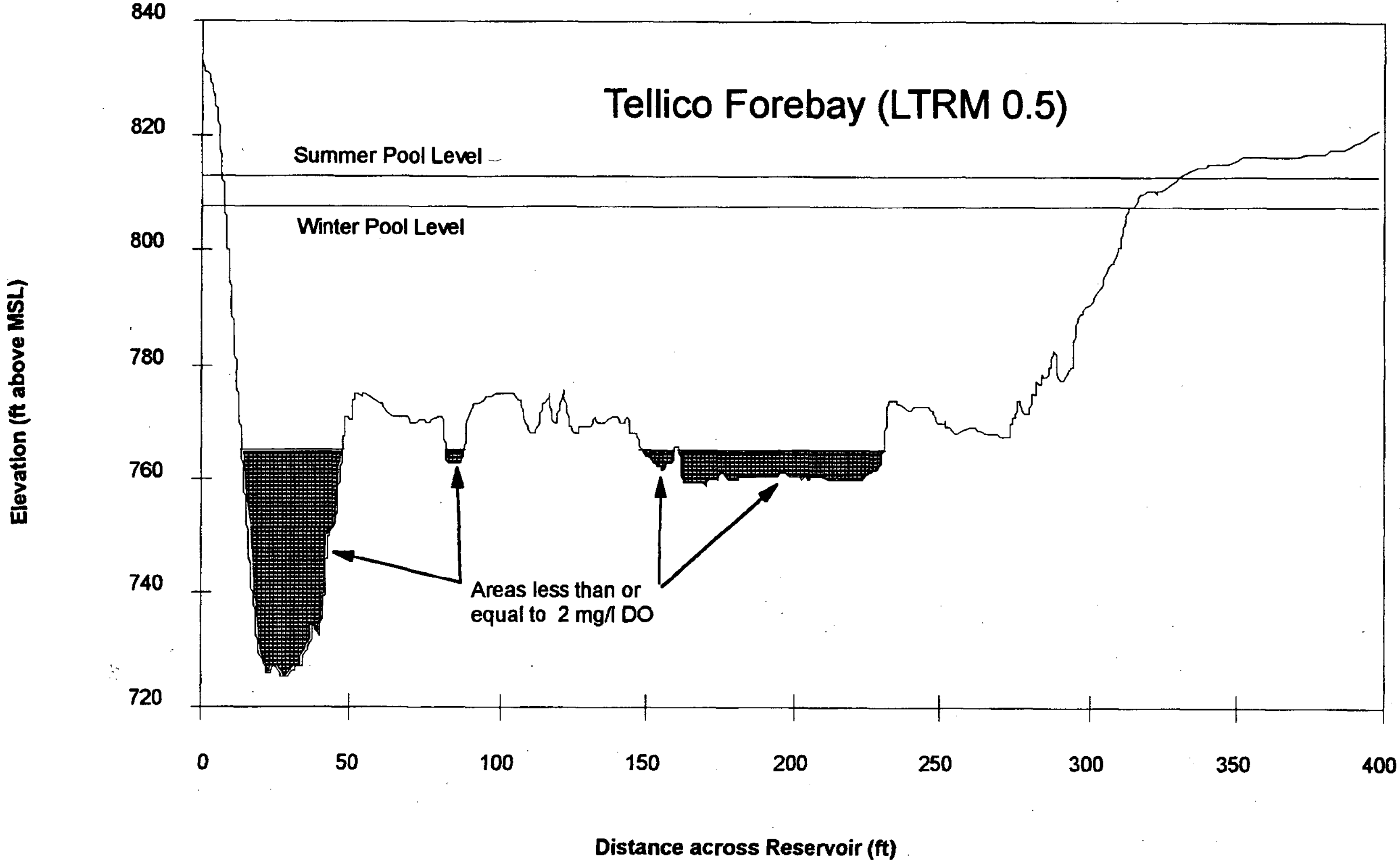


Table 3.1
1993 Vital Signs Monitoring

Reservoir Benthic Macroinvertebrate Community metrics and scoring criteria developed for Tennessee Valley Reservoirs, with a score of 5 representing highest quality, and a score of 1 the poorest.

Run-of-the-River Reservoirs

Benthic Community Metrics	Forebay			Transition			Inflow		
	5	3	1	5	3	1	5	3	1
Taxa Richness	>6.1	4.6-6.1	<4.6	>7.6	6.5-7.6	<6.5	>8.0	5.2-8.0	<5.2
Long Lived Species	>1.2	0.35-1.2	<0.35	>2.4	1.3-2.4	<1.3	>1.9	1.3-1.9	<1.3
EPT (mayfly, stonefly, caddisfly)	>0.95	0.5-0.95	<0.5	>0.95	0.6-0.95	<0.6	>1.4	0.6-1.4	<0.6
% Chironomidae	<30	30-45	>45	<25	25-40	>40	<10	10-30	>30
% Tubificidae	<25	25-50	>50	<20	20-40	>40	<11	11-25	>25
% Dominant Taxa	<75	75-90	>90	<65	65-70	>70	<70	70-80	>80

Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Res/Inflow		
	5	3	1				5	3	1
Taxa Richness	>4.3	2.3-4.3	<2.3	--	--	--	>6.2	3.4-6.2	<3.4
Long Lived Species	>1.0	0.15-1.0	<0.15	--	--	--	>0.45	0.15-0.45	<0.15
EPT (mayfly, stonefly, caddisfly)	>0.35	0.15-0.35	<0.15	--	--	--	>0.3	0.09-0.3	<0.09
% Chironomidae	<30	30-50	>50	--	--	--	<25	25-70	>70
% Tubificidae	<30	30-60	>60	--	--	--	<45	45-75	>75
% Dominant Taxa	<78	78-91	>91	--	--	--	<70	70-80	>80

Table 3.2
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Chestnut lamprey	PS		L
Spotted gar	PI		
Longnose gar	PI	TOL	
Shortnose gar	PI	TOL	
Bowfin	PI		
American eel	PI		
Skipjack herring	PI	INT	
Gizzard shad	OM	TOL	
Threadfin shad	PL		
Mooneye	IN		L
Chain pickerel	PI		
Central stoneroller	HB		
Common carp	OM	TOL	
Goldfish	OM	TOL	
Silver chub	IN	INT	
Golden shiner	OM	TOL	
Emerald shiner	IN		
Ghost shiner	IN		
Spotfin shiner	IN		
Mimic shiner	IN	INT	
Steelcolor shiner	IN		
Pugnose minnow	IN		
Bluntnose minnow	OM		
Fathead minnow	OM		
Bullhead minnow	IN		
River carpsucker	OM		
Quillback	OM		
Northern hog sucker	IN	INT	L
Smallmouth buffalo	OM		
Bigmouth buffalo	PL		
Black buffalo	OM		
Spotted sucker	IN	INT	L
Silver redhorse	IN		L
Shorthead redhorse	IN		L
River redhorse	IN	INT	L
Black redhorse	IN	INT	L
Golden redhorse	IN		L

Table 3.2 (continued)
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Blue catfish	OM		
Black bullhead	OM	TOL	
Yellow bullhead	OM	TOL	
Brown bullhead	OM	TOL	
Channel catfish	OM		
Flathead catfish	PI		
Blackstripe topminnow	IN		
Blackspotted topminnow	IN		
Mosquitofish	IN	TOL	
Brook Silverside	IN		
White bass	PI		L
Yellow bass	PI		L
Rock bass	PI	INT	
Redbreast sunfish	IN	TOL	
Green sunfish	IN	TOL	
Warmouth	IN		
Orangespotted sunfish	IN		
Bluegill	IN		
Longear sunfish	IN	INT	
Redear sunfish	IN		
Spotted sunfish	IN		
Smallmouth bass	PI		
Spotted bass	PI		
Largemouth bass	PI		
White crappie	PI		
Black crappie	PI		
Yellow perch	IN		
Logperch	IN		L
Sauger	PI		L
Walleye	PI		L
Freshwater drum	IN		

*Designations:
Trophic: herbivore (HB), parasitic (PS), planktivore (PL), omnivore (OM), insectivore (IN), piscivore (PI)
Tolerance: tolerant (TOL), intolerant (INT)
Lithophilic spawning species (L)

Table 3.3
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Run-of-the-River*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Transition			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	>27	21-27	<21	>25	19-25	<19	>25	21-25	<21
	G	--	--	--	>21	18-21	<18	>19	17-19	<17
2. Piscivore species	E	>9	5-9	<5	>8	6-8	<6	>8	7-8	<7
	G	--	--	--	>9	7-9	<7	>9	8-9	<8
3. Sunfish species	E	>4	3-4	<3	>5	4-5	<4	>5	4-5	<4
	G	--	--	--	>2	2	<2	>2	2	<2
4. Sucker species	E	>5	4-5	<4	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	>4	3-4	<3	>2	2	<2	>2	2	<2
	G	--	--	--	>2	2	<2	>2	2	<2
6. Percent tolerant individuals	E	<40	40-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<20	20-35	>35	<25	25-40	>40
7. Percent dominance by one species	E	<30	30-50	>50	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-40	>40	<30	30-40	>40
Trophic Composition										
8. Percent individuals as omnivores	E	<30	30-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<35	35-55	>55	<35	35-50	>50
9. Percent individuals as insectivores	E	>50	30-50	<30	>70	40-70	<40	>60	30-60	<30
	G	--	--	--	>15	5-15	<5	>10	5-10	<5
Reproductive Composition										
10. Lithophilic spawning species	E	>7	5-7	<5	>4	3-4	<3	>5	4-5	<4
	G	--	--	--	>5	5	<5	>5	5	<5
Abundance and Health										
11. Total catch per unit effort	E	>120	70-120	<70	>130	70-130	<70	>130	80-130	<80
	G	--	--	--	>30	15-30	<15	>40	20-40	<20
12. Percent individuals with anomalies	E	<1	1-3	>3	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.3 (continued)
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Tributary*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Mid-Reservoir			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	--	--	--	>17	15-17	<15	>25	21-25	<21
	G	--	--	--	>16	13-16	<13	>14	11-14	<11
2. Piscivore species	E	--	--	--	>6	5-6	<5	>5	4-5	<4
	G	--	--	--	>7	7	<7	>6	5-6	<5
3. Sunfish species	E	--	--	--	>3	3	<3	>4	3-4	<3
	G	--	--	--	>1	1	<1	>1	1	<1
4. Sucker species	E	--	--	--	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	--	--	--	>2	2	<2	>3	2-3	<3
	G	--	--	--	>1	1	<1	>1	1	<1
6. Percent tolerant individuals	E	--	--	--	<20	20-40	>40	<20	20-40	>40
	G	--	--	--	<20	20-40	>40	<20	20-40	>40
7. Percent dominance by one species	E	--	--	--	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
Trophic Composition										
8. Percent individuals as omnivores	E	--	--	--	<15	15-30	>30	<20	20-40	>40
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
9. Percent individuals as insectivores	E	--	--	--	>70	50-70	<50	>70	40-70	<40
	G	--	--	--	>10	5-10	<5	>15	5-15	<5
Reproductive Composition										
10. Lithophilic spawning species	E	--	--	--	>5	4-5	<4	>4	3-4	<3
	G	--	--	--	>4	3-4	<3	>3	2-3	<2
Abundance and Health										
11. Total catch per unit effort	E	--	--	--	>100	60-100	<60	>120	60-120	<60
	G	--	--	--	>25	15-25	<15	>20	10-20	<10
12. Percent individuals with anomalies	E	--	--	--	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.4
1993 Vital Signs Monitoring

Benthic Macroinvertebrate Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Benthic Index of Biotic Integrity Metrics				
Metric	**Sampling Gear**	**Score**		
		1	**3**	**5**
Taxa Richness and Community Composition				
1. Taxa Richness	Surber or Hess	<9	9-17	≥18
2. Occurrence of mollusk species*	Combined	0	--	≥1
3. Number of mayfly (Ephemeroptera) taxa	Surber or Hess	<3	3-5	≥6
4. Number of stonefly (Plecoptera) taxa	Surber or Hess	<2	--	≥2
5. Number of caddisfly (Trichoptera) taxa	Surber or Hess	<2	2-3	≥4
6. Number of EPT taxa*	Combined	<14	14-24	≥25
7. Proportion of oligochaetes	Surber or Hess	≥0.05	0.01-0.049	<0.01
8. Proportion of the two most abundant taxa	Surber or Hess	≥0.75	0.5-0.749	<0.5
Trophic and Functional-Feeding Group				
9. Proportion as omnivores and scavangers	Surber or Hess	≥0.9	0.6-0.89	<0.6
10. Proportion as collectors/filterers	Hess	≥0.5	0.2-0.49	<0.2
	Surber	≥0.6	0.3-0.59	<0.3
11. Proportion as predators	Surber or Hess	≤0.04	--	>0.04
Abundance				
12. Total abundance in quantitative samples (Lower scores given for extremely low and high values)	Combined	≤400 >5000	401-500 4001-5000	501-4000
* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.				

Table 3.5
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Duck River 22.5			Bear Creek 25.2			Sequatchie River 7.1			Hiwassee River 37.0		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<27	27-53	>53	<23	23-44	>44	<23	23-45	>45	<21	21-41	>41
2. Number of darter species	<5	5-9	>9	<4	4-7	>7	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	<3	3-5	>5	<3	3-5	>5	<3	3-5	>5	<2	2-3	>3
4. Number of sucker species	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7
5. Number of intolerant species	<4	4-6	>6	<2	2-3	>3	<3	3-4	>4	<2	2	>2
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Little Tenn River 94.3			Emory River 21.7			Powell River 65.4			Clinch River 172.3		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<11	11-20	>20	<15	15-29	>29	<21	21-39	>39	<22	22-42	>42
2. Number of darter species	<3	3-4	>4	<5	5-8	>8	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	0	1	>1	<2	2	>2	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<2	2-3	>3	<2	2	>2	<3	3-4	>4	<3	3-5	>5
5. Number of intolerant species	<2	2	>2	<2	2	>2	<3	3-4	>4	<3	3-5	>5
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<7	7-13	>13	<7	7-13	>13	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Holston River 118.0			Nolichucky River 8.5			French Broad R 78.0		
	1	3	5	1	3	5	1	3	5
Species Richness and Composition									
1. Number of native species	<20	20-38	>38	<19	19-36	>36	<21	21-40	>40
2. Number of darter species	<4	4-7	>7	<5	5-8	>8	<4	4-7	>7
3. Sunfish species, less Micropterus	<2	2-3	>3	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<3	3-5	>5	<4	4-6	>6	<4	4-6	>6
5. Number of intolerant species	<3	3-4	>4	<2	2-3	>3	<2	2-3	>3
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition									
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health									
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<7	7-13	>13
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.6
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Wilson Reservoir - 1993 (Run-of-the-river reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:		No Samples	Tailrace DOs	1	No Rating	4
Less Than 2 mg/L (Summer Avg.)				(poor)		(fair)
% of X-Sectional Area	11.0 (1)	-	-			
% of X-Sectional Bottom Length	44.2 (1)*	-	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	-	Yes*	*Minimum DO was 4.3 mg/L		
Chlorophyll-a, µg/L:		No Samples	No Samples	3	No Rating	No Rating
Summertime Average	10.2	-	-	(fair)		
Maximum Concentration	25.0	-	-			
Sediment Quality:		No Samples	No Samples	4.5	No Rating	No Rating
Toxicity	T1 T2			(good)		
Ceriodaphnia Survival	100% 95%	-	-			
Rotifer Survival	65% 85%	-	-			
Chemistry						
Metals/NH3/pesticides	None (5)	-	-			
Benthic Community:		No Samples		3	No Rating	5
Dominance	5		5	(fair)		(good)
Tubificidae	5		5			
Chironomidae	1		5			
EPT	1		5			
Long-lived	3		5			
Taxa richness	5		5			
Total	20	-	30			
Fish Community:		No Samples		4	No Rating	4
Electrofishing Score	46		-	(fair)		(fair)
Gill Netting Score	38		42			
Overall	42	-	42			
		Sampling Location Sum		15.5 of 25	--	13 of 15
		Reservoir Sum		28.5 of 40 [71%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
- Less than 52% - poor (red)
- 52% to 72% - fair (yellow)
- Greater than 72% - good (green)

Table 3.7
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Cherokee Reservoir - 1993 (Tributary storage reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:			No Samples	1	1	No Rating
Less Than 2 mg/L (Summer Avg.)				(poor)	(poor)	
% of X-Sectional Area	21.5 (1)	26.0 (1)	-			
% of X-Sectional Bottom Length	43.0 (1)*	52.0 (1)*	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	No				
Chlorophyll-a, µg/L:			No Samples	5	5	No Rating
Summertime Average	7.6	9.4	-	(good)	(good)	
Maximum Concentration	17.0	14.0	-			
Sediment Quality:			No Samples	4	2	No Rating
Toxicity				(fair)	(poor)	
Ceriodaphnia Survival	100% (5)	95% (1)	-			
Rotifer Survival	90%	75%	-			
Chemistry						
Metals/NH3/pesticides	NH3 (3)	Cu, NH3 (3)	-			
Benthic Community:		No Samples		3	No Rating	5
Dominance	3		5	(fair)		(good)
Tubificidae	3		5			
Chironomidae	1		3			
EPT	3		5			
Long-lived	1		5			
Taxa richness	5		5			
Total	16	-	28			
Fish Community:				3	3	3
Electrofishing Score	32	30	34	(fair)	(fair)	(fair)
Gill Netting Score	40	38	36			
Overall	36	34	35			
		Sampling Location Sum		16 of 25	11 of 20	8 of 10
		Reservoir Sum		35 of 55 [64%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
Less than 57% - poor (red)
>57% and <72% - fair (yellow)
Greater than 72% - good (green)

4.0 HYDROLOGIC OVERVIEW OF 1993

Many water quality characteristics (e.g., temperature, dissolved oxygen, conductivity, water clarity, suspended solids, etc.) exhibit changes due to seasonal variations in atmospheric temperature and rainfall. During those times of the year when runoff is minimal (normally August-October), streamflow is largely derived from the base flow of groundwater. Because of greater contact between the water and the soil/rock and the longer groundwater residence times, groundwater contains more dissolved minerals (i.e., higher concentrations of hardness and alkalinity, higher pHs and conductivities, etc.) than does surface water. During those times of the year when runoff is higher (normally January-March), streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution.

Consequently, during those times of the year with higher rainfall and subsequent higher flows, base flow accounts for a smaller proportion of the total streamflow, resulting in lower concentrations of most dissolved constituents. In addition, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams, often carrying large loads of nonpoint source pollutants (nutrients, suspended solids, fecal bacteria, etc.) to streams and rivers.

In addition to flood control, electric power generation, and navigation, an important benefit of the TVA's system of dams and reservoirs is its ability to maintain adequate streamflow during extended periods of low rainfall and low runoff by the controlled release of water from tributary storage impoundments. However, this alteration of natural streamflow (diminishing high flows during floods and augmenting low flows during droughts) by storing and then slowly releasing water from tributary storage impoundments creates conditions of strong thermal stratification and low dissolved oxygen in the bottom waters of these tributary storage impoundments. (Additional details about reservoir stratification and water quality impacts are discussed in Chapter 5.)

From a water quality perspective, the lower streamflows occurring during the warmer summer months, combined with naturally occurring higher water temperatures and lower dissolved oxygen concentrations, result not only in lakes becoming thermally stratified but also having less water and less oxygen available to dilute and assimilate the wastes discharged to them. In addition, the warmer water temperatures increase aquatic biological processes (respiration, bacteriological decomposition, etc.). This results in oxygen being used at a faster rate, which can further lower oxygen concentrations. In combination, these factors (low streamflows and diminished assimilative capacity, warmer temperatures and higher biological oxygen consumption rates, and the inhibition of mixing and reaeration caused by thermal stratification) result in low dissolved oxygen concentrations and adversely impact the health of aquatic life. The summer of 1993 was a case in point. July 1993 was the hottest month on record (since 1890s) in the Tennessee Valley. Valley-wide temperatures averaged almost 83°F (28.3°C), about 5°F (2.8°C) above normal for July. For example, in Chattanooga, all 31 days in July had temperatures above 90°F (32.2°C), with temperatures up to 104°F (40.0°C) and 15 days with temperatures 98°F (36.7°C) or higher. This record-breaking heat (and low streamflows) resulted in high water temperatures in the Tennessee River. In fact, all nine mainstem Tennessee River reservoirs had surface water temperatures that exceeded 86°F (30.0°C), some with highs up to 90°F (32.2°C).

In addition, Tennessee Valley rainfall and runoff were well below normal in the summer of 1993. In July, Valley-wide rainfall averaged only 1.76 inches (45 mm), a deficit of 3 inches (76 mm) below the long-term July mean of 4.77 inches (121 mm) as a result rainfall runoff was only 0.66 inches (17 mm), compared to the long-term July mean of 1.03 inches (26 mm). Further, runoff was significantly lower in the western half of the Tennessee Valley than in the eastern half. In July, runoff above Chattanooga was 90 percent of the long-term mean, while runoff was only 64 percent of the long-term mean above Kentucky Dam. For the period of January through July, runoff above Chattanooga was 80 percent of the long-term mean, while runoff was 72 percent of the long-term mean above Kentucky Dam. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

The high temperatures and low flows of July 1993 adversely impacted dissolved oxygen concentrations in the Tennessee River, particularly in the downstream reservoirs. In mid-July, hypolimnetic anoxia (DOs equal to 0 mg/L) was found in the forebays of Kentucky, Pickwick, Wilson, Wheeler, and Chickamauga Reservoirs. All time low concentrations of DO were recorded in the releases from Chickamauga Dam on July 16 (2.2 mg/L) and Nickajack Dam on July 19 (1.8 mg/L) when flows from both dams were only 9000 cfs. During the first two weeks of July (July 1 to 15), daily flows averaged only about 17,250-17,500 cfs at Chickamauga and Nickajack Dams, or about 55 percent of the normal flow for this period of time. Once the effects of the high temperatures and low flows on DOs in the Tennessee River were recognized, flows were immediately increased (by drawing water from tributary storage reservoirs) and DO concentrations improved. For example, at Chickamauga Dam, from July 16-31, average daily flows were increased to an average of about

24,500 cfs (about 80 percent of the normal flow for July) and DOs in the releases increased to an average of about 4.3 mg/L, ranging from 3.2 to 6.3 mg/L. Compounding this whole situation were the record-setting rains and flooding occurring in the mid-West along the Mississippi and Missouri Rivers during the "flood of the century." During this period, TVA minimized discharge from the Tennessee River through Kentucky Dam so as to not increase flood crests on the lower Ohio and Mississippi Rivers and worsen the already catastrophic flooding in those areas.

Obviously, examining atmospheric temperature, rainfall, and runoff patterns during 1993 aids in interpretation of the Vital Signs monitoring data and the ecological health assessments of the streams and reservoirs. Interestingly, interpretation of the biological components of stream monitoring results for 1993 is not influenced by these extreme hydrologic conditions. The low rainfall and low streamflows during the spring and early summer allowed benthic sample collection before the more stressed conditions developed in mid-to-late summer.

4.1 Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit, °F (15.6 degrees Celsius, °C), with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce (USDOC) climatic data, atmospheric temperatures in the TVA region averaged only about 0.3°F (0.2°C) warmer than normal in 1993; however, 1993 was a year of extremes (USDOC, 1993). January and July were unusually warm with 5.0°F (2.8°C) and 4.7°F (2.6°C) above normal, respectively; while, March and April were below normal with departures greater than -2.0°F (-1.1°C) (Figure 4.1a).

In review, 1993 began with an unusually warm January but cooled to below normal in February. As has often occurred in the last 15 years, another cold spring with late freezes was experienced. A record-breaking late season blizzard struck the Valley in mid-March and hit hardest in the eastern half. Summer was hotter than normal, with Tennessee, Alabama, Georgia, North Carolina, and Virginia all having the hottest July on record since the 1890s. The persistent heat and high humidity created great stress on livestock and people. The daily records for Chattanooga Airport provide an indication of the unusual conditions. All 31 days had maximums above 90°F (32.2°C), with the observed maximums ranging from 92°F (33.3°C) to 104°F (40°C) and 15 days of 98°F (36.7°C) or higher. The last four months had near or below normal temperatures, and the annual average temperature was only slightly above normal.

4.2 Rainfall

The Tennessee River basin averages about 51-52 inches (1295-1320 millimeters [mm]) of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches (2360 mm) in the mountains of southwestern North Carolina near Highlands, North Carolina, to a low of about 37 inches (940 mm) in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches (127 mm to 254 mm) of the basin average. March is usually the wettest month and October the driest.

Rainfall across the Tennessee Valley in 1993 averaged only 39.8 inches (1011 mm), almost 12 inches (about 300 mm) or 23 percent less than the long-term 100-year average. The diminished rainfall in 1993 followed another dry year, 1992, when annual rainfall was about 8 inches (204 mm) or about 15 percent below the long-term average. The period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. During 1993, only the month of December had rainfall greater than normal (6.1 inches [155 mm] compared to normal December rainfall of 4.8 inches [122 mm]); the greatest rainfall deficit occurred in July (1.8 inches [45 mm] compared to the normal July rainfall of 4.8 inches [122mm]). In addition to the extremes of December and July, March and September precipitation was close to average while February, April, June and October were more than an inch (254 mm) below average (Figure 4.1b). During March 1993, the Tennessee Valley received the equivalent of 5.4 inches (137 mm) of rain, much of this during the "Winter Snow Storm of the Century" when many areas received record amounts (greater than 20 inches [about 500 mm]) of snowfall.

The unusually persistent hot weather and below average rainfall in the summer was related to an unusual upper air pattern, which kept the storm track well west and north of the region and allowed very few cold fronts to reach the Tennessee Valley. This nearly stationary position of a strong upper air trough over the Rocky Mountains was associated with the record flooding in the middle of the country and kept the Southeast hot and dry. This general pattern was most persistent in the summer, but frequently alternated with a pattern having an upper trough over or to the east of the Valley in the other seasons. This latter trough kept most storms associated with it to the south of the TVA region. These two upper air patterns dominated the weather during 1993, so significant rainfall events tended to occur only when there was a transition period between one and the other.

4.3 Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation and transpiration also significantly reduce the amount of runoff. Watersheds that receive 50 to 60 inches (1270 to 1524 mm) of precipitation annually average about 20 to 30 inches (508 to 762 mm) of runoff. In a normal year, the discharge of the Tennessee River (approximately 66,000 cfs [1868 meters^3/second]) corresponds to about 22 inches (about 560 mm) of runoff distributed over the 40,900 square mile (105,930 square kilometer) drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and autumn months. Average rainfall in the eastern and western portions of the Tennessee Valley (above and below Chattanooga) is about equal. However, topographic differences (viz. the largely steep and mountainous terrain in the eastern portion of the Valley, compared with the mostly flat and rolling terrain in the western portion of the Valley) and generally shallower soils result in higher amounts of runoff above Chattanooga.

In 1993, runoff for the Tennessee River basin was well below normal, particularly from February through July and particularly in the western half of the Valley. Runoff above Chattanooga was only slightly below normal in 1993, 21.4 inches, or 92 percent of the long-term mean of 23.4 inches. However, runoff above Kentucky Dam was only 17.6 inches, a deficit of almost 5 inches and only 78 percent of the long-term mean of 22.5 inches (Figure 4.1c.). Table 4.1 shows that the 1993 releases from tributary reservoirs in the western part of the Valley (e.g., Normandy, Tims Ford, etc.) were below their long-term means, while the releases from tributary reservoirs in the eastern part of the Valley (e.g., South Holston, Watauga, etc.) were close to normal. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

Figure 4.2 presents the relative contributions of streamflow based on long term averages from major tributaries and local inflows to each of the mainstem Tennessee River reservoirs. The flow through each mainstem reservoir is dominated by the inflow from the immediately adjacent upstream reservoir. However, several large tributaries (e.g., Hiwassee River, Elk River, Duck River) do provide substantial inputs to a few mainstem reservoirs, and consequently can have a significant impact on water quality, depending on the volume and chemical quality of the inflows.

FIGURE 4.1 Temperature, Precipitation, and Runoff – Tennessee River Basin, 1993

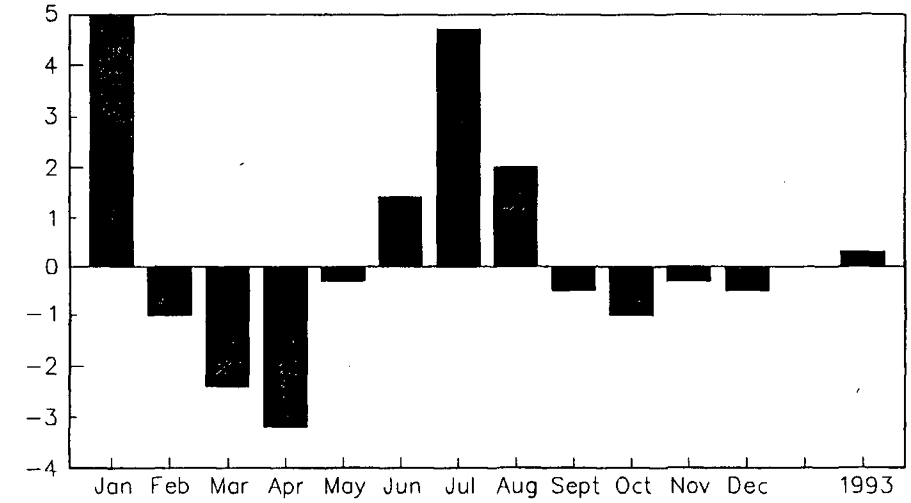


FIGURE 4.1a. Temperature Departures From Long-Term Mean (deg F) in the TVA Region

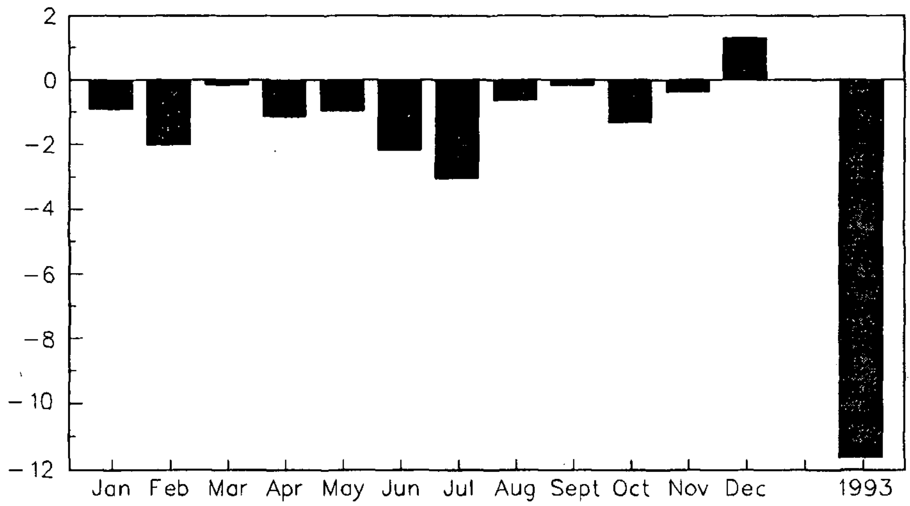


FIGURE 4.1b. Precipitation Departures From Long-Term Mean (Inches)
For The Tennessee River Basin

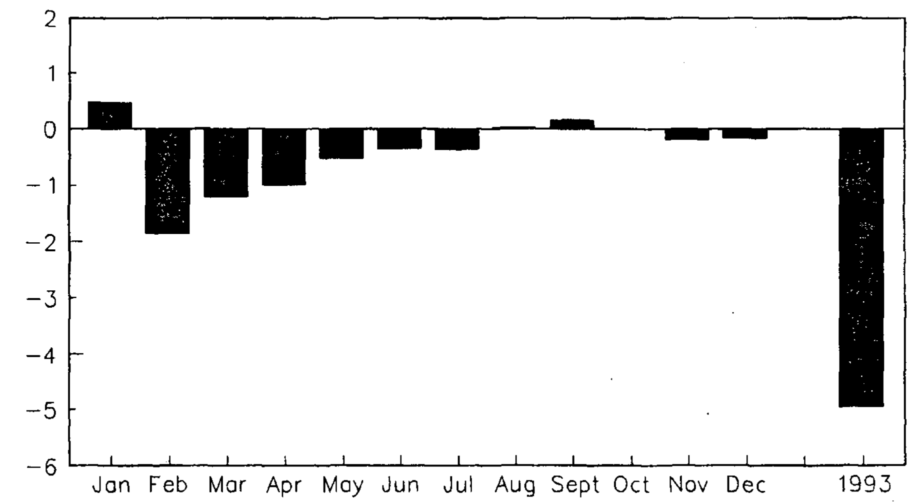


FIGURE 4.1c. Runoff Departures From Long-Term Mean (Inches)
For Tennessee River Basin, Above Kentucky Dam

Figure 4.2 Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

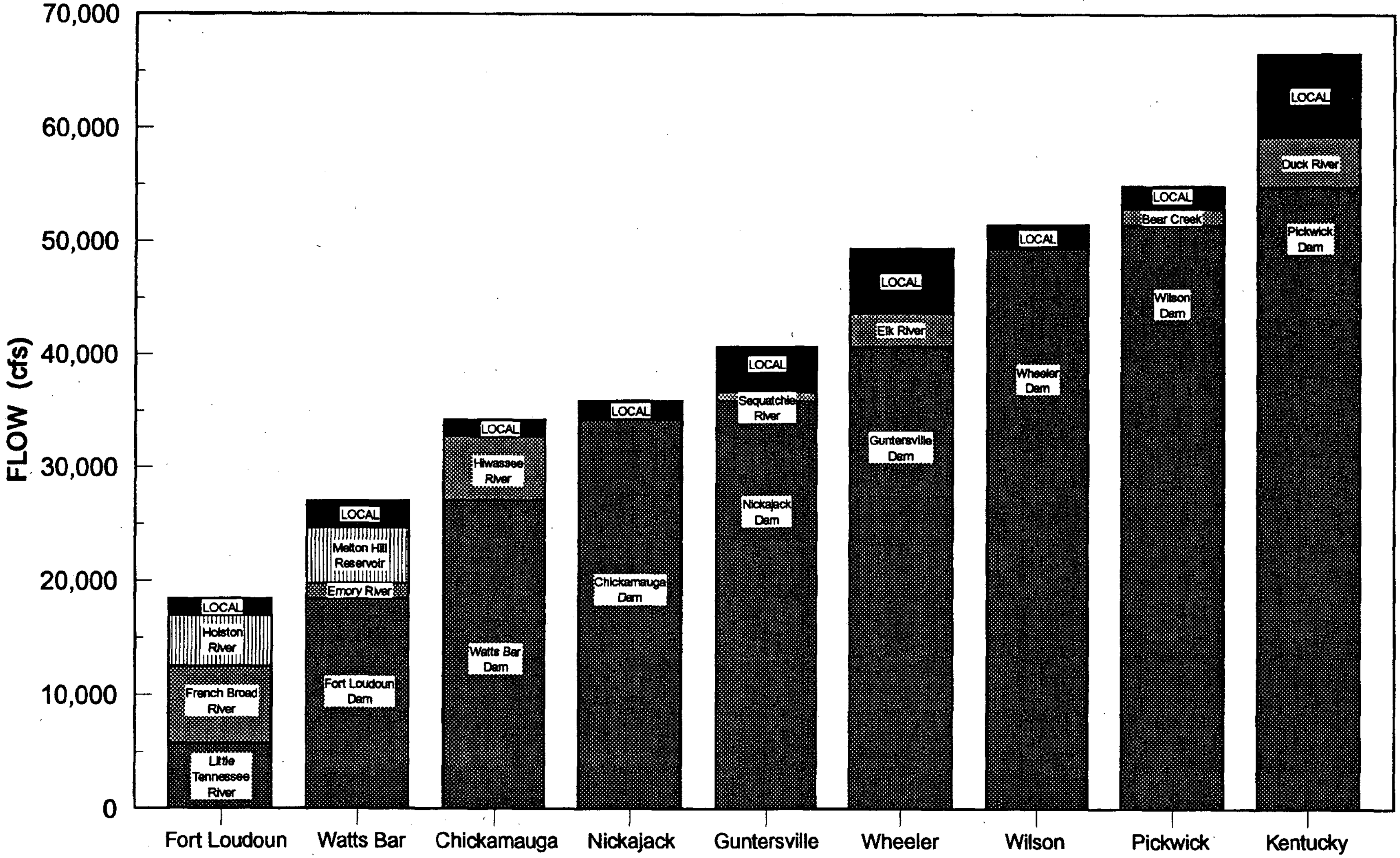


Table 4.1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1993[a] (days)	CY 1993 Reservoir Flow (cfs)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	27.5	52,097
Pickwick	32,820	52.7	43.1	84	924	6	54,900	9.6	48,566
Wilson	30,750	15.5	15.5	108	634	3	51,500	6.8	47,236
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	11.4	46,264
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	12.9	39,691
Nickajack	21,870	46.3	10.4	60	241	0	35,900	3.6	34,092
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	9.6	32,887
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	19.5	26,145
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	9.7	18,897
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	12.7	4,764
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	34.0	6,159[d]
Tributary, Storage Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	249.4	4,124
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	162.2	4,604
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	109.4	6,490
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	5.6	2,423
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	38.5	2,477
South Holston	703	23.7	7.6	239	658	33	976	341.3	972
Watauga	468	16.3	6.4	274	569	26	714	403.5	711
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	173.5	4,126
Hiwassee	968	22.2	6.1	255	422	45	2,020	98.8	2,154
Chatuge	189	13.0	7.0	124	234	10	459	291.3	405
Nottely	214	20.2	4.2	167	170	24	416	228.0	376
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	33.1	1,296
Blue Ridge	232	11.0	3.3	156	193	36	614	156.2	623
Tims Ford	529	34.2	10.6	143	530	12	940	328.7	813
Bear Creek	232	16.0	0.7	74	10	11[e]	380	14.4	337
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	185.7	255
Little Bear Creek	61	7.1	1.6	82	45	12[e]	101	253.9	90
Beech	16	5.3	0.9	32	11	1[e]	14	616.2	9
Normandy	195	17.0	3.2	83	110	11	320	201.7	275

[a] Measurements based on normal maximum pool.
[b] Tennessee River and Reservoir System Operation and Planning Review, Final EIS, TVA/RDG/EQS-91/1, 1990.
[c] Major/minor arms of reservoir.
[d] Estimated flow based on releases from Chilhowee Dam (POR avg. = 4770cfs), and adjusted based on the additional drainage area between Chilhowee Dam (1977 sq miles) and Tellico Dam (2627 sq miles).
[e] Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

5.0 DISCUSSION

The quality of water in a river system is a result of the quality of water flowing into it from many sources (e.g., tributary streams, discharges from metropolitan areas, overland runoff) and the internal physical, chemical, and biological processes which occur within the river. The water quality of major tributaries to a river is governed by geologic characteristics, rainfall, and human activities within the watershed.

The Tennessee River originates with the confluence of the French Broad and Holston Rivers at Knoxville, Tennessee. It receives water from a variety of tributaries reflecting the geochemical characteristics of the watersheds they drain. For example, the French Broad and Holston Rivers are nutrient-rich and moderately hard, with greater hardness in the Holston; the Little Tennessee and Hiwassee Rivers are soft and nutrient-poor; the Clinch River is hard with moderate nutrients; while the other two large tributaries, the Elk and Duck Rivers, are relatively hard and nutrient-rich.

Each tributary exerts its influence based on a wide variety of factors, but primarily the volume of inflow and concentrations of various chemical constituents. Nutrient levels are particularly important because of their direct influences on algal primary production and indirect influences on dissolved oxygen.

Just as the characteristics of the Tennessee River are a composite of its major tributaries, each major tributary has characteristics of its tributaries. Given the widely varying geochemical attributes and many different types of land use within a watershed, characteristics of streams and reservoirs vary greatly among major tributary watersheds. These characteristics are further influenced by the location, design, and operation of dams on streams in the watershed.

This report summarizes results and conclusions from 1993 monitoring activities in the Tennessee Valley. This chapter (Chapter 5) examines these results from a Valley-wide perspective. Chapters 6-17 present a watershed-by-watershed perspective for each of 12 delineated drainages that together comprise the Tennessee Valley. Volume II of this report is a detailed summary of the 1993 monitoring results in each of these 12 watershed areas.

5.1 Vital Signs Monitoring

5.1.1 Reservoirs

Reservoirs were divided into two categories for comparative purposes: run-of-the-river reservoirs (the nine mainstream reservoirs plus the two navigable tributary reservoirs) and the 19 tributary storage reservoirs. The primary differences between these two categories are retention time and changes in pool level due to winter drawdown; both have a great effect on the aquatic ecosystem. For comparative purposes, all reservoirs were categorized as good, fair, or poor based on their respective ecological health evaluations.

Run-Of-The-River Reservoirs--The ecological health of all 11 run-of-the-river reservoirs rated fair or better in 1993. The score for Fort Loudoun Reservoir (58 percent) was the lowest of the run-of-the-river reservoirs. This score fell just within the fair range; but low enough to be considered poor-fair. Three reservoirs rated fair - Tellico (63 percent), Watts Bar (68 percent) and Melton Hill (68 percent); four rated good - Nickajack (88 percent), Chickamauga (83 percent), Guntersville (78 percent), and Kentucky (75 percent); and the remaining three reservoirs fell close to the break point used to separate good and fair reservoirs ($\geq$72 percent) - Pickwick (73 percent), Wheeler (72 percent), and Wilson (71 percent).

Figure 5.1 shows an interesting geographical trend to these results. Reservoirs with the lowest scores were at the upstream end of the Tennessee River, followed by reservoirs with the highest scores, and then reservoirs with intermediate scores in the downstream portion of the Tennessee River. There are many factors which in combination result in the observed ecological conditions, and care must be taken not to oversimplify complex ecosystem dynamics. However, one obvious consideration would be the nutrient rich waters from the French Broad and Holston Rivers, coupled with high human population densities in east Tennessee. Together, these create a high potential for undesirable ecological conditions to exist in the upper Tennessee River. Inputs of fairly pristine waters from the Little Tennessee River, further supplemented by inflows from Hiwassee River with low nutrients further downstream, act to dilute the water in the Tennessee River and help diminish the potential for eutrophic conditions in Chickamauga, Nickajack, and Guntersville Reservoirs. In the lower half of the Tennessee River, water naturally rich in nutrients flows from the Elk River to Wheeler Reservoir and from the Duck River to Kentucky Reservoir, stimulating algal growth and potentially shifting ecological conditions toward a more productive state.

The four reservoirs with the lowest ecological health scores (Fort Loudoun, Tellico, Melton Hill, and Watts Bar) had multiple indicators that rated poor or very poor. These were generally dissolved oxygen, sediment, benthos, and/or fish assemblage. For the three reservoirs which scored good (Chickamauga, Nickajack, and Guntersville), all ecological health indicators rated fair or better, except for dissolved oxygen at the inflows to Nickajack and Guntersville Reservoirs. Scores for the next four reservoirs which scored fair to good (Wheeler, Wilson, Pickwick, and Kentucky) varied greatly depending upon the number and location of sample sites within the reservoir. Indicator ratings at sample sites on the Tennessee River portion of each reservoir (i.e., the main body of the reservoir) were fair or better, except for dissolved oxygen at the Wheeler and Wilson forebays. Sample sites in major embayments generally had several indicators with poor or very poor ratings.

Embayments were not monitored prior to 1993. Four of the largest embayments in the Tennessee Valley were included in 1993 monitoring activities--Big Sandy River embayment on Kentucky Reservoir, Bear Creek embayment on Pickwick Reservoir, Elk River embayment on Wheeler Reservoir, and Hiwassee River embayment on Chickamauga Reservoir. All four embayments have surface areas of about 5000 acres (about 2000 hectares) or greater and local drainage areas greater than 500 square miles (1295 km^2). Water quality characteristics within an embayment and the resulting ecological health conditions are largely controlled by factors within the embayment's immediate watershed and the rate of water exchange between the embayment and the main body of the reservoir. The Hiwassee and Elk River embayments have substantial flow through them. The Big Sandy and Bear Creek embayments have much smaller inflows and less water exchange with the main body of the reservoir.

Results from the Hiwassee River and Elk River embayment sites substantiate the above discussion of the potential for inflows from these rivers to affect conditions in the Tennessee River. All five ecological indicators rated good or excellent in the Hiwassee embayment. Three ecological health indicators were poor or very poor, one fair and one good in the Elk River embayment.

Inclusion of monitoring results from embayments had a substantial effect on reservoir health ratings for three of the reservoirs compared to previous years. For example, Kentucky Reservoir rated good (75 percent) in 1993, lower than the 1992 rating, when Kentucky had the best rating (88 percent) of all reservoirs examined. The primary factor responsible for this decrease was addition of the sample site in Big Sandy River embayment. If results from the Big Sandy River embayment were excluded from the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992. Pickwick Reservoir had an ecological health rating of 73 percent for 1993. However, if the Bear Creek embayment information were deleted, the reservoir score would be 80 percent. A similar situation is true for Wheeler. The overall health rating for Wheeler would change from 72 percent to 82 percent if results from the Elk River embayment were excluded. Interestingly, the overall ecological health score for Chickamauga Reservoir would change little if results from the site in Hiwassee River embayment were excluded (i.e., 83 percent with and 81 percent without).

Another factor which lowered ecological health scores in the run-of-the-river reservoirs in 1993 was relatively low dissolved oxygen during summer 1993. Extreme summer weather in 1993 caused record high water temperatures and low DO in much of the Tennessee River. Special dam operations and water releases to reduce impacts from these conditions were started as soon as the low DO conditions were detected. Special monitoring showed these releases improved DO concentrations. However, DO concentrations were lower than in previous years causing lower scores for the overall health rating. (See Chapter 4, Hydrologic Overview of 1993, for additional detail.)

The ecological health score for one other reservoir (Tellico) changed substantially from previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993; it had previously been rated poor. Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site; and the other three indicators rated poor. The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than scores in previous years.

Tributary Reservoirs--Monitoring on tributary reservoirs was not fully implemented until 1993. The number of tributary reservoirs included in Vital Signs monitoring expanded from three in 1990 to 19 in 1993. Also, the number of ecological health indicators expanded in 1993 when sediment quality and benthic macroinvertebrates were sampled for the first time on tributary reservoirs. Sample design for tributary reservoirs specifies less intensive monitoring for water chemistry constituents (most notably nutrients) than on the run-of-the-river reservoirs because of the more static nature of water within tributary reservoirs. Monitoring efforts for other ecological indicators (chlorophyll, sediment, benthos, and fish) were the same on both run-of-the-river and tributary reservoirs for the first time in 1993.

The ecological health evaluations for the tributary reservoirs are more tentative than for the run-of-the-river reservoirs. The data base generally is quite small, and our understanding of how to weigh and integrate results from various ecological health indicators is still in development.

A problem associated with evaluating the ecological health of tributary reservoirs is the individuality of each reservoir. There is substantial variation in physical characteristics (depth, shoreline development, area, length), reservoir operations (retention time, drawdown, depth of outflow, etc.), watershed geochemistry, and land use. This individuality makes it difficult to establish reference or expected conditions, against which to rate the observed ecological characteristics as good, fair, or poor ecological health. (See Section 3.1 for additional discussion.)

Two attributes, long retention times and deep drawdowns, of tributary reservoirs particularly are significant. Long retention times create high potential for thermal and chemical stratification. As solar warming occurs in upper strata during spring and summer, bottom strata remain cold, and thermal stratification develops. If oxygen demand is sufficient, which is the typically the case, anoxia occurs in the bottom waters. Under these conditions, iron and manganese become more soluble, and their concentrations increase. If anoxia continues long enough, high levels of ammonia and sulfide also can develop. These conditions cause stresses to aquatic life and result in low ecological health ratings.

Deep drawdowns of the pool during winter, sometimes below the elevation of the summer thermocline, also have a pronounced effect on aquatic systems of tributary reservoirs. For example: (1) stable shoreline habitats cannot develop or persist; (2) benthic substrates in upper riverine reaches of the reservoir can be covered with sand and silt when the reservoir is full but be washed to gravel or bedrock when the area returns to a riverine environment at winter, low pool elevations; and (3) spring spawning sites can be left dry or covered with many feet of water depending upon dam operations during spring filling. Again, these have undesirable ecological effects.

Considering these factors, the ecological health of tributary reservoirs is not expected to be as good as run-of-the-river reservoirs. Results for 1993 support this expectation. No tributary reservoir rated good for ecological health, and only two rated fair-to-good. Both Fort Patrick Henry Reservoir and Blue Ridge Reservoir scored 72 percent, just at the break point used to indicate good or fair ecological health conditions. Interestingly, Fort Patrick Henry, even though a tributary reservoir, has retention time and drawdown characteristics like a run-of-the-river reservoir. Blue

Ridge Reservoir has quite low primary productivity, which, coupled with essentially a full depth withdrawal from the dam, helps prevent dissolved oxygen problems.

Only one tributary reservoir rated poor. Parksville (Ocoee No. 1) Reservoir scored 52 percent with poor scores for four of the five indicators. Dissolved oxygen had an excellent rating. This is contrary to expectations for a tributary reservoir, but this reservoir represents an unusual case. A very low oxygen demand exists in the hypolimnion due to very low primary productivity rates. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. A more thorough discussion of Parksville Reservoir is provided in Section 12.5. Two reservoirs (Normandy and Cedar) scored 56 percent, right at the break point between poor and fair. Dissolved oxygen was the primary problem in both cases. Of the remaining 14 reservoirs, eight rated near the middle of the fair range and six rated in the fair range just above poor (Figure 5.2).

Figure 5.2 indicates there were no geographical patterns associated with overall reservoir scores. No particular watershed had mostly high scoring or low scoring reservoirs. Also, physical characteristics such as size or depth seemed to have little influence on reservoir score.

The ecological health indicator which was most often associated with low ecological health scores was DO. As discussed above, this was expected. Poor or very poor DO scores occurred at one or more sample sites in 13 of the 19 tributary reservoirs sampled. All six tributary reservoirs in the middle and western part of the Tennessee Valley were in this group, along with seven of the 13 tributary reservoirs in the eastern, mountainous area of the Valley. The six reservoirs in the middle and western end of the Valley (Tims Ford, Normandy, Bear Creek, Little Bear Creek, Cedar Creek, and Beech Creek) exhibit strong thermal stratification, generally have high chlorophyll concentrations, and have substantial agriculture activities in their watersheds. The seven in the eastern end of the Valley vary greatly in a number of characteristics. Of these, four (Norris, Douglas, Cherokee, and Nottely Reservoirs) had all or mostly very poor DO ratings, followed by South Holston with one very poor rating and Boone and Fontana with only one poor rating and no very poor ratings.

Of the six reservoirs with fair, good, or excellent DO scores, two were in the Holston watershed (Fort Patrick Henry and Watauga), and four were in the Hiwassee watershed (Hiwassee, Chatuge, Blue Ridge, and Parksville). All except Fort Patrick Henry had relatively low nutrient and chlorophyll concentrations (most with seasonal chlorophyll averages below 3.0 $\mu g/L$). Although Fort Patrick Henry had high chlorophyll values, lack of stratification and short retention time helped maintain good DO concentrations.

In most cases, reservoirs with poor DO concentrations would be expected to have poor benthic macroinvertebrate communities. This was true for seven of the 13 reservoirs with DO problems. Interestingly, the remaining six reservoirs with poor DO had fair, good, or even excellent benthos scores. Norris and Cherokee Reservoirs in east Tennessee and Little Bear Creek, Cedar Creek, and Beech Creek Reservoirs in the western end of the Valley had very poor DO scores, yet fair benthic macroinvertebrate communities. Bear Creek, also in the western end of the Valley, had a very poor DO score yet an excellent benthos score. These results and their potential implications are difficult to interpret with only one year of benthic macroinvertebrate data available. Additional monitoring results should help clarify these results. An initial interpretation is that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possibility is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors may have contributed to the observed ratings.

Just as reservoirs with poor DO ratings typically would be expected to have poor benthos, reservoirs with good DO levels would be expected to have a good benthos community, unless some other factor was negatively influencing the benthos. This was the case on Watauga, Hiwassee, and Parksville Reservoirs. All had fair to excellent DO scores yet all had poor or very poor benthic macroinvertebrate communities. Poor scores for Parksville Reservoir were not surprising, given the problems that reservoir has experienced over the years from upstream mining activities. Results for the other two reservoirs were unexpected. Acute toxicity to at least one test animal was observed in all three reservoirs. More detailed assessment efforts would be required to determine whether there is a real relationship between the apparent toxicity and poor benthic communities. Results from additional monitoring in 1994 will be examined closely to determine whether more detailed assessments should be planned.

5.1.2 Streams

Twelve of the major Tennessee River tributaries were included in Vital Signs Stream Monitoring in 1993 (Table 2.2). Six additional streams will be monitored beginning in 1994.

Results for 1993 showed a wide range of ecological conditions among the 12 streams. Three, Clinch, Powell, and Little Tennessee Rivers, had the highest possible scores for all four ecological health indicators (nutrients, sediment, benthic macroinvertebrates, and fish community).

The lowest score (50 percent) was for the French Broad River where nutrients and fish rated poor, benthos rated fair, and sediments rated good.

Scores for the remaining eight streams were evenly distributed within this range. The Emory and Hiwassee Rivers had good overall scores (90 and 88 percent, respectively) with fair ratings for benthos, the only indicator rating less than the maximum score at each stream. The Nolichucky and Sequatchie Rivers also rated good with scores of 80 percent each. At both streams, two indicators rated good and two fair. Three streams rated fair (Duck River-70 percent, Bear Creek-70 percent, and Holston River-68 percent). High nutrient concentrations on the Duck and Holston Rivers caused a poor rating for nutrients; the other three indicators rated fair or good. The lower score for Bear Creek was due to most indicators rating fair, rather than due to any indicator rating poor. Ratings for the remaining stream, Elk River, must be used conservatively because only three indicators were monitored in 1993. The fish community was not sampled in 1993. The overall score for the other indicators was 60 percent; nutrients rated poor, benthos fair, and sediment good. The fish community will be sampled in 1994.

The ecological health indicator that rated poor most often was nutrients. Four streams (Duck, Elk, Holston, and French Broad Rivers) received poor ratings for nutrients. Bear Creek and the Nolichucky River received a fair rating for nutrients and the remaining six streams rated good. All of these results were expected based on individual watershed characteristics.

5.2 Use Suitability Monitoring

5.2.1 Bacteriological Studies

Fifty-nine designated swimming beaches, 12 informal swimming areas, and 14 canoe launching or landing sites were sampled in 1993. All of the designated swimming beaches and informal swimming areas and eight of the canoe access sites met the regulatory criterion of having geometric mean concentrations of fecal coliform bacteria less than 200/100 mL if rainfall samples were excluded. Two swimming beaches, one each on Tims Ford and Watts Bar Reservoirs, and the canoe site sampled on the Elk River, slightly exceeded the criterion when rainfall samples were included. The four access sites on the Duck River exceeded the geometric mean criterion for both rainfall and nonrainfall samples.

Thirty-five nonrecreation sites were also sampled to provide generic bacteriological water quality data on Wilson, Guntersville, Nickajack, Fort Loudoun, Norris, Douglas, Cherokee, Fort Patrick Henry, Boone, South Holston, and Watauga Reservoirs; four sites were sampled on the

Duck, Clinch, and South Holston Rivers; and three sites on Spring, Beidleman, and Thomas Creeks. All but one reservoir site (Nickajack) and two stream sites (Beidleman and Thomas Creeks) met recreation criteria.

A comparison of the results of this survey with surveys in 1974, 1986, and 1989 through 1992 shows bacteria concentrations in 1974 and 1993 were similar, and lower than during the other years. The differences are probably caused by different weather conditions and sampling methods rather than reflecting long-term changes in bacteriological water quality.

Fecal coliform samples were taken in conjunction with Vital Signs monitoring activities on the 11 run-of-the-river reservoirs from April through September 1993. Fifteen of the 155 samples analyzed had concentrations greater than the normal detection limit of 10/100 mL, seven exceeded 100/100 mL. No location had more than one sample exceed 100/100 mL.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

5.2.2 Fish Tissue Studies

Availability of results for fish tissue studies is usually delayed because of the intricate laboratory procedures required to analyze fish tissue samples. This process usually takes several months; so results for samples collected in autumn usually are not available until the next spring. Results in this report are for fish collected during summer and autumn 1992. Additional fish were collected in summer and autumn 1993 but results were not available in time to be included in this report.

Screening Studies--Results of screening studies in 1992 did not indicate any new reservoirs or streams in need of intensive investigations. Two streams and six reservoirs had at least one analyte slightly elevated indicating a need to resample in autumn 1993 at the screening level. Streams included the Emory River (PCB concentration in channel catfish 1.1 μg/g) and the Holston River (mercury concentration in largemouth bass 0.57 μg/g). Reservoirs included Pickwick (DDTr 2.5 μg/g), Bear Creek (mercury 0.45 μg/g), Little Bear Creek (mercury 0.56 μg/g), Norris (PCBs 0.9 μg/g), Fontana (PCBs 1.1 μg/g and mercury 0.53 μg/g), and Cherokee (PCBs 0.8 μg/g). Although most reservoirs had multiple sites sampled, an elevated concentration of an analyte at any site would cause that reservoir to be included in this list.

All sites listed above were resampled in autumn 1993 for the same fish species. In addition, because several tributary reservoirs had somewhat elevated mercury concentrations, efforts in autumn 1993 were directed at better evaluating this condition by analyzing both channel catfish, the species typically used as the indicator, and largemouth bass, a top predator which would be expected to have higher mercury concentrations than catfish.

Intensive Studies--Six TVA reservoirs (Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Parksville) were examined intensively in 1992. Intensive studies are conducted on reservoirs where a contaminant problem is known or suspected. PCBs was the contaminant of interest on all these reservoirs, except Wheeler, where DDTr (total DDT) is the problem. Chlordane was also of interest in some of these reservoirs. Fish consumption advisories which recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all six reservoirs except Parksville. These advisories issued by the Tennessee Department of Environment and Conservation and by the Alabama Department of Public Health are based in part on the results of these studies.

Results from autumn 1992 collections indicated somewhat lower concentrations of DDTr in fish from Wheeler Reservoir and PCBs in fish from Nickajack Reservoir. Lower concentrations in one year should not be interpreted as a significant decrease in contaminant concentration. Previous results have shown substantial year-to-year variability. The long-term study on Watts Bar Reservoir identified substantially lower PCB concentrations in 1989 and 1990 than in previous years. Subsequent results for 1991 and 1992 returned to the higher concentrations of previous years. For this reason, comparable studies were repeated on these reservoirs in autumn 1993.

Results of 1992 fish tissue samples from Watts Bar, Fort Loudoun, and Melton Hill Reservoirs generally fell within the range observed in previous years. Likewise, limited results for Tellico Reservoir fell within historical ranges.

Screening studies on Parksville (Ocoee No. 1) Reservoir over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish from there in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish - the average of ten fish was 1.5 $\mu g/g$ at the forebay and 1.0 $\mu g/g$ at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish--averages at the two sites were 0.6 and 0.7 $\mu g/g$, respectively. Bluegill sunfish and rainbow trout composites from these areas had low concentrations. There had been no action taken on these results at the time this report was prepared.

Figure 5.1 Overall Ecological Health of Run-of-the-River Reservoirs in the Tennessee Valley in 1993. (Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

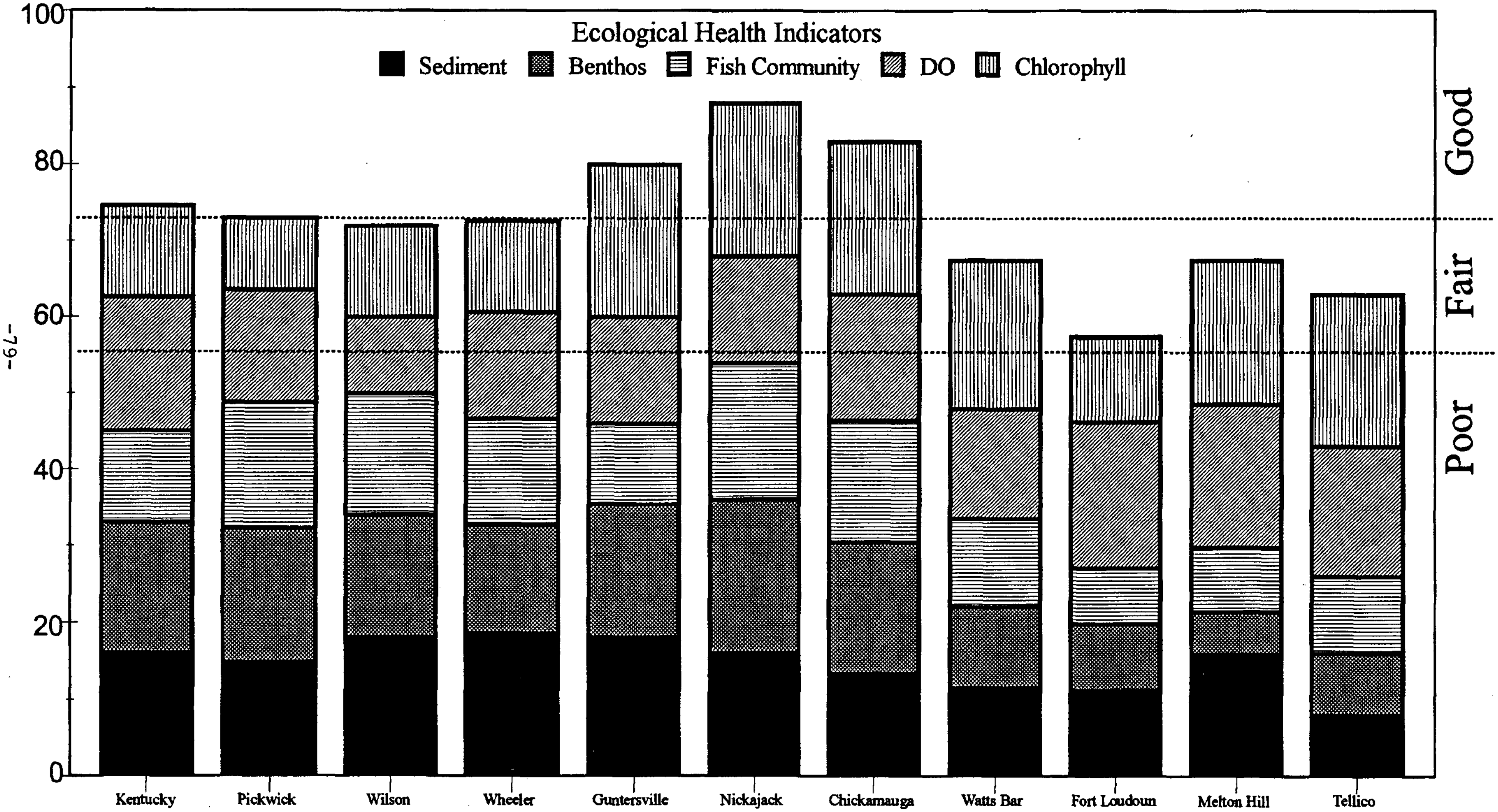
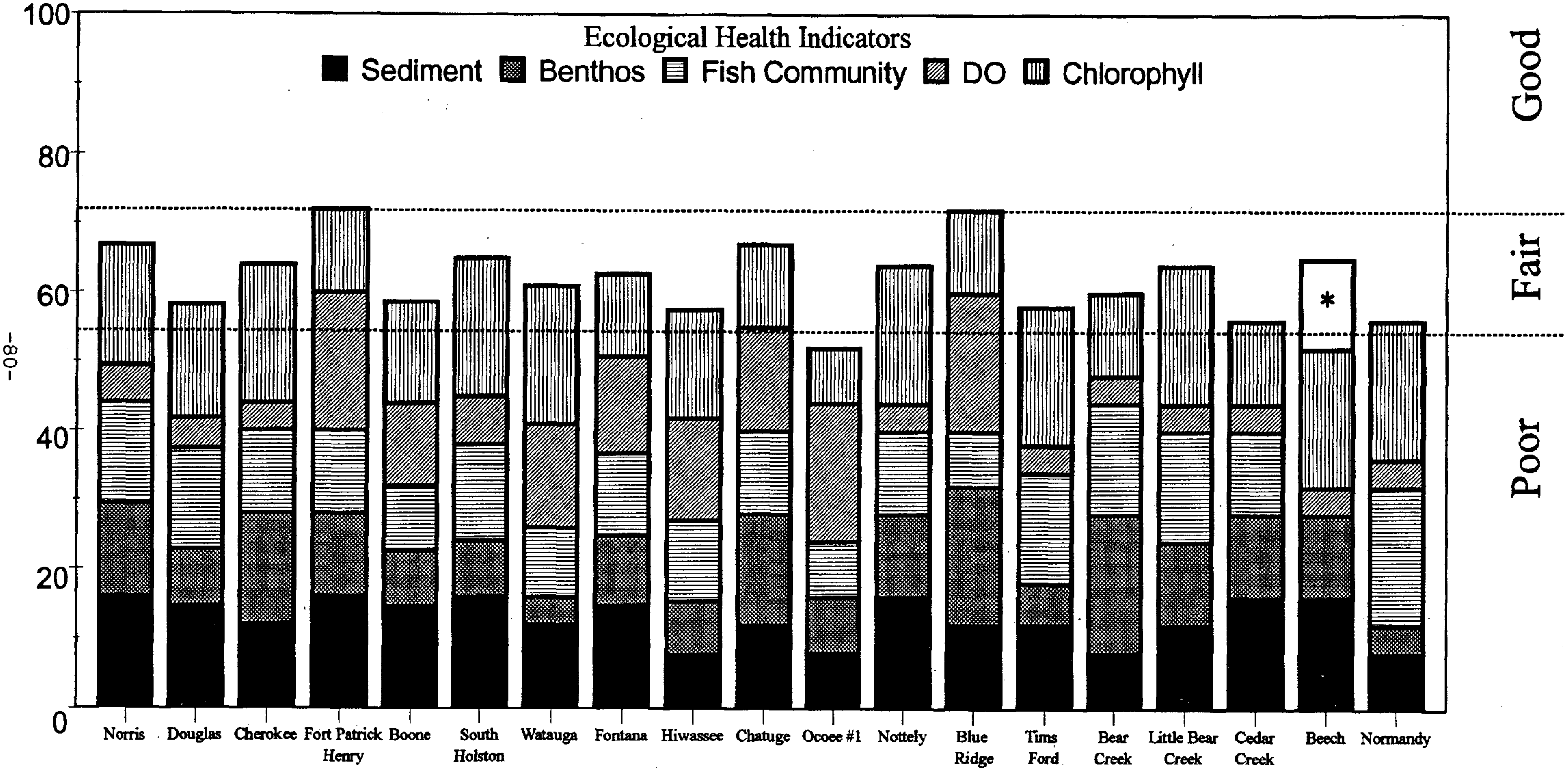


Figure 5.2 Overall Ecological Health of Tributary Reservoirs in the Tennessee Valley in 1993.

(Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)



* Beech Reservoir score is based on four rather than five indicators; indicator and overall scores are shown on the same scale as other reservoirs to facilitate comparisons.

6.0 KENTUCKY RESERVOIR WATERSHED

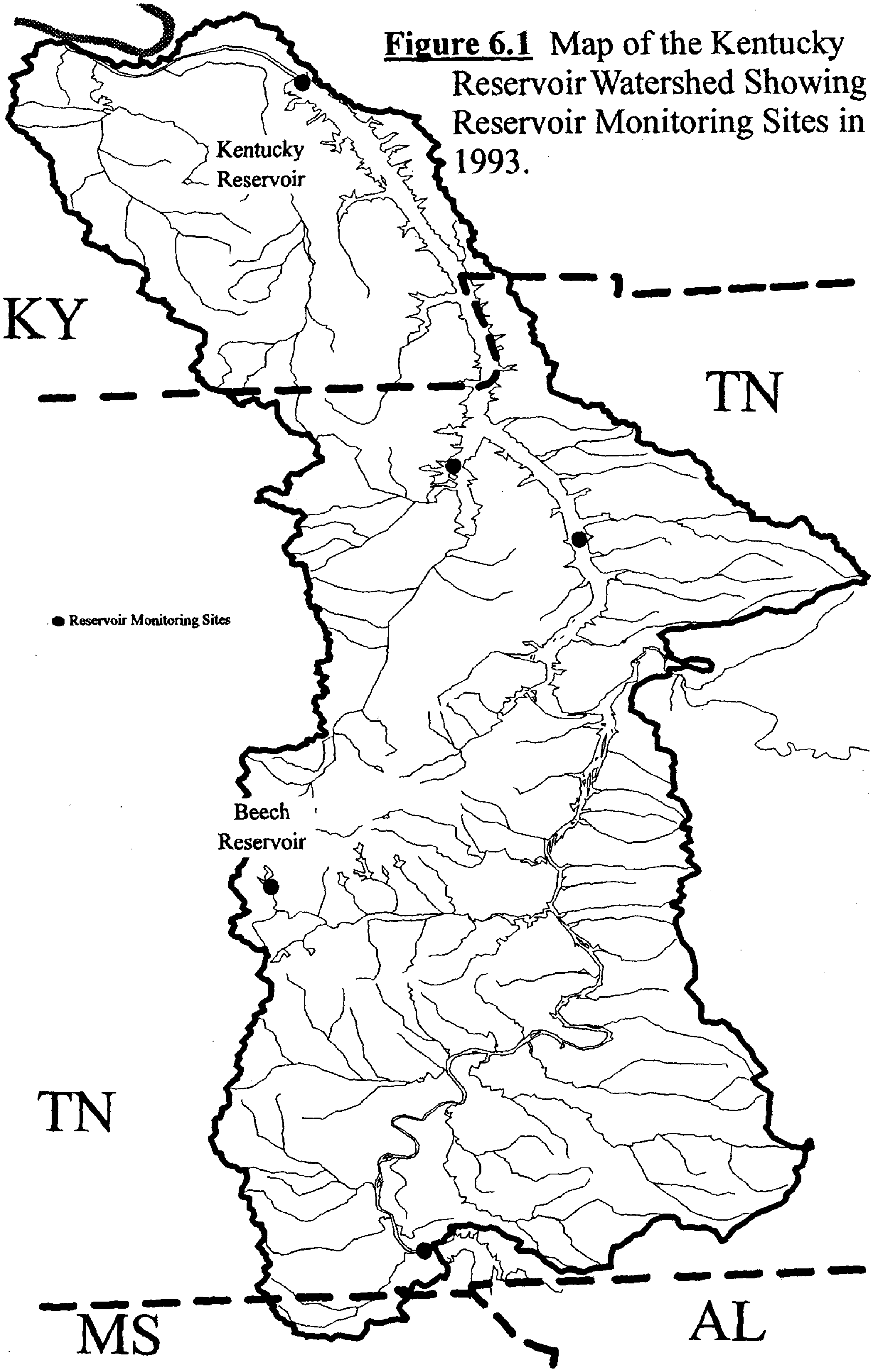
The Kentucky Reservoir watershed area includes all streams flowing into the Tennessee River downstream of Pickwick Landing Dam at Tennessee River mile (TRM) 206.7 to the confluence of the Tennessee River with the Ohio River. The one exception is the Duck River which is considered a separate watershed. The Kentucky Reservoir watershed area is relatively large (4590 square miles) and has an average annual discharge of about 66,600 cfs. Of that, about 82 percent (54,000 cfs) comes into Kentucky Reservoir from Pickwick Landing Dam. The Duck River supplies about 6 percent (4075 cfs), with the remaining 11 percent coming from local inflows.

Kentucky Reservoir is the dominant feature of this watershed. There are four monitoring sites on Kentucky Reservoir--forebay, transition zone, inflow, and Big Sandy River embayment (Figure 6.1 and Table 2.1). Information from 1993 monitoring activities on Kentucky Reservoir is provided in Section 6.1.

The watershed also includes the seven small reservoirs on the Beech River. The largest, Beech Reservoir, is the only one included in Vital Signs monitoring. Given its small size, the forebay is the only site monitored (Figure 6.1). Monitoring information for Beech Reservoir for 1993 is in Section 6.2.

There were no stream monitoring sites in this watershed in 1993. Beginning in 1994, a site will be established on the Clarks River for monitoring biological conditions.

Figure 6.1 Map of the Kentucky Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.



6.1 Kentucky Reservoir

Physical Description

Kentucky Reservoir is the largest reservoir on the Tennessee River. The dam is located at Tennessee River Mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2280 miles. Average annual discharge is about 66,600 cfs, which provides an average hydraulic retention time of about 22 days. Additional information about Kentucky Reservoir is provided in Table 4.1.

The Duck River, a major tributary to the Tennessee River (and Kentucky Reservoir), provides about 6 percent of the total flow through Kentucky Reservoir. The confluence of the Duck River with the Tennessee River is at TRM 110.7.

The transition zone sample location was moved prior to the 1992 sample season from TRM 112.0 to TRM 85.0. Results for 1990 and 1991 at TRM 112.0 indicated that location was more representative of a riverine environment than a transition environment. The 1992 and 1993 results indicate the new transition zone site is correctly located.

Vital Signs monitoring was expanded in 1993 to include a sample site in four of the largest embayments in the Tennessee Valley. One, the Big Sandy River embayment on Kentucky Reservoir, is the largest embayment in the Tennessee Valley. It covers 15,238 surface acres and has over 93 miles of shoreline. Because its watershed is only 629 square miles, there is very little water exchange.

Ecological Health

The ecological health of Kentucky Reservoir rated good (75 percent) in 1993. This is lower than the ecological health index for 1992, when Kentucky had the best rating (88 percent) of all reservoirs examined. It is also lower than the overall rating in 1991. Primary factors responsible for this decrease were lower dissolved oxygen (DO) concentrations due to the hot, dry summer of 1993, and the addition of a sample site in Big Sandy River embayment. If results for the sample site in Big Sandy embayment were excluded from calculating the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992.

The transition zone was the best of the four sites examined in 1993. All ecological health indicators (DO, chlorophyll-a, sediment quality, benthos, and fish) rated good or excellent at that site. The site in the Big Sandy embayment approached the other extreme. Three indicators rated poor or very poor: chlorophyll because of high concentrations, sediment quality because of high ammonia and toxicity to test organisms, and fish assemblage because of low fish abundance and species richness. No indicators at the other two sites (forebay and inflow) rated poor or very poor.

Aquatic plants covered about 3465 acres in 1993 compared to about 2600 acres in 1992 and 2800 in 1991. Most plants were found around islands and shallow embayments downstream of the Duck River.

Reservoir Use Suitability

Use Suitability monitoring activities did not identify any impairments on Kentucky Reservoir in 1993. Twenty-four recreation sites have been sampled for fecal coliform bacteria one or more times on Kentucky Reservoir since 1989. None has exceeded the geometric mean criteria for recreation. In 1992 three sites exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. In 1993 these three sites were resampled, and all met the EPA guideline. Fecal coliform bacteria concentrations have been very low at the Vital Signs locations sampled since 1990.

Examination of channel catfish fillets in autumn 1992 from six locations between Kentucky and Pickwick Dams found only low levels of heavy metals and pesticides at all locations. The only analyte high enough to be of interest was lead at 0.6 $\mu g/g$ at one location in 1992. Similar concentrations have been found sporadically in previous years, but there has been no pattern in space or time.

6.2 Beech Reservoir

Physical Description

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir is only 5.3 miles long and averages only about 12 feet deep. It has no hydropower generating facilities, but is the primary source of water for the city of Lexington. The reservoir is an urban lake with considerable residential lakefront development. Consequently, it receives a large amount of recreational use relative to its small size (about 900 acres). Discharge from Beech Dam averages only about 14 cfs per day, resulting in a long hydraulic residence times of 300 to 400 days.

Reservoir Health

During 1991 and 1992 only water quality monitoring was conducted in Beech Reservoir. The 1991 and 1992 data indicated poor ecological health in Beech Reservoir, as evidenced by very low concentrations of dissolved oxygen and high chlorophyll-a concentrations.

In 1993 four of the five ecological health indicators (algae, dissolved oxygen, sediment quality, and benthos) were sampled on Beech Reservoir. Overall, the ecological health rated fair (65 percent). Chlorophyll rated excellent (at the upper end of the mesotrophic range), below observed concentrations during 1991 and 1992. As expected, DO rated very poor. Sediment quality rated good and benthic macroinvertebrates rated fair. The fish assemblage will be added to the sampling regime in 1994.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. Fecal coliform concentrations were low at the swimming beach in 1990. There are no fish consumption advisories on Beech Reservoir. Fish tissue samples have not been collected by TVA from this reservoir.

7.0 DUCK RIVER WATERSHED

The Duck River Watershed includes all streams flowing into the Duck River. It has an area of 3500 square miles and an average annual discharge of 4075 cfs to Kentucky Reservoir on the Tennessee River. The Duck River basin is underlain almost entirely by limestone, or phosphatic limestone; consequently, waters in the streams draining this basin are fairly hard and contain large concentrations of minerals. Large deposits of phosphate ores permit phosphate mining and refining operations in the basin. Phosphate concentrations in surface and groundwater are significantly higher than in most of the Tennessee Valley. The soils are thin with limestone outcrops at the surface in many places, and sinkholes are common throughout the watershed.

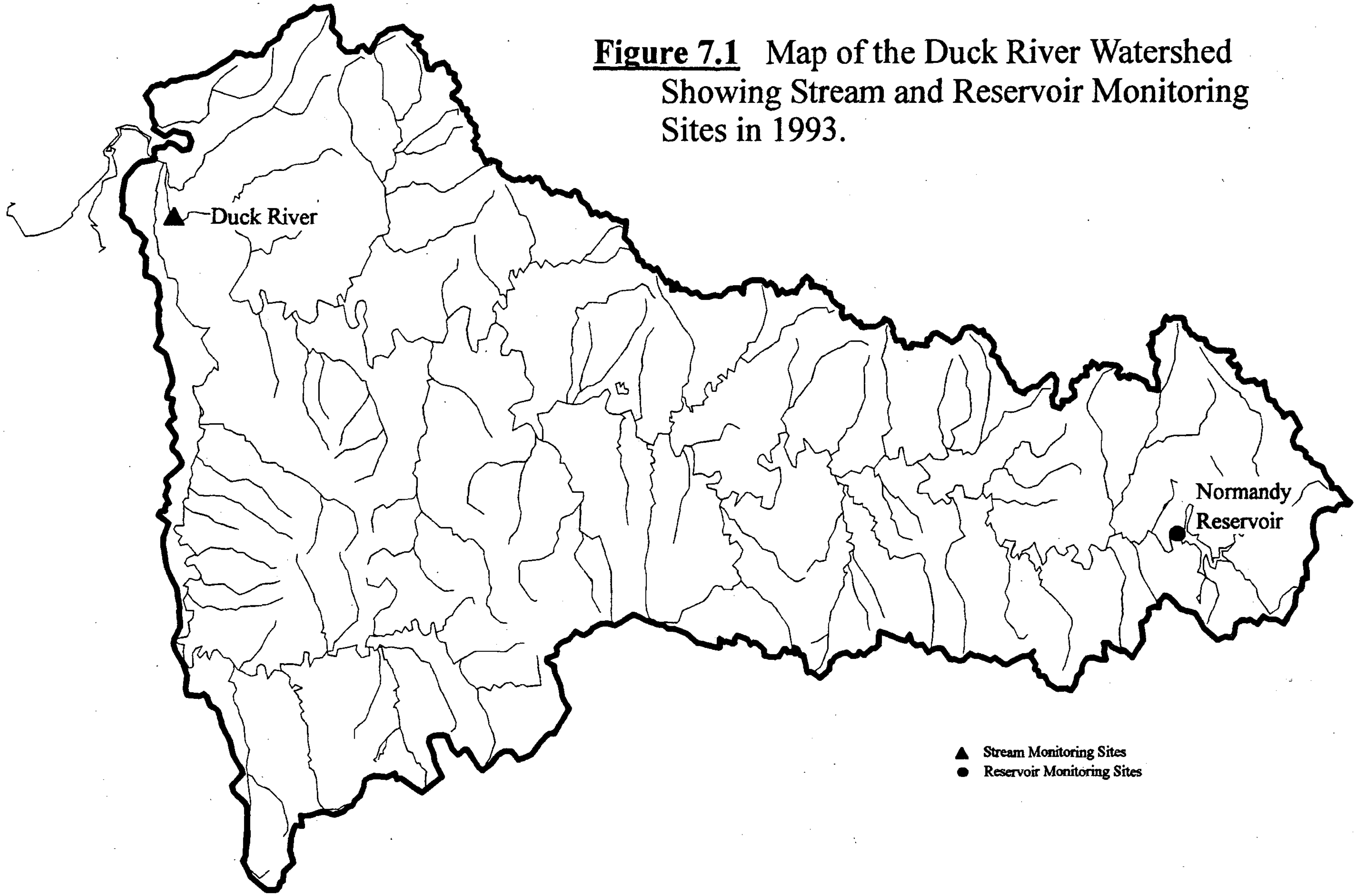
Normandy Reservoir is the only reservoir in this watershed. This is a relatively small reservoir and only the forebay is included in the Vital Signs monitoring program (Figure 7.1).

There is one stream monitoring site on the Duck River at mile 26.0 (Figure 7.1).

Information from monitoring activities on Normandy Reservoir and the Duck River are in Sections 7.1 and 7.2, respectively.

-88-

Figure 7.1 Map of the Duck River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



7.1 Normandy Reservoir

Physical Description

Normandy Reservoir is formed by Normandy Dam at Duck River mile (DRM) 248.6. Normandy Reservoir, constructed primarily for flood control and water supply, has a drainage area of 195 square miles and no electric power generation capacity. One of TVA's smaller reservoirs, Normandy at full pool elevation has about 3200 surface acres, 73 miles of shoreline, and about 17 miles of impounded backwater. The reservoir has an average depth of about 35 feet and an average annual drawdown of about 11 feet. The average annual discharge from Normandy Dam is about 320 cfs, providing an average annual retention time of about 175 days.

Ecological Health

The ecological health of Normandy Reservoir rated poor-fair (56 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir, although several special studies had been completed. As expected, DO conditions were among the poorest observed on any Vital Signs reservoir in 1993. DO rated very poor because anoxia existed, 77 percent of the cross-sectional bottom length had DO concentrations <2.0 mg/L, and 48 percent of the cross-sectional area had DO levels <2.0 mg/L. Sediment quality rated poor due to high levels of ammonia and toxicity to test animals. Benthic macroinvertebrates also rated very poor, likely due to such poor bottom conditions.

Based on past studies, there was concern about very high levels of primary productivity in Normandy Reservoir. Sampling in 1993 did not find this to be the case. Chlorophyll rated good at the forebay sample location because the annual average chlorophyll concentration was within the mesotrophic range, and no single sample had a very high chlorophyll concentration.

The other indicator, fish assemblage, rated excellent. Normandy Reservoir had one of the best fish assemblages examined on tributary reservoirs in 1993. Most of the 12 metrics received the highest possible score.

Reservoir Use Suitability

Fecal coliform samples were collected at two swimming beaches and three boat ramps in 1992. While concentrations were low at the boat ramps, several samples were high at each of the beaches, although the geometric means were well within recreation criteria. The two beaches were sampled again in 1993. Fecal coliform concentrations were much higher, but the geometric means were still within criteria. Local geese populations are the probable source of the high bacteria concentrations.

There are no fish consumption advisories on Normandy Reservoir. A composite sample of channel catfish collected from the forebay in autumn 1992 was screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations.

7.2 Duck River Stream Monitoring Site

Physical Description

The Duck River flows westward from its headwaters in northwestern Coffee County, Tennessee, for more than 280 miles through the Nashville basin and Highland Rim physiographic provinces in middle Tennessee to meet the Tennessee River. The basin is approximately 125 miles long and 30 miles wide and drains 3500 square miles.

The stream monitoring location is at the USGS stream gage above Hurricane Mills, Tennessee. The Duck River basin above Hurricane Mills is 2557 square miles or 73 percent of the entire Duck River basin. Principal tributaries in the monitored area include the Piney River (223 square miles), Big Swan Creek (155 square miles), Lick Creek (101 square miles), and Big Bigby Creek (129 square miles) which drain the Highland Rim province; and Rutherford Creek (116 square miles), Fountain Creek (103 square miles), Big Rock Creek (121 square miles), and Garrison Fork (130 square miles) which drain the Nashville Basin. Normandy Dam forms the only major impoundment located on the upstream reach of the Duck River stream monitoring site.

A principal tributary that flows into the Duck River below the stream monitoring location is the Buffalo River that drains 764 square miles (22 percent of the Duck River basin). The Buffalo River basin lies entirely within the Highland Rim province and the streams generally contain low concentrations of dissolved minerals.

Ecological Health

The stream monitoring site on the Duck River showed generally fair ecological health in 1993, similar to 1992. This was driven by high phosphorus concentrations and fair conditions for the fish community. Sediment quality and the benthic macroinvertebrate community both rated good, an improvement over 1992 observations. Undesirable conditions at this site included extensive bank erosion and unstable bottom substrate conditions. Although the Duck contributes only about 6.5 percent of the total flow of Kentucky Reservoir under average flow conditions, it can contribute significant amounts of nutrients and sediment to the reservoir.

Use Suitability

A reach of the Duck River from 3.5 to 7.1 miles downstream of Normandy Dam was found to greatly exceed bacteriological criteria for water contact recreation in 1993, probably due to dairies.

All metal and organic analytes in fish tissue samples were not detected or found in low concentration.

8.0 PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir and Wilson Reservoir on the Tennessee River are the most notable features of this drainage area. Only a small part of the flow leaving this watershed actually originates within the watershed itself. The average annual discharge from Pickwick Dam is 54,900 cfs. Of that, 49,500 cfs (90 percent) is the discharge from Wheeler Dam into Wilson Reservoir. About 2100 cfs enters Wilson Reservoir through local tributaries and about 3400 cfs originates in tributaries to Pickwick Reservoir. The streams within this watershed drain an area of about 3230 square miles. The largest tributaries are Bear Creek, a tributary to Pickwick Reservoir with a drainage area of about 945 square miles, and Shoal Creek, a tributary to Wilson Reservoir, with a drainage area of about 445 square miles.

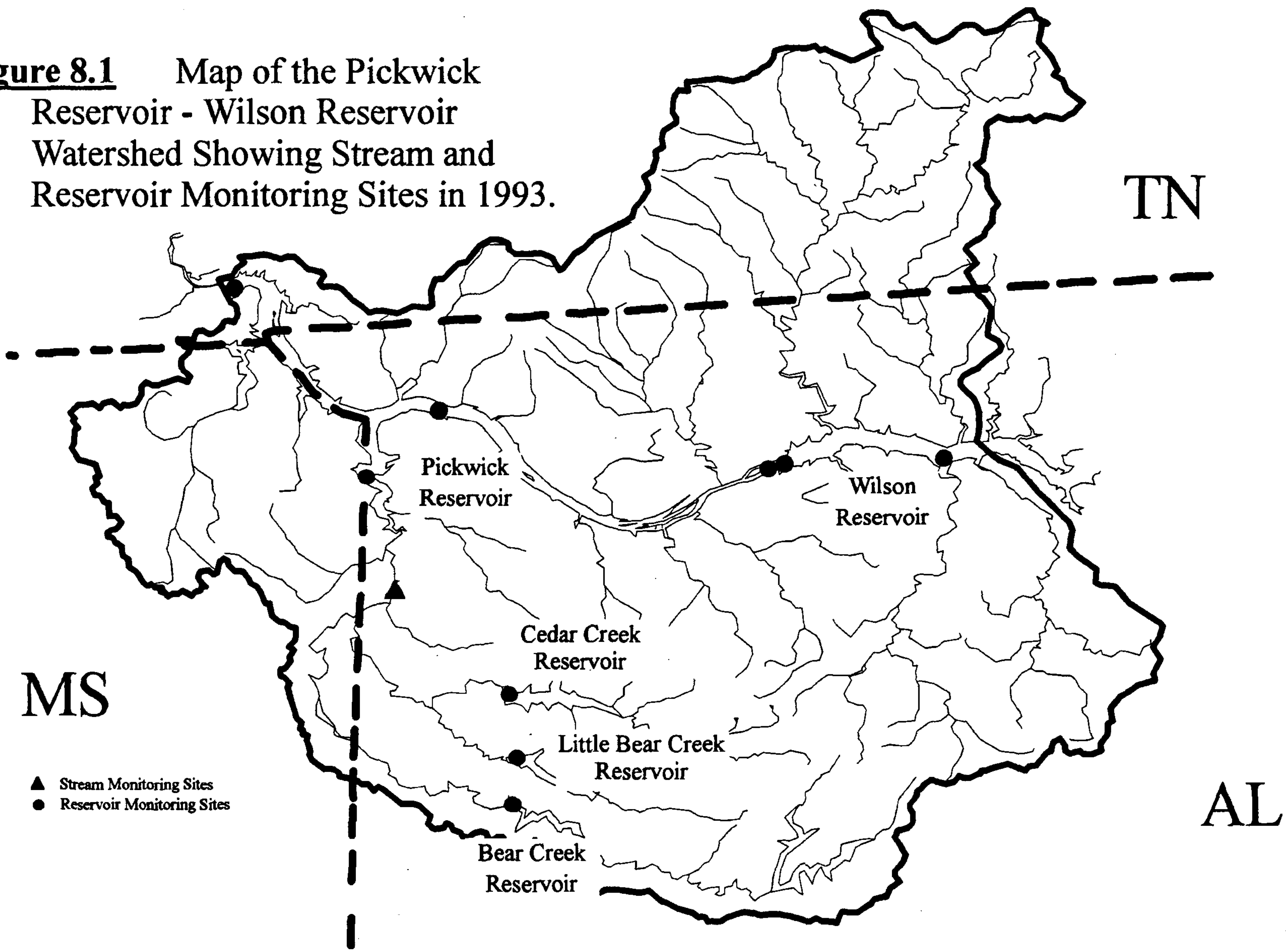
Four small reservoirs were built on Bear Creek in the late 1970s and early 1980s for flood control and recreation. These are Bear Creek, Little Bear Creek, Cedar Creek, and Upper Bear Creek Reservoirs.

Reservoir monitoring activities occur at the forebay, transition zone, and inflow on Pickwick Reservoir and at the forebay and inflow on Wilson Reservoir (Figure 8.1). Wilson is relatively short and has no definable transition zone. Because of their smaller size, only the forebays of Bear Creek, Little Bear Creek, and Cedar Creek Reservoirs are monitored. No monitoring activities are conducted on Upper Bear Creek because of TVA's program to destratify and oxygenate water in the forebay.

The only stream monitoring site is on Bear Creek at Bear Creek mile 27.3. Results for 1993 reservoir and stream monitoring activities within this watershed are provided in the following sections:

8.1 Pickwick Reservoir
8.2 Wilson Reservoir
8.3 Bear Creek Reservoir
8.4 Little Bear Creek Reservoir
8.5 Cedar Creek Reservoir
8.6 Bear Creek Stream Monitoring Site

Figure 8.1 Map of the Pickwick Reservoir - Wilson Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



8.1 Pickwick Reservoir

Physical Description

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream, run-of-the-river reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is about 55,000 cfs, which provides an average hydraulic retention time of about eight days. Additional information about reservoir characteristics is in Table 4.1.

A major tributary, Bear Creek, joins the Tennessee River in Pickwick Reservoir at about mile 225. Bear Creek provides, on the average, about 2.5 percent of the flow through Pickwick Reservoir.

Reservoir Monitoring activities were expanded on Pickwick Reservoir in 1993 to include a Vital Signs monitoring site in Bear Creek embayment. This rather large embayment (7200 acres) extends from the mouth of Bear Creek upstream about 17 miles to the point where flow is not affected by backwater from Pickwick Dam.

Ecological Health

The ecological health of Pickwick Reservoir was fair to good in 1993 (73 percent), similar to 1992 and 1991. All ecological health indicators rated between fair and excellent at all locations, except chlorophyll, which rated very poor (indicating high algal productivity) at the new sample site in Bear Creek embayment. There was a general decline in DO conditions throughout the reservoir in 1993 with DO rated fair to good at all locations. In 1992 DO was good to excellent at all locations. Summer 1993 was characterized by low rainfall, low flows, and high temperatures, hence lower DO concentrations were expected.

Conditions at the transition zone improved in 1993 for chlorophyll and sediment quality. Sediments contained lower mercury concentrations than in previous years; however, concentrations were still slightly above background. Although chlorophyll concentrations were in the fair range in 1993 (because of relatively high average concentrations), this was an improvement over 1992 when concentrations were even higher.

Benthic macroinvertebrates at the inflow location, downstream of Wilson Dam, were improved in 1993, rating excellent as compared to fair in 1992 and poor in 1991. The improvement between 1991 and 1992 was partly due to an improved evaluation system and partly due to actual improvements in the health of the community of bottom animals. The 1993 results indicate continued improvements in the benthos.

At the forebay, the fish assemblage evaluation has shown substantial variation from year to year. The rating was good in 1991, poor in 1992 (very few fish collected), and good in 1993. Interestingly, a low number of fish were collected from this location by electrofishing in 1993, yet an abundance of fish were collected by gill netting. The 1992 rating was based only on electrofishing results, whereas the 1993 rating was based on results from both techniques. Overall, there appeared to be little change in the fish assemblage among years.

The new sample site in Bear Creek embayment had one very poor indicator (chlorophyll--too high), three fair indicators (DO--zero on bottom; sediment--toxicity to test organisms; benthos--mostly tolerant organisms present), and one good indicator (fish). Of the four sites sampled on Pickwick Reservoir in 1993, the Bear Creek embayment site had the poorest ecological health. If results for this site were deleted from calculating the overall reservoir score, the reservoir score would be 80 percent.

There were only about 105 acres of aquatic plants on Pickwick Reservoir in 1993, similar to the 100 acres in 1992.

Reservoir Use Suitability

Use Suitability monitoring did not identify bacteriological nor fish tissue contamination problems. There are no fish consumption advisories on Pickwick Reservoir based on fish collected from 1988 through 1992. Concentrations of metals, PCBs, and pesticides in composited catfish fillets were relatively low except for total DDT concentrations in the fall 1992 inflow sample. Given the rare occurrence of elevated total DDT concentrations in fish from Pickwick, it is likely that one of the catfish in the composite came from Wheeler Reservoir, which has a significant, localized DDT contamination problem. Fecal coliform bacteria concentrations were low at ten swimming areas sampled in 1993. Bacteria concentrations at the Vital Signs locations sampled since 1990 have been low.

8.2 Wilson Reservoir

Physical Description

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short, deep pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 51,500 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

Ecological Health

Ecological health of Wilson Reservoir improved somewhat in 1993 compared to 1992 and 1991. Overall, Wilson Reservoir rated fair to good (71 percent) in 1993 compared to 60-70 percent in previous years. One of the persistent problems in Wilson Reservoir is low concentrations of dissolved oxygen (< 1 mg/L) in the forebay during summer months. The problem was more severe in summer 1993 due to the drought conditions (high temperatures, low rainfall, and low flows). Anoxia developed near the bottom, and a large proportion of the bottom and water column had DO concentrations <2.0 mg/L, leading to a very poor rating.

A massive algal bloom caused extremely high chlorophyll concentrations at the forebay in 1992 resulting in a poor rating that year. Chlorophyll concentrations were lower in 1993, but still relatively high and, therefore, rated fair in 1993. The benthic macroinvertebrate community at the forebay rated better in 1993 (fair) compared to previous years (consistently poor). Poor ratings had been attributed to the low concentrations of DO near bottom during summer. Given that benthos collections were made in March 1993, prior to the severe DO problems later that summer, these samples would have been more representative of 1992 conditions. Even though DO concentrations in summer 1992 were not good, they were the best documented on Wilson since the Vital Signs monitoring program began in 1990. The duration of low DO concentrations was relatively short in 1992 and the proportion of bottom with low DO concentrations was small. These conditions may have provided sufficient opportunity for recolonization of several benthic species resulting in the improved community rating for 1993. Samples to be collected in March 1994 will help determine whether this hypothesis is correct. If correct, the benthos rating for 1994 should be poor because of the severe DO conditions in summer 1993.

Sediment quality at the forebay was good in 1992 and 1993, indicating no impairment due to bottom substrates. This was an improvement over 1991 when fair sediment quality conditions were found due to lower survival rates for test organisms. All ecological health indicators measured at the inflow location (DO, fish, and benthos) were good or excellent in 1993.

There were only 54 acres of aquatic plants on Wilson Reservoir in 1993.

Reservoir Use Suitability

There are no fish consumption advisories on Wilson Reservoir based on fish tissue studies conducted over the past several years.

Fecal coliform bacteria concentrations were very low at the two boat ramps tested in 1993 and at the Vital Signs location in the forebay. The low rainfall in 1993 may have contributed to low concentrations at the boat ramps. All fecal coliform samples collected in the forebay since 1990 have been low.

8.3 Bear Creek Reservoir

Physical Description

With a surface of only 700 acres, Bear Creek is one of the smallest reservoirs in the TVA system. It is relatively long (16 miles), narrow, and deep (74 feet at the dam). The average annual discharge is 380 cfs providing an average hydraulic retention time of about 13 days. Average annual drawdown is about 11 feet. Bear Creek Reservoir stratifies in the summer and develops hypolimnetic anoxia. Another water quality concern is abandoned strip mines in the watershed.

Ecological Health

The ecological health of Bear Creek Reservoir rated fair (60 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir. This reservoir appears to have a high rate of primary productivity and significant hypolimnetic DO depletion. Summer chlorophyll concentrations were higher on Bear Creek Reservoir than on any of the other tributary reservoirs monitored in 1993. Only one of the five indicators (benthic macroinvertebrates) rated excellent and one rated good (fish). Such high ratings would not be expected given the very poor rating for DO (anoxia and large proportion of the water column with low DO concentrations) and poor rating for sediment quality (high ammonia and toxicity to test animals). Continued monitoring in future years will help to better define the ecological health of Bear Creek Reservoir.

Use Suitability

Fecal coliform bacteria concentrations were low at both of the swimming areas surveyed in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were higher, but still well within water quality criteria for recreation. A single composite of channel catfish was collected from the forebay in autumn 1992. All metal and organic analytes were low or not detected, except for mercury which was high enough to warrant reexamination in autumn 1993 but not high enough to indicate a need for an in-depth, intensive study.

8.4 Little Bear Creek Reservoir

Physical Description

Little Bear Creek Reservoir is relatively short (7.1 miles long) and deep (84 feet at the dam). It has a surface area of 1600 acres. With an average annual discharge of 101 cfs, the hydraulic retention time is 225 days. Compared to Bear Creek Reservoir, the lower flow into the reservoir and larger reservoir volume make the retention time much longer in Little Bear Creek Reservoir. Average annual drawdown is about 12 feet.

Ecological Health

Little Bear Creek Reservoir had a fair (64 percent) ecological health rating in 1993. This was the first year for Vital Signs monitoring on Little Bear Creek Reservoir. Similar to the other reservoirs in the Bear Creek watershed, the most obvious problem was very poor DO conditions at the forebay. Other indicators rated good (chlorophyll and fish assemblage) or fair (sediment quality and benthos). Given the hot, dry summer of 1993, additional information in future years will help to better evaluate and define the ecological health of Little Bear Creek Reservoir.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were very low at both swimming areas tested in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were much higher at both beaches. During the 1991 survey period, bacteriological water quality at both sites was within state water quality criteria for recreation; however, both exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL.

A composite of channel catfish was collected from the forebay of Little Bear Creek Reservoir in autumn 1992. Only one metal analyte (mercury) was detected, and no PCB or pesticide analytes were detected. The mercury concentration (0.56 $\mu g/g$) was relatively high. As a result, channel catfish from this site were reexamined in autumn 1993. Results were not available at the time this report was prepared.

8.5 Cedar Creek Reservoir

Physical Description

Like the other reservoirs in the Bear Creek watershed, Cedar Creek Reservoir is small (only nine miles long and 4200 acres surface area) and deep (79 feet at the dam). The low average annual discharge from the dam (282 cfs) creates a relatively long average retention time (168 days). This combination of physical features lead to thermal stratification and hypolimnetic anoxia in the summer. Average annual drawdown is about 14 feet.

Ecological Health

The ecological health of Cedar Creek Reservoir rated poor-fair (56 percent) in 1993, the first year of Vital Signs monitoring. As expected based on the other reservoirs in the Bear Creek watershed, DO rated very poor because of anoxic conditions and a very large proportion of both the bottom and the water column with DO concentrations <2.0 mg/L. Chlorophyll, benthos, and fish assemblage all rated fair. The only fair to good rating was for sediment quality. There were no excellent ratings.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were low at the Slickrock Ford swimming area in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a previous survey period in 1991 with more normal rainfall, higher fecal coliform concentrations were found. Despite being higher, they were within state water quality criteria for recreation.

A single composite of channel catfish fillets collected from the forebay of Cedar Creek Reservoir in autumn 1992 did not have detectable concentrations of any pesticide or PCB analyte. Mercury, found at a low concentration, was the only metal analyte detected.

8.6 Bear Creek Stream Monitoring Site

Physical Description

Bear Creek flows through the southwest boundary of the Highland Rim physiographic province in northwestern Alabama (85 percent) and northeastern Mississippi to join the Tennessee River as an embayment of Pickwick Reservoir. The Bear Creek watershed is approximately 65 miles long and 15 miles wide and drains 946 square miles.

The watershed area above the Bishop, Alabama, monitoring location is 667 square miles or 70 percent of the entire Bear Creek basin. Within the monitored area, Cedar Creek, with a drainage area of 329 square miles, is the principal tributary. There are four reservoirs (Cedar Creek, Little Bear Creek, Bear Creek, and Upper Bear Creek) that control the runoff from about half of the watershed.

The Bear Creek basin is underlain by sandstone or has limestone outcroppings. Approximately 70 percent of the watershed is forested, the remainder agricultural. Some iron ore has been mined in the basin and bacterial pollution from agricultural operations has been recognized as a water quality concern. Several active and abandoned coal mines are located on the uppermost portions of the watershed above the upper Bear Creek Reservoir. Russellville and Haleyville, Alabama, are the primary urban areas.

Ecological Health

The monitoring location on Bear Creek, far upstream of any influence of impoundment from Pickwick Reservoir, showed fair ecological health in 1993. The fish community was fair in 1993; but not as good as in 1992, which was much improved over past years. Benthic macroinvertebrates also rated fair in 1993, similar to 1992.

Use Suitability

The only bacteriological samples collected from the Bear Creek watershed in 1993 were those collected for reservoir Vital Signs monitoring and are reported with those sections.

Fish for tissue analysis are not collected from the Bear Creek stream monitoring site.

9.0 WHEELER RESERVOIR - ELK RIVER WATERSHED

The Wheeler Reservoir - Elk River watershed drains about 5140 square miles in north central Alabama and south central Tennessee. Wheeler Reservoir is the fourth of nine reservoirs on the Tennessee River. About 24,500 square miles of the Tennessee Valley are upstream of this watershed. Wheeler Reservoir receives an average annual inflow of 40,700 cfs from Guntersville Dam. Discharges from Wheeler Dam average 49,400 cfs on an annual basis leaving 8700 cfs which originate within the watershed.

The largest tributary to Wheeler Reservoir is the Elk River, which has a drainage area of about 2250 square miles and contributes about 3000 cfs. The remaining flow enters from tributaries directly to Wheeler Reservoir.

Wheeler Reservoir is the largest reservoir within this watershed followed by Tims Ford Reservoir on the Elk River. There are four Vital Signs monitoring sites on Wheeler Reservoir--forebay, transition zone, inflow, and the Elk River embayment (Figure 9.1 and Table 2.1). Two sites are monitored for Vital Signs on Tims Ford Reservoir--forebay and mid-reservoir. Woods Reservoir on the Elk River is not included in this monitoring program because it is property of the Arnold Engineering Development Center, Arnold Air Force Base.

The only stream monitoring site within this watershed is on the Elk River at mile 36.5.

Results from 1993 monitoring activities are provided in Section 9.1 for Wheeler Reservoir, Section 9.2 for Tims Ford Reservoir, and Section 9.3 for the stream site on the Elk River.

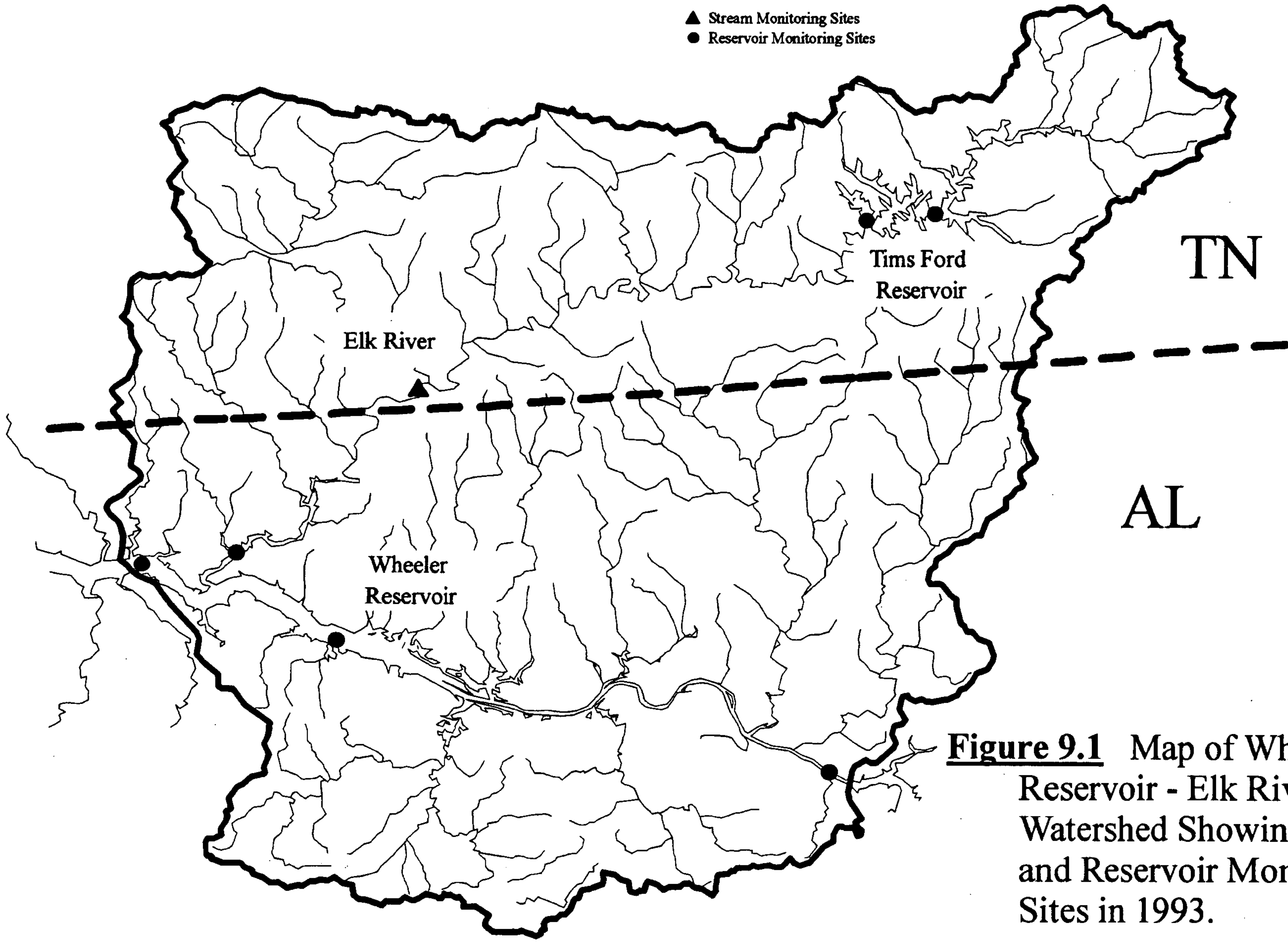


Figure 9.1 Map of Wheeler Reservoir - Elk River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

9.1 Wheeler Reservoir

Physical Description

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is about 49,400 cfs which provides an average hydraulic retention time of about 11 days. Information collected in 1990 and 1991 indicated a more riverine than transition environment at TRM 307.5; consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 295.9. Results for 1992 and 1993 are being evaluated to determine if this new site is suitably located or if it needs to be moved further downstream.

The Elk River joins the Tennessee River in the downstream portion of Wheeler Reservoir at about mile 284 and provides, on the average, about 6 percent of the flow through Wheeler Reservoir.

Vital Signs monitoring activities were expanded in 1993 to include a site in the Elk River embayment. This was one of four embayments added to the Vital Signs program in 1993. The Elk River embayment covers about 4900 acres. Given the relatively high flows in the Elk River (about 3000 cfs annual average), there is substantial water exchange in this embayment.

Reservoir Health

Like several other Tennessee River reservoirs, the overall ecological health index of Wheeler Reservoir was lower in 1993 compared to 1992 and 1991. Overall, Wheeler Reservoir rated fair to good (72 percent) in 1993 compared to good in 1992 (80 percent) and in 1991 (87 percent). The primary contributor to this lower reservoir rating was addition of information from the Elk River embayment, which had three poor ratings (chlorophyll--very poor; DO and benthos--poor). Of the four sites monitored on Wheeler Reservoir in 1993, the Elk River embayment site had the poorest ecological health. If data from the Elk River site were deleted from the overall score, Wheeler would rate good (82 percent), consistent with findings in 1991 and 1992.

DOs less than 2 mg/L were measured at lower depths in the forebay during summer with an anoxic area near bottom. As a result, DO rated poor at the forebay. (Ratings for DO at the forebay had been good in 1991 and fair in 1992.) This stressed condition was likely related to the low flows during the 1993 summer. Interestingly, DO rated excellent at the inflow and transition zone, indicating the problem developed within the downstream, forebay region of the reservoir. When low reservoir flows and high water temperatures occur, respiration and oxygen demand (both sediment and biological) increase and can exceed the DO made available by reaeration and photosynthesis. This downstream portion of Wheeler Reservoir usually has relatively high algal productivity due to input of high levels of phosphorus from Elk River. The combination of stagnant water and a high oxygen demand required to decompose dead algae settling to the bottom contributes to low DOs in lower depths at the forebay. All other ecological health indicators rated fair, good, or excellent, similar to previous years. The transition zone and inflow had mostly good or excellent rating for all indicators. The fish assemblage and sediment quality were fair, good, or excellent at all sample sites.

Aquatic macrophytes colonized about 6600 acres on Wheeler Reservoir in 1993, compared to about 4400 acres in 1992 and 3500 acres in 1991.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993. In 1990, bacteriological water quality met the Alabama criterion for recreation at the four swimming beaches and four boat ramps tested. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations in the forebay and transition zones. Since 1990, only two samples have been high, one in 1990 and one in 1993, both in the transition zone.

The Alabama Department of Public Health advises that most fish species from within the Indian Creek embayment on Wheeler Reservoir should not be eaten due to DDT contamination. An intensive study was conducted in autumn 1991 to determine if high concentrations existed in fish from the Tennessee River in an area 15 miles downstream to five miles upstream of the Indian Creek embayment. Based on the 1991 results the public was further advised not to eat largemouth bass, channel catfish, and smallmouth buffalo from within one mile either side of the area where Indian Creek and the Tennessee River join. Other bottom feeding fish species (such as carp and suckers) from the area should also be avoided. Furthermore, channel catfish caught from the Tennessee River between Indian Creek and the Interstate 65 bridge should not be eaten. Fish were again collected from these areas in the Tennessee River in 1992 to continue examining DDT concentrations. The 1992 fish had much lower concentrations than those in 1991. The study was reported in autumn 1993, but results were not available at the time this report was prepared.

9.2 Tims Ford Reservoir

Physical Description

Tims Ford Reservoir in middle Tennessee is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir is 34 miles long at full pool and has a surface area of 10,600 acres. The depth at the dam is 143 feet and the average depth is about 50 feet. Average annual discharges from Tims Ford Dam are about 940 cfs, resulting in a hydraulic residence time of about 280 days. Tims Ford Reservoir is designed for a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection; however, annual drawdowns average about 18 feet.

Ecological Health

The ecological health of Tims Ford Reservoir rated poor-fair (58 percent) in 1993 with very little change from previous years of Vital Signs monitoring. The most obvious ecological health problem was the low concentrations of DO near bottom (rated very poor at both the forebay and mid-reservoir sites in 1993). Although undesirable, low DO concentrations often exist in deep, tributary storage reservoirs like Tims Ford with long detention times and strong summer stratification. In spite of these low dissolved oxygen conditions, the fish assemblage rated good at both monitoring sites in 1993. However, the benthos, sampled for the first time in 1993, rated very poor at the forebay and poor at the mid-reservoir site. Sediment quality, also sampled for the first time in 1993, had high levels of ammonia at both locations and toxicity to test animals at the mid-reservoir site which rated poor. Chlorophyll ratings at both locations on Tims Ford Reservoir were good in 1993, indicating adequate primary productivity to support the food web, but not overly productive, potentially leading to eutrophic conditions.

Reservoir Use Suitability

Four sites were tested for fecal coliform bacteria in 1992; two sites were retested in 1993 because of high concentrations. The 1993 concentrations were low at the Estill Springs Park, but at the Dry Fork swimming area, bacteria concentrations were within state criteria only if samples collected within 24-hours of rainfall are excluded.

There are no fish consumption advisories for Tims Ford Reservoir. All analytes were either not detected or found in only low concentrations in channel catfish composites collected from the forebay and transition zone in autumn 1992.

9.3 Elk River Stream Monitoring Site

Physical Description

The Elk River flows for more than 200 miles from its headwaters near Monteagle, Tennessee, on the edge of the Cumberland plateau, southwest through south-central Tennessee into northern Alabama where it meets the Tennessee River about nine miles above Wheeler Dam. The basin, which lies principally in the Highland Rim province, is approximately 100 miles long and 50 miles wide at its greatest width, but it averages only 25 miles wide. Approximately one-third of the north central basin above the Elk River lies in the Nashville basin. The Elk River drainage basin area is 2249 square miles.

The TVA monitoring station is located at the USGS stream gage near Prospect, Tennessee. At this location, 1784 square miles or 79 percent of the entire Elk River basin is monitored. Major tributaries of the Elk River basin include Sugar Creek (177 square miles), Richland Creek (488 square miles), Cane Creek (106 square miles), Mulberry Creek (99 square miles), and Beans Creek (92 square miles). Tims Ford Dam and Elk River Dam control most of the runoff from the upper quarter of the watershed.

The Elk River drains an area underlain for the most part by limestone. Consequently, the water is high in dissolved minerals and fairly hard. About 60 percent of the Elk River basin is farmland. Urban areas include Pulaski, Fayetteville, Tullahoma, and Winchester, Tennessee.

Ecological Health

The monitoring site on the Elk River, far upstream of any influence of backwater from Wheeler Reservoir, was rated poor to fair in 1993, a slight improvement over 1992. Improvements were noted in sediment quality and benthic macroinvertebrates. (Fish were not sampled in 1993.) Nutrient concentrations were quite high, resulting from phosphorus-rich soils in the watershed. These high nutrient inflows from the Elk River can stimulate algal blooms in Wheeler Reservoir.

Use Suitability

Bacteriological water quality at an access location about one and one-half miles downstream of Tims Ford Dam was poor immediately after rainfall, but met recreation criterion if samples collected within 24-hours of rainstorms were excluded.

All analytes in fish tissue samples collected in summer 1992 were either not detected or found in low concentrations.

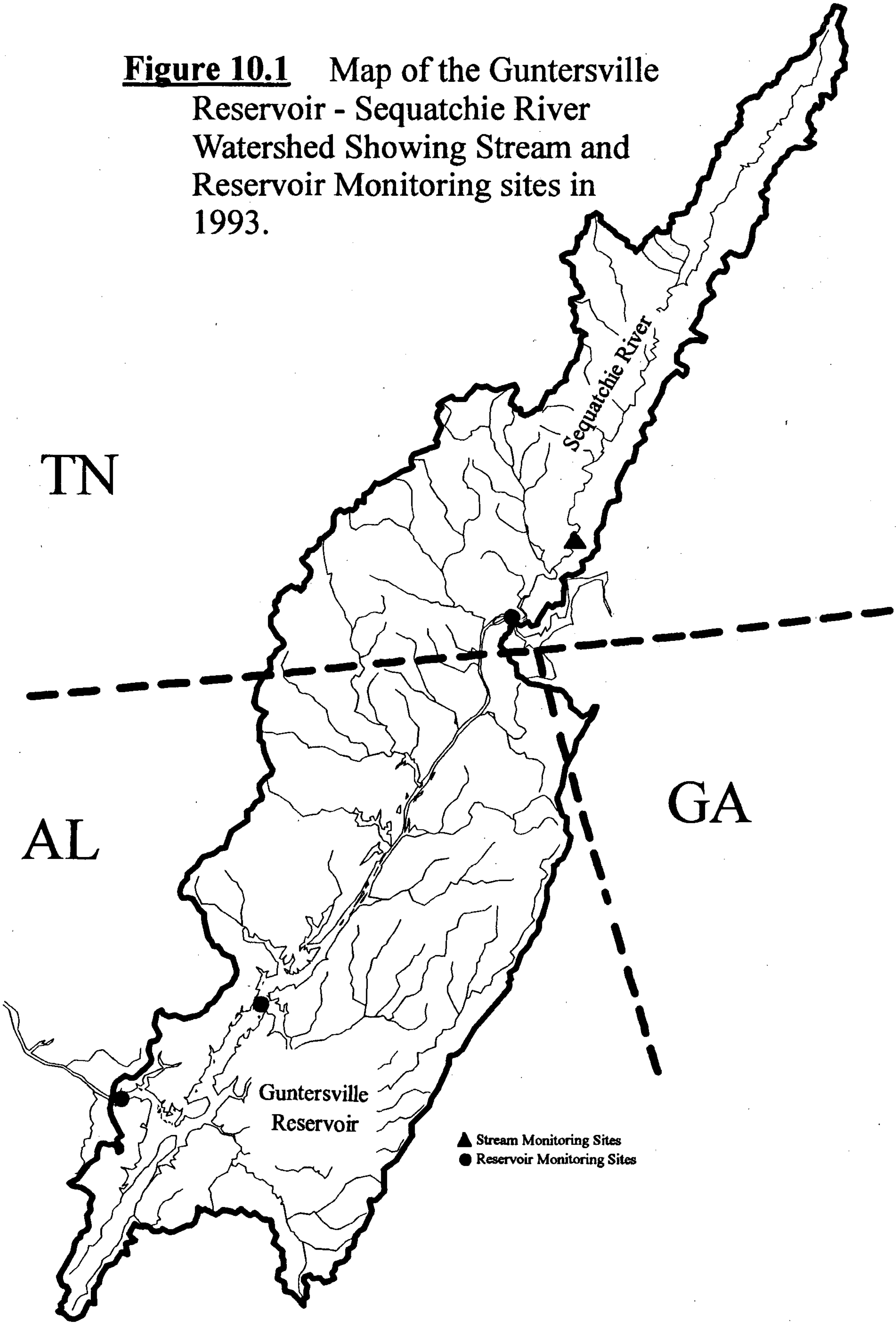
10.0 GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

This watershed includes Guntersville Reservoir and all tributaries draining directly to Guntersville Reservoir. As with the other watershed areas on the mainstem of the Tennessee River, most of the water leaving the watershed through Guntersville Dam enters the watershed area through discharges from the upstream dam (Nickajack). About 35,900 cfs enter from Nickajack Dam and about 40,700 cfs is discharged from Guntersville Dam on an annual average basis. The remaining 4800 cfs originates with the Guntersville Reservoir-Sequatchie River watershed area. The largest contributor of this flow is the Sequatchie River (about 800 cfs). The total watershed area is 2669 square miles. The area drained by the Sequatchie River is about 600 square miles.

Guntersville Reservoir is the dominant characteristic of this watershed. There are three Vital Signs monitoring site on Guntersville Reservoir: forebay, transition zone, and inflow (Figure 10.1 and Table 2.1). Information from 1993 monitoring activities is provided in Section 10.1.

There is a stream monitoring site on the Sequatchie River at mile 6.3. Monitoring information for this site for 1993 is provided in Section 10.2.

Figure 10.1 Map of the Guntersville Reservoir - Sequatchie River Watershed Showing Stream and Reservoir Monitoring sites in 1993.



10.1 Guntersville Reservoir

Guntersville Dam, located at TRM 349.0, creates a 76 mile long reservoir with a surface area of 67,900 acres and a shoreline of 949 miles at full pool. Average annual discharge is about 40,700 cfs, corresponding to an average hydraulic retention time of about 13 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics, but it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. This is due to the shallow nature of Guntersville Reservoir at the inflow area and extensive shallow overbank areas. As a result, winter drawdown on Guntersville Reservoir is nominal to maintain navigation. The shallow drawdown allows the large overbank areas to be permanently wetted creating good habitat for aquatic macrophytes. Guntersville has the greatest area coverage of aquatic plants of any TVA reservoir.

The Sequatchie River joins the Tennessee River at about TRM 423, in the upstream portion of Guntersville Reservoir, just downstream from Nickajack Dam. On the average the Sequatchie River contributes less than 2 percent to the total flow of the Tennessee River through Guntersville Reservoir.

Data collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 396.8. Consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 375.2. Results from the new site are being reviewed to determine if it is suitably located.

Ecological Health

Ecological health conditions were good (78 percent) in Guntersville Reservoir in 1993, similar to those observed in 1992 (83 percent). All ecological health indicators rated fair, good, or excellent at all reservoir sites, except for DO at the inflow, which rated very poor (compared to fair in previous years). A very low DO concentration (1.8 mg/L, the lowest ever recorded in the discharge from Nickajack Dam) was measured in July and was related to the usual flow patterns associated with the summer drought and special hydroelectric operations.

As in 1992, 1993 results indicated the transition zone had the best ecological health of the three sample sites on Guntersville Reservoir. Four of the five aquatic health indicators from this site had excellent ratings both years; only the fish assemblage rated less than excellent (fair).

Aquatic macrophytes covered about 7600 acres in 1993 compared to 5993 acres in 1992 and 5165 acres in 1991. Guntersville Reservoir contains more acres of aquatic plants than any other reservoir in the TVA system.

Reservoir Use Suitability

All sites tested for fecal coliform bacteria in 1992 and 1993 in Guntersville Reservoir met the Alabama water quality criterion for recreation. At most sites, bacteria concentrations were quite low. High fecal coliform concentrations were found in the Vital Signs sampling at the forebay in 1990 and 1991, but bacteria concentrations at both the forebay and transition zone were very low in 1992 and 1993.

There are no fish consumption advisories on Guntersville Reservoir. Channel catfish composites collected from Guntersville Reservoir in autumn 1990 had sufficiently high PCB concentrations to warrant further examination but were not high enough for the state to issue an advisory. Catfish collected from the same locations in 1991 and 1992 had progressively lower concentrations than those from 1990 with the 1992 concentrations generally indicative of "background" levels found in channel catfish throughout the Tennessee River. Other analytes were low or nondetectable in the 1992 samples.

10.2 Sequatchie River Stream Monitoring Site

Physical Description

The Sequatchie River basin is a narrow limestone valley of the Valley and Ridge physiographic province, surrounded by the Cumberland Plateau to the west and Walden Ridge to the east. The Sequatchie flows from its headwaters south of the Emory-Obed River basin for more than 110 miles to form an embayment at the upstream end of Guntersville Reservoir, just downstream from Nickajack Dam. The Sequatchie River drainage basin is 605 square miles.

The TVA monitoring station is located at the Valley Road bridge near Jasper, Tennessee. The upstream drainage basin is 575 square miles or 95 percent of the entire Sequatchie River basin. Principal tributaries in the monitored area include the Little Sequatchie River (132 square miles) and Big Brush Creek (69 square miles).

Dolomite and limestone underlie the floor of the Sequatchie River valley, which is predominantly farmland. Sandstones underlie the surrounding steep escarpments and plateaus, which are predominantly forested. Coal mines operate in some areas of the Cumberland Plateau. Whitwell, Dunlap, and Pikeville, Tennessee, are the primary urban area in the basin.

Ecological Health

The ecological health of the Sequatchie River monitoring site was good in 1993. All ecological health indicators were either good or fair. Coal mining activities may be hindering the fish community and bottom-dwelling animals as indicated by deposits of coal fines and other sediments.

Use Suitability

Four canoe sites were sampled in 1992 and 1993 for fecal coliform bacteria. Although some samples collected after rainfall had high concentrations, all sites met Tennessee water quality criterion for recreation both years.

Fish tissue samples from the Sequatchie River collected during summer 1992 had nondetectable or only low concentrations of all analytes.

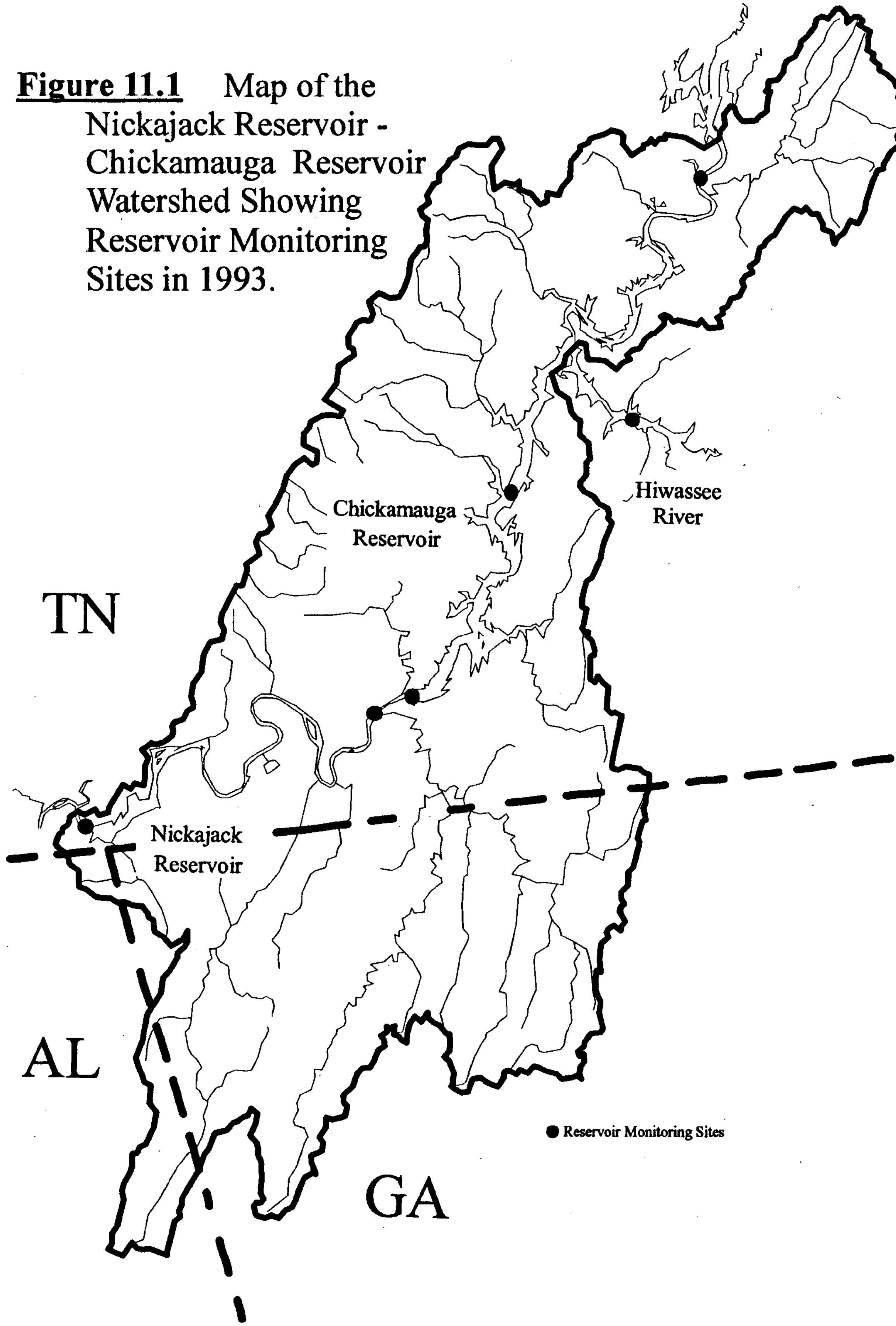
11.0 NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack and Chickamauga Reservoirs are primary features of this watershed. The Hiwassee River is the only sizeable tributary which merges with the Tennessee River within the watershed area. The drainage basin of the Hiwassee River is large enough to be designated a separate watershed (see Section 12). The remaining area drained by tributaries to these two reservoirs is 1780 square miles. On an annual average basis, about 3200 cfs is contributed to the Tennessee River from streams within this watershed. This compares to 27,100 cfs entering the upper end of Chickamauga Reservoir from Watts Bar Dam and 5600 cfs from the Hiwassee River, for a total average annual discharge from Nickajack Dam of 35,900 cfs.

There are two Vital Signs monitoring sites on Nickajack Reservoir, one at the forebay and one at the inflow. There is no transition zone site on Nickajack because the reservoir is short and water exchange is quite rapid. This causes conditions at the location that might be considered the transition zone to be similar to those at the forebay. Chickamauga Reservoir has four Vital Signs monitoring sites--the forebay, the transition zone, the inflow, and a new site established in 1993 in the Hiwassee River embayment (Figure 11.1).

Results from 1993 monitoring activities are in Section 11.1 for Nickajack Reservoir and 11.2 for Chickamauga Reservoir.

Figure 11.1 Map of the Nickajack Reservoir - Chickamauga Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.



11.1 Nickajack Reservoir

Physical Description

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is approximately 35,900 cfs which provides an average hydraulic retention time of only about three or four days, the shortest retention time among the reservoirs monitored in this program.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sampling sites had quite similar water quality. This was expected since the two sites are relatively close together (separated by only 7.5 river miles), and Nickajack is a well-mixed, run-of-the-river reservoir. Therefore, sampling at the transition zone in Nickajack Reservoir was discontinued in 1992.

Ecological Health

Nickajack Reservoir had a good ecological health rating (88 percent) in 1993, the same as in 1992 and 1991 (83 percent both years). Nickajack had the highest overall ecological health rating of all Vital Signs reservoirs in 1993. The only poor rating was for DO at the upper end of Nickajack Reservoir. This was due to low DOs (minimum 2.2 mg/L) in the releases from Chickamauga Dam in July 1993. Low DO concentrations had been observed there in previous years, but concentrations measured in 1993 were the lowest ever recorded from Chickamauga Dam. These concentrations were not low enough to cause mortality for common species present, but were low enough to affect organism health and growth. Although the DO rating at the Nickajack forebay was excellent (no DO concentrations less than 2.0 mg/L were measured), it cannot be concluded that no DO problems existed. Because low DO concentrations were found in water entering Nickajack Reservoir from Chickamauga Dam and low DO concentrations were found in water leaving Nickajack Dam, it is clear that low DOs existed in the Nickajack forebay at some time. The lack of low measurements at the forebay likely is due to the timing of monthly measurements; sampling dates in July and August bracketed the period with most severe DO problems.

Other than the poor DO rating for the inflow, all other ecological health indicators at the forebay and inflow sample sites scored good or excellent. Even if low DO concentrations had been measured at the forebay, the high scores for the other indicators would have kept the overall rating for Nickajack Reservoir in the good range.

Aquatic macrophytes on Nickajack Reservoir covered about 1000 acres in 1993 compared to 830 acres in 1991 to 580 acres in 1992.

Reservoir Use Suitability

The Tennessee Department of Environment and Conservation has issued an advisory that catfish should not be eaten by children, pregnant women, and nursing mothers because of PCB levels (about 1.0 $\mu g/g$); other individuals should limit consumption to no more than 1.2 pounds per month. Fillets from catfish collected autumn 1992 had PCB concentrations about half those previously found in the five years of fish tissue studies on Nickajack Reservoir. The study was repeated in autumn 1993 to determine if lower PCB concentrations are found again. Results were not available at the time this report was prepared.

Fecal coliform bacteria concentrations in areas of Nickajack Reservoir tested during the recreation site sampling in 1992 and 1993 and Vital Signs sampling since 1990 were generally low. Exceptions include the boat ramp at Smith's Camp-On-The-Lake, where large populations of geese probably account for the high concentrations, and North Chickamauga Creek after rainfall.

11.2 Chickamauga Reservoir

Physical Description

Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is approximately 34,200 cfs which provides an average hydraulic retention of nine to ten days (Table 4.1).

The Hiwassee River, a major tributary to the Tennessee River, flows into the middle portion of Chickamauga Reservoir at about TRM 499. The flow from the entire Hiwassee River watershed contributes approximately 16.5 percent of the flow through Chickamauga Reservoir. About 10 percent of the 16.5 percent is from the Ocoee River and tributaries in the lower end of the Hiwassee watershed (i.e., downstream of Apalachia Dam).

Vital Signs monitoring activities were expanded in 1993 to include a site in the Hiwassee River embayment, which covers about 6500 acres. Given the relatively high flows in the Hiwassee River (about 5600 cfs annual average), there is substantial water exchange in this embayment, much greater than in any of the other three embayments monitored.

Ecological Health

The overall ecological health rating for Chickamauga Reservoir was good in 1993 (83 percent), the second-highest rating of all reservoirs. This is an improvement over the fair to good rating in 1992 (73 percent) and is more like the good rating in 1991 (90 percent). Unlike the other three reservoirs which had a major embayment monitored for the first time in 1993 (Kentucky, Pickwick, and Wheeler), results from the Hiwassee River embayment did not lower the overall rating of Chickamauga Reservoir. Of the five ecological health indicators, two were excellent (chlorophyll and DO) and three were good (sediment quality, benthos, and fish assemblage) at the Hiwassee embayment site. If results from the Hiwassee River embayment site were excluded from determining the overall score for Chickamauga Reservoir, the score would be changed slightly to 81 percent.

Several health indicators had higher ratings in 1993 than in 1992. In particular, the sediment quality rating improved from poor in 1992 to fair in 1993 at both the forebay and transition zone. The poor ratings at these two sites in 1992 resulted from elevated concentrations of copper and zinc and toxicity to test organisms. In 1993 copper and zinc (in addition to trace levels of chlordane) were again found at the forebay, but no toxicity was found, resulting in a fair rating. The fair rating at the transition zone in 1993 was caused by an indication of toxicity (some mortality of rotifers, although not significantly different from controls) and presence of chlordane in the sediment; copper and zinc were not elevated. Chlordane in sediments was detected for the first time in 1993. This is related to improved laboratory methods rather than a true environmental change. New equipment which allowed better extraction of organic contaminants from sediments was used on 1993 samples.

DO levels on Chickamauga Reservoir were not impacted as much by the hot, dry summer as on several other Tennessee River reservoirs in 1993. The DO ratings at the forebay and transition zone were good, but there were small areas during June and July with very low DO concentrations. These areas are thought to have been too short in duration and too small in area to have had a significant impact. DO at the inflow rated fair due to a relatively low concentration (3.7 mg/L) in one sample from the releases of Watts Bar Dam.

Improvements in ratings for both the benthos (poor in 1992 and fair in 1993) and fish assemblage (fair in 1992 and excellent in 1993) were noted at the inflow. About twice as many benthic macroinvertebrate taxa were found in 1993 as in 1992, indicating improved conditions. Most fish assemblage metrics were excellent; this was a distinct improvement over 1992 results. Aquatic macrophytes on Chickamauga Reservoir covered 1185 acres in 1993 compared to 387 acres in 1992 and 680 acres in 1991. Aquatic macrophytes peaked at about 7500 acres in 1988 and continuously declined until summer 1993.

Reservoir Use Suitability

There are no fish consumption advisories for Chickamauga Reservoir. Fillets from Chickamauga Reservoir catfish have been examined for several years as part of a variety of studies. Study results have indicated no consistent or reservoir-wide problems. Results from most of these studies have usually found higher concentrations of PCBs in catfish from the inflow area than from other sites in the reservoir. Channel catfish were collected for screening purposes in autumn 1992 from the inflow, transition zone, and forebay. Concentrations of all analytes from all locations were low, including PCBs.

No bacteriological studies were conducted at recreation sites on Chickamauga Reservoir in 1993. Bacteriological water quality met the Tennessee criterion for recreation at the ten sites tested in 1989 and 1990. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations during all years monitoring activities have occurred.

12.0 HIWASSEE RIVER WATERSHED

The headwaters of the Hiwassee River extend into the Blue Ridge Mountains in Tennessee, North Carolina, and Georgia. Streams in this watershed have naturally low concentrations of nutrients and dissolved minerals. These streams change from steep gradient, cold water trout streams in the mountains to lower gradient warm water streams in the valley.

The Hiwassee River Watershed has an area of 2700 square miles and an average annual discharge to the Tennessee River of 5640 cfs. The confluence of the Hiwassee River with the Tennessee River is in Chickamauga Reservoir at Tennessee River Mile 499.4. The lower portion of the Hiwassee River is impounded by backwater from Chickamauga Dam. The impounded portion of the Hiwassee River forms a large embayment (about 6500 surface acres) which extends over 20 miles up the Hiwassee River.

The largest tributary to the Hiwassee River is the Ocoee River, with a drainage area of about 640 square miles. Due to past copper mining and industrial activities in the Copperhill area, several streams and reservoirs in the Ocoee River basin have degraded water quality.

There are eight TVA reservoirs in the Hiwassee River watershed (Figure 12.1 and Table 2.1). Vital Signs monitoring activities are conducted on the five largest reservoirs: Hiwassee Reservoir (forebay, mid-reservoir, and inflow); Chatuge Reservoir (forebay sites on the Hiwassee River and Shooting Creek arms); Nottely Reservoir (forebay and mid-reservoir); Ocoee Reservoir No. 1 (forebay only); and Blue Ridge Reservoir (forebay only). Apalachia, Ocoee No. 2, and Ocoee No. 3 Reservoirs are not included in this monitoring because of their small size.

There is a stream monitoring site on the Hiwassee River at HiRM 36.9, about 2.5 miles upstream of the confluence of the Ocoee River. A new site will be added in 1994 on the Ocoee River at mile 2.5. Vital Signs monitoring also includes a site on the Hiwassee River embayment (at HiRM 10) of Chickamauga Reservoir. Results from that monitoring site are provided in Chapter 11.

Results from 1993 reservoir and stream Vital Signs and Use Suitability monitoring activities are provided in the following sections:

12.1 Hiwassee Reservoir

12.2 Chatuge Reservoir

12.3 Nottely Reservoir

12.4 Blue Ridge Reservoir

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

12.6 Hiwassee River Stream Monitoring Site

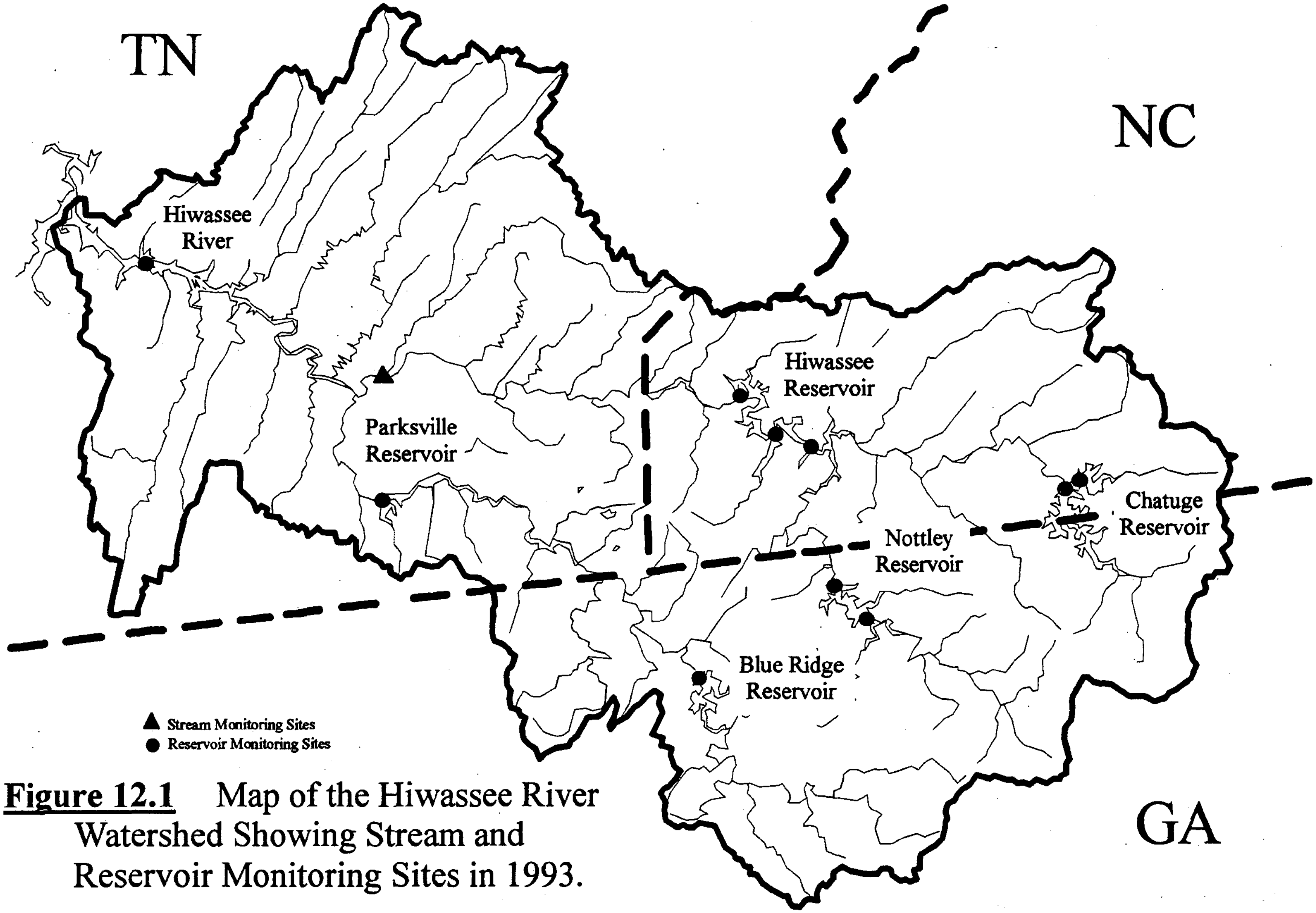


Figure 12.1 Map of the Hiwassee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

12.1 Hiwassee Reservoir

Physical Description

Hiwassee Reservoir, in the southwestern corner of North Carolina, is the second-largest of the five reservoirs in the Hiwassee River watershed included in the Vital Signs monitoring program. Hiwassee Reservoir is impounded by Hiwassee Dam at river mile 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet (with a maximum depth of about 255 feet at the dam). It has an average annual discharge of about 2020 cfs and average residence time of about 105 days. Hiwassee Reservoir has an average annual drawdown of 45 feet.

Ecological Health

Ecological health of Hiwassee Reservoir rated poor-fair (58 percent) in 1993; lower than in 1992 and 1991. The primary factor contributing to reduced ecological health rating was addition of sediment quality and benthic macroinvertebrates sampling in 1993. Both these indicators rated poor or very poor at both the forebay and mid-reservoir sites. There were no other poor ratings for any indicator, not even for DO, which was poor at the forebay in 1992. If scores for these two new indicators (sediment quality and benthos) were deleted from calculating the overall ecological health rating for Hiwassee Reservoir, the rating would change substantially to fair-good (72 percent), consistent with rating for previous years. Poor ratings for sediment quality were due to toxicity to test organisms and detectable concentrations of chlordane. Most benthos metrics were very poor and received the lowest score possible.

Like most deep, tributary storage reservoirs with long retention times, thermal stratification occurs during the summer in Hiwassee Reservoir. During periods of extended thermal stratification, low concentrations of dissolved oxygen develop near the bottom of the reservoir when oxygen is consumed by respiration and biochemical processes in the reservoir and in the sediment at a faster rate than it is replenished by photosynthesis and reaeration from the atmosphere. Although this low DO area develops in Hiwassee Reservoir, especially in the forebay, it is relatively small. Hence, DO rated fair at the forebay and good at the mid-reservoir site in 1993.

The upper Hiwassee River watershed is largely forested with few sources of waste to the river. Consequently, concentrations of nutrients are generally low and primary productivity in the Hiwassee watershed reservoirs is also generally low. This can be seen in the fair chlorophyll rating at the Hiwassee Reservoir forebay in 1993 caused by low chlorophyll concentrations. Chlorophyll concentrations were just high enough at the mid-reservoir site to rate in the good range. As is frequently the case in oligotrophic reservoirs, lower standing stocks of fish reflect the small food base. The fish assemblage rated fair at all locations.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at four boat ramps was sampled. Fecal coliform bacteria concentrations were very low at all four sites.

There are no fish consumption advisories on Hiwassee Reservoir. The most recent fish tissue information is for a channel catfish composite from the forebay collected in autumn 1991. No pesticide or PCB analytes were detected. With the exception of mercury, metal concentrations in fish tissue were low or at expected concentrations. The mercury concentration, however, was relatively high (0.69 $\mu g/g$) and so was further investigated in autumn 1993. Both channel catfish and largemouth bass composites were collected from the forebay and transition zone during autumn 1993. Results were not available at the time this report was prepared.

12.2 Chatuge Reservoir

Physical Description

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HiRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 459 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL), however, the annual drawdown averages only ten feet.

Only the forebay of Chatuge Reservoir was monitored prior to 1993. A new monitoring site was added in 1993 in the Shooting Creek arm to further evaluate this rather large part of the lake. Because of its physical features, the Shooting Creek site would be expected to be representative of forebay conditions.

Ecological Health

The ecological health of Chatuge Reservoir rated better in 1993 than in previous years of Vital Signs monitoring. Chatuge rated fair (67 percent) in 1993 compared to poor-fair in 1992 (56 percent) and 1991 (60 percent). One of the reasons for the higher rating in 1993 was improved scores for DO, which rated good at the forebay site on the Hiwassee River and fair at the forebay site on Shooting Creek. In 1992 DO rated poor at the forebay and a mid-reservoir site. Besides an actual slight improvement in DO conditions, the higher DO rating in 1993 was due to an improvement in the method for scoring for DO. Also, inclusion of scores for benthic macroinvertebrates, sampled for the first time in 1993 and rated good at both sample sites, helped to elevate the overall ecological health rating for Chatuge.

All other indicators (chlorophyll, sediment quality, and fish assemblage) rated fair at both sample sites. The fair ratings for chlorophyll were due to naturally low concentrations, indicative of the low availability of nutrients characteristic of the Hiwassee watershed. The fair ratings for sediment quality were due to toxicity to test organisms at the forebay site on the Hiwassee River and elevated concentrations of chromium, copper, and nickel at the Shooting Creek site.

Reservoir Use Suitability

There are no fish consumption advisories on Chatuge Reservoir. The most recent information available is from a channel catfish composite collected from the forebay in autumn 1991. None of the pesticide or PCB analytes were detected. Although several metals were detected, they occurred at low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at three swimming beaches, three boat ramps, and five locations in the middle of the channel were sampled. Fecal coliform bacteria concentrations were very low at all sites.

12.3 Nottely Reservoir

Physical Description

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 415 cfs which result in an average hydraulic retention time of about 206 days. The annual drawdown averages about 24 feet on Nottely Reservoir.

Ecological Health

The ecological health of Nottely Reservoir rated fair again in 1993 (64 percent), slightly higher than the fair rating in 1992 and 1991 (60 percent). The primary concern in Nottely Reservoir is low DO conditions near bottom as evidenced by very poor DO ratings at both the forebay and mid-reservoir locations in 1993. The only other poor rating for an indicator in 1993 was benthos at the forebay. Interestingly, the benthos rated good at the mid-reservoir despite the very poor DO conditions. Chlorophyll rated good at both sample sites in 1993 and sediment quality rated excellent at the mid-reservoir site. The fish assemblage rated fair at both sample sites in 1993.

Nottely Reservoir's ecological health may not be as good as these monitoring results suggest, however. For example, there was a fish kill near the dam in the fall of 1992 which was probably related to low dissolved oxygen. Also, the water in Nottely Reservoir is frequently turbid due to excessive erosion on the lands surrounding the reservoir. Of the five reservoirs in the Hiwassee watershed (Hiwassee, Chatuge, Nottely, Blue Ridge, and Ocoee No. 1), Nottely has had the lowest water clarity, highest chlorophyll concentrations, and highest phosphorus concentrations over the last three years.

Reservoir Use Suitability

No fish consumption advisories have been issued for Nottely Reservoir. The most recent fish tissue results are for a channel catfish composite collected from the forebay in autumn 1991. The only organic analyte detected was PCBs (at a concentration of 0.2 $\mu g/g$) just above the detection limit. A few metals were detected but only mercury (0.47 $\mu g/g$) was sufficiently high to be of interest. Similar concentrations have been found, although not consistently, in previous screening studies on reservoirs in the Hiwassee basin. Both channel catfish and largemouth bass composites were collected from the forebay in autumn 1993 and analyzed for mercury to further examine this situation. Results were not available at the time this report was prepared.

No information was collected for bacteriological contamination at recreation areas on Nottely Reservoir in 1993. However, the recreation area at Poteet Creek was sampled in 1990 for fecal coliform bacteria and found to fully support water contact recreation.

12.4 Blue Ridge Reservoir

Physical Description

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with a average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. The annual drawdown of Blue Ridge Reservoir averages 36 feet.

Ecological Health

The ecological health of Blue Ridge Reservoir was good in 1993 (72 percent), similar to that found in 1992 and 1991. Blue Ridge is an oligotrophic reservoir as evidenced by very low summer chlorophyll concentrations at the forebay, rated fair in 1993. The excellent rating for DO was in part related to the low primary productivity because a low oxygen demand would be required to decompose relatively few dead algal cells. The benthic macroinvertebrate community, sampled for the first time in 1993, rated excellent at the forebay. The fish assemblage rated poor due to low abundance and diversity, as might be expected in an oligotrophic reservoir. Compared to the other reservoirs in the Hiwassee watershed, Blue Ridge has had the highest water clarity and lowest nitrogen concentrations over the three years of Vital Signs monitoring.

Reservoir Use Suitability

There are no fish consumption advisories on Blue Ridge Reservoir. The most recent fish tissue information from Blue Ridge Reservoir is from a channel catfish composite from the forebay collected in autumn 1991. Most pesticide and PCB analytes were not detected; those that were, occurred in low concentrations. Likewise, all metal analytes were either not detected or were found in low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at one swimming beach was sampled. Fecal coliform bacteria concentrations were very low.

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

Physical Description

Ocoee No. 1 Reservoir, also known as Parksville Reservoir, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has a surface area of about 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin, and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet and is about 115 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), its annual drawdown averages about seven feet.

Ecological Health

The ecological health of Ocoee No. 1 Reservoir rated poor in 1993 (52 percent), with little change from the previous years of Vital Signs monitoring activities. Four indicators rated poor--chlorophyll, sediment quality, benthic macroinvertebrates, and the fish assemblage. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. Sediment quality, sampled for the first time in 1993, reflected these historic problems with very high concentrations of copper, lead, and zinc. Also, PCBs were detected in forebay sediments in 1993.

In spite of the apparent availability of nutrients, algal productivity was low. High DO concentrations (rated excellent in 1993) existed in Parksville Reservoir throughout the year. High DO concentrations were present even in the hypolimnion at the forebay. As expected under such conditions, the fish assemblage rated poor in 1993, comparable to previous years.

Reservoir Use Suitability

There are no fish consumption advisories in effect for Parksville Reservoir. However, screening studies over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish; the average of ten fish was 1.5 μg/g at the forebay and 1.0 μg/g at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish; averages at the two sites were 0.6 and 0.7 μg/g, respectively. Bluegill sunfish and rainbow trout composites from these areas had low PCB concentrations (≤0.3 μg/g). The state of Tennessee had taken no action on these results at the time this report was prepared.

No bacteriological studies were conducted in 1993. In 1991, the swimming area at Mac Point was surveyed. Fecal coliform bacteria concentrations were low.

12.6 Hiwassee River Stream Monitoring Site

Physical Description

The headwaters of the Hiwassee River are in the Chattahoochee, Nantahala, and Cherokee Forests of the Blue Ridge physiographic province. It emerges from the mountains to flow through the Valley and Ridge province to join the Tennessee River as an embayment of Chickamauga Reservoir.

The TVA monitoring station is located at the Patty Bridge near Benton, Tennessee. The watershed area above the sampling site is 1300 square miles or 48 percent of the Hiwassee River basin. Principal tributaries in the Hiwassee watershed include the Valley River (117 square miles), Nottely River (287 square miles), Conasauga Creek (103 square miles), Toccoa-Ocoee River (639 square miles), Chestuee Creek (132 square miles), and Oostanaula Creek (69 square miles). Oostanaula Creek, Chestuee Creek, and the Ocoee River are located below this station.

Igneous and metamorphic rocks underlie much of the basin yielding water that is very soft and low in dissolved minerals. The major urban areas of the Hiwassee River basin include Athens, Etowah, and Cleveland, Tennessee, in the lower basin. The smaller urban communities of the mountains include Andrews and Murphy in North Carolina, Blue Ridge and McCaysville in Georgia, and Copperhill in Tennessee. Runoff from land denuded by historical mining and ore processing near Copperhill affects water quality in the Ocoee River and its three reservoirs downstream to the confluence with the Hiwassee River.

Ecological Health

The ecological health of the stream monitoring site on the Hiwassee River was good in 1993, as in 1992. All ecological health indicators (nutrients, sediment quality, benthos, and fish community) rated either good or fair.

Use Suitability

No fecal coliform samples were collected in 1993. In 1989, the canoe sites, Shallow Ford Bridge on Toccoa River upstream of Blue Ridge Reservoir, and at Mission Dam on the Hiwassee River between Chatuge and Hiwassee Reservoirs were sampled. In 1991, the two access locations on the Ocoee River upstream of Parksville Reservoir, and the three access sites on Hiwassee River upstream of Chickamauga Reservoir were sampled. Bacteriological water quality at each of the sites met the appropriate state's criterion for recreation.

All metal and organic analytes in fish tissue samples were either not detected or found in low concentrations.

13.0 WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

This watershed area is relatively small (1370 square miles) and includes three reservoirs: Fort Loudoun and Watts Bar Reservoirs on the Tennessee River and Melton Hill Reservoir on the Clinch River. All three are run-of-the-river reservoirs with relatively short retention times and annual pool drawdowns of only a few feet. The inflow of Fort Loudoun Reservoir is actually the origin of the Tennessee River. The Holston and French Broad Rivers merge at that point to form the Tennessee River. The Little Tennessee River, another major tributary to the Tennessee River, enters Fort Loudoun Reservoir near the forebay. Watts Bar Reservoir is immediately downstream of Fort Loudoun. The Clinch River, another major tributary, merges with the Tennessee River upstream of the transition zone on Watts Bar Reservoir. Melton Hill Dam bounds the upper end of Watts Bar Reservoir on the Clinch River and Fort Loudoun Reservoir bounds it on the Tennessee River.

Like the other watershed areas formed around one or more of the reservoirs on the mainstream of the Tennessee River, very little of the water leaving this watershed area originates from within. The average annual discharge through Watts Bar Reservoir is about 27,000 cfs. Of this, about 25 percent (6800 cfs) enters from the French Broad River, 16 percent (4500 cfs) from the Holston River, 21 percent (5700 cfs) from the Little Tennessee River, and 15 percent (4200 cfs) from the Melton Hill Dam on the Clinch River. Another five percent (1400 cfs) is contributed by the Emory River, a tributary to the Clinch River near the confluence with the Tennessee River. The remaining 18 percent (4800 cfs) originates from streams which drain directly to one of these reservoirs.

Vital Signs monitoring activities are conducted at the forebays, transition zones, and inflows of all three of these reservoirs. Watt Bar Reservoir has two inflow sites, one near Fort Loudoun Dam and one near Melton Hill Dam. There is one stream monitoring site on the Emory River at Emory River Mile 18.3 (Figure 13.1).

Results for 1993 monitoring activities are provided in the following sections:

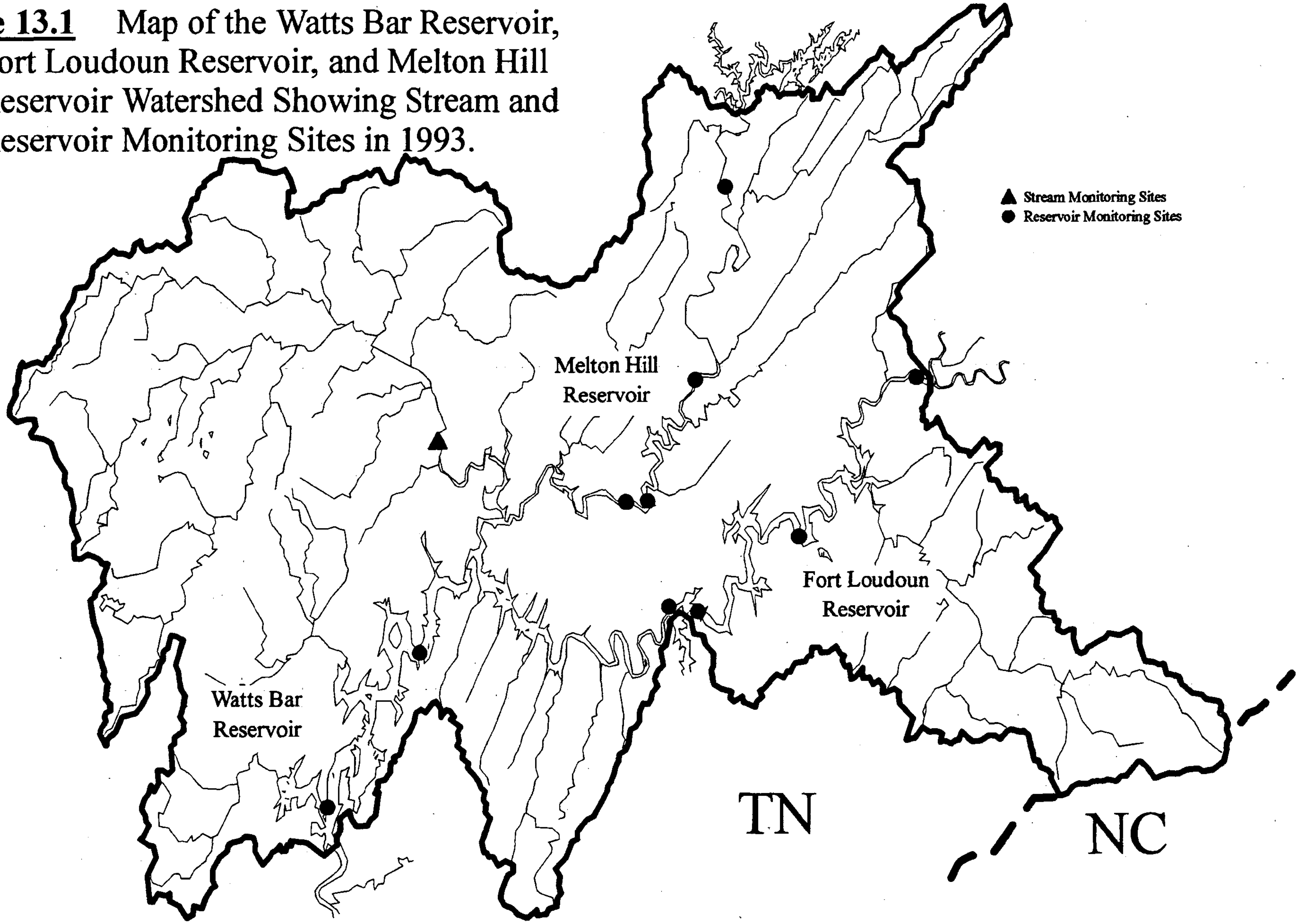
13.1 Watts Bar Reservoir

13.2 Fort Loudoun Reservoir

13.3 Melton Hill Reservoir

13.4 Emory River Stream Monitoring Site

Figure 13.1 Map of the Watts Bar Reservoir, Fort Loudoun Reservoir, and Melton Hill Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



13.1 Watts Bar Reservoir

Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are: Watts Bar Dam located at Tennessee River Mile (TRM) 529.9, Fort Loudoun Dam located at TRM 602.3, and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,000 cfs, providing an average hydraulic retention time of about 19 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone sampling location in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the Tennessee River and Clinch River inflows. Water entering Watts Bar from Melton Hill Reservoir is quite cool due to the hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

The Emory River is a major tributary to the Clinch River arm of Watts Bar Reservoir and supplies about 5 percent of the average annual flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow, and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

Ecological Health

The ecological health of Watts Bar Reservoir was fair in 1993 (68 percent), similar to 1992 (71 percent) and 1991 (69 percent). Chlorophyll rated good at both the forebay and transition zone locations. Sediment quality testing at the forebay found low survival of test organisms and high concentrations of ammonia, leading to a poor rating. A fair to good rating for sediments at the transition zone was due to traces of chlordane; no other chemical analyte was problematic and no toxicity was found. Because of the release of water with low DOs from Fort Loudoun Dam, DO concentrations were less than 5 mg/L (minimum 3.9 mg/L) in the Tennessee River inflow to Watts Bar Reservoir. Benthic macroinvertebrates rated poor in 1993 at this site (as in both 1992 and 1991), possibly related to the low DO concentrations. The fish assemblage was also poor at this inflow site in 1993. The inflow site on the Clinch River, downstream of Melton Hill Dam, had good DOs, but the benthos were poor and fish assemblage fair. Compared to 1992, this was a slight decrease for the benthos, but was similar to the previous results. All aquatic health indicators were good or excellent at the transition zone, generally similar to 1992 observations.

Aquatic plants have declined from about 700 acres in the late 1980s to about ten acres in 1993.

Reservoir Use Suitability

Fourteen swimming areas were tested for fecal coliform concentrations in 1993. Two other swimming sites were tested in 1990. Bacteriological water quality was within criteria at 14 sites. The other two sites met criteria if rainfall samples are excluded. Fecal coliform concentrations at Watts Bar swimming beaches are generally higher than at other Tennessee River Reservoirs. Monthly fecal coliform bacteria samples have been collected at the Vital Signs locations since 1990. All samples collected from April through September have been very low.

As a result of PCB contamination, the Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of several fish species from Watts Bar Reservoir. In the Tennessee River portion a "do not consume" advisory exists for catfish, striped bass, and striped bass/white bass hybrids. A precautionary advisory (children and pregnant or lactating women do not eat fish; all others limit fish consumption to 1.2 pounds per month) is in effect for largemouth bass, white bass, sauger, carp and smallmouth buffalo. In the Clinch River arm striped bass should not be eaten, and a precautionary advisory is in effect for catfish and sauger.

Also, TDEC has issued a "do not consume" advisory for fish taken from the east fork of Poplar Creek due to mercury, metals, and organic chemical contamination.

13.2 Fort Loudoun Reservoir

Physical Description

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 18,400 cfs which provides an average hydraulic retention time of about ten days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments, each having long retention times. Both of these deep storage impoundments become strongly stratified during summer months resulting in the release of cool, low DO, hypolimnetic water during operation of the hydroelectric units. Some warming and reaeration of the water occurs downstream from Cherokee and Douglas Dams, but both temperature and DO levels are sometimes low when the water reaches Fort Loudoun Reservoir.

Fort Loudoun Reservoir also receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. (Since Tellico Dam has no outlet, under most normal conditions, water flows into Fort Loudoun Reservoir from Tellico Reservoir.) Water from Tellico Reservoir (Little Tennessee River) is often cooler and higher in DO, and has a much lower conductivity than water in Fort Loudoun Reservoir (Tennessee River). In 1992, the forebay sampling location on Fort Loudoun Reservoir (originally located at TRM 603.2) was moved upstream to TRM 605.5. This resulted in a better assessment of the water quality conditions of the Tennessee River in the forebay portion of Fort Loudoun Reservoir by minimizing the effects of the Little Tennessee River and Tellico Reservoir on the data gathered in the forebay of Fort Loudoun Reservoir.

Although Fort Loudoun Reservoir is a mainstream reservoir, its complex set of hydrologic conditions (cool water inflows from the Holston, French Broad, and Little Tennessee Rivers) often causes it to exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than in other mainstream reservoirs.

Ecological Health

Vital Signs monitoring information showed the ecological health of Fort Loudoun Reservoir was between fair and poor in 1993 (58 percent), basically similar to 1992 (53 percent) and 1991 (60 percent). The only ecological health indicator which rated good or excellent on Fort Loudoun was DO at the forebay and transitions zone (no data were available from the inflow). Such good ratings for DO were surprising based on observations of lower DOs in 1993 in other mainstream reservoirs and historical concerns about DO in Fort Loudoun Reservoir.

Several indicators rated poor or very poor. Sediment quality at the forebay rated poor due to high zinc concentrations, presence of chlordane, and toxicity to Ceriodaphnia. Transition zone sediments rated fair with similar conditions as the forebay, but no toxicity to test organisms was found. These findings are consistent with results found in previous years. The fish assemblage rated poor at all three sample sites (forebay, transition zone, and inflow) mostly due to low species richness and low capture rate of individuals (similar to previous years). Benthic macroinvertebrates rated very poor at the inflow site due to low species richness and abundance (comparable to previous years). Benthos rated fair at the forebay and transition zone. Similar results had been found at the transition zone in previous years, but benthic invertebrates at the forebay improved in several metrics, especially species richness and reduced dominance by tolerant organisms.

Aquatic macrophytes only covered 25 acres on Fort Loudoun Reservoir in 1993. Coverage over the past decade has ranged 25 to 140 acres.

Reservoir Use Suitability

TDEC has issued advisories on consumption of two fish species from Fort Loudoun Reservoir. Tennessee advises people not to eat catfish taken from Fort Loudoun Reservoir because of high levels of PCBs. Also, largemouth bass should not be eaten if they weigh over two pounds or are caught in the Little River embayment due to PCB contamination.

Fort Loudoun Reservoir has had a PCB problem for more than 20 years. Initially, TVA and state agencies examined a variety of species from throughout the reservoir to document the geographical and species variation. The study now continues as a trend study in which there is an annual collection of catfish from one location. PCB concentrations in catfish have varied over the years with no distinct trend.

Fecal coliform concentrations at one boat ramp tested in 1993 were within criteria for recreation. In 1989, 1990, and 1992, fecal coliform samples were collected at a total of three swimming beaches and 16 other sites. Bacteria concentrations were low at the swimming beaches and other sites in the downstream portion of the reservoir. Concentrations in the upstream portion of the reservoir, especially near downtown Knoxville, were much higher, with four sites exceeding Tennessee criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1990 have been very low except for the April 1993 samples.

13.3 Melton Hill Reservoir

Physical Description

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream from Melton Hill Dam about 44 miles. Melton Hill Reservoir has about 170 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is about 4900 cfs resulting in an average retention time of approximately 12 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant factor influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and mid-reservoir areas, is the cold water entering from Norris Dam discharges. During summer, water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a re-regulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

Ecological Health

The ecological health of Melton Hill Reservoir was in the upper end of the fair range in 1993 (68 percent, similar to 1992 and 1991). Chlorophyll and DO were excellent at both the forebay and the transition zone. However, a poor fish assemblage was found at forebay and inflow, generally similar to previous years. Primary problems in the fish assemblage were low species richness and abundance in electrofishing samples. Cool water flowing in from the bottom layer of Norris Lake causes problems for fish in Melton Hill, especially in the middle and upper sections. The water is too cold to support fish that like warm water, but too warm to support fish that thrive in cold water. The benthic macroinvertebrate community rated poor at the forebay and very poor at the transition zone and inflow, generally similar to previous years. Components of the benthos resulting in poor metrics were absence of long-lived and intolerant species and dominance by tolerant species.

Aquatic macrophyte coverage on Melton Hill Lake in 1993 was about 240 acres. During the past decade, coverage has ranged from about 100 to 250 acres.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1989, samples were collected at four boat ramps during a period of high rainfall, and fecal coliform concentrations were high. In 1990, two swimming beaches and six other sites were tested during a more normal rainfall period. Concentrations were lower and within recreation criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have generally been low.

TDEC has advised the public to avoid consumption of catfish from Melton Hill Reservoir because of PCB contamination. Samples are collected annually from the transition zone and near the inflow by TVA and from the forebay by the Oak Ridge National Laboratory as part of ongoing, cooperative studies. PCB concentrations in catfish collected in autumn 1992 generally fell within the range found in previous years.

13.4 Emory River Stream Monitoring Site

Physical Description

The majority of the Emory River drainage area lies in the Cumberland Plateau and flows through the Tennessee counties of Cumberland, Morgan, and Roane. The Emory River leaves the plateau and cuts more than 600 feet down the eastern escarpment to join the Clinch River in the Valley and Ridge physiographic province as a major embayment to Watts Bar Reservoir.

The TVA monitoring station is located at the USGS stream gage at Oakdale. The Emory River drainage above Oakdale is 764 square miles or 88 percent of the entire Emory River basin. The principal tributary to the Emory is the Obed River (520 square miles). The principal tributaries to the Obed are Clear Creek (173 square miles) and Daddy's Creek (175 square miles).

Sandstone, shale, and conglomerates underlie most of the Emory River basin. Most of the basin is forested. About one-fourth of the basin lies within the Catoosa Wildlife Management Area, while about 5 percent is used for agriculture and 1 percent is used for surface coal mining. The only urban area above Oakdale is Crossville, Tennessee, near the headwaters of the Obed River.

Ecological Health

The overall ecological health of the Emory River at the stream monitoring site was good in 1993. This is an improvement over 1992 when fair conditions were found. The primary problem found in 1992 was poor sediment quality, evidenced by poor survival of test organisms. This was not the case for 1993 as no sediment toxicity was found.

Use Suitability

There were no bacteriological studies conducted on the Emory River in 1993.

A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Only PCBs in channel catfish were high enough to be of interest. The concentration was near that used to indicate need of more intensive investigation. Samples collected in summer 1993 should help evaluation of this situation.

14.0 CLINCH RIVER AND POWELL RIVER WATERSHED

This long, narrow watershed lies in southwest Virginia and northeast Tennessee. Streams in the watershed have high concentrations of dissolved minerals and generally low concentrations of nutrients.

For management purposes, an artificial ending point of the watershed has been established at Norris Dam, which is near Clinch River mile 80. The remainder of the Clinch River is associated with the Watts Bar, Fort Loudoun, and Melton Hill Reservoir Watershed area. As defined, this watershed drains an area of 2912 square miles and has an average annual discharge of about 4200 cfs. The Clinch and Powell Rivers contribute about 80 percent of this flow.

Norris Reservoir is the only major reservoir in the watershed; essentially all streams upstream from Norris are free flowing. There are three Vital Signs monitoring sites in Norris Reservoir (forebay and mid-reservoir sites on the Clinch and Powell arms) and two stream sites, one each on the Clinch and Powell Rivers (Figure 14.1). Results from 1993 monitoring activities are in Section 14.1 for Norris Reservoir, Section 14.2 for the Clinch River stream monitoring site, and Section 14.3 for the Powell River stream monitoring site.

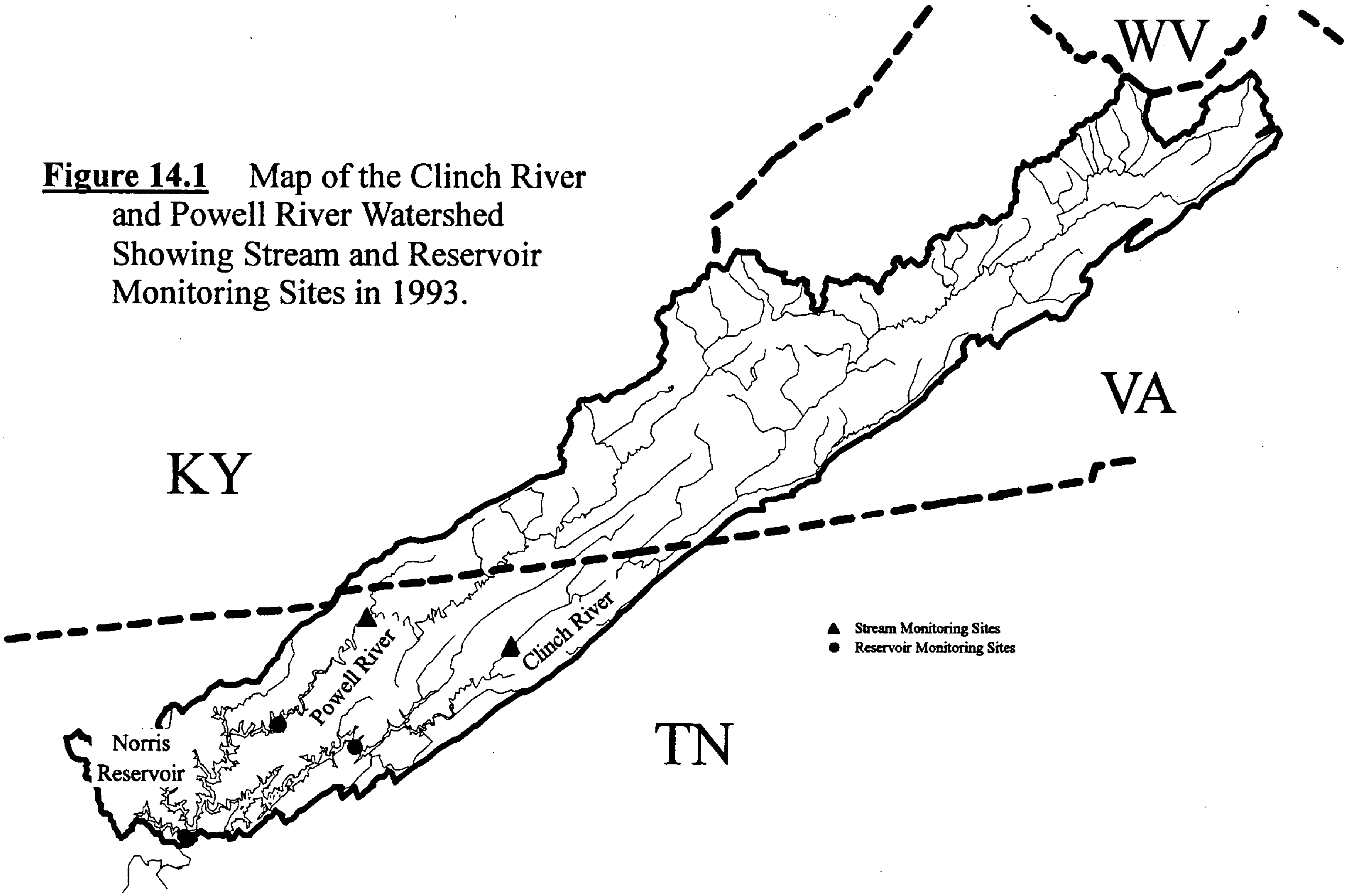


Figure 14.1 Map of the Clinch River and Powell River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

14.1 Norris Reservoir

Physical Description

Norris Reservoir is formed by Norris Dam at Clinch River mile (CRM) 79.8. It is a large, dendritic, tributary storage impoundment of the Clinch and Powell Rivers which flow together about nine miles upstream of the dam. Norris is one of the deeper TVA tributary reservoirs, with depths over 200 feet. Annual drawdown averages about 32 feet. At full pool, the surface area of the reservoir is 34,200 acres, the shoreline is about 800 miles in length, and water is impounded 73 miles upstream on the Clinch River and 53 miles upstream on the Powell River. Norris Reservoir has a long average retention time (about 245 days) and an average annual discharge of approximately 4200 cfs. Due to the great depth and long retention time of Norris Reservoir, significant vertical stratification is expected. Additional information about the physical and hydrologic characteristics of Norris Reservoir are given in Table 4.1.

Because of the confluence of the Clinch and Powell Rivers relatively close to the dam, three reservoir sampling locations were established: one forebay site; and two mid-reservoir sites--one on the Clinch River and one on the Powell River.

Ecological Health

Norris is an oligotrophic reservoir with very clear water. There is little algal primary production because of phosphorus limitations. The ecological health of Norris Reservoir in 1993 was fair (67 percent), with conditions about the same as in 1992 and 1991 (60-67 percent). Dissolved oxygen concentrations in the deeper portions of Norris Reservoir, particularly at the mid-reservoir locations on the Clinch and Powell Rivers, have historically been low. This condition, although undesirable, is often observed in deep, thermally stratified tributary reservoirs with long retention times.

As expected, 1993 DO concentrations rated very poor at both mid-reservoir sites. The rating for DO at the forebay was poor in 1993 compared to fair in 1992. The 1992 results had indicated a slight improvement over 1991 conditions.

As in the past, low nutrient concentrations in the forebay resulted in low algal levels and a fair rating for chlorophyll in 1993. The effects of low primary productivity usually manifests itself throughout the food chain and results in a low overall abundance of fish. The fish assemblage rated fair at the forebay in 1993, primarily due to low abundance and low species richness. At both mid-reservoir sites, both chlorophyll and fish assemblages rated good. The benthic macroinvertebrate community rated fair at the forebay and mid-reservoir site on the Clinch arm of Norris Reservoir and good at the mid-reservoir site on the Powell arm. Given the low DO concentrations near the bottom, fair to good ratings for benthic macroinvertebrates are better than would be expected. This suggests that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possible explanation is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors contributed to the observed ratings.

Reservoir Use Suitability

There are no fish consumption advisories on Norris Reservoir. Channel catfish were collected for screening purposes in autumn 1992. All analytes were low or not detected except PCBs. The highest PCB concentration was 0.9 $\mu g/g$. Concentrations this high had not been found before. Areas were resampled in autumn 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform bacteria samples were collected at five sites in 1993. Concentrations were very low at all five sites. In 1991, ten sites were sampled. Fecal coliform concentrations were generally higher in 1991 than in 1993, possibly due to higher rainfall in 1991. However, in 1991 all sites met the geometric mean bacteriological water quality criterion for recreation. In 1991 three sites exceeded one of EPA's recommended guidelines; more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. Fecal coliform sampling at the Vital Signs locations was discontinued in 1993. Fecal coliform concentrations at the three Vital Signs stations sampled from 1990 to 1991 were very low.

14.2 Clinch River Stream Monitoring Site

Physical Description

The TVA stream monitoring station is located at the USGS stream gage near Tazewell, Tennessee, just upstream of the impounded water of Norris Reservoir, at CRM 159.8. The Clinch River basin above the monitoring site is 1474 square miles or 33 percent of the total Clinch River basin. Three-quarters of the monitored area lies within Virginia. Principal tributaries in the monitored area are the North Fork Clinch River (87 square miles), Guest River (102 square miles), Little River (126 square miles), Copper Creek (133 square miles), and Big Cedar Creek (86 square miles).

The headwaters of the upper Clinch River drain the eastern escarpment of the Cumberland Plateau (including portions of the Jefferson National Forest), then flow southwest through the Valley and Ridge physiographic province in a valley parallel to and southeast of the Powell River. Land use in the basin is 70 percent forestry and 30 percent agriculture. Coal mining occurs in some areas.

Ecological Health

The overall ecological health of the Clinch River at this site was good as in 1992. Conditions for fish and bottom-dwelling animals remained good in 1993. Sediment quality showed an improvement over 1992, with the rating changing from fair to good.

Use Suitability

Concentrations of fecal coliform bacteria were very low in 1993 at the weir and canoe launch site in the Clinch River downstream of Norris Dam. Concentrations were higher in 1991 when the canoe launch site had been tested.

All analytes in fish tissue samples collected during summer 1992 were either not detected or found in low concentrations.

14.3 Powell River Stream Monitoring Site

Physical Description

The Powell River joins the Clinch River 10 miles upstream from Norris Dam and forms a major embayment to Norris Reservoir. Most of the Powell River headwaters and tributary streams drain portions of the eastern border of the Cumberland Plateau, but the main river is predominantly in the Valley and Ridge physiographic province. The river flows for more than 195 miles through southwestern Virginia and northeastern Tennessee. The total drainage of the Powell River basin is 938 square miles.

The TVA monitoring station is located near Arthur, Tennessee. Above this location the area of the basin is 685 square miles or 73 percent of the entire Powell River watershed. Principal tributaries above Arthur include Indian Creek (66 square miles) and the North Fork Powell River (90 square miles).

Land use in the basin is 75 percent forest, 20 percent agriculture, and almost 5 percent surface mining, primarily in the upper reaches in southwestern Virginia. Only small urban areas are located in the Powell River watershed.

Ecological Health

Conditions for fish and bottom-dwelling animals improved to good in 1993. The change from a fair to a good classification was a result of greater numbers and higher quality bottom-dwelling organisms present. The Powell River watershed is heavily mined for coal and has a history of illegal discharges of blackwater into the river from coal washing facilities.

Use Suitability

There were no bacteriological studies conducted on the Powell River in 1993.

All analytes in fish tissue samples collected in summer 1993 wre either nondetectable or found low concentrations.

15.0 LITTLE TENNESSEE RIVER WATERSHED

The Little Tennessee River Watershed encompasses 2672 square miles, mostly in Tennessee and North Carolina with a small area in Georgia. Much of the watershed is forested, with the headwaters in the Blue Ridge Mountains. The basin is underlain mostly by crystalline and metasedimentary rocks of the Blue Ridge province. This watershed is home to a large variety of federally listed threatened and endangered species.

Most of the streams in the watershed are steep gradient and generally have low concentrations of both dissolved minerals and nutrients. The two largest tributaries to the Little Tennessee River are the Tuckasegee River which merges with the Little Tennessee in Fontana Reservoir and the Tellico River which merges with the Little Tennessee in Tellico Reservoir.

There are several reservoirs in the watershed but only Fontana Reservoir in the mountainous area and Tellico Reservoir at the lower end of the watershed are monitored (Figure 15.1). TVA does not monitor the other reservoirs either because of their small size or because they are owned by the Aluminum Company of America (ALCOA).

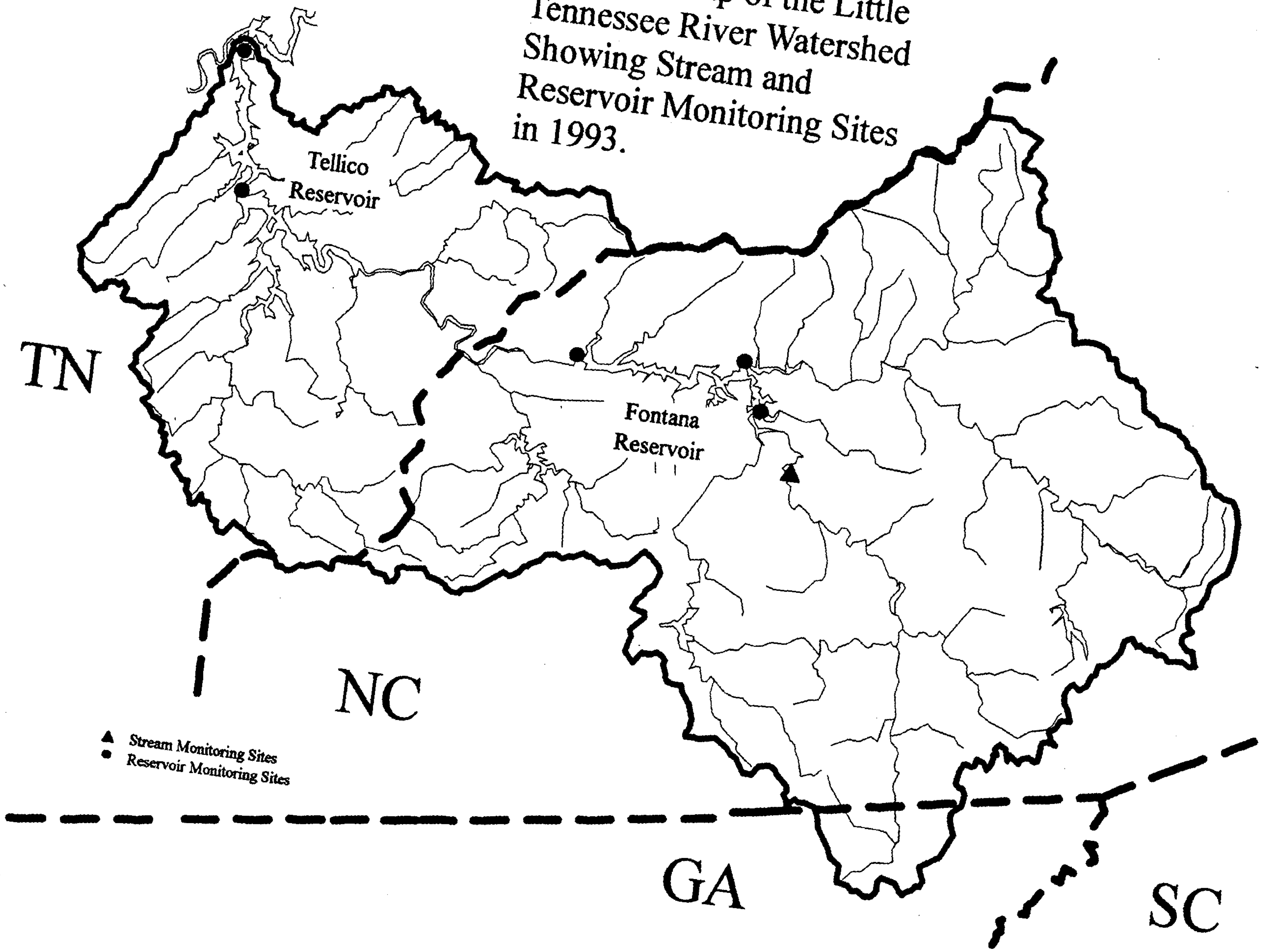
Two sites are monitored on Tellico Reservoir (the forebay and transition zone) and three sites on Fontana Reservoir (the forebay and mid-reservoir sites on the Little Tennessee River and Tuckasegee River). There is one stream monitoring site in the watershed, on the Little Tennessee River upstream of Fontana Reservoir. Another stream monitoring site (on the Tuckasegee River) is being added in 1994. Results of 1993 monitoring activities are provided in the following sections:

15.1 Tellico Reservoir

15.2 Fontana Reservoir

15.3 Little Tennessee River Stream Monitoring Site

Figure 15.1 Map of the Little Tennessee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



15.1 Tellico Reservoir

Physical Description

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It is the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of about 16,000 acres at full pool. The average estimated flow through Tellico Reservoir is approximately 5700 cfs which provides an average retention time of about 37 days. Very little of this water is discharged through Tellico Dam. Rather, it is diverted through a navigation canal to Fort Loudoun Reservoir near the dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably as discussed in Section 13.2, Fort Loudoun Reservoir. The hydrodynamics and exchange of water via the inter-connecting canal significantly affect water quality within Tellico Reservoir (and Fort Loudoun Reservoir). The canal is only 20-25 feet deep, but the depth of Tellico Reservoir at the forebay is about 80 feet. Thus, water at strata below about 25 feet is essentially trapped and becomes anoxic during much of the summer in the forebay of Tellico Reservoir.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico Rivers. The transition zone site selected for sample collection in 1990, 1991, and 1992 was in the Little Tennessee River, just upstream of the confluence with the Tellico River at Little Tennessee River Mile (LTRM) 21.0. Water conditions at that site are largely controlled by discharges from Chilhowee Dam at LTRM 33.6. This water is cold, nutrient poor, and has a low mineral content, conditions that are not conducive to establishing a diverse, abundant aquatic community. In 1993, the transition zone sampling location in Tellico Reservoir was moved six miles downstream to LTRM 15.0, just below the confluence of the Tellico River--a site more characteristic of lacustrine rather than riverine conditions.

Ecological Health

Tellico Reservoir received a better ecological health rating in 1993 than in previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993, whereas it had preciously been rated poor every year. Other than that change, all indicators at the forebay rated the same in 1993 as in previous years--poor sediment quality and benthic macroinvertebrate community, good chlorophyll, and fair fish assemblage.

Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site. The other three rated poor--sediment quality (presence of chlordane and significant toxicity), benthos (mostly due to absence of long-lived and sensitive organisms), and fish assemblage (few fish collected in gill netting efforts, which affected several metrics).

The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than previous scores.

Most of the 246 acres of aquatic macrophytes on Tellico Lake in 1993 were in the Tellico River arm of the reservoir.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1992, fecal coliform samples were collected at four swimming beaches and five other sites on the reservoir. Bacteria concentrations were low. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have been very low.

The state has advised that catfish from Tellico Reservoir should not be eaten because of PCB contamination. Fish were collected in autumn 1992 for tissue analysis. Channel catfish were collected as part of a continuing effort to examine the trend in PCB concentrations. Results indicate the PCB problem continued to exist with no downward trend.

15.2 Fontana Reservoir

Physical Description

Fontana Reservoir is located in the Blue Ridge Mountains of western North Carolina. Fontana is the deepest reservoir in the TVA system. At full pool it has a maximum depth of 460 feet, a length of 29 miles, a shoreline of 248 miles, and a surface area of 10,640 acres. Fontana Reservoir has a relatively large drawdown, which averages about 64 feet annually. Every fifth year Fontana is drawn even deeper to allow sluice gate access for maintenance.

Fontana Dam is located at Little Tennessee River Mile 61.0. Average annual discharge is 3840 cfs which provides an average hydraulic retention time in the reservoir of 186 days.

Water in Fontana Reservoir is quite clear due to limited photosynthetic activity and a mostly forested watershed. Water entering the reservoir is low in nutrients and dissolved minerals.

Ecological Health

Fontana Reservoir rated fair in 1993 (64 percent), the first year of Vital Signs monitoring. Fontana is an oligotrophic reservoir with very low chlorophyll concentrations resulting in fair ratings at all three sites. Further evidence of the low primary productivity is the clear, blue water (indicating low abundance of algae and lack of green phytoplankton pigments). Secchi depths averaged almost 6 meters in the forebay of Fontana in 1993. The fish assemblage also rated fair at all locations, probably related to the low primary productivity. Ratings for DO varied from excellent at the mid-reservoir site on the Little Tennessee River to poor at the mid-reservoir site on the Tuckasegee River, with a fair rating at the forebay. Sediment quality also varied greatly among the three locations--poor at the forebay, good at the mid-reservoir site on the Tuckasegee arm, and excellent on the Little Tennessee arm. Rating for the benthic macroinvertebrate community also varied greatly from very poor at the forebay to fair at the Little Tennessee River mid-reservoir site. The benthos rating at the forebay was not included in determining the overall ecological health score because part of the transect sampled was in the drawdown zone.

Reservoir Use Suitability

Channel catfish were collected in autumn 1992 from the forebay and mid-reservoir site on the Little Tennessee River. Analysis of composited fillets from each area found most analytes were not detected or had low concentrations. The exceptions to this were mercury at both locations (maximum of 0.53 $\mu g/g$) and PCBs at the forebay (1.1 $\mu g/g$). Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

There were no bacteriological studies conducted on Fontana Reservoir in 1993.

15.3 Little Tennessee River Stream Monitoring Site

Physical Description

The Little Tennessee River drains 2727 square miles and flows more than 140 miles through the Blue Ridge physiographic province of western North Carolina and the Valley and Ridge province of East Tennessee. It joins the Tennessee River near Lenoir City, Tennessee.

The TVA monitoring station is located near Needmore, North Carolina. The drainage area upstream from the monitoring site is 440 square miles or 16 percent of the entire Little Tennessee River basin. Principal tributaries to the Little Tennessee River include Abrams Creek (88 square miles), Cheoah River (215 square miles), Nantahala River (175 square miles), Cullasaja River (93 square miles), and the Tuckasegee-Oconaluftee River (734 square miles). The Cullasaja River is the only major tributary within the monitored area. The basin has been extensively developed with TVA reservoirs (Tellico and Fontana) and private power dams (Chilhowee, Calderwood, Cheoah, Santeetlah, Nantahala, Franklin, and Thorpe).

Igneous and metamorphic rock underlies all of the basin. Much of the basin is located within the federally managed lands of the Great Smoky Mountains National Park and Cherokee and Nantahala National Forests. Franklin, Sylva, Bryson City, and Robbinsville, North Carolina, are the primary urban areas in the basin.

Ecological Health

The stream monitoring site on the Little Tennessee River (at LTRM 94.5) had a very good ecological health rating in 1993 (as in 1992). All indicators (nutrients, sediment quality, benthos, and fish) were rated good.

Use Suitability

No bacteriological studies have been conducted in the streams of this watershed under this monitoring program.

All analytes in fish tissue samples collected during summer 1993 were either below detection limits or found in low concentrations.

16.0 FRENCH BROAD RIVER WATERSHED

The French Broad River watershed is one of the largest (5124 square miles) watersheds in the Tennessee Valley. About half the watershed is in Tennessee and half is in North Carolina. The French Broad River and its two large tributaries (Nolichucky and Pigeon Rivers) originate in the Blue Ridge Mountains. All three of these rivers merge at the upper end of Douglas Reservoir, the only sizable reservoir in the watershed. The water in the French Broad River is moderately hard and relatively high in nutrients.

There are three reservoir Vital Signs monitoring sites on Douglas Reservoir and one stream monitoring site each on the French Broad and Nolichucky Rivers (Figure 16.1). A stream monitoring site on the Pigeon River is being added in 1994. All stream monitoring sites are upstream of Douglas Reservoir.

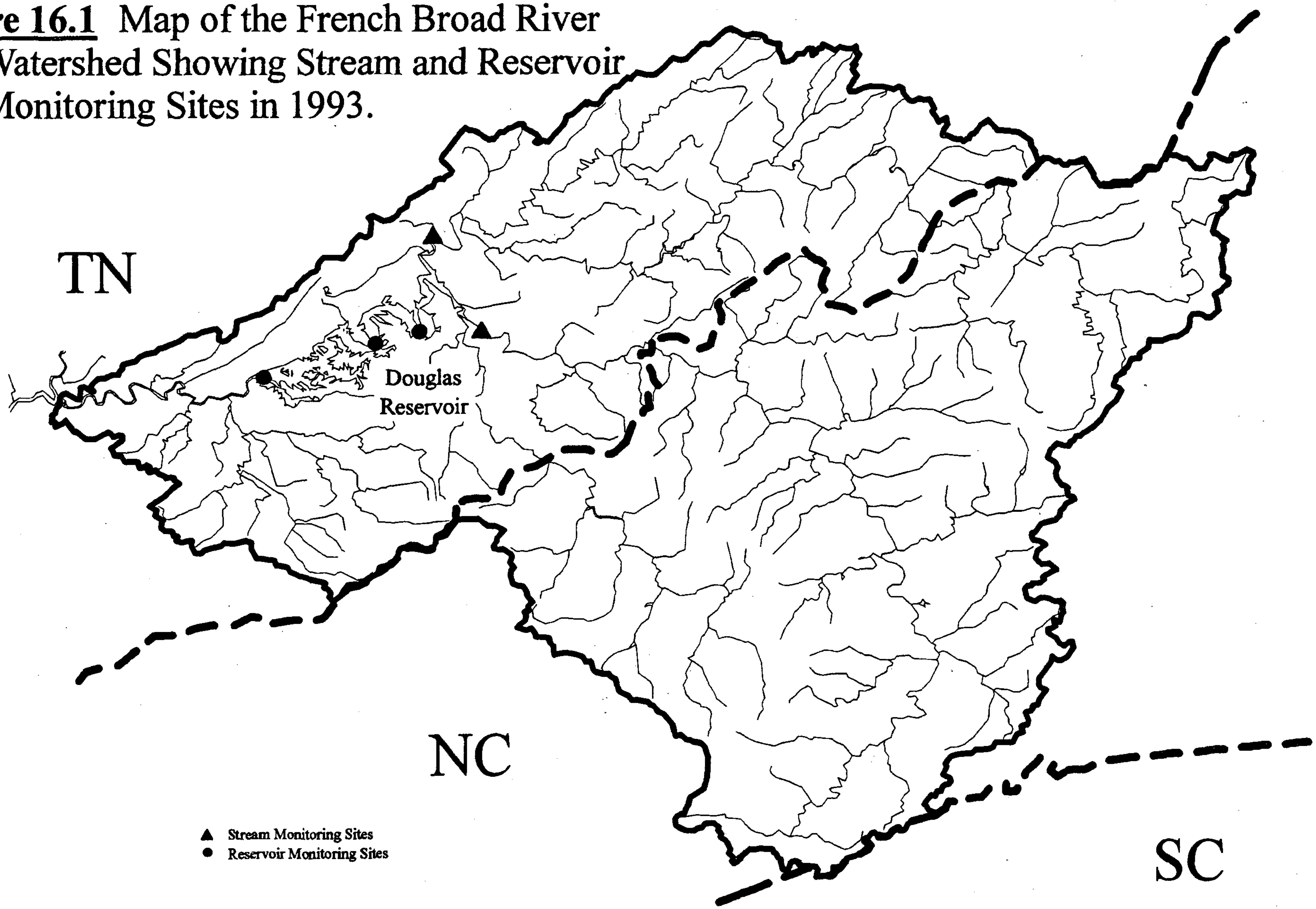
Results from 1993 Vital Signs monitoring activities are provided in the following sections:

16.1 Douglas Reservoir

16.2 French Broad River Stream Monitoring Site

16.3 Nolichucky River Stream Monitoring Site

Figure 16.1 Map of the French Broad River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



16.1 Douglas Reservoir

Physical Description

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston Rivers which form the Tennessee River. Reservoir drawdown during late summer and autumn is rather large, with an annual average of about 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, maximum depth at the dam is 127 feet, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is approximately 6780 cfs, which provides an average hydraulic retention time of about 105 days.

Lengthy retention times and lack of mixing due to their deep nature tend to cause storage impoundments to have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extends from the forebay to the mid-reservoir sampling location.

Ecological Health

The ecological health of Douglas Reservoir was fair to poor (58 percent) in 1993, with little change compared to 1991 and 1992. Factors adversely affecting the ecological health of Douglas Reservoir were strong thermal stratification and high nutrient loadings. This combination results in hypolimnetic anoxia and release of iron and manganese, phosphorus, and ammonia from the sediment and excessive eutrophication of the reservoir. Ratings for DO were very poor at both the forebay and mid-reservoir sites in 1993 due to very low hypolimnetic DO at both locations and low surface DO at the forebay. This hypolimnetic anoxia promoted the release of ammonia (and sulfide) from the sediment and negatively impacted the benthic community. The benthic macroinvertebrates rated poor at the forebay (samples were not collected from the mid-reservoir site). Sediment quality rated good at the forebay but poor at the mid-reservoir site. The fish assemblage was fair at the forebay and good at the mid-reservoir site. Chlorophyll rated good at the forebay, but only fair at the mid-reservoir site because concentrations were relatively high, indicative of high nutrients and high primary productivity.

Reservoir Use Suitability

There are no fish consumption advisories on Douglas Reservoir. However, fish from the Pigeon River upstream of Douglas Reservoir should not be eaten because of dioxin contamination. The most recent collection of fish from Douglas Reservoir was in autumn 1992. TVA collected fish samples and provided fillets to the Tennessee Department of Environment and Conservation for analysis. Results were not available at the time this report was prepared.

Fecal coliform concentrations were very low at the swimming beach and two boat ramps tested in 1993. Fecal coliform bacteria sampling at the two Vital Signs stations was dropped in 1993. From 1990 to 1992, concentrations were very low.

16.2 French Broad River Stream Monitoring Site

Physical Description

The French Broad River is a major tributary to the Tennessee River system, flowing westward out of the Appalachian Mountains for more than 220 miles to meet the Holston River and form the Tennessee River.

The drainage basin above the stream monitoring site at the USGS stream gage at near Newport, Tennessee, is 1858 square miles or 36 percent of the watershed. Principal tributaries in the monitored area include Big Laurel Creek (132 square miles), Ivy Creek (161 square miles), the Swannanoa River (133 square miles), Hominy Creek (104 square miles), and Mud Creek (113 square miles). Two major tributaries enter the French Broad River below the monitoring site. They include the Nolichucky River (1756 square miles) and the Pigeon River (689 square miles).

Ecological Health

The ecological health of the stream monitoring site at the French Broad River site rated poor in both 1993 and 1992. Nutrients rated poor because of high concentrations of phosphorus. Inflows of nutrients promote the excessive algal productivity in Douglas Reservoir. The fish community on the French Broad River was poor in 1993, same as in 1992. Given the poor water quality of the Nolichucky and French Broad Rivers flowing into Douglas Reservoir, the poor-fair ecological health of the reservoir is not unexpected. Together the Nolichucky and French Broad Rivers provide about 75 percent of the total inflow to Douglas Reservoir.

Use Suitability

No bacteriological studies were conducted as part of the monitoring program in 1993. All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

16.3 Nolichucky River Stream Monitoring Site

Physical Description

The Nolichucky River is a major tributary to the French Broad River basin and joins the French Broad River at the upstream end of Douglas Reservoir. The Nolichucky River Basin is 1756 square miles. The upper portion of the basin (approximately 60 percent) lies in the Blue Ridge physiographic province while the remainder lies in the Valley and Ridge province.

The stream monitoring location is at the TVA stream gage at the David Thomas bridge near Lowlands, Tennessee. The Nolichucky River basin above the monitoring site is 1686 square miles or 96 percent of the entire Nolichucky River basin. Principal tributaries in the monitored area include North Toe River (442 square miles) and Cane River (158 square miles) in the Blue Ridge physiographic province and Lick Creek (266 square miles) in the lower Valley and Ridge province.

The upper portion of the Nolichucky River basin is primarily forested, while the lower portion is agricultural. High concentrations of solids from mica and feldspar mining and processing near Spruce Pine on the North Toe River have severely impacted the streambed downstream. In addition to Spruce Pine, other urbanized areas include Greeneville and Erwin, Tennessee.

Ecological Health

The overall ecological health of the Nolichucky River at this site was good in 1993, as opposed to fair in 1992. The change was driven by improvements in the fish community, the absence of acute sediment toxicity, and improvements in nutrient concentrations. The conditions for bottom-dwelling animals remained unchanged.

Use Suitability

Bacteriological studies were not conducted as part of this monitoring program in this watershed in 1993.

All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

17.0 HOLSTON RIVER WATERSHED

The Holston River Watershed encompasses 3776 square miles, mostly in upper east Tennessee and southwest Virginia and a small area in North Carolina. The area is relatively highly populated with substantial industrial development.

Much of the area is underlain with limestone and dolomite which results in high concentrations of dissolved minerals in the streams. There is also substantial zinc mining in the watershed.

There are several reservoirs in the watershed with varying size, depth, flow, and water quality characteristics. The largest is Cherokee Reservoir on the Holston River near the lower end of the watershed. The uppermost reservoirs are Watauga Reservoir on the Watauga River and South Holston Reservoir on the South Fork Holston River. Downstream from these reservoirs, the Watauga and South Holston Rivers merge in Boone Reservoir. Immediately downstream from Boone Dam is Fort Patrick Henry Reservoir, the smallest of the five reservoirs in this watershed included in the Vital Signs Monitoring Program. A few miles downstream from Fort Patrick Henry Dam the South Fork and North Fork Holston Rivers merge to form the Holston River.

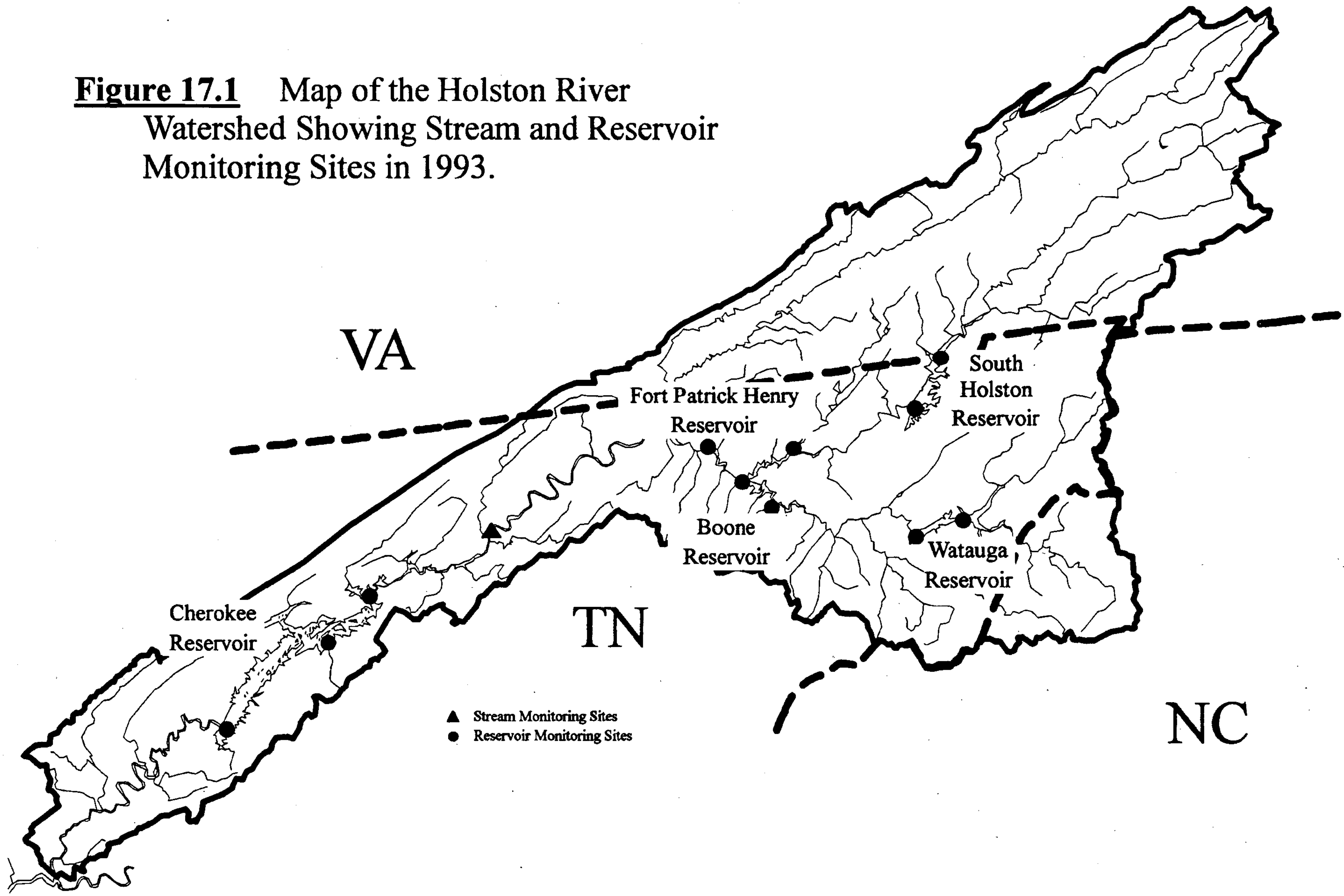
Vital Signs monitoring activities are conducted at one, two, or three locations depending on reservoir size and characteristics (Figure 17.1). There is also a stream monitoring site on the Holston River upstream of Cherokee Reservoir.

The average annual discharge from Cherokee Dam is 4460 cfs. The Holston River merges with the French Broad River at Knoxville to form the Tennessee River.

Results from Vital Signs monitoring activities in 1993 are in the following sections:

17.1 Cherokee Reservoir
17.2 Fort Patrick Henry Reservoir
17.3 Boone Reservoir
17.4 South Holston Reservoir
17.5 Watauga Reservoir
17.6 Holston River Stream Monitoring Site

Figure 17.1 Map of the Holston River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



17.1 Cherokee Reservoir

Physical Description

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile (HRM) 52.3. Like Norris and Douglas Reservoirs, it is a large, relatively deep, tributary storage impoundment with a substantial drawdown which begins in late summer. When the water surface is at full pool, maximum depth at the dam is 163 feet and winter drawdown is 53 feet. However, full pool is not reached most years, and the long-term average drawdown is about 28 feet. At full pool, Cherokee Reservoir is 54 miles long, has a surface area of 30,300 acres, and a shoreline of 393 miles. Average annual discharge is about 4500 cfs which provides an average hydraulic retention time (at full pool) of approximately 165 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit on Cherokee is one of the worst of all Vital Signs monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

Ecological Health

The ecological health of Cherokee Reservoir rated fair (64 percent) in 1993, which was higher than poor ratings in 1992 (55 percent) and poor to fair ratings in 1991 (60 percent). The improved ecological health rating compared to 1992 resulted mostly from addition of benthic macroinvertebrate information from the upper reservoir sample site, and from slight improvements (decreases) in chlorophyll concentrations at the mid-reservoir site. Although benthos data were collected from Cherokee Reservoir in 1992, ratings were not available for 1992 results because of an insufficient data base to establish expected (reference) conditions for the benthic macroinvertebrate community in tributary storage reservoirs. Additional benthos sampling in 1993 on Cherokee plus several other similar reservoirs provided sufficient data to establish at least preliminary expectations for reservoirs of this type. The benthic community rated fair at the forebay and excellent at the upper monitoring site indicating very good conditions there. Improvements noted for chlorophyll at the mid-reservoir site in 1993, rated good compared to fair in 1992 (due to high averages during summer), also helped elevate the overall ecological rating in 1993 compared to 1992.

A problem consistently found in Cherokee Reservoir is very low DO concentrations at the forebay and mid-reservoir sites. Both rated very poor in 1993. This near-bottom low dissolved oxygen condition, often observed in deep tributary reservoirs with long retention times, is especially severe in Cherokee Reservoir, resulting in high concentrations of un-ionized ammonia in sediment. The fair fish community observed at all monitoring sites in 1993 was probably also influenced to some extent by the low oxygen concentrations in Cherokee Reservoir. Sediment quality rated poor at the mid-reservoir site due to high ammonia and copper concentrations coupled with significant toxicity to rotifers.

Reservoir Use Suitability

There are no fish consumption advisories on Cherokee Reservoir. Channel catfish for screening tissue analysis were collected in autumn 1992. All analytes were not detected or found in low concentrations except PCBs. Maximum PCB concentrations were 0.8 $\mu g/g$ at the forebay in 1992. Screening samples were collected again in 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform concentrations were low at all test sites in 1993--a swimming beach, seven boat ramps, and one other site tested. Fecal coliform bacteria sampling at the two Vital Signs stations was discontinued in 1993. From 1990 to 1992, concentrations were very low.

17.2 Fort Patrick Henry Reservoir

Physical Description

Fort Patrick Henry Reservoir is one of the smaller reservoirs included in the Vital Signs Monitoring Program. It is only ten miles long, has a surface area of about 870 acres, and has a shoreline of 37 miles. Although it is a tributary reservoir, it has characteristics of a run-of-river reservoir, rather than a storage reservoir. Annual fluctuation in elevation is only five feet. Also, retention time is short; with an average discharge of 2650 cfs, the hydraulic retention time is only about five days. Maximum depth is about 80 feet. Fort Patrick Henry Dam is located at South Fork Holston River mile 8.2.

This reservoir had not been sampled as part of this monitoring effort prior to 1993. Because of its small size, only the forebay is monitored for Vital Signs.

Ecological Health

The ecological health of Fort Patrick Henry Reservoir was fair to good (72 percent) in 1993. DO was the only indicator which rated excellent and sediment quality was the only indicator which rated good. Chlorophyll rated fair, with the average annual concentration only slightly above the level considered good. The benthos and fish assemblage also rated fair.

Reservoir Use Suitability

Fecal coliform concentrations at Warriors Path State Park were within Tennessee's criteria for recreation during 1993 studies. TVA's first fish tissue studies on this reservoir were conducted in autumn 1993; results were not available at the time this report was prepared.

17.3 Boone Reservoir

Physical Description

Boone Dam is located at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, an average depth of 44 feet, and a maximum depth of 129 feet near the dam. Annual average discharge from Boone Dam is about 2500 cfs, which results in an average hydraulic residence time of about 38 days. Annual drawdowns of Boone Reservoir usually average about 25 feet.

Three locations were selected for ecological health monitoring in Boone Reservoir, one at the forebay and two mid-reservoir sampling locations, one on the Watauga River arm and one on the South Fork Holston River arm. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of Boone Reservoir was lower in 1993 compared to 1992. The rating for 1993 was toward the low end of the fair range (59 percent) whereas it was in the middle of the range in 1992 (64 percent). Ecological health ratings in both 1992 and 1993 were higher than in 1991 when poor conditions were found (51 percent). Primary contributors to lower scores in 1993 compared to 1992 were lower ratings for DO (fair at two locations and poor at one); lower ratings for the fish assemblage (poor at two locations and fair at one); and addition of ratings for the benthic macroinvertebrates (fair at two locations and poor at one). The ecological health indicator with the best rating in 1993 was chlorophyll, which rated good at the forebay.

The DO problem at the forebay and mid-reservoir site on the South Fork Holston River arm is different than other tributary, storage reservoirs. The typical problem is hypolimnetic anoxia, which is the case at the Watagua River mid-reservoir site. At the other two Boone Reservoir sites, the DO problem occurs in the middle stratum of the water column (metalimnion) due to oxygen demand of local sewage treatment plant discharges.

Reservoir Use Suitability

Studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state-issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. Additional fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

Bacteriological sampling was conducted at two swimming areas and four boat ramps in 1993. The geometric mean concentrations of fecal coliform bacteria were well within Tennessee's criteria for recreation, although one sample at the Boone Dam swimming area was high.

17.4 South Holston Reservoir

Physical Description

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles long, over 230 feet deep near the dam, with an average depth of 86.5 feet and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, the average hydraulic residence time is almost one year (340 days)--one of the longest residence times of any TVA reservoir. Average annual drawdown of South Holston Reservoir is about 33 feet.

Two locations are monitored for Vital Signs--the forebay and mid-reservoir. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of South Holston Reservoir was fair (65 percent) in 1993, slightly better than in 1992 (57 percent) and 1991 (60 percent). A consistent problem has been with DO concentrations (as is the case with most deep storage impoundments), which rated poor at the forebay and very poor at the mid-reservoir site in 1993. Despite the poor ratings for DO, conditions were slightly improved at the forebay in 1993, compared to 1992. The ecological health indicator primarily responsible for the higher overall reservoir rating in 1993 was sediment quality (rated good at both sample sites). Sediments had not been sampled in previous years. Another indicator added in 1993, the benthic macroinvertebrate community, received a very poor rating at the forebay (with most metrics receiving the lowest score possible) and a fair rating at the mid-reservoir sample site. Interestingly, scores for the benthos do not parallel those for DO at the two sample sites, indicating other factor(s) may be affecting benthic macroinvertebrates at the forebay. The fish assemblage rated good at the forebay and fair at the mid-reservoir site.

Reservoir Use Suitability

There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples for fish collected in autumn 1991 found low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury which was slightly elevated).

17.5 Watauga Reservoir

Physical Description

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the second-deepest reservoir sampled as part of TVA's Vital Signs Monitoring Program. With an annual average discharge of about 700 cfs, Watauga Reservoir also has the longest hydraulic residence time of any of the Vital Signs reservoirs (about 400 days). Average annual drawdown of Watauga Reservoir is about 26 feet.

Two locations are monitored on Watauga Reservoir, the forebay and mid-reservoir. Sediment quality and benthic macroinvertebrates were examined for the first time in 1993.

Ecological Health

The overall ecological health for Watauga Reservoir was fair in 1993 (61 percent), about the same as in 1992 (57 percent). The ecological health in both 1992 and 1993 rated lower than in 1991, although all three years fell within the fair range. Similar to previous years, chlorophyll rated good at both sample sites in 1993. DO rated excellent at the forebay and fair at the mid-reservoir sites in 1993, a slight improvement compared to 1992. The fish assemblage was poor at the forebay in 1993 due to low abundance and diversity and rated fair at the mid-reservoir site, mostly due to low abundance. The benthic macroinvertebrate community, not sampled in Watauga Reservoir prior to 1993, was very poor at both locations. The benthos community was among the poorest in all Vital Signs reservoirs examined in 1993. This would not appear to be related to low DO concentrations; instead, the poor sediment quality at the forebay (due to toxicity to test animals and high ammonia) may have contributed to the poor benthos.

Reservoir Use Suitability

There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury which was sightly elevated) were low or not detected.

Fecal coliform bacteria concentrations were very low at all five sites tested in 1993, which included one designated and an informal swimming area.

17.6 Holston River Stream Monitoring Site

Physical Description

The TVA stream monitoring station on the Holston River is located near Church Hill, Tennessee. The Holston River basin above this location is 2819 square miles or 74 percent of the entire Holston River basin. Two major tributaries, the North Fork Holston River (729 square miles) and the South Fork Holston River (2048 square miles), meet above Church Hill to form the Holston River. Principal tributaries to the South Fork Holston River include the Watauga River (869 square miles) and the Middle Fork Holston River (244 square miles). Two notable tributaries to the Watauga River include the Doe River (137 square miles) and Roan Creek (167 square miles).

There are five reservoirs in the basin. Fort Patrick Henry Dam and Boone Dam impound the lower South Fork Holston River. The South Fork Holston Dam impounds the upper South Fork Holston River and the Middle Fork Holston River. Wilbur Dam and Watauga Dam impound the Watauga River.

Although most of the basin land use is agricultural or forestry, several urban areas (Kingsport, Johnson City, and Elizabethton, Tennessee, and Marion and Abingdon, Virginia) are within the basin.

Ecological Health

The overall ecological health of the Holston River at this site was fair for 1993 as in 1992. Sediment quality improved from fair to good, and the fish community showed a slight improvement over 1992. Bottom-dwelling animals and nutrient ratings remain unchanged.

Use Suitability

Seven sites between Fort Patrick Henry Reservoir and South Holston Dam were tested for fecal coliform bacteria in 1993. South Fork Holston River met bacteriological water quality criteria for water contact recreation, and was only slightly impacted by the two tributaries tested. Thomas and Beidleman Creeks did not meet criteria.

A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.5 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

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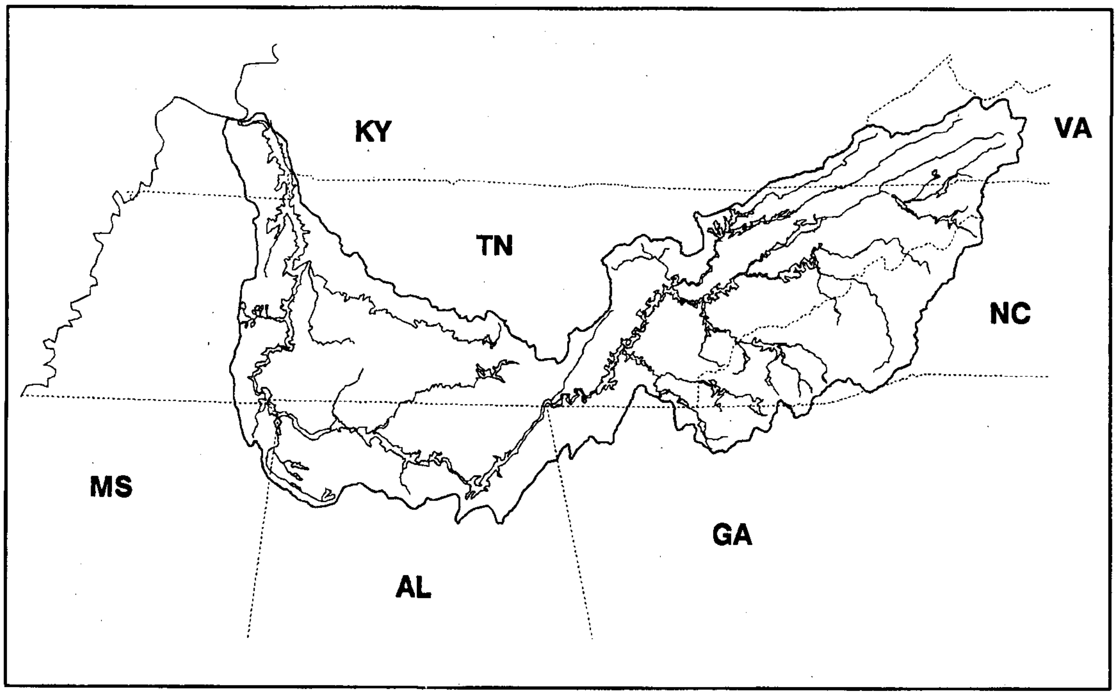
TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

VOLUME II



CLEAN WATER INITIATIVE

TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

Volume II

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INTRODUCTION

The Tennessee Valley Authority (TVA) initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component and a reservoir component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary by sampling location within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-or-evidence approach was used— a stream or reservoir was deemed healthy if most of the physical, chemical, and biological components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used— dissolved oxygen, chlorophyll *a*, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll *a* concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging form 1 to 5 representing very poor to excellent conditions. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year , the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these with perfect scores), three streams rated fair to good, and one stream rated poor. Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993. The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of -the-river reservoirs and deep storage reservoirs. Separate scoring criteria are used for the two categories. Overall ratings for the 11 run-of-the-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (74 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent). Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), fourteen rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Results did not yield any "big surprises"— most streams and reservoirs fell within expected categories. Similar results were observed in both 1991 and 1992, primarily due to similar meteorological conditions and reservoir flows during the period. Generally poorer ratings observed in storage reservoirs were primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is mostly due to strong thermal stratification that occurs in deep reservoirs.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies.

Bacteriological Studies

Bacteriological samples are collected at over 200 sites in the Tennessee Valley: designated swimming areas, canoe access sites, highly used recreational areas, and selected non-recreation sites that provide information on pollution sources or inflow stream quality. Not all sites are sampled each year. Beginning in 1993, each recreation site will be revisited at least every other year.

In 1993, bacteriological sampling at recreation sites was conducted at 71 swimming areas and 14 canoe access points. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points (all on the Duck River) exceeded the criterion, in dry or wet weather.

Bacteriological sampling at non-recreation areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality is most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies

Fish tissues studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data are provided to appropriate state agencies to determine the need for further study and possible issuance of fish consumption advisories. Fish tissue data reported here represent autumn 1992 collections. Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time required for laboratory analysis.

Results of screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies where there are know or suspected problems) did not indicate substantial changes from previous years.

KENTUCKY RESERVOIR WATERSHED

Kentucky Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), the coolest surface water temperatures in Kentucky Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 13.6°C to a maximum of 31.5°C at the forebay; from 15.8°C to 31.6°C at the transition zone; and from 16.1°C to 30.9°C at the sampling location in Big Sandy embayment. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.2 mg/l in July to a high of 10.4 mg/l in April at the forebay; from 5.8 mg/l in August to 10.1 mg/l in June at the transition zone; and from 6.2 mg/l in July to 10.3 mg/l in April at the sampling location in Big Sandy embayment. At the inflow sampling site (i.e. the tailrace of Pickwick Dam) a minimum DO of 4.2 mg/l was recorded in July. The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5m depth.

The temperature and DO data depict a seasonal warming and very weak thermal stratification of Kentucky Reservoir in June-July 1993. The greatest surface-to-bottom temperature differential (ΔT) was only about 3°C in June and July at the forebay and about 4½°C in Big Sandy embayment in June. However, during July, a rather strong oxycline developed at Kentucky forebay and in the Big Sandy embayment due to the drought like conditions and low flows through Kentucky Reservoir and the Tennessee River system (see discussion in Section 4.0, Hydrologic Overview of 1993). In late July, forebay dissolved oxygen ranged from surface concentrations of about 8-9 mg/l to bottom concentrations approaching 0 mg/l. (The minimum DO observed in Kentucky Reservoir in 1993 was 0.1 mg/l in July at the bottom of the reservoir in the forebay.) Similar conditions were found in Big Sandy embayment, although near bottom DO concentrations were never actually measured below 1 mg/l. The transition zone DO concentrations were much more uniform and well mixed with the minimum bottom DO being 3.6 mg/l in July.

For the overall reservoir ecological health evaluation for Kentucky Reservoir, DO rated excellent at the transition zone; good to excellent in Big Sandy embayment; and good at the forebay and inflow (i.e., Pickwick Dam tailrace). The good rating at the forebay would have rated higher had it not been for the anoxic conditions which were found to exist for a short time (i.e. July) in the hypolimnion near Kentucky dam. Likewise, the good rating at the inflow would also have been higher if oxygen levels had not fallen below 5 mg/l in the releases from Pickwick dam (i.e. DO concentrations less than State of Tennessee's 5 mg/l criteria, measured at the 1.5m depth).

In 1993, values of pH ranged from 6.7 to 9.2 on Kentucky Reservoir. Near surface values exceeding 8.5 were observed at the forebay in July and in Big Sandy embayment in June and August. These high pH's were coincident with high DO saturation values (exceeding 100 percent) and elevated chlorophyll *a* concentrations, indicative of significant photosynthetic activity. The State of Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average total phosphorus (0.073 mg/l) and dissolved ortho phosphorus (0.029 mg/l) concentrations at the transition zone were higher than at all other monitoring locations on the Tennessee River, an effect of the upstream inflows from the Duck River with naturally high concentrations of phosphorus (median total phosphorus concentrations of about 0.24 mg/l). Total phosphorus concentrations in the Tennessee River are approximately doubled by the inflows from the Duck River (annual mean daily flow of approximately 4,100 cfs), and gradually decline downstream. The Duck River joins with the Tennessee River at TRM 110.7, about 25 river miles upstream from the Kentucky Reservoir transition zone sampling site. (For additional information see Section 5.0, Duck River Watershed.) Because of high phosphorus concentrations, TN/TP ratios for samples collected at both the forebay and transition zone were quite low ranging from 5 to 13, indicating very little nutrient limitation and conditions highly supportive of primary productivity.

Chlorophyll *a* concentrations averaged 10.4 µg/l at the forebay, 9.2 µg/l at the transition zone, and 18.0 µg/l in Big Sandy embayment during the summer of 1993. In addition, high chlorophyll *a* concentrations were measured in August (31 µg/l) and September (35 µg/l) in Big Sandy embayment, indicative of nuisance level algal blooms. [It is also interesting to note that the Big Sandy embayment had among the highest organic nitrogen (= 0.51 mg/l), organic carbon (= 4.2 mg/l), and color (= 19 PCU) concentrations measured at any Vital Signs reservoir monitoring location in 1993.] Chlorophyll *a* values which average greater than 10 µg/l are generally indicative of eutrophic conditions while values greater than 15 µg/l are often indicative of hyper-eutrophic conditions. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Kentucky Reservoir were fair at the forebay, good at the transition zone, and poor in the Big Sandy embayment.

Sediment Quality—Chemical analyses of sediments in Kentucky Reservoir in 1993 did not reveal any metal or organic analyte to be a concern in the two sample locations (i.e. forebay and transition zone) in the main reservoir. However, high levels of un-ionized ammonia were measured (510 µg/l) in the Big Sandy embayment. Toxicity tests detected no acute toxicity in the main reservoir, however, acute toxicity to both daphnids (15 percent survival) and rotifers (20 percent survival) was detected in the Big Sandy embayment. Particle size analysis showed sediments from the forebay and the Big Sandy embayment to be almost entirely silt and clay (99 percent at each site), while those from the transition zone were 65 percent silt and clay, 35 percent sand.

Sediment quality ratings used in the overall Kentucky Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone, and poor in the Big Sandy embayment (due to the presence of ammonia and toxicity to the test organisms).

Benthic Macroinvertebrates—The benthic communities were excellent in the forebay and transition zone, fair in the inflow, and good in the Big Sandy embayment. The forebay had a total of 26 taxa with 1,658 organisms/m^2. The dominant taxa at the forebay were Tubificidae (18%), Corbicula sp (17 percent), and Musculium sp (17 percent). The transition zone represented a more diverse (33 taxa) but less abundant (1,307 organisms/m^2) community than the forebay with Tubificidae as the dominant taxa (22 percent), followed closely by Hexagenia limbata (22 percent). The inflow site had 25 taxa and a total of 234 organisms/m^2 with Cheumatopsyche sp (32 percent) and Corbicula sp (29 percent) as the dominant taxa. The Big Sandy embayment site had 20 taxa and 1,683 organisms/m^2 with Chironomus sp (37 percent), and Coelotanypus tricolor (33 percent) as the principal taxa.

The forebay and transition zone sites on Kentucky Reservoir rated excellent primarily because of the abundance of long-lived species such as Corbicula sp and Hexagenia sp, and because of a diverse and balanced benthic community. The inflow rated only fair, in spite of an abundance of Corbicula sp, because of reduced diversity and EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa. The Big Sandy embayment received a good rating due to the diversity of organisms present and the evenness of dominant organisms. An abundance of chironomids resulted in this site receiving a good rating instead of an excellent rating.

Though not included in the overall health survey, the Kentucky tailwater benthic community was also sampled. Diversity and a good EPT community, as well as low numbers of chironomids and tubificids, allowed this site to obtain an excellent rating.

Aquatic Macrophytes—Aquatic plants increased from 2,616 acres in 1992 to 3,465 acres in 1993. Kentucky Reservoir had the third largest amount of aquatic vegetation within the TVA system. Aquatic macrophytes peaked at about 7,100 acres in 1987. Significant declines in spinyleaf and southern naiad populations have occurred in recent years. Eurasian watermilfoil was the dominant macrophyte on Kentucky Reservoir and generally occurred in monospecific stands. However, it was sometimes mixed with coontail and naiads. Aquatic vegetation on Kentucky Reservoir was primarily found from TRM 107 downstream to near the vicinity of Kentucky Dam.

Fish Assemblage—Fish data collection at near shore (45 electrofishing transects) and offshore bottom areas (26 net-nights) showed a diverse fish assemblage of 46 species dominated in numbers by gizzard shad (64 percent). Other abundant species included emerald shiners (5.6 percent), bluegill (4.8 percent), and largemouth bass (2 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (1,634) and transition zones (1,762) with considerably lower numbers in the inflow zone (405). Gill netting fish abundance was also highest in the forebay (696) and transition (494) areas. Abundance at the inflow zone (69) was not comparable because of reduced effort. Gizzard shad made up 36 percent of the total fish collected in gill net samples followed by yellow bass (15.7 percent), skipjack herring (9.9 percent), and channel catfish (6.0 percent).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), transition (RFAI=34), and inflow (RFAI=40) zones of Kentucky Reservoir. The lower scores in transition and forebay zones were influenced by low numbers of sucker species, a high percentage of tolerant species and omnivorous individuals, and high percentage of dominance by a single species. The gill netting RFAI rated the transition zone excellent (RFAI=56) and the forebay good (RFAI=42). Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. The excellent score of 56 in the transition was the highest ever observed and resulted from maximum scores in all metrics except number of sucker species and percent tolerant species.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=37) and the electrofishing RFAI for the inflow (RFAI=40) were rated fair. The combined transition RFAI (RFAI=45) ranked good exhibiting the second highest score of all run-of-the-river transition zones, due primarily to the excellent gill netting results noted above.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (24 net-nights) produced a total of 1,587 individuals including 27 species in the Big Sandy River embayment. There were four times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of gizzard shad which made up 71 percent of the total sample.

The electrofishing RFAI score of 32 rated fair. The gill netting RFAI of 22 was the lowest recorded for any of the embayment study sites in 1993, and resulted from minimum scores for eight of the twelve metrics. The combined RFAI scores (RFAI=27) rated the Big Sandy embayment poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming beaches and one informal swimming area were tested for fecal coliform bacteria in 1993. Bacteria concentrations were generally low at all 15 sites. The highest geometric mean at any site was 47 colonies per 100 milliliters (47/100 ml), well below the recreation criterion of 200/100 ml. No site had more than one sample exceed 400/100 ml, so EPA's guideline of no more than 10 percent of all samples exceeding 400/100 ml was also met. Two sites, Eva Park and Greenhead Recreation Area, each had one sample exceed the Tennessee single sample criterion of 1,000/100 ml. The geometric mean of all samples at these two sites were 14 and 15/100 ml. The six monthly Vital Signs samples collected at the forebay and transition zones were all at or below the detection limit of 10/100 ml.

Fish Tissue—Channel catfish composites were collected in 1992 from generally the same locations (except TRM 85 was sampled instead of TRM 100 to coincide with the transition zone location) as in previous years. As in past years, concentrations of all analytes were low. One analyte of interest was lead with a concentration of 0.6 µg/g at TRM 85. Similar levels have occurred sporadically with no pattern in locations over the five years screening samples have been collected from Kentucky Reservoir.

Beech Reservoir

Summary of 1993 Conditions - Ecological Conditions

Water—Beech Reservoir is the smallest and shallowest of the monitored reservoirs. The average flow through the reservoir in 1993 was only 64 percent of normal, making the average residence time over 600 days. The maximum temperature difference in the water column was 9.2°C in July, and had disappeared by September. The maximum surface temperature was 29.7°C in July. The extent of the area of depleted DO gave Beech Reservoir a poor DO rating for the reservoir ecological health index. DO depletion (<1.0 mg/l) began at the bottom of the water column in May and expanded to within four meters of the surface in June and July. As the reservoir destratified the bottom waters became re-aerated, although there was some low DO (2.2 mg/l) at the bottom in October.

Conductivities were generally in the 31 to 45 µmhos/cm range, but were much higher at the bottom during times of DO depletion, reaching a maximum of 141 µmhos/cm in August. Only in April and June did pH exceed 8.0, and the maximum was only 8.3. The minimum pH was 6.6 and occurred at greater depths during DO depletion.

Virtually all of the nitrogen was in the form of organic nitrogen. Total nitrogen increased slightly from 0.42 mg/l in April to 0.51 mg/l in August. Total and dissolved ortho phosphorus concentrations dropped from 0.04 and 0.01 mg/l in April to 0.02 and 0.002 mg/l in August, respectively. The TN/TP ratio thus increased from 11 to 26.5 from April to August. Secchi depths varied only from 1.0m in April and September to 1.5m in May and June, the second lowest water clarity of the 19 tributary reservoir forebays in 1993. Chlorophyll *a* concentrations were 3 µg/l in April, 6 µg/l in May, and varied from 9 to 14 µg/l for the rest of the sampling period. The average chlorophyll *a* concentration was 9.0 µg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon dropped from 5.4 mg/l in April to 3.3 mg/l in August. Total phosphorus and total organic carbon concentrations were the second lowest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment—Chemical analyses of sediments in the forebay of Beech Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to the two organisms tested; however, survival of daphnids (68 percent survival) was reduced. Particle size analysis showed sediments in the forebay were 97 percent silt and clay.

Because of the slightly reduced survival of daphnids, the forebay sediment quality rating used in the 1993 Beech Reservoir ecological health evaluation was good.

Benthic Macroinvertebrates—The forebay on Beech Reservoir supported a fair benthic community. There were 24 taxa and 1,417 organisms/m^2, with Einfeldia sp (39 percent of the total) and Chironomus sp (35 percent of the total) as the dominant species. This site had 2 metrics which rated good: diversity and proportion of the sample composed of tubificids. Fair representations of EPT and long-lived taxa were observed. An abundance chironomids negatively impacted the benthic community rating.

Fish Assemblage—No fish assemblage information was collected in autumn 1993 because water levels prevented access to the lake.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—TVA has not conducted fish tissue studies on Beech Reservoir.

DUCK RIVER WATERSHED

Normandy Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average residence time in Normandy Reservoir was 201 days in 1993 as flows were 91 percent of normal. The maximum temperature difference in the water column was 23°C in July. The maximum surface temperature was 32.3°C in July, the only month when the maximum temperature exceeded 30.5°C, Tennessee's criteria for aquatic life. Metalimnetic and near-bottom oxygen depletion began in June. By August, DO was below 0.1 mg/l from the bottom to six meters from the surface. Surface temperatures had cooled enough to mix with the metalimnion in October, increasing the depth of aerated water to 10m. The extent of the area of depleted DO gave Normandy a poor DO rating for the reservoir ecological health index. Surface DO reached saturation levels of 120 percent or more on each sample date from May through July.

Conductivities were about 100 μmhos/cm early in the year, began increasing at the bottom in June and reached about 160 μmhos/cm in September and October. Normandy had slightly basic water (pH from 7.5 to 8.3) in April. Surface pH was over 9 from May through July, with a maximum pH of 9.5 in May. Bottom pH dropped slightly during the summer to a minimum of 6.6 in September.

Total nitrogen concentration dropped from 0.72 mg/l in April to 0.46 mg/l in August. The decline was due to the elimination of nitrates, 0.25 mg/l in April and <0.01 mg/l in August. Total phosphorus and dissolved ortho-phosphorus concentrations were 0.04 and 0.004 mg/l in April and 0.01 and <0.002 mg/l in August, respectively. The TN/TP ratio went from 18 in April to 46 in August. Secchi depths generally increased through the sampling period from 1.1m in April to 3.0m in October. Chlorophyll *a* was 10 μg/l in April, increased to 12 μg/l in May and July, and then dropped to 5 μg/l in August as available nutrients were depleted. The average chlorophyll *a* concentration was 8.9 μg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon varied little from 3.6 mg/l in April to 4.2 mg/l in August. Total phosphorus and total organic carbon concentrations in the forebay were the third highest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment Quality—Chemical analyses of sediments in the forebay of Normandy Reservoir in 1993 indicated very high levels of un-ionized ammonia (720 μg/l). Toxicity tests detected acute toxicity to daphnids (60 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 99 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and the high concentrations of ammonia, a poor sediment quality rating was used in the 1993 Normandy Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The Normandy forebay received a poor rating for its benthic community. There were 198 organisms/m^2 representing only 6 taxa; the dominant organisms were Tubificidae, Limnodrilus sp, and Chironomus sp, which comprised 38, 35, and 24 percent of the total, respectively. The low diversity, paucity of EPT and long-lived taxa, and the abundance of tubificids all negatively impacted the benthic community rating at the Normandy forebay.

Fish Assemblage—Only the forebay zone was sampled on Normandy in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,307 individuals with 29 species represented. Sixty-four percent of the total catch consisted of the sunfish species (rock bass, warmouth, redbreast, green, bluegill, and longear).

The Reservoir Fish Assemblage Index (RFAI) rated the Normandy Reservoir forebay fish community excellent, as determined by both electrofishing (RFAI=52) and gill netting (RFAI=54). The electrofishing and gill netting RFAI's, as well as the combined scores (RFAI=53), were the highest recorded for tributary forebays. Normandy received midrange or maximum scores in most metrics for both gear types; the only minimum score was percent anomalies in the electrofishing sample.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches were tested for fecal coliform bacteria in 1993. The geometric mean of bacteria concentrations were relatively high, 146 and 174/100 ml, but within criterion for water contact recreation. At both sites, geometric means after rainfall were over 200/100 ml, and both sites had three of twelve samples exceed 400/100 ml. EPA recommends that not more than 10 percent of samples exceed 400/100 ml. Both sites had large flocks of resident geese which were the probable cause of the high fecal coliform concentrations.

Fish Tissue—Because of the small size of Normandy Reservoir, only the forebay was sampled for fish tissue screening. Five channel catfish were collected in autumn 1992. Fillets were composited and analyzed for selected metals, pesticides, and PCBs. Of the five metal analytes, only lead and mercury were detected, both at low levels. The only organic analyte detected was chlordane, also at a low level.

Duck River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Duck River is moderately hard (average hardness of 130 mg/l) and alkaline (average total alkalinity of 118 mg/l). The median pH for the stream monitoring site was 7.7. The river was well oxygenated with dissolved oxygen levels of 82 to 115 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Duck River ranked among the highest in average concentrations of organic nitrogen (0.421 mg/l), total phosphorus (0.617 mg/l), and dissolved orthophosphate (0.177 mg/l). The average concentrations of ammonia nitrogen (0.027 mg/l) and nitrate+nitrite-nitrogen (0.48 mg/l) were near median for all sites. The high total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (4 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded the EPA guidelines for protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 105 taxa and 3,789 organisms/m^2. Conditions in 1992 rated fair (MBIBI score 34) with 61 taxa and 528 organisms/m^2. The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (62 percent), mayflies (20 percent), and caddisflies (7 percent). Dipteran midge larvae were also the dominant organism in 1992 (26 percent), followed by coleopteran riffle beetles (22 percent) and caddisflies (17 percent). Excessive nutrients, streambank erosion, and substrate instability are a continuous problem at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 46 and showed little improvement since it rated fair (IBI = 42) in 1992. Improvement in 1993 was seen mostly in increased fish density and absence of hybrid fish. Problems persisted in species composition and trophic structure indicating less than optimum conditions. Diversity was low for darter, sunfish, and intolerant species, and the proportion of tolerant fish was abnormally high. Fish most dependent on a diverse and stable aquatic macroinvertebrate community were out-numbered by fish that live by a more flexible feeding strategies, and the proportion of piscivorous fish was abnormally low. Adverse conditions observed were extensive bank erosion and the predominance of unstable substrate.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Five sites on the Duck River from 1.7 miles downstream of Normandy Dam to Shelbyville were tested for fecal coliform bacteria. At the first site downstream of Normandy Dam, the geometric mean of all fecal coliform samples was 104/100 ml. At the other four sites from 1.8 to 5.4 miles further downstream, the geometric mean ranged from 1100 to 2150/100 ml. There were several rainstorms during the sampling period, and concentrations were much higher after rainfall. If all samples within 24-hours of rainfall are excluded, the geometric mean of the four most downstream site range from 510 to 960/100 ml. These are among the highest concentrations found anywhere in the Tennessee Valley during the five years of sampling under the current program. The probable cause of the high concentrations are dairies.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Lead and mercury were detected in all samples but at low concentrations. Chlordane was detected in one sample and PCBs in two, again at only low concentrations.

PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), coolest surface water temperatures in Pickwick Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 18.4°C to a maximum of 30.5°C at the forebay; from 16.2°C to 29.1°C at the transition zone; and from 22.8°C (in May-no samples in April) to 29.6°C in Bear Creek embayment. The State of Alabama's maximum water temperature criteria for the protection of fish and aquatic life is 30.0°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in August to a high of 12.0 mg/l in April at the forebay; from 6.6 mg/l in August to 11.6 mg/l in June at the transition zone; and from 6.7 mg/l in September to 10.1 mg/l in August at the sampling location in Bear Creek embayment. At the inflow sampling site (i.e. the tailrace of Wilson dam) a minimum DO of 3.1 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict a seasonal warming and very weak, transient thermal stratification of Pickwick Reservoir. The maximum observed surface to bottom temperature differential (ΔT), in Pickwick Reservoir in 1993 was 4.7°C at the forebay in June. However, there was a rather strong oxycline at all three sampling locations in June and July when differences between surface and bottom DO's were about 7 to 9 mg/l at the forebay, transition zone, and in Bear Creek embayment. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at all three sampling locations (the forebay, transition zone, and Bear Creek embayment) in Pickwick Reservoir. Due to the drought like conditions and low flows into and through Pickwick Reservoir (see discussion in Section 4.0, Hydrologic Overview of 1993) sediment oxygen demands were consuming oxygen at a rate greater than it was being replenished by inflowing water. Flows increased to normal levels in August and September, resulting in less stratification and higher near bottom DO levels.

DO ratings used in the overall reservoir ecological health evaluation for Pickwick Reservoir were good at the forebay and transition zone; fair to good in Bear Creek embayment; and fair at the inflow. The forebay, transition zone, and Bear Creek embayment would all have rated higher had it not been for the very low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Pickwick Reservoir was a result of oxygen levels being measured approximately 2 mg/l below the Alabama criteria in the releases from Wilson dam in the summer of 1993 as mentioned above.

Values of pH ranged from 6.8 to 9.0 on Pickwick Reservoir in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed at all three sampling locations. Many of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8.5.

In 1993, all three sampling locations on Pickwick Reservoir also had fairly high chlorophyll *a* concentrations averaging 15 µg/l, 12 µg/l, and 16.8 µg/l, respectively, at the forebay, transition zone, and Bear Creek embayment. The chlorophyll *a* concentrations measured in Pickwick Reservoir were among the highest measured in the Tennessee River reservoirs in 1993, indicative of eutrophic conditions.

Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Pickwick Reservoir were only fair at the forebay and transition zone, and poor in Bear Creek embayment.

Sediment—Although mercury has been found in sediment in Pickwick Reservoir at levels of concern in past years, levels in 1993 were lower and not above sediment quality guidelines for mercury (i.e., 1.0 mg/kg). Mercury levels in 1993 were 0.47 mg/kg at the forebay and 0.62 mg/kg at the transition zone sampling sites. Un-ionized ammonia was detected at levels of concern (220 μg/l) in one of the two forebay samples. Although no acute toxicity was detected in the main reservoir, acute toxicity to both daphnids (30 percent survival) and rotifers (45 percent survival) was detected in the Bear Creek embayment. Tests in 1991 and 1992 showed a potential for toxicity with MicrotoxR at the forebay. Particle size analysis showed sediments from the forebay were about 66 percent silt and clay, 34 percent sand; from the transition zone were 47 percent silt and clay, 53 percent sand; and from Bear Creek embayment were 99 percent silt and clay.

Sediment quality ratings used in the overall Pickwick Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); excellent at the transition zone; and, fair in the Bear Creek embayment (toxicity to the test organisms).

Benthic Macroinvertebrates—The benthic communities at the forebay and inflow sites were excellent, the transition zone was good, and the Bear Creek embayment rated fair. The forebay site had 23 taxa and 533 organisms/m^2 with Coelotanypus sp (26 percent), Corbicula fluminea (20 percent), and Hydrobiidae (15 percent) as the dominant taxa. The transition zone had a slightly more diverse fauna than the forebay, with 25 taxa and 745 organisms/m^2. Corbicula fluminea (23 percent) and Hexagenia sp (21 percent) were the most abundant taxa. The inflow had the greatest diversity and of all sites sampled, with 42 taxa and 699 organisms/m^2. The benthic community there was dominated by Corbicula fluminea (65 percent).

Bear Creek embayment, a major component of Pickwick Reservoir, was also sampled and received a fair rating. It had a total of 1,188 organisms/m^2 and 15 taxa. Tubificidae (33 percent), Einfeldia (25 percent) and Coelotanypus tricolor (21 percent) were the dominant taxa. Although this site had a good diversity of benthic organisms and an evenness of dominant taxa, the abundance of chironomids and the paucity of EPT taxa contributed to this site only receiving a fair rating.

Aquatic Macrophytes—There were an estimated 105 acres of submersed plants on Pickwick Reservoir in 1993, primarily in the upstream portion of Yellow Creek embayment. Historically, most of the aquatic vegetation on Pickwick Reservoir has been in the Yellow Creek embayment, and in 1993 naiads and muskgrass were the most abundant macrophytes.

Fish Assemblage—Fish collections at near shore areas (45 electrofishing transects) and offshore bottom areas (30 net-nights) from the three zones of Pickwick Reservoir resulted in the collection of 2,526 fish including 42 species. Three non-game species, including skipjack herring, gizzard shad, and brook silverside, comprised 50 percent of all fish collected. Other dominant species groups were the sunfishes (green, bluegill, longear, and redear), catfishes (blue, channel, and flathead), and black basses (smallmouth, spotted, and largemouth), which made up 12, 7, and 6 percent of the total sample, respectively. Fish abundance was greatest in the forebay zone (1,563) followed by the transition (659), and inflow zones (304). Total catch was significantly higher in the forebay than the other two zones with both gear types (even considering reduced netting effort in the inflow).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in all three zones of the reservoir (forebay RFAI=46, transition RFAI=42, and inflow RFAI=46). The Pickwick forebay score of 46 was, along with Wilson forebay, the highest recorded in run-of-the-river reservoirs in 1993. The slightly lower transition score was influenced by lesser numbers of piscivorous and sunfish species. The gill netting RFAI rated the transition (RFAI=46) and forebay (RFAI=42) good. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=44), transition (RFAI=44), and the electrofishing RFAI for the inflow (RFAI=46) rated all areas as good.

Fish samples taken in the shoreline areas (15 electrofishing transects) and offshore/deep areas (12 net-nights) in Bear Creek embayment produced a total of 975 individuals represented by 36 species. By far the two most dominant species were gizzard shad (35 percent) and skipjack herring (22 percent). No other species were captured in significant numbers. Number of individuals captured was similar with both gear types.

Both electrofishing (RFAI=42) and gill netting (RFAI=46) RFAI's rated the Bear Creek embayment good, ranking it the highest of the four embayment study sites. Both gear types received the highest score for five of the twelve metrics.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and six informal swimming areas were tested for fecal coliform bacteria in 1993. Bacteria concentrations at all ten sites were very low (geometric mean <20/100 ml). There were no significant rainfall events during the survey. This may have contributed to the very low concentrations at some sites. Monthly sampling at the three Vital Signs locations (forebay, transition zone, and Bear Creek Embayment) produced equally low fecal coliform concentrations.

Fish Tissue—One composite sample of five channel catfish was collected at the forebay, transition zone, and inflow in autumn 1992. Concentrations of all metals were low. Mercury was detected in most samples but at relatively low concentrations (maximum of 0.24 µg/g). Pesticides and PCBs were generally low. The exception was DDTr, which was relatively high at the inflow (2.4 µg/g) yet not detected at the other two locations. This is not thought to represent a problem because concentrations of this magnitude have not been observed in previous years of screening. It is possible that one of the catfish in the composite was from Wheeler Reservoir where there is a problem with DDT contamination in one area resulting in high concentrations in fish. Relatively high concentrations of chlordane in 1990 were not found in 1991 or 1992. PCBs were detected in all samples (range 0.2 to 0.7 µg/g) with concentrations tending to be higher at the inflow. Samples were recollected at the inflow site in autumn 1993 to ensure that a possible problem with DDTr, chlordane, or PCBs is not overlooked; results were not available at the time this report was prepared.

Wilson Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), surface water temperatures ranged from 13.7°C in April to 31.6°C in July at the forebay sampling location. Temperatures above 30.0°C exceed State of Alabama water quality criteria for fish and aquatic life. Values for DO at the 1.5m depth ranged from a high of 13.8 mg/l in May (during a large algal bloom) to a low of 5.7 mg/l in September at the forebay. At the Wheeler dam tailrace a minimum DO of 4.3 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and DO data show seasonal warming and both thermal and oxygen stratification in the forebay from May through August. The greatest degree of thermal stratification was observed in July, as might be expected, during the period of high temperatures and low flows (see discussion in Section 3.0, Hydrologic Overview of 1993). In July, temperatures at the forebay ranged from 31.6°C (surface) to 21.5°C (bottom), a differential of 10.1°C.

Periods of strong DO stratification, with surface to bottom DO differentials ranging from about 7 to 12 mg/l, were also observed during these four months, May through August. For example, in June, surface DO concentrations of about 12 mg/l (during a large algal bloom) were contrasted with near bottom DO concentrations of about 0 mg/l. The depth of Wilson Reservoir (approximately 100 feet at the dam) and the unseasonably low flows during the summer of 1993 combined to have a pronounced effect on hypolimnetic DO in Wilson forebay. Bottom DO concentrations were at or near 0 mg/l for approximately three months (June, July, and August), and the volume of hypolimnetic anoxia was greater in the summer of 1993 than has been observed in the prior three years of Vital Signs monitoring (1992 to 1990). For the summer, DO concentrations in Wilson forebay averaged only 5.9 mg/l, lower than at any other Vital Signs monitoring location on run-of-the-river reservoirs.

Consequently, the forebay DO rating used in the overall ecological health rating of Wilson for 1993 was very poor. A good rating for DO was assigned to the Wilson reservoir inflow sampling site (i.e., Wheeler dam tailrace) because oxygen levels fell only slightly below 5 mg/l in releases from Wheeler dam during the summer of 1993 (i.e. DO's less than State of Alabama's 5 mg/l criteria, measured at the 1.5 meter depth).

Values of pH ranged from 6.7 to 9.1. In May and June near-surface values of pH were measured greater than 9.0. These high pH values coincided with periods of high photosynthetic activity, high temperatures, high dissolved oxygen measurements (percent oxygen saturation values exceeding 150%), and high chlorophyll a concentrations. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Summer chlorophyll *a* concentrations in Wilson forebay averaged about 10.2 µg/l in 1993, slightly higher than preferred, but much better than in 1992 when a massive algal bloom (chlorophyll *a* concentrations of 146 µg/l) occurred in May on Wilson reservoir. A forebay chlorophyll *a* rating of fair was used in the ecological health evaluation of Wilson Reservoir in 1993.

Historically, the water in the forebay of Wilson is quite clear relative to the other Tennessee River reservoirs. In the summer of 1993, Secchi depths averaged over 1.7 meters and suspended solids (TSS) averaged only about 3.2 mg/l, among the highest Secchi's and lowest TSS's measured on the run-of-the-river reservoirs.

Sediment—Chemical analyses of sediment did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to either species tested; however, reduced survival of rotifers (65 and 85 percent survival) was seen in samples from the forebay. Toxicity to rotifers was detected in 1991. Particle size analysis showed sediments from the forebay were about 99 percent silt and clay.

The forebay sediment quality rating used in the overall Wilson Reservoir ecological health evaluation for 1993 was very good, instead of excellent, due to the slightly reduced survival of rotifers.

Benthic Macroinvertebrates—Wilson forebay and inflow sites showed improvements in their benthic communities. The forebay improved from poor to fair, and the inflow from good to excellent. The forebay had 803 organisms/m^2 representing 22 taxa with Chironomus sp (42 percent) as the dominant organism. The inflow site had 683 organisms/m^2 representing 48 taxa with Corbicula sp (41 percent) as the dominant organism.

The Wilson forebay scored as high as possible on three metrics: taxa richness, percentage of the community comprised of tubificids, and the evenness of dominant organisms. The two metrics that brought down the overall benthic score were the high numbers of chironomids present and the low number of EPT taxa present. These factors resulted in a fair rating for the forebay site. The inflow site received a perfect score for every metric and received an excellent rating. This epitomizes a healthy benthic community: high diversity, the presence of a good EPT community, an abundance of long-lived organisms, low numbers of tubificids and chironomids, and an evenness of dominant organisms.

Aquatic Macrophytes—There were 54 acres of aquatic plants on Wilson Reservoir in 1993. Muskgrass was the dominant species and colonized shallow water sloughs. Eurasian watermilfoil historically occurred as localized populations on Wilson Reservoir, but has not been observed on Wilson in several years.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore gill netting (19 net-nights) at the forebay and inflow of Wilson Reservoir produced 3,567 individuals of 38 species, and showed fish were most abundant in the inflow (69 percent of the total fish collected). Species representing the largest portion of the Wilson fish assemblage included emerald shiners (25 percent), brook silversides (22 percent), gizzard shad (19 percent), and bluegill (11 percent). Most of the inflow electrofishing catch (66 percent) consisted of emerald shiners and gizzard shad. There were also moderate numbers (CPUE= 234 per transect) of young-of-year (YOY) threadfin shad in the inflow area.

The 12 electrofishing RFAI metrics described the littoral fish community of both the inflow (RFAI=42) and the forebay (RFAI=46) zones as good. The Wilson and Pickwick forebay ratings of 46 were the highest recorded in run-of-the-river reservoirs in 1993. The 1993 forebay (RFAI=46) rating also represented an increase over the 1992 RFAI score of 38. The forebay scores were the same or higher for all metrics with exception of the average number of individuals (i.e., average catch per transect). The gill netting RFAI rated the forebay (38) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=42) good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The boat ramps at Fleet Hollow and Lock Six were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml). The monthly Vital Signs samples collected in the forebay were all less than 10/100 ml.

Fish Tissue—Composited channel catfish samples were collected from the forebay and inflow areas in autumn 1992. All analytes were low or not detected. PCB concentrations have been relatively high in occasional samples during past years. Interestingly, 1992 samples from both locations were below the detection limit.

Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 89 percent of normal. Even with the relatively short average residence time, 14.4 days, the maximum temperature difference in the forebay water column was 14.6°C in July. The maximum surface temperature was 31.3°C in July. The Alabama maximum water temperature criterion for fish and wildlife is 32.2°C (90 F). Depleted DO conditions began at the bottom in May and by June 21 the area of DO <2.0 mg/l extended to within four meters of the surface, resulting in a poor DO rating in the reservoir's ecological health index. The cooling surface temperatures in September allowed surface mixing with the metalimnion, extending the depth with DO >2.0 mg/l to seven meters.

Conductivities in April were about 50 µmhos/cm. Conductivities in the DO depleted zone rose throughout the summer reaching 182 µmhos/cm in September. The maximum pH was about 8.5 at the surface in July. The minimum pH was about 6.1 in the upper portion of the depleted DO zone in August and September.

The total nitrogen concentration was 0.79 mg/l in April, about 60 percent as nitrates. By August, nitrates had disappeared, reducing the total nitrogen concentration to 0.37 mg/l. Total phosphorus and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April, and 0.01 and <0.002 in August, respectively. The TN/TP ratio was between 37 and 40 in both surveys. Secchi depths were the lowest of the 19 tributary reservoir forebays, ranging from 0.75 to 1.75 meters. Chlorophyll *a* concentrations were the highest of the 33 tributary stations, ranging from 8 to 17 µg/l. The average chlorophyll *a* concentration of 12.3 µg/l gave Bear Creek a fair rating for chlorophyll in the reservoir's ecological health index. Total organic carbon concentrations were 2.5 and 2.8 mg/l in April and August, respectively.

Sediment Quality—Chemical analyses of sediments in the forebay of Bear Creek Reservoir in 1993 indicated elevated levels of un-ionized ammonia (280 µg/l). Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (65 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and rotifers and the presence of ammonia, a very poor sediment quality rating was used in the overall 1993 Bear Creek Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Bear Creek forebay, the only site sampled on the reservoir, had 18 taxa and 216 organisms/m^2. Procladius sp accounted for 37 percent of the total. Bear Creek forebay supported an excellent benthic community in 1993, with 5 of the 6 metrics receiving a good score. The proportion of the sample comprised by chironomids was the only metric to receive a poor score.

Fish Assemblage—Only the forebay zone was sampled on Bear Creek Reservoir in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 1,632 individuals with 28 species represented. Bluegill was the most abundant taxon in Bear Creek Reservoir (28 percent of total fish sampled). Green sunfish (14 percent), gizzard shad

(7 percent), spotted bass (7 percent), and longear sunfish (6 percent) followed in order of density. Species diversity was much higher in electrofishing samples (24 species) than in gill netting efforts (14 species).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) excellent (RFAI=52) and received maximum scores in all metrics except percent tolerant species, average number of individuals, and percent anomalies. Fifty-two was the highest RFAI recorded in all TVA tributary reservoir forebays (Normandy Reservoir forebay also scored 52). The gill netting RFAI of 40 was rated fair. The combined electrofishing and gill netting RFAI of 46 rated Bear Creek forebay good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Piney Point and Horseshoe Bend were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml) except for one sample at Horseshoe Bend (4800/100 ml).

Fish Tissue—A five fish composite of channel catfish was collected from the forebay during autumn 1992. There were no pesticides or PCBs detected in the sample. Of the five metals examined, only mercury was found above the detection limit. The concentration (0.45 μg/g) was relatively high, although far below the concentration of 1.0 μg/g used by the U.S. Food and Drug Administration to remove products from commerce. Another sample of channel catfish was collected from the same area in autumn 1993 to further evaluate this result.

Little Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through the reservoir in 1993 was about 89 percent of normal, with an average residence time of 254 days. The reservoir was thermally stratified throughout the sampling period with a maximum temperature difference in the water column of 20.5°C in July. The maximum surface temperature of 31.1°C in July was less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). The area of DO depletion (DO < 2.0 mg/l) began at the bottom in June, extended to within 8 meters of the surface in July and August, and still comprised over one-half the water column in October. This resulted in a poor DO rating in the reservoir ecological health index. During June, very high DO concentrations and corresponding high pH values occurred in the metalimnion. DO was 16.2 mg/l and pH was 9.4 at the six meter depth; a DO saturation of 172 percent. This was below the area at which the composited surface sample was collected, thus the chlorophyll concentration in June was probably much higher than the measured 5 μg/l.

Surface pH varied from 8.0 to 8.9 from April to August. The minimum pH was 6.7 near the bottom in September. Conductivities throughout the water column were slightly over 100 μmhos/cm until DO was depleted at the bottom. Then bottom conductivities rose continually to a maximum of 167 μmhos/cm in October.

Organic nitrogen concentrations were constant, 0.28 mg/l in April and 0.29 mg/l in August, while nitrates dropped from 0.2 mg/l in April to <0.01 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April and 0.008 and <0.002 mg/l in August. Total organic carbon concentrations were 2.3 mg/l in April and 2.9 mg/l in August. The water was relatively clear, with Secchi depths ranging from 2.0 meters in April to 4.0 meters in August. Productivity was relatively low—the chlorophyll concentration averaged 3.8 μg/l with a maximum of 7 μg/l in August. These chlorophyll concentrations are in the range considered good in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. This resulted in a fair rating for sediments in the ecological health index. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Benthic Macroinvertebrates—The Little Bear Creek forebay site had a fair benthic community, with high densities and low diversity. There were 3,898 organisms/m^2 representing only 11 taxa, primarily Tubificidae (96 percent of the total). The abundance of Tubificidae, essentially a tolerant family, had the largest negative impact on the benthic community. The metrics of number of EPT taxa, number of long-lived taxa, and diversity all received fair scores. The only metric to receive a good score was the low proportion of the sample comprised of chironomids.

Fish Assemblage—Only the forebay was sampled on Little Bear Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (10 net-nights) yielded 2,946 individuals represented by 27 species. Thirty-eight percent of the total catch consisted of bluntnose minnows, followed by bluegill (21 percent), largemouth bass (6 percent), and green sunfish (5 percent). The primary forage base in Little Bear Creek Reservoir was comprised mainly of sunfish and minnows, as shad were collected in very low numbers in both electrofishing and gill netting samples.

Fish assemblage rated good for both electrofishing (RFAI=46) and gill netting (RFAI=50) in the forebay. Scores for the electrofishing sample were midrange or maximum for all metrics except number of piscivore species and percent omnivores. Scores in the gill netting samples were midrange or maximum for all metrics. The overall RFAI (combining electrofishing and gill netting results) rated Little Bear Creek forebay as good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Eliott Branch and Williams Hollow were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—A five-fish composite of channel catfish was collected from the forebay in autumn 1992. There were no pesticides or PCBs detected in the sample. Mercury was the only metal analyte found; arsenic, cadmium, lead, and selenium were not detected. The mercury concentration (0.56 μg/g) was high enough to warrant further examination in autumn 1993 but not high enough to warrant a detailed study. The 1993 results were not available at the time this report was prepared.

Cedar Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow was about 90 percent of normal. The average residence time was about 186 days, and thermal stratification was moderate to strong. The maximum temperature difference in the water column was 17.9°C in July. The maximum temperature was 30.9°C in July, less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). DO depletion (DO < 2.0 mg/l) began at the bottom in May, extended to within 7 meters of the surface in August, and remained depleted at the bottom in October. This resulted in a poor rating for DO in the reservoir ecological health index. Conductivities in Cedar Creek were the third highest of the 19 tributary reservoirs, averaging about 240 μmhos/cm in the water column in April, and increasing in the anoxic zone throughout the summer to a maximum of 295 μmhos/cm at the bottom in October. Surface pH was over 8.0 from April through September, with a maximum of 8.6 in May. Cedar Creek water is slightly basic, the minimum bottom pH was 7.1 in September.

Both organic and nitrate nitrogen concentrations decreased sharply from April to August. Organic nitrogen concentrations were 0.41 and 0.11 mg/l, while nitrate concentrations were 0.17 and <0.01 mg/l, respectively. Total and dissolved ortho phosphorus concentrations were 0.02 and 0.004 mg/l in April, and 0.004 and <0.002 mg/l in August. Total organic carbon concentrations were 2.9 and 2.7 mg/l in April and August, respectively. Water clarity was low to moderate, Secchi depths varied from 1.0 meter in April to 2.75 meters in June. Chlorophyll *a* concentrations were low, averaging 2.8 μg/l with a maximum of 5 μg/l in May. These low chlorophyll concentrations gave Cedar Creek Reservoir a fair chlorophyll rating in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 ecological health evaluation.

Benthic Macroinvertebrates—The Cedar Creek forebay supported a fair benthic community with 387 organisms/m^2 representing 10 species. Chironomus sp and Tubificidae were the dominant taxa, comprising 42 and 40 percent of the total, respectively. All 6 metrics received a fair score.

Fish Assemblage—Only the forebay zone was sampled on Cedar Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 662 individuals represented by 18 species (second lowest diversity in all TVA reservoirs). Thirty-eight percent of the total catch consisted of brook silversides, followed by gizzard shad (20 percent), spotted bass (13 percent), and spotted suckers (11 percent).

The Reservoir Fish Assemblage Index (RFAI) rated the forebay of Cedar Creek Reservoir fair (RFAI=32) as determined by electrofishing samples and good (RFAI=46) as determined by gill netting. The low electrofishing rating could be attributed to low diversity, and low catch. Combined electrofishing and gill netting ratings (RFAI=38) determined the reservoir fish community to be fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Slickrock Ford was tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—Five channel catfish were collected from the Cedar Creek forebay in autumn 1992. Composited fillets were analyzed for pesticides, PCBs, and selected metals. All pesticides and PCBs were below detection limits. Of the five metal analytes, only mercury was detected - at a relatively low concentration of 0.21 μg/g.

Bear Creek Stream Monitoring Site

Summary of 1993 conditions - Ecological Health

Water— The water of Bear Creek is soft (average hardness of 50 mg/l) and moderately alkaline (average total alkalinity of 50 mg/l). The median pH for the stream monitoring site was 7.6 . The river is well oxygenated with dissolved oxygen levels ranging from 80 to 94 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, Bear Creek ranked among the lowest in average concentrations of nitrate+nitrite-nitrogen (0.24 mg/l) and dissolved orthophosphate (0.005 mg/l). It was among the highest stations with average ammonia nitrogen and organic nitrogen concentrations of 0.044 mg/l and 0.332 mg/l. The average total phosphorus concentration of 0.065 mg/l was near the median for all stations. The fair total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium (6 of 6 samples), dissolved nickel (2 of 6 samples), and dissolved zinc (1 of 6 samples) were detected, but at levels within the EPA guideline for protection of human health and aquatic life. Dissolved lead in one of six samples exceeded the EPA guideline for chronic toxicity to aquatic life.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 40, with 91 taxa and 1,697 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 74 taxa and 2,044 organisms/m^2. The number of taxa was greater in 1993 but densities were lower. The benthic fauna in 1993 was composed mostly of dipteran midge larvae (31 percent), the Asian clam Corbicula (22 percent), and river snails (21 percent). Dipteran midge larvae were also dominant in 1992 (52 percent), followed by Asian clams (17 percent) and nutrient-tolerant oligochaeta worms (12 percent). Streambank erosion and unstable substrates are a continuing problem affecting benthic organisms at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 40), deteriorating considerably from the good (IBI = 48) rating in 1992. Fish sampled in 1993 included fewer native species and fewer intolerant species. A decrease was also seen in the proportion of specialized insectivores, fish that depend most on a diverse and stable macroinvertebrate community. Fish density changed most drastically, declining by approximately 50 percent since 1992. Adverse conditions observed at this station include extensive bank erosion and a predominance of shifting gravel substrate.

Summary of 1993 conditions - Use Suitability

There were no bacteriological samples or fish tissue samples collected from the Bear Creek stream site in 1993.

WHEELER RESERVOIR - ELK RIVER WATERSHED

Wheeler Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Wheeler Reservoir was generally well mixed and lacked persistent thermal stratification in 1993. During the April-September monitoring period, coolest surface water temperatures in Wheeler Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.3°C to a maximum of 31.9°C at the forebay; from 15.4°C to 29.6°C at the transition zone; and from 18.7°C to 31.2°C in the Elk River embayment. The 31.9°C temperature in the forebay of Wheeler Reservoir was the warmest Tennessee River temperature measured as part of the Vital Signs monitoring program (1990-1993), and is evidence of the effect the very warm meteorological conditions had on surface water temperatures in July of 1993. (See discussion in Section 4.0, Hydrologic Overview of 1993). Temperatures above 30.0°C exceed the State of Alabama's water quality criteria for fish and aquatic life.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in September to a high of 11.6 mg/l in April at the forebay; from 6.2 mg/l in August to 9.4 mg/l in April at the transition zone; and from 6.1 mg/l in September to 14.1 mg/l in April at the sampling location in the Elk River embayment. At the inflow sampling station site (i.e. the tailrace of Guntersville dam) a minimum DO of 5.4 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data give evidence of the seasonal warming and a weak thermal stratification in the downstream portion of Wheeler Reservoir (i.e. at the forebay and Elk River embayment). The maximum surface to bottom temperature differential (ΔT) occurred in June and was 5.8°C at the forebay and 7.0°C in the Elk River embayment. The transition zone was well mixed throughout the summer with ΔT's almost never exceeding 1.0°C.

As was the case for several other Tennessee River reservoirs, during the drought like conditions of the summer of 1993, a strong oxycline developed in June, July, and August in the downstream portions of Wheeler Reservoir. At the forebay, surface to bottom DO differentials (DO) were 9.7, 9.5, and 7.1 mg/l, respectively, in June, July, and August. In the Elk River embayment DO's of 11.0, 10.4, and 11.4 mg/l were measured in June, July, and August, respectively. As streamflows decreased and water temperatures increased, naturally occurring decomposition processes at the bottom of the reservoir used available oxygen at a rate faster than it was replenished by inflows. DO's at or near 0 mg/l occurred at the bottom in the forebay in July; and in the Elk River embayment in June, July, and August. However, in contrast, the transition zone was well mixed and lacked any DO stratification (DO differentials never exceeded 1 mg/l and minimum DO's were never less than 6 mg/l). In addition, DO's were never observed to fall below 5 mg/l at the inflow sampling site (i.e. the tailrace of Guntersville dam).

Based on the above information, the DO component of the overall reservoir ecological health evaluation for Wheeler Reservoir rated poor at the forebay and Elk River embayment; and excellent at the transition zone and inflow. The forebay and Elk River embayment rated poor because of the near bottom anoxia and the duration and volume of water with oxygen concentrations less than 2 mg/l.

Values of pH ranged from 6.7 to 9.1 in Wheeler Reservoir during the summer of 1993. Near surface values of pH equal to or greater than 8.5 were observed in April, June, July, and August at the forebay and in the Elk River embayment; but no pH's were ever less than 7.2 nor greater than 7.8 at the transition zone. Coincident with these pH's greater than 8.5 (particularly in the Elk River embayment) were oxygen saturation values ranging from 120% to 175% and high chlorophyll *a* concentrations, evidence of very high photosynthetic activity.

Ammonia nitrogen concentrations measured in Wheeler Reservoir, at both the forebay and the transition zone, were relatively high. As has been the case in previous years (1990-1992), ammonia nitrogen concentrations measured in 1993 were higher than at any other Vital Signs Monitoring location on the Tennessee River and averaged approximately 0.07 mg/l at the forebay and 0.11 mg/l at the transition zone. Given the volume of flow of the Tennessee River through Wheeler Reservoir and the lack extended periods of anoxia, the high ammonia concentrations could be indicative of large point and non-point waste discharge(s) to Wheeler Reservoir.

Historically (1990-1992), the forebay of Wheeler Reservoir has the highest total organic carbon (TOC) and organic nitrogen concentrations of any Vital Signs sampling site on the Tennessee River. In 1993, TOC averaged 2.6 mg/l (one of the highest TOC concentrations) and organic nitrogen averaged 0.32 mg/l (highest organic nitrogen concentration among the Tennessee River sampling sites) at the forebay. These data and other water quality characteristics (total phosphorus, total nitrogen, and chlorophyll *a*,) show substantial increases in concentration between the transition zone sampling site at Tennessee River Mile (TRM) 295.9 and the forebay sampling site at TRM 277.0. These data suggest a dramatic increase in primary productivity between the two sampling sites, likely stimulated by the input of large amounts of nutrients from the Elk River which joins Wheeler Reservoir about seven miles upstream of the forebay at TRM 284.3. The Elk River has a median total phosphorus and total nitrogen concentration of about 0.18 mg/l and 1.10 mg/l, respectively, and an annual mean daily flow of about 3050 cfs. (For additional information see discussion below on the Elk River embayment.)

The dramatic increase in primary productivity in Wheeler Reservoir between the transition zone and the forebay is reflected in the chlorophyll *a* results. During the summer of 1993, chlorophyll *a* concentrations measured at the forebay were as high as 24 μg/l in April and August, and averaged about 13.5 μg/l. This is over a 300% increase in chlorophyll *a* concentrations from those measured at the transition zone, where chlorophyll *a* concentrations averaged only about 4 μg/l during the summer of 1993.

Water quality in the Elk River embayment was unique in several aspects, largely reflecting the natural characteristics of the Elk River. During the summer of 1993, concentrations of several water quality parameters were higher in the Elk River embayment than at any other embayment or run-of-the-river sampling site. For example, total nitrogen and ammonia nitrogen averaged 0.72 mg/l and 0.11 mg/l, respectively. Total phosphorus and dissolved ortho phosphorus averaged 0.175 mg/l and 0.067 mg/l, respectively. Consequently, as might be expected, chlorophyll *a* concentrations were very high, averaging 23 μg/l and with concentrations as high as 39 μg/l measured during massive algal blooms. These chlorophyll *a* concentrations measured in the Elk River embayment were higher than at any of the other Vital Signs monitoring locations during 1993.

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Wheeler Reservoir were fair at the forebay (average exceeding 10 μg/l), good at the transition zone, and poor in the Elk River embayment (average exceeding 15 μg/l and large algal blooms).

Finally, true color values in the forebay of Wheeler Reservoir are among the highest measured on the Tennessee River and show a relatively large increase between the transition zone and the forebay. The

1990-1992 average for true color was 15.4 and 11.8 PCU's at the forebay and transition zone, respectively. During the summer of 1993, true color values averaged 12.5 PCU's at the forebay (the highest among the Tennessee River sampling sites in 1993) and 7.0 PCU's at the transition zone (one of the lowest of the Tennessee River sampling sites in 1993). These summer color values at the forebay are even higher than those measured throughout the year in the Elk River, which averaged about 12 PCU's, from 1986-1991. These data suggest that even though some color is added to the Tennessee River by inflows from the Elk River, there are other additional sources of color to Wheeler Reservoir between the transition zone and the forebay.

Sediment Quality—Chemical analyses of sediment in Wheeler Reservoir in 1993 indicated elevated levels of un-ionized ammonia (340 μg/l) from the Elk River embayment. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the three sites tested. Particle size analysis showed sediments from the forebay were 98 percent silt and clay; from the transition zone were 25 percent silt and clay, 75 percent sand; and from the Elk River embayment were 73 percent silt and clay, 27 percent sand.

Sediment quality ratings used in the overall Wheeler Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone; and slightly lower, i.e. good, in the Elk River embayment due to the presence of ammonia.

Benthic Macroinvertebrates—The benthos rated fair at the forebay in 1993, same as in 1992. The transition zone improved from fair in 1992 to good in 1993, and the inflow improved from good in 1992 to excellent in 1993. A major are of Wheeler Reservoir, the Elk River embayment, was sampled for the first time in 1993 and received a poor rating. The forebay location had 14 taxa and 633 organisms/m^2, dominated by the chironomid Coelotanypus (71 percent). The transition zone had 32 taxa and 870 organisms/m^2, with Hexagenia limbata as the dominant taxon comprising 38 percent of the total. The inflow site had 30 taxa present and 651 organisms/m^2 with Corbicula fluminea as the dominant organism present (61 percent). The Elk River embayment had 25 taxa and 1,488 organisms/m^2 with Tubificidae (37 percent) and Coelotanypus sp (16 percent) as the two dominant taxa.

Wheeler forebay received a fair rating; this is partially due to the high numbers of chironomids and low EPT taxa present at the site. Interestingly, tubificids made up only a small portion of the sample, and this boosted the rating slightly. The other metrics, taxa richness and abundance of long-lived species, were mediocre. At the transition site, a good rating was attained because of good diversity, EPT taxa richness, and low numbers of chironomids and tubificids. The only metric that brought the rating down was the evenness of dominant organisms; in this case one organism comprised an inordinate amount of the total organisms present. The inflow site on Wheeler received a perfect score due to its taxa richness, presence of a good EPT community, presence of several long-lived taxa, evenness of dominant organisms, and low numbers of tubificids and chironomids. Elk River embayment did not fare as well as the rest of the sites on Wheeler, primarily because it had large numbers of chironomids and tubificids, and very few EPT taxa and long-lived organisms. A perfect score on the taxa richness metric kept this site from receiving a very poor rating.

Aquatic Macrophytes—Aquatic plants increased from 4,412 acres in 1992 to 6,597 acres in 1993. Wheeler Reservoir had the second largest amount of aquatic vegetation within the TVA system. Dominant submersed species were Eurasian watermilfoil and spinyleaf naiad. These were most abundant in shallow overbank habitats from TRM 296 upstream to TRM 309. Wheeler Reservoir also had large populations (1,431 acres) of American lotus concentrated in Flint Creek embayment, overbank sloughs upstream of Flint Creek, and in Swan Creek embayment.

Fish Assemblage—Fish data collected in near shore and offshore bottom areas showed that 3,211 individuals of 47 species were recorded in both electrofishing (45 transects) and gill netting (26 net-nights) samples. Electrofishing results indicated total numbers of fish captured were higher in the inflow (1,277) than in the transition (934) or forebay (473) zones of the reservoir. Gizzard shad (32 percent) comprised the majority of the total individuals collected, followed by emerald shiners (18 percent), bluegill (8 percent), and skipjack herring (7 percent). Threadfin shad numbers were moderate in the transition (catch per unit effort, CPUE=271 per 300m transect) and high in the forebay (CPUE=851 per 300m transect) of Wheeler Reservoir. Gill netting catch rates were slightly higher in the forebay (CPUE=30 per net night) than the transition (CPUE=11 per net night) or the inflow (CPUE=14), due to much higher numbers of skipjack herring in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) good in the forebay (RFAI=44) and inflow (RFAI=44) and fair in the transition (RFAI=40). A high percentage of tolerant individuals (75 percent) and a lower average number of individuals (62) influenced the fair rating in the transition. Indices, determined by gill netting, for the transition and forebay zones of Wheeler Reservoir were 42 (good) and 40 (fair), respectively. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=44) were rated good. The combined transition RFAI (RFAI=41) ranked fair.

Electrofishing (15 transects) and gill netting (12 net-nights) results from the Elk River embayment yielded 5,126 individuals of 30 species. Gizzard shad were the most abundant species, comprising 78 percent of the total number of fish sampled. Other species of interest were bluegill (8 percent) and largemouth bass (2 percent). High numbers of gizzard shad accounted for the wide margin in catch rates for both gear types (4,776 individuals in electrofishing and 350 for gill netting). Unusually high numbers of young-of-year threadfin shad (3,356 per transect) were also observed in the electrofishing sample.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) good in the Elk River embayment (RFAI=42). Metrics receiving high scores were number of species, and number of piscivorous, intolerant, and lithophilic spawning species. The gill netting RFAI of 34 rated fair with metric values being somewhat evenly distributed throughout the range of possible scores. The combined electrofishing and gill netting RFAI of 34 rated the Elk River embayment of Wheeler Reservoir as fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Elk River Embayment, were very low (geometric mean <20/100 ml). The highest concentration for any sample was 219/100 ml in the transition zone in September.

Fish Tissue—Composite catfish samples for screening purposes were collected from the forebay, transition zone, and inflow in autumn 1992. Intensive studies were also conducted during this same time period to examine DDTr concentrations in a 20 mile stretch of Wheeler Reservoir near the Indian Creek embayment, located between the inflow and the transition zone. Three five-fish composites of channel catfish, largemouth bass, and smallmouth buffalo were collected from four locations for the intensive study.

Samples for screening purposes indicated all metals were low or not detected. DDTr was the only pesticide detected with a range of 1.0 to 1.6 μg/g. Relatively high PCB concentrations reported for 1990 (maximum 1.4 μg/g) were again found in 1991 (maximum 1.3 μg/g) but generally lower levels were found in 1992 (maximum 0.8 μg/g). PCB concentrations during all years were higher at upstream locations.

Samples from the intensive study in 1991 found quite high concentrations of DDTr. At least one sample of one test species exceeded 5 μg/g at all four sites. Highest concentrations were in smallmouth buffalo (maximum 43 μg/g) from near the mouth of Indian Creek with lower concentrations at the upstream location and the location at the downstream end of the study reach. Largemouth bass tended to have lower concentrations than the other two species. Samples for the intensive study in autumn 1992 (samples actually collected in January 1993) had substantially reduced concentrations. Only two samples exceed 5 μg/g whereas 15 from 1991 exceeded that concentration. Also, the geographical pattern was not distinct in these samples. Because of the discrepancy between the two years, the intensive study was repeated in autumn 1993 but results were not available at the time this report was prepared.

Tims Ford Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Tims Ford Reservoir in 1993 was about 86 percent of normal, making the average residence time about 329 days. The reservoir was strongly stratified with a maximum temperature difference of 22.9°C in the water column at the forebay in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. July surface temperatures were 31.3°C at the forebay and 31.5°C at the mid-reservoir station, the only time the temperature criterion was exceeded. DO depletion (DO <2.0 mg/l) began in May at the bottom of the water column at mid-reservoir, and in June in the metalimnion at mid-reservoir and in the forebay in both the metalimnion and at the bottom. The two areas of depleted DO expanded and met in July at mid-reservoir and September at the forebay. The extensive area of depleted DO resulted in a poor DO rating for Tims Ford in the reservoir ecological health index. As surface temperatures cooled in the early fall, the area of depleted DO declined as metalimnetic water mixed with surface water. Some extremely high DO concentrations occurred at the forebay in the upper part of the metalimnion. Both June and July DO concentrations exceeded 15 mg/l.

Conductivities in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. Conductivities were about 180 μmhos/cm in April, increased throughout the year in the DO depleted bottom waters to a maximum of 242 and 285 μmhos/cm in October at the forebay and mid-reservoir, respectively. Conductivities declined in the DO supersaturated surface water in the summer to a minimum of 145 μmhos/cm at the forebay in July and 136 μmhos/cm in June at mid-reservoir. The waters in Tims Ford are somewhat basic, as the minimum pH in April was 7.6 in the mid-reservoir. In June, surface pH was over 9.0 in both the forebay and mid-reservoir. The minimum pH was 6.8 at the bottom of the water column in September in mid-reservoir.

Organic nitrogen concentrations in June were 0.30 and 0.38 mg/l at the forebay and mid-reservoir, respectively, and 0.22 and 0.43 mg/l in August. Nitrates were 0.30 and 0.76 mg/l in April, declining to <0.01 at both locations in August. Total nitrogen concentrations at mid-reservoir in 1993 was the second highest concentration of the 33 tributary reservoir stations. Total phosphorus concentrations were 0.01 mg/l during both surveys at the forebay, and 0.02 and 0.005 mg/l at mid-reservoir in April and August, respectively. The TN/TP ratios were very high, ranging from 24 at the forebay to 90 at mid-reservoir, both in August. Dissolved ortho phosphorus concentrations were <0.002 mg/l at both stations during both surveys. Average total organic carbon concentrations in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. The minimum total organic carbon concentration was 2.6 mg/l in April, the maximum was 3.2 mg/l in August, both at mid-reservoir.

Chlorophyll *a* concentrations averaged 5.4 μg/l at mid-reservoir and 4.3 μg/l at the forebay. Some of the highest DO concentrations were below the depth at which the chlorophyll composite was collected in the forebay, thus the average sampled forebay concentration may be a little lower than actual values. The chlorophyll concentrations rated good in the reservoir ecological health index. Secchi depths varied from 1.3 meters in April to 5.5 meters in May at the forebay, and 1.3 meters in April to 8.0 meters in September at mid-reservoir.

Sediment Quality—Chemical analyses of sediments in Tims Ford Reservoir in 1993 indicated high levels of nickel in the forebay (51 mg/kg). Elevated levels of un-ionized ammonia were also found in both the forebay (230 μg/l) and mid-reservoir (410 μg/l) sediment samples. Toxicity tests detected acute toxicity to daphnids (5 percent survival) and rotifers (65 percent survival) in the mid-reservoir. Particle size analysis showed sediments in the forebay were 99 percent silt and clay; and in the mid-reservoir were 55 percent silt and clay, and 45 percent sand.

Sediment quality ratings used in the overall Tims Ford Reservoir ecological health evaluation for 1993 were good at the forebay sampling site, rather than excellent due to nickel and ammonia; and poor at the mid-reservoir sampling site (because of acute toxicity to daphnids and rotifers and presence of ammonia).

Benthic Macroinvertebrates—Two sites were chosen for sampling the first year on Tims Ford Reservoir, a forebay site and a mid-reservoir site of the Elk River arm. The forebay location had only 2 taxa and 122 organisms/m^2. Tubificidae accounted for 90 percent of the total. The inflow site had 108 organisms/m^2 representing 12 species and was dominated by Chironomus sp (32 percent) and Branchiura sowerbyi (27 percent). The forebay had a very poor benthic community, and scored poor on 5 of the 6 metrics: diversity, number of long-lived species, number of EPT species, proportion of the sample as tubificids, and unevenness of the dominant species. The only metric to get a good score was the proportion of the sample represented by chironomids. The inflow site rated only a little better than the forebay with a poor benthic community. Low diversity, absence of long-lived species, and a disproportionate number of the dominant taxa accounted for this site rating poor.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore experimental gill netting (24 net-nights) yielded 2,726 individuals with 32 species represented. The dominant species by number included bluegill (50 percent), green sunfish (8 percent), spotfin shiners (7 percent), and brook silversides (6 percent). Catch rates for most species (except for bluegill and green sunfish), utilizing both gear types, were higher at the transition zone than the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in the forebay zone (RFAI=40) and good in the transition (RFAI=46) of Tims Ford Reservoir. The transition received midrange to maximum scores for all metrics, except average number of individuals per transect, resulting in a slightly higher rating than the forebay. Identical gill netting scores for ten of the twelve metrics resulted in a good rating (RFAI=44) at both reservoir sample zones. Combined electrofishing and gill netting RFAI scores rated both the forebay (RFAI=42) and the transition (RFAI=45) zone good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming area on Dry Creek and an area in Estill Springs Park were tested for fecal coliform bacteria in 1993. Bacteria concentrations were low at Estill Springs Park, geometric mean of 38/100 ml for all samples. In Dry Fork, bacteria concentrations were high in samples collected within 24-hours of rainfall, geometric mean of 389/100 ml, but were within Tennessee criteria if the rainfall samples were excluded, geometric mean of 151/100 ml.

Fish Tissue—Channel catfish composites collected from the forebay and transition zone in autumn 1992 were screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations. One point of interest was absence of PCBs in these samples because previous screening studies had typically found PCBs, sometimes at slightly elevated levels.

Elk River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Elk River is moderately hard (average hardness of 130 mg/l) and moderately alkaline (average total alkalinity of 103 mg/l). The median pH for the stream monitoring site was 7.7. The river was generally well oxygenated with dissolved oxygen levels ranging from 54 to 108 percent of saturation. Five of the six dissolved oxygen levels were above 85 percent of saturation. At the lowest dissolved oxygen saturation level, the dissolved oxygen concentration was 5.4 mg/l.

Of the 12 streams monitored across the Tennessee Valley, the Elk River ranked among the highest in average concentrations of total phosphorus (0.374 mg/l), dissolved orthophosphate (0.173 mg/l), nitrate+nitrite-nitrogen (0.68 mg/l), ammonia nitrogen (0.042 mg/l). The high total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded EPA guidelines for the protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when the sediment quality rated only fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 73 taxa and 2,384 organisms/m^2. Conditions in 1992 rated poor (MBIBI score 27) with 52 taxa and 2,454 organisms/m^2. The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (69 percent), coleopteran riffle beetles (8 percent), and caddisflies (7 percent). Dipteran midge larvae were also the most dominant organism in 1992 (70 percent), followed by nutrient tolerant oligochaeta worms (18 percent) and coleopteran riffle beetles (5 percent). Siltation from agricultural land usage along the river and unstable substrates are a serious problem affecting benthic organisms at this site.

Fish Community Assessment—Fish community was not evaluated in the Elk River in 1993.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The canoe access location at Garner Ford on the Elk River, about one and one-half miles downstream of Tims Ford Dam, was tested for fecal coliform bacteria in 1993. Five of the 12 samples were collected within 48-hours of rainfall of at least one-half inch. Bacteriological water quality for samples collected more than 24-hours after rainfall easily met the Tennessee water quality criterion for recreation, but rainfall samples greatly exceeded criterion.

Fish Tissue—Smallmouth Buffalo, channel catfish, and spotted bass were collected in summer 1992. One five fillet of each species was analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

Guntersville Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, Guntersville Reservoir was well mixed and exhibited only weak thermal stratification. Surface water temperatures ranged from 16.2°C in April to 30.5°C in July at the forebay and from 15.1°C to 30.9°C for the same months at the transition zone. Temperatures above 30.0°C exceed the state of Alabama's water quality criteria for fish and aquatic life.

Values for DO at the 1.5m depth ranged from 10.1 mg/l in April to 6.5 mg/l in September at the forebay and from 9.3 mg/l in April to 5.6 mg/l in August at the transition zone. At the inflow sampling station site (i.e. the tailrace of Nickajack Dam) a minimum DO of 1.8 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Summer (April-September) temperature data for the forebay depict weak thermal stratification in the downstream portion of Guntersville Reservoir in 1993. Maximum surface to bottom temperature differentials (ΔT's = 3.3°C) occurred at the forebay in May and June. However, June and July showed the development of a oxycline in the forebay, with surface DO's being 5.5 and 6.3 mg/l, respectively, greater than bottom DO's. The minimum DO measured in Guntersville reservoir in 1993 was 0.6 mg/l at the bottom in July in the forebay; however, this apparently persisted for only a short period of time and by August bottom DO's were back up to 5 mg/l.

The transition zone was well mixed throughout the summer with maximum ΔT's (2.2°C) and ΔDO's (3.4 mg/l) occurring in June. One interesting observation was the very warm temperatures which existed throughout the water column at the transition zone in July, when surface temperatures were 30.9°C and bottom temperatures were 30.0C. The minimum DO measured at the transition zone was 5.5 mg/l at the bottom in July.

The very low DO concentration of 1.8 mg/l, measured in July in the tailrace below Nickajack Dam (i.e., the inflow site), was the lowest ever recorded in the releases from Nickajack Dam. In addition, releases of water from Nickajack Dam were consistently below Alabama's DO water quality criteria for the protection of fish and aquatic life of 5.0 mg/l (at the 1.5 meter depth) in July, potentially impacting the ecological health of the inflow site on Guntersville Reservoir.

These data resulted in DO ratings used in the overall reservoir ecological health evaluation for Guntersville Reservoir to be good at the forebay (minor hypolimnetic anoxia); excellent at the transition zone; and very poor at the inflow (due to low DO's in the releases from Nickajack dam).

Values of pH ranged from 6.9 to 8.3. Surface water pH values in excess of 8.5 (Alabama's pH water quality criteria for the protection of fish and aquatic life of 8.5) were not observed in Guntersville Reservoir in the summer of 1993.

At the forebay, the highest chlorophyll *a* concentration of 9 µg/l was measured in July (average summer chlorophyll *a* concentration was 5-6 µg/l in 1993). At the transition zone chlorophyll *a* concentrations were lower, averaging about 4 µg/l. TN/TP ratios frequently exceeded 20 at both the forebay and transition zone, indicating conditions when phosphorus concentrations may have limited photosynthesis.

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Guntersville Reservoir were good at both the forebay and the transition zone (i.e., average concentrations between 3 and 10 μg/l).

Historically, water clarity on Guntersville Reservoir has been among the highest of the mainstem Tennessee River reservoirs. In 1993, at the forebay and transition zone, respectively, average Secchi depth was 1.8 and 1.6 meters; total suspended solids was 3.7 and 3.2 mg/l; and true color was 8.3 and 7.1 PCU.

Sediment—Chemical analyses of sediment in Guntersville Reservoir in 1993 indicated the presence of chlordane (15 μg/g) in samples collected at the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the two sites tested (i.e. forebay and transition zone). Particle size analysis showed sediments from the forebay were 98 percent silt and clay; and from the transition zone were 39 percent silt and clay, 61 percent sand.

Sediment quality ratings used in the overall Guntersville Reservoir ecological health evaluation for 1993 were good at the forebay (presence of chlordane); and excellent at the transition zone.

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone had an excellent benthic community, and the inflow had a fair benthic community. The forebay had 20 taxa and 772 organisms/m^2 with Coelotanypus tricolor (27 percent) and Corbicula fluminea (18 percent) as the dominant taxa. The transition zone had 1340 organisms/m^2 representing 38 taxa; the dominant taxa were Corbicula fluminea (26 percent) and Coelotanypus tricolor (17 percent). The inflow site had 35 taxa and 672 organisms/m^2 with Corbicula fluminea (39 percent) and Tubificidae (24 percent) as the dominant taxa.

The forebay site fell short of an excellent rating primarily because high numbers of chironomids and a mediocre EPT community. All other metrics were excellent. The transition zone scored excellent, and fell just short of perfect because the percentage of the community made of chironomids was slightly elevated. The absence of adequate long-lived taxa, depressed diversity and EPT taxa, and unevenness of the dominant organisms all contributed to the inflow site receiving a fair rating. Metrics which rated food at the inflow were (due to their relatively low numbers) were tubificids and chironomids.

Aquatic Macrophytes—Aquatic macrophytes on Guntersville Reservoir increased from 5,993 acres in 1992 to 7,613 acres in 1993. The reservoir had the largest acreage of aquatic plants in the TVA system. About 99 percent of the total amount of vegetation was upstream of TRM 363 and primarily confined to shallow embayments and overbank areas adjacent to the river channel. Eurasian watermilfoil was the dominant submersed macrophyte species and colonized about 6,500 acres in 1993. About three acres of "topped out" hydrilla occurred on Guntersville Reservoir in 1993 compared to about 2,900 acres in 1988 when aquatic vegetation coverage peaked at about 20,200 acres. In 1990, the reservoir was stocked with 100,000 triploid grass carp for aquatic vegetation control.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (29 net-nights) produced 8,441 fish representing 41 species. Both sampling techniques indicated higher catch rates in the forebay than the other two zones of the reservoir. Gizzard shad (19 percent) was the dominant species, followed by bluegill (17 percent), and emerald shiners (14 percent). Results indicated that largemouth bass

(4.3 percent) was the only major sport fish species to comprise more that one percent of the electrofishing sample. As in previous years, largemouth bass were five times more abundant in the transition zone than either of the other two zones.

Electrofishing RFAI analysis determined that fish communities in both the inflow (RFAI=30) and transition zone (RFAI=28) rated poor, while that present in the forebay zone (RFAI=38) rated fair. Compared to other mainstream reservoirs, the Guntersville inflow and transition zones were in the lower third and the forebay zone the upper third. The poor designation of the transition also represented a significant decrease from the good rating in 1992. Metrics contributing to the poor designation for the inflow and transition areas were low numbers of sucker and intolerant species, depressed fish abundance, and high percentages of anomalies. Gill netting results showed both zones to be fair (transition RFAI=34 and forebay RFAI=38). Transition zone scores were midrange (most metrics received a score of three), while forebay scores tended to be very low or very high (metrics received a score of one or five) for most metrics. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI values for both the forebay (RFAI=38) and transition (RFAI=31) were classified as fair, followed by the electrofishing RFAI for the inflow (RFAI=30) which was poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, the middle of the channel under five causeways, both Vital Signs locations, and an area downstream of Guntersville sewage treatment plant were each tested twelve times in 1993 for fecal coliform bacteria. No samples were collected within 48-hours of a rainfall of one-half inch or greater. The sampled swimming beaches were the Camp Barber Boy Scout Camp, and the Camp Trico Girl Scout Camp.

The 1993 survey at the causeways was intended to identify the watersheds having the most potential for affecting the bacteriological water quality in the main channel of Guntersville Reservoir. The other sites were selected to determine the impacts discharges or runoff from urban areas have on Guntersville Reservoir. At all but two sites, the bacteria concentrations were very low (geometric means <20/100 ml). At the Polecat Creek Causeway and at the Crow Creek boat ramp the fecal coliform bacteria samples had geometric mean concentrations of 69 and 67/100 ml, respectively. The lack of rainfall during the sampling period may have resulted in lower concentrations at some sites. For the regular monthly Vital Signs sampling, all fecal coliform concentrations were very low.

Fish Tissue—Composite catfish samples were collected from the forebay, transition zone, and near the inflow in autumn 1992. One reason for resampling was that relatively high PCB concentrations of chlordane and PCBs had been found in 1990 (chlordane levels at the forebay were 0.10 μg/g and those from near the inflow were 0.11 μg/g; whereas, PCB concentrations at these two locations were 1.2 and 1.3 μg/g, respectively). Chlordane was not detected in any of the 1992 samples and PCB concentrations decreased progressively from year to year (maximum 0.9 μg/g in 1991 and 0.4 μg/g in 1992). Other pesticides and metals were relatively low during all years at all locations.

Sequatchie River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Sequatchie River is moderately hard (average hardness of 90 mg/l) and moderately alkaline (average total alkalinity of 74 mg/l). The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 72 to 93 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Sequatchie River ranked among the highest in average concentrations of organic nitrogen (0.372 mg/l) and ammonia nitrogen (0.090 mg/l). It was among the lowest in average total phosphorus with a concentration of 0.022 mg/l. The average nitrate+nitrite-nitrogen (0.42 mg/l) and average dissolved orthophosphate (0.009 mg/l) concentrations ranked mid-way of all station medians. The low average total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 5 samples. However, the concentrations did not exceed the EPA guideline for the protection of aquatic life or human health. Additional metals analyses included total and dissolved forms of iron and manganese. Total iron (2 of 6 samples) and total manganese (1 of 6 samples) exceeded the EPA guideline for combined consumption of fish and water.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. The sediment quality also rated good in 1992.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 44, with 80 taxa and 3,951 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 93 taxa and 2,096 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (38 percent), caddisflies (27 percent), and mayflies (12 percent). Nutrient tolerant oligochaete worms were the dominant group in 1992 (22 percent), followed by dipteran midge larvae (20 percent) and caddisflies (16 percent). Conditions have improved between sampling years. The fair rating (score 44) given for 1993 is borderline good for this site; however, siltation from agricultural land use along the river and coal mining in the Sequatchie watershed continues to impact benthic communities in the river.

Fish Community Assessment—No change was seen as the fish community rated fair with an Index of Biotic Integrity (IBI) score of 42 during both 1993 and 1992. Problems continued to occur in species richness and composition and in fish density. Forty-six to 69 native fish species were expected at this station, but only 38 were found. This loss of diversity was most noticeable among darters and intolerant species. Fish density was one of the lowest found at the 11 stations sampled in 1993. Poor conditions observed at this station were sedimentation of shoreline habitats and occasional bank erosion.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four canoe access sites on the Sequatchie River from river mile 35.6 to 51.3 were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48-hours of a rainfall greater than one-half inch. The geometric mean of fecal coliform bacteria concentrations for all samples at the four sites ranged from 43 to 103/100 ml, all well within the Tennessee bacteriological criterion for recreation. Concentrations were higher in the two rainfall samples.

Fish Tissue—Five freshwater drum, channel catfish, and largemouth bass were collected from the Sequatchie River during summer 1992. Composited fillets for each species were analyzed for selected metals, pesticides, and PCBs. Most analytes were not detected. Those that were had low concentrations.

NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperatures during the April to September monitoring period ranged from a 17.6°C in April to 29.2°C in July at the forebay; and DO at the 1.5m depth ranged from 5.6 mg/l in August to 10.2 mg/l in April at the forebay. At the inflow sampling station site (i.e., the tailrace of Chickamauga dam) a minimum DO of 2.2 mg/l was recorded in July. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only three to four days, results in it being the best mixed of any of the Vital Signs reservoirs. Temperature data reflect a lack of thermal stratification in Nickajack Reservoir in 1993. A maximum surface to bottom temperature differential of 1.8°C was measured at the forebay in May. However, summer DO data reflect a small oxycline in the forebay of Nickajack Reservoir when surface to bottom DO differentials were 3.0, 3.1, 4.8, and 2.1 mg/l, respectively, from May through August. The drought like conditions and low flows also depressed concentrations of oxygen. For example, minimum oxygen concentrations measured at the bottom in the forebay of Nickajack Reservoir were 4.6, 4.7, and 5.0 mg/l, respectively, for 1990, 1991, and 1992. However, in 1993, minimum DO concentrations at the bottom in the forebay of Nickajack Reservoir were 3.0 mg/l. In addition, in late July (between the mid-July and mid-August field surveys), releases from Nickajack Dam were recorded as low as 1.8 mg/l, indicating a short period when DO concentrations in the hypolimnion of the forebay were less than 2 mg/l. Also in July, DO's as low as 2.2 mg/l and frequently in the mid-3's mg/l were measured in the releases from Chickamauga dam (i.e., the inflow to Nickajack Reservoir).

Because DO concentrations were frequently below Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life (5.0 mg/l at the 1.5 meter depth), the DO rated poor at inflow sampling site in the overall ecological health evaluation of Nickajack Reservoir. Based on no DO's actually being measured in the hypolimnion of the forebay of Nickajack Reservoir below 2 mg/l, the forebay sampling site's DO rating was excellent.

Values of pH varied over a rather narrow range, from 7.0-8.0 during the summer of 1993. At the forebay, the highest chlorophyll *a* concentration of about 10 µg/l was measured in May and averaged about 6 µg/l in the summer of 1993. Consequently, the chlorophyll *a* rating used in the 1993 ecological health evaluation for Nickajack Reservoir was good (i.e., average concentration between 3 and 10 µg/l).

Sediment—Chemical analyses of sediments in Nickajack Reservoir in 1993 indicated the presence of chlordane (21 µg/g) from the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the forebay. Particle size analysis showed sediments from the forebay about 92 percent silt and clay.

The sediment quality rating used in the overall Nickajack Reservoir ecological health evaluation for 1993 was good (rather than excellent because chlordane was detected.

Benthic Macroinvertebrates—Both the forebay and inflow sites on Nickajack had excellent benthic macroinvertebrate communities, an improvement from the previous years. The forebay site had 21 taxa and 535 organisms/m^2 with Hexagenia limbata comprising 30 percent of the total. The inflow site had 38 taxa and 1458 organisms/m^2; Cheumatopsyche sp and Tubificidae were dominant, comprising 22 and 19 percent of the total organisms present, respectively.

The forebay site fell short of a perfect score due to a slightly elevated chironomid community, but still received an excellent rating. All other metrics were perfect. The inflow site scored perfect for each metric evaluated, resulting in an excellent benthic community evaluation.

Aquatic Macrophytes—Aquatic plants on Nickajack Reservoir increased from 583 acres in 1992 to 1,000 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species and occurred in mixed colonies or occasionally with other species such as American pondweed and southern naiad. Aquatic macrophytes were most abundant from TRM 425 upstream to TRM 440.

Fish Assemblage—Fish collections in the littoral (30 electrofishing transects) and offshore/benthic areas (16 net-nights) of Nickajack Reservoir found fish to be more concentrated in the inflow zone (2,181) than the forebay (1,337) particularly as indicated by electrofishing results. Although gill netting effort was reduced in the inflow, catch per unit effort (CPUE) was similar between forebay and inflow zones. Bluegill was the most abundant species (29 percent), followed by emerald shiners (20 percent). The majority of the forage base in the Nickajack sample was comprised of several shiner species (golden, emerald, spotfin, and steelcolor) instead of shad, which is unusual for run-of-the-river reservoirs.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish (based on electrofishing results) excellent in the inflow (RFAI=52) and fair in the forebay (RFAI=40) zones of Nickajack Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of piscivorous, sucker, and intolerant species, and percent anomalies. The gill netting RFAI rated the forebay good (RFAI=48). Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the forebay (RFAI=44) was determined to be good. The electrofishing RFAI for the inflow (RFAI=52) was rated excellent. High inflow RFAI indices in 1992 and 1993 indicate Nickajack to have possibly the best fish community among run-of-the-river inflows.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and a boat ramp near Nickajack Dam, and one boat ramp and two informal swimming areas in the North Chickamauga Creek Embayment were tested for fecal coliform bacteria twelve times each in 1993. Two samples at each site were collected within 48-hours of a rainfall of at least one-half inch. The geometric mean of the bacteria concentrations were very low (<20/100 ml) at five of the eight sites. The geometric means at one formal and one informal swimming area was 49 and 31/100 ml, well within Tennessee water quality criterion for recreation. At Smith's Camp-On-The-Lake boat ramp, the geometric mean was 657/100 ml. All the Vital Signs monthly samples at the forebay were 10/100 ml or less.

Fish Tissue—The PCB concentration in channel catfish has averaged about 1.0 μg/g over the last three years. The TDEC has issued a precautionary advisory due to PCB contamination in catfish from

Nickajack Reservoir. This means that children, pregnant women, and nursing mothers should not consume catfish, and all others should limit consumption to 1.2 pounds per month.

Fish tissue studies conducted in autumn 1992 were aimed at examining the long-term trend of PCB concentrations in channel catfish and developing a data base for carp. Ten individuals of both species were collected at two sites, one near the forebay, and the other in the upper end of the reservoir about 13 miles downstream of the inflow. The 1992 study also included collection of striped bass (including hybrid striped bass x white bass) from just downstream of Chickamauga Dam. PCB concentrations in the catfish and carp were substantially reduced (about half) from those previously found. The average for channel catfish was 0.4 and 0.5 μg/g (maximum 0.8 μg/g) at the forebay and upper location, respectively. Concentrations in carp were similar to those in catfish. Highest concentrations were found in striped bass (average 0.8 μg/g and maximum 1.1 μg/g). The reduced concentrations in catfish and carp need to be verified, so these species, along with striped bass, were resampled in autumn 1993. Results were not available at the time this report was prepared.

Chickamauga Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, coolest surface water temperatures in Chickamauga Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.0°C to a maximum of 31.7°C at the forebay; from 16.2°C to 30.1°C at the transition zone; and from 19.1°C to 28.8°C in the Hiwassee River embayment. Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.9 mg/l in September to a high of 11.4 mg/l in April at the forebay; from 5.7 mg/l in September to 10.3 mg/l in April at the transition zone; and from 7.3 mg/l in August to 9.9 mg/l in April at the sampling location in the Hiwassee River embayment. At the inflow sampling site (i.e., the tailrace of Watts Bar dam) a minimum DO of 3.7 mg/l was recorded in August. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict seasonal warming and weak thermal stratification in Chickamauga Reservoir from May through July. The maximum observed surface to bottom temperature differentials (ΔT's), occurred in July. ΔT's were 5.5°C at the forebay, 3.2°C at the transition zone, and 4.1°C in the Hiwassee River embayment. There was also an oxycline at the forebay and transition zone in June and July when differences between surface and bottom DO's (DO's) were about 6 to 9 mg/l at the forebay and transition zone. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at the forebay and a minimum of 1.6 mg/l was measured on the bottom at the transition zone. Better DO conditions were observed in the Hiwassee River embayment portion of Chickamauga Reservoir, where maximum DO's were only 1.7 mg/l and near bottom DO's only slightly below 6 mg/l.

DO ratings used in the overall reservoir ecological health evaluation for Chickamauga Reservoir were good at the forebay; good to excellent at the transition zone; excellent in Hiwassee River embayment; and fair at the inflow. The forebay would have rated higher had it not been for the low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Chickamauga Reservoir was a result of oxygen levels being measured about 1.5 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Watts Bar dam.

Values of pH ranged from 6.8 to 8.8 on Chickamauga Reservoir, in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed on only two occasions (April and July), both at the forebay. Both of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Total nitrogen (TN), total phosphorus (TP), and dissolved ortho phosphorus (DOP) were low in the Tennessee River portion of Chickamauga Reservoir in 1993. TN averaged only 0.37 mg/l at the forebay, the lowest TN concentration measured at any of the Tennessee River sampling sites in 1993. At both the forebay and the transition zone, TP and DOP concentrations averaged only about 0.026 mg/l and 0.005 mg/l, respectively, and were among the lowest TP and DOP concentrations measured at any of the Tennessee River sampling sites in 1993. Because of these low concentrations (and because TN/TP ratios often exceeded 20), periods of phosphorus limitation on algal productivity were likely to have occurred.

In 1993, Chickamauga Reservoir chlorophyll *a* concentrations averaged 8.5 μg/l, 7.8 μg/l, and 5.5 μg/l, respectively, at the forebay, transition zone, and Hiwassee River embayment. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Chickamauga Reservoir were good (i.e., falling in the 3 to 10 μg/l range) at all three locations.

Sediment Quality—As in 1990, 1991, and 1992, chemical analyses of sediments from Chickamauga Reservoir in 1993 found high levels of copper (64 mg/kg) and zinc (320 mg/kg) in the forebay. High levels of copper (50 mg/kg) were also found in the Hiwassee River embayment, which was sampled for the first time in 1993. Chlordane was also detected in the forebay (16 μg/g) and the transition zone (15 μg/g). Toxicity tests indicated no acute toxicity to either species from the three sites tested, but survival of rotifers (75 percent survival) was reduced in the transition zone. Toxicity to rotifers was detected in both forebay and transition zone samples in 1992. Particle size analysis showed sediments from the forebay were 97 percent silt and clay; from the transition zone were 86 percent silt and clay, 14 percent sand; and from the Hiwassee River embayment were 63 percent silt and clay, 37 percent sand.

Sediment quality ratings used in the overall Chickamauga Reservoir ecological health evaluation for 1993 were fair at the forebay (presence of copper, zinc and chlordane); fair at the transition zone (presence of chlordane and reduced survival of rotifers); and, good in the Hiwassee River embayment (presence of copper).

Benthic Macroinvertebrates—The forebay and transition zone sites had excellent benthic communities, and the inflow site was fair. The Hiwassee embayment, a major component of Chickamauga Reservoir, was also included in the ecological health rating. It was shown to support a good benthic community. The forebay site had 19 taxa and 847 organisms/m^2. The most numerous taxa collected were the chironomid Coelotanypus sp (29 percent), the mayfly Hexagenia limbata (20 percent), the asiatic clam Corbicula fluminea (19 percent) and Tubificidae (17 percent). The transition zone was represented by 25 taxa and 897 organisms/m^2 with Hexagenia limbata comprising 26 percent of the total organisms and Tubificidae comprising 18 percent of the total organisms. The inflow had 21 taxa and 845 organisms/m^2. Gammarus fasciatus, an amphipod, was the dominant species present comprising 36 percent of the total organisms. The Hiwassee embayment had the greatest diversity and abundance of organisms than any other site on Chickamauga Reservoir. It had 2312 organisms/m^2 representing 49 species; Tubificidae were the dominant taxa collected (36 percent) followed by the snail Musculium transversum (17 percent).

The forebay on Chickamauga supported an excellent benthic community, however, the overall benthic score was lowered due to an elevated chironomid community and lowered EPT community. The transition zone also received an excellent rating but fell short of perfect because of an elevated chironomid community and lowered numbers of long-lived taxa. The inflow site rated fair primarily because of an absence of long-lived organisms such as Corbicula sp and Hexagenia sp, and because of reduced diversity and EPT taxa present. The Hiwassee embayment supported a good benthic community in 1993 because of an excellent EPT representation, diversity, low numbers of Chironomids, and evenness of the dominant species. An abundance of tubificids and a lack of long-lived species contributed to this site receiving a good rating instead of an excellent rating.

Aquatic Macrophytes—Coverage of aquatic macrophytes increased from 387 acres in 1992 to 1,185 acres in 1993. Most macrophytes were in Dallas Bay embayment and in small embayments and overbank habitat upstream of TRM 499. Aquatic macrophytes on Chickamauga Reservoir peaked at about 7,500 acres in 1988 and continuously declined until 1993 when coverage increased. Spinyleaf and southern naiad were the dominant species in 1993 although small colonies of Eurasian watermilfoil, American pondweed, and American lotus also were present.

Fish Assemblage—Fish data collected in littoral (45 electrofishing transects) and offshore zones (28 net-nights) of the forebay resulted in the collection of 44 species (6,994 individuals). Emerald shiner was the most abundant species (collected at the rate of 56 per 300 meter electrofishing transect), accounting for 36 percent of the total number of fish collected. Gizzard shad comprised 16 percent of the sample, followed closely by bluegill at 14 percent. Electrofishing results showed approximately twice as many individuals in the inflow (2,624) and transition (2,300) zones as the forebay (1,229), due to numbers of gizzard shad and bluegill in the sample. Numbers of YOY threadfin shad followed a similar pattern with high catch rates in the forebay (CPUE=810 per 300m transect) and transition (CPUE=1,707 per 300m transect) and very high catch rates in the inflow zone (CPUE=3,559 per 300m transect). Gill netting fish abundance was higher in the transition (454) than the forebay (229); although abundance at the inflow zone (158) was lower because of reduced effort, catch rate was similar to the transition zone.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), good in the transition (RFAI=46), and excellent in the inflow (RFAI=52) zones of Chickamauga Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of sucker and tolerant species, dominance by a single specie, and percent anomalies. In 1992 the inflow rated only fair (RFAI=34).

The gill netting RFAI rated the transition zone excellent (RFAI=52) and the forebay fair (RFAI=36). The excellent score of 52 in the transition zone was the second highest ever observed for run-of-the-river reservoirs and resulted from maximum scores for all metrics except number of sucker, intolerant, and lithophilic spawning species, and percent insectivores. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the transition (RFAI=49) and forebay (RFAI=34) were rated good and fair, respectively. The electrofishing RFAI for the inflow (RFAI=52) zone received an excellent rating, which was one of the highest scores for all inflows sampled in 1993.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (12 net-nights) produced a total of 2263 individuals including 31 species in the Hiwassee River embayment of Chickamauga Reservoir. The three most abundant species were redear sunfish (29 percent), gizzard shad (19 percent), and bluegill (16 percent). There were six times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of sunfishes inhabiting shoreline areas.

The electrofishing RFAI score of 36 rated the embayment community as fair and gill netting results indicated good (RFAI=50) fish community conditions. Combining RFAI scores (RFAI=43) rated the Hiwassee River embayment good (scoring criteria for run-of-the-river transition was used to obtain RFAI ratings). Metrics for both electrofishing and gill netting that influenced the high scoring included low percent dominance by a single species, low percent omnivores, and high numbers of lithophilic spawning species.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Chickamauga Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Hiwassee River Embayment, were all 10/100 ml or less except for one sample. The April sample in the Hiwassee River Embayment had a concentration of 300/100 ml.

Fish Tissue—There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA priority pollutant list). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 µg/g at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 µg/g at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

HIWASSEE RIVER WATERSHED

Hiwassee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Hiwassee Reservoir was about 107 percent of normal and the average residence time was about 99 days. The reservoir was strongly stratified with a maximum temperature difference in the water column at the forebay of 20.9°C in July. The maximum surface temperature was 28.7°C in July, both at the forebay and mid-reservoir. North Carolina's standard for maximum temperature of Class C waters is 29°C. Low DO water (DO <5.0 mg/l) first appeared at mid-reservoir in June and at the forebay in July at the bottom of the water column at both locations. Depleted DO water (DO < 2.0 mg/l) occurred at both locations at the bottom of the water column in August and September. The limited area of DO depletion provided ratings for the reservoir ecological health index of fair at the forebay and good at mid-reservoir.

Conductivities averaged about 30 µmhos/cm in April, increased slightly in the DO-depleted area to a maximum of 40 and 38 µmhos/cm at the forebay and mid-reservoir, respectively. The average conductivity in Hiwassee Reservoir was the fourth lowest of the 19 tributary reservoirs. Only in June, July, and August did pH reach or exceed 8.4, and only in the four to eight meter depth. Summer DO concentrations were normally higher at these depths.

The organic nitrogen concentration, in April and August respectively, was 0.12 and 0.26 mg/l at the forebay, and 0.14 and 0.09 mg/l at mid-reservoir. The April nitrate-nitrogen concentration was 0.12 and 0.10 mg/l at the forebay and mid-reservoir, respectively. The August concentrations were <0.01 mg/ at both locations. Total phosphorus concentrations were 0.007 mg/l in April and 0.002 mg/l in August at both locations. Dissolved ortho phosphorus concentration was 0.01 mg/l in April at mid-reservoir, and otherwise <0.002 mg/l.

These low concentrations of nutrients resulted in low concentrations of total organic carbon and chlorophyll and high water clarity. Total organic carbon concentrations were 0.9 mg/l in April and approximately double that in August at both locations. Chlorophyll *a* concentrations averaged 2.2 µg/l at the forebay (third lowest of 19 tributary reservoir forebays) and 3.7 µg/l at mid-reservoir. The chlorophyll concentrations rated fair at the forebay and good (near the low end of the range) at mid-reservoir for the reservoir ecological health index. Hiwassee Reservoir water clarity was the third highest of the tributary reservoir forebays, and the highest of all tributary mid-reservoir stations. Secchi depths varied from 2.4 m at both locations in April, to 5.1 m at mid-reservoir and 5.6 m at the forebay in July.

Sediment Quality—Chemical analyses of sediments in Hiwassee Reservoir in 1993 indicated the presence of chlordane in the forebay (15 µg/g) and mid-reservoir (16 µg/g). Toxicity tests detected acute toxicity to daphnids in both forebay (15 percent survival) and mid-reservoir (10 percent survival) samples. Toxicity to rotifers was also detected in the mid-reservoir (65 percent survival). Particle size analysis showed sediments in the forebay were 99 percent silt and clay, and in the mid-reservoir were 90 percent silt and clay.

Sediment quality ratings used in the overall Hiwassee Reservoir ecological health evaluation for 1993 were poor at the forebay (due to toxicity to daphnids and presence of chlordane) and poor at the mid-reservoir site (due to toxicity to daphnids and rotifers and presence of chlordane).

Benthic Macroinvertebrates—Until 1993, no TVA data on the benthic macroinvertebrate community in Hiwassee Reservoir existed. Sampling revealed that the forebay and mid-reservoir sites had poor benthic communities, and the inflow had a fair benthic community. The forebay site had 5 taxa and 127 organisms/m^2 and was dominated by Tubificidae (86 percent). The mid-reservoir site had 11 taxa and 2,111 organisms/m^2 with Tubificidae as the dominant taxon comprising 86 percent of the total. The Hiwassee inflow had the greatest number of taxa (16) and had 1,605 organisms/m^2. Tubificidae (61 percent) was the dominant taxon followed by Procladius sp (21 percent).

The Hiwassee forebay and mid-reservoir benthic samples rated poor due to low diversity, an absence of EPT and long-lived taxa, and an abundance of tubificids. The inflow fared better than the previous sites, but still rated only fair.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (36 net-nights) from the three zones of Hiwassee Reservoir resulted in the collection of 2,958 fish including 27 species. When green sunfish (39 percent of total catch) were disregarded, the dominant taxa by number in the remaining sample were bluegill (43 percent), gizzard shad (9 percent), smallmouth bass (8 percent), white bass (7 percent), and black crappie (6 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (952) and transition (931) zones with considerably lower numbers in the inflow (326) zone.

The Reservoir Fish Assemblage Index (RFAI) showed the littoral fish community (based on results of electrofishing samples) to be poor in all three sample zones of Hiwassee Reservoir (forebay RFAI=28, transition RFAI=26, and inflow RFAI=28). Gill netting RFAI results rated all three zones good (forebay RFAI=50, transition RFAI=46, and inflow RFAI=42).

The trophic composition metric group showed maximum scores for both gear types; all other metric group scores generally reflected the total RFAI score. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=39), transition (RFAI=36) and inflow (RFAI=35)zones were rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Hiwassee Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Chatuge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Chatuge Reservoir in 1993 was about 88 percent of normal. The average residence time was 291 days. The reservoir was strongly stratified, with a maximum temperature difference of 19.1°C in the water column at the forebay in July. The maximum surface temperature was 29.0°C at the forebay and 28.6°C in Shooting Creek Embayment, both measurements in July. North Carolina's standard for maximum temperature of Class °C waters is 29°C. At both locations, low DO (<5.0 mg/l) conditions began developing at the bottom of the water column in July, and depleted DO (<2.0 mg/l) conditions occurred from August through October. Depleted DO conditions also occurred in the metalimnion at the forebay in September. The limited extent of the area of DO depletion gave the forebay a good rating and Shooting Creek Embayment a fair rating in the reservoir ecological health index.

Conductivities were the fourth lowest of the 19 tributary reservoirs, averaging about 25 μmhos/cm in April. Conductivities decreased slightly in the photic zone (supersaturated with DO) in the summer and increased to a maximum of 45 μmhos/cm at the bottom of the water column at the forebay in September. The only time pH exceeded 8.0 was in June and July from the four to eight meter depth. The minimum pH was 5.8 at the forebay and 5.9 in Shooting Creek Embayment, both in September.

Organic nitrogen concentrations increased from April to August at both locations, 0.04 and 0.23 mg/l at the forebay and 0.09 and 0.30 mg/l in Shooting Creek Embayment. Nitrate concentrations dropped from 0.09 to <0.01 mg/l at both locations. Total phosphorus concentrations at the two sites tied for the third lowest concentrations of the 33 tributary reservoir stations. The maximum concentration was 0.004 mg/l in Shooting Creek Embayment in April. Consequently, TN/TP ratios were very high, ranging from 47 at the forebay in April to 160 in Shooting Creek Embayment in August. Total organic carbon concentrations were low, 0.8 and 0.7 mg/l in April, and 1.5 and 1.8 mg/l in August at the forebay and Shooting Creek Embayment, respectively. Chlorophyll *a* concentrations averaged 2.8 μg/l at both locations. This concentration is in the range considered fair in the reservoir ecological health index. Chatuge had the fourth clearest water of the tributary reservoirs. Secchi depths varied from 2.4 m in August to 4.6 m in July in Shooting Creek Embayment, and from 3.1 m in April and August to 4.4 m in July at the forebay.

Sediment Quality—Chemical analyses of sediments in 1993 indicated high levels of chromium (89 mg/kg), copper (56 mg/kg) and nickel (48 mg/kg) in the Shooting Creek forebay area of Chatuge Reservoir. Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the Hiwassee River forebay. Toxicity to daphnids (50 percent survival) was also detected in the water column in this forebay. Reduced survival of daphnids was also detected (60 percent survival) in the Shooting Creek forebay water column. Particle size analysis showed sediments in the forebay were about 75 percent silt and clay, 25 percent sand. In the Shooting Creek forebay sediments were 99 percent silt and clay.

Sediment quality ratings used in the overall Chatuge Reservoir ecological health evaluation for 1993 were fair at the Hiwassee River forebay sampling site (toxicity to daphnids in both water and sediment); and also fair at the Shooting Creek forebay sampling site (presence of chromium, copper, and nickel and reduced survival of daphnids).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Chatuge Reservoir was 1993. Two forebay sites were chosen on Chatuge, and both had good benthic communities. The first forebay site, at HiRM 122.0, had 1,431 organisms/m^2 representing 22 taxa; Tubificidae was the dominant taxon comprising 52 percent of the total. The other site, at Shooting Creek mile 1.5, had 23 taxa and 1,065 organisms/m^2 with Tubificidae (37 percent) and the chironomid Zalutschia zalutschicola (19 percent) as the dominant taxon.

Both forebay sites had excellent diversity and excellent EPT representations, and an average amount of long-lived organisms in the community. The Shooting Creek site suffered slightly from an above average density of tubificids, and the HiRM 122 site was slightly impacted from an above average density of chironomids.

Fish Assemblage—Electrofishing samples (30 transects) in shoreline areas and experimental gill netting samples (24 net-nights) offshore collected 1,999 individuals with 20 species represented. Bluegill was the most abundant taxon in Chatuge Reservoir (47 percent of total fish sampled). Redbreast sunfish (19 percent), spotted bass (7 percent), white bass (5 percent), and gizzard shad (5 percent) followed in order of density. Note: Three percent of the total sample was comprised of snail bullheads which is the first documentation of this species in a TVA reservoir. Electrofishing catch rates were much higher in the forebay zone (78 per 300m transect) than the Shooting Creek arm (32 per 300m transect). However, gill netting catch rates were similar between the two stations.

The Reservoir Fish Assemblage Index (RFAI) rated both the forebay and Shooting Creek sites fair for electrofishing (Forebay RFAI=36 and Shooting Creek RFAI=32) and gill netting (forebay RFAI=34 and Shooting Creek RFAI=32) samples. The only metric grouping with consistently high scores was trophic composition (percent omnivores and insectivores) in the electrofishing sample. Combined electrofishing and gill netting RFAI's rated both areas fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Chatuge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Nottely Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Nottely Reservoir in 1993 was about 90 percent of normal, with an average residence time of 228 days. The reservoir was stratified from April through September, with a maximum temperature difference in the water column at the forebay of 18.9°C in July. The maximum surface temperature was 29.3°C at both the forebay and mid-reservoir in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. In June, low DO (<5.0 mg/l) conditions began developing in the forebay bottom waters, while depleted DO (<2.0 mg/l) conditions had already developed at mid-reservoir. An area of depleted DO developed at the forebay in July, and remained at both locations through September. The extensive areas of depleted DO gave both locations poor ratings for DO in the reservoir ecological health index. The vertical mixing of the reservoir in October eliminated areas of low DO. The area of DO depletion extended to within 7 meters of the surface in July at mid-reservoir.

Conductivities were the fifth lowest of the 19 tributary reservoirs, with an average of about 30 µmhos/cm in April, decreased slightly in the supersaturated (DO) photic zone in the summer and increased to a maximum of 49 and 79 µmhos/cm in September at the bottom of the water column at the forebay and mid-reservoir, respectively. The only time pH exceeded 8.0 was in June and July. The highest values at the forebay were from the 4 to 7 m depth, and from the 3 to 5 m depth at mid-reservoir. The maximum pH was 8.8 at both locations. The minimum pH was 5.9 in the depths at both locations from July to September.

Organic nitrogen concentrations were 0.14 mg/l in April at both locations, and 0.17 and 0.13 mg/l in August at the forebay and mid-reservoir, respectively. Nitrate-nitrogen concentrations were 0.12 and 0.15 mg/l in April at the forebay and midreservoir, respectively, dropping in <0.01 mg/l in August at both locations. Total phosphorus concentrations at both locations were 0.02 mg/l in April, dropping to 0.005 and 0.008 mg/l in August at the forebay mid-reservoir, respectively. Dissolved ortho phosphorus ranged from a maximum concentration of 0.004 mg/l in April at mid-reservoir to a minimum of 0.002 mg/l at both locations in August. Total organic carbon concentrations varied from a low of 1.2 mg/l in April to a maximum of 2.2 mg/l in August, both at mid-reservoir. Chlorophyll *a* concentrations averaged 3.4 µg/l at the forebay and 5.0 µg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index. Secchi depths varied from 1.4 m in April at both locations, to 4.2 and 2.4 m in June at the forebay and mid-reservoir, respectively.

Sediment Quality—Chemical analyses of sediments in Nottely Reservoir in 1993 did not reveal any metal or organic analytes to be of concern. Toxicity tests detected acute toxicity to daphnids (70 percent survival) and rotifers (60 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 89 percent silt and clay, 11 percent sand; and in the mid-reservoir were about 100 percent silt and clay.

Sediment quality ratings used in the overall Nottely Reservoir ecological health evaluation for 1993 were fair at the forebay sampling site (toxicity to daphnids and rotifers); and excellent at the mid-reservoir sampling site.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Nottely Reservoir was 1993. The forebay site, which had a poor benthic community, had 11 taxa, 452 organisms/m^2, and was dominated by Tubificidae (50 percent) and Chironomus sp (29 percent). The inflow site had a good benthic community. There were more taxa (20) and a greater density (933 organisms/m^2) than at the forebay site. Tubificidae (34 percent), Chironomus sp (26 percent), and Procladius sp (23 percent) dominated the benthic community.

A deficiency of EPT taxa and long-lived organisms were the two primary contributing factors for the poor benthic community at the forebay. Elevated numbers of chironomids and tubificids also contributed to the poor rating. At the inflow, an opposite scenario surfaced: EPT and long-lived taxa had an excellent representation, and the tubificid metric was excellent, therefore contributing to a good benthic community structure.

Fish Assemblage—Only the forebay of Nottely Reservoir was sampled in fall 1992. However, in 1993 a transition zone sample was added to better assess the quality of the fish community. Shoreline electrofishing (30 transects) in the littoral zone and experimental gill netting (24 net-nights) in the offshore/deeper areas collected 2,275 individuals with 20 species represented. The four most abundant species represented in the samples were bluegill (63 percent), black crappie (6 percent), green sunfish (5 percent), and carp (5 percent). Electrofishing results indicated the primary forage available in Nottely consisted of sunfish species (69 percent of total catch) instead of shad, as is usually the case.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition zone (RFAI=36) and poor in the forebay (RFAI=30) of Nottely Reservoir. Generally low metric scores in both zones were directly related to low species diversity. Both areas (transition RFAI=32, and forebay RFAI=34) of Nottely were rated fair by gill netting RFAI analysis. When electrofishing and gill netting RFAI scores are combined both forebay (RFAI=32) and transition (RFAI=34) zones rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Nottely Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Blue Ridge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The flow through Blue Ridge Reservoir in 1993 was about normal, with an average residence time of about 156 days. The reservoir was thermally stratified from April through September; there was no sampling in October. The maximum temperature difference in the water column was 17.7°C, and the maximum surface temperature was 29.8°C, both in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. Low DO (<5.0 mg/l) conditions developed in August; the lowest DO measured was 3.4 mg/l in September. The absence of an area of depleted DO gave Blue Ridge a good rating for DO in the reservoir ecological health index.

Conductivities averaged about 20 µmhos/cm, the lowest of the 19 tributary reservoirs, and showed little stratification. The maximum pH was 8.8 at the 7 m depth in July. The minimum pH was 5.6 at the 20 m depth in September.

Organic nitrogen concentrations were 0.04 and 0.08 mg/l in April and August, respectively. Nitrate-nitrogen concentrations decreased from 0.06 to <0.01 mg/l from April to August. Total and dissolved ortho phosphorus concentrations were 0.003 for both in April, and 0.004 and <0.002 in August. Total organic carbon concentrations went from 0.7 mg/l in April to 1.5 mg/l in August, tied for the second lowest concentrations in the tributary reservoirs. Chlorophyll *a* concentrations were the second lowest of the 33 tributary reservoir stations, averaging 1.8 µg/l. This concentration is in the fair range in the reservoir ecological health index. Water clarity was the second highest of the tributary reservoir forebays, with Secchi depths varying from 3.4 meters in April to 5.4 meters in June.

Sediment Quality—Chemical analyses of sediments in Blue Ridge Reservoir in 1993 did not reveal any metals or organic analytes to be a concern. Toxicity tests detected acute toxicity to daphnids (20 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 95 percent silt and clay.

Because of the toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 Blue Ridge Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Blue Ridge Reservoir was 1993. The forebay, the only sample location, had an excellent benthic fauna, with 1,308 organisms/m^2 representing 23 taxa. The dominant taxa were Pisidium sp (33 percent), Procladius sp (21 percent), Spirosperma nikolskyi (18 percent), and Tubificidae (17 percent). This site received good scores for five of the six metrics: diversity, number of EPT taxa, number of chironomids, number of tubificids, and evenness of dominant species. Depressed numbers of long-lived taxa was the only metric that rated fair.

Fish Assemblage—Only the forebay of Blue Ridge Reservoir was sampled in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 856 individuals with 15 species represented. By far the predominant species captured was bluegill (59 percent) followed distantly by white bass (10 percent), smallmouth bass

(8 percent), and redbreast sunfish (5 percent). There were three times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of bluegill inhabiting shoreline areas.

The electrofishing RFAI score of 28 rated poor and gill netting results indicated fair (RFAI=34) fish community conditions. The combined RFAI scores (RFAI=31) rated the Blue Ridge forebay fair. Scoring for both electrofishing and gill netting RFAI metrics was influenced by low diversity, low catch, and dominance by a single species (bluegill).

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Blue Ridge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Ocoee Reservoir No. 1 (Parksville Reservoir)

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 91 percent of normal. The high elevation outlet at the dam allows the hypolimnetic water to remain in place all spring and summer. In October, the bottom temperature was 7.7°C. The very cold bottom temperatures mean that the reservoir was strongly stratified; there was a temperature difference in the water column of 21.4°C in July. The maximum surface temperature was 28.7°C in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. Very little DO depletion occurs in the reservoir; the minimum DO during the survey was 5.8 mg/l at the bottom in October. The maximum DO saturation was 108 percent at the surface in May. The lack of low DO in the reservoir resulted in a good rating for DO in the reservoir ecological health index.

Conductivities were low, usually between 50 and 60 μmhos/cm with little stratification. The lack of DO depletion and low primary productivity resulted in little variation in pH, which varied from 7.5 to 6.3.

Concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll were all among the lowest six of the 33 tributary reservoir stations. Organic- and nitrate-nitrogen concentrations were 0.03 and 0.09 mg/l in April, and 0.06 and 0.04 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.005 and 0.003 mg/l in April, and 0.002 and <0.002 mg/l in August. Total organic carbon concentrations were very low, 0.8 and 1.4 mg/l in April and August, respectively. Chlorophyll *a* concentrations averaged 2.5 μg/l. This chlorophyll concentration is considered fair in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 3.6 m in July, September, and October.

Sediment Quality—Chemical analysis of sediments in Parksville Reservoir in 1993 indicated extremely high levels of copper (1,500 mg/kg), lead (1,300 mg/kg) and zinc (1,500 mg/kg) in the forebay sediment. Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (10 percent survival) at an upper reservoir site sampled only for sediments (not included in the overall ecological health score). Acute toxicity to daphnids and rotifers was also detected in near bottom water collected at the forebay (0 and 20 percent survival, respectively); and at the upper reservoir sampling site (0 percent survival for both species). Particle size analysis showed sediments in the forebay were 99 percent silt and clay. No chemical analyses or particle size analyses were conducted for the upper reservoir sediment sample.

Because of the acute toxicity of the forebay bottom water to daphnids and rotifers and the very high concentrations of copper, lead, and zinc found in the forebay sediment, a poor sediment quality rating was used in the overall 1993 Parksville Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Only one site was chosen for sampling the first year on Ocoee No. 1, located in the forebay. The benthic community there was poor, with only 10 taxa, 372 organisms/m^2, and dominated by Tubificidae (65 percent) and Limnodrilus hoffmeisteri (27 percent). This site rated poor on 3 of the 5 metrics: number of EPT taxa, number of long-lived taxa, and proportion of tubificids. It received a good score only on the proportion of chironomids metric, and diversity was fair.

Fish Community—Only the forebay of Parksville Reservoir was sampled in fall 1993. Shoreline electrofishing (15 transects) and offshore netting (12 net-nights) produced a total of 524 individuals including 15 species. Bluegill and largemouth bass were the most abundant species collected, comprising 76 and 7 percent of the total sample, respectively. Channel catfish (4 percent) and yellow perch (3 percent) were also frequently encountered.

The electrofishing Reservoir Fish Assemblage Index (RFAI) rated the Parksville littoral fish community as poor (RFAI=28) and the gill netting RFAI rated the limnetic bottom fish community as very poor (RFAI=20).

Overall RFAI analysis (combined electrofishing and gill netting) determined that the quality of the reservoir fish community was poor. The Parksville Reservoir forebay RFAI of 24 was the lowest recorded for storage reservoir forebays, receiving minimum scores for seven of the twelve metrics utilized for the electrofishing RFAI analysis, and ten of the twelve metrics analyzed for gill netting.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—There are no fish consumption advisories on Parksville Reservoir. However, screening studies conducted 1987 through 1991 consistently found relatively high PCB concentrations (about 1.0 µg/g) and higher than expected selenium concentrations (about 1.0 µg/g) at the forebay. Because of the consistently elevated PCB concentrations, TVA, TDEC, and TWRA designed and conducted a more intensive effort on Parksville Reservoir for autumn 1992. The study included individual analyses on channel catfish and largemouth bass from the forebay and upper reservoir area and composite analysis of bluegill sunfish from both areas and rainbow trout from the lower portion of the reservoir. PCBs, chlordane, selenium, and mercury were the analytes of interest. Results generally fell along expected lines. PCB concentrations in channel catfish were relatively high (averages 1.5 and 1.0 µg/g and maxima 3.0 and 1.9 µg/g at the forebay and upper locations, respectively). PCB concentrations in largemouth bass were not as high (averages 0.6 and 0.7 µg/g and maxima 1.7 and 2.0 µg/g at the forebay and upper location, respectively). PCB concentrations in the bluegill and trout composites were only slightly above detection limits. Chlordane and mercury concentrations were low or not detected in all samples. Selenium concentrations fell generally as expected (around 1.0 µg/g). At the time this report was prepared, no action had been taken on these results. Additional composite samples of channel catfish from the forebay and inflow areas were collected in autumn 1993, but results were not available at the time this report was prepared.

Hiwassee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Hiwassee River is soft (average hardness of 15 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.2. The river was well oxygenated with dissolved oxygen levels remaining around 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Hiwassee River ranked among the lowest average concentrations of organic nitrogen (0.089 mg/l), nitrate+nitrite-nitrogen (0.16 mg/l), and total phosphorus (0.025 mg/l). It ranked near the middle in average ammonia nitrogen (0.030 mg/l) and dissolved orthophosphate (0.007 mg/l) concentrations. The low total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. One sample exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline only for chronic toxicity to aquatic life.

Sediment— Sediment quality rated good in 1993 with no acute toxicity observed. No PCBs or pesticides exceeded the EPA guidelines; however, nickel exceeded the EPA guidelines. This is an improvement over 1992 when the sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 38, with 81 taxa and 828 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 34) with 65 taxa and 953 organisms/m^2; however, the MBIBI score of 34 was very close to a poor rating. Dominant organisms in 1993 were dipteran midge larvae (33 percent), caddisflies (18 percent), and mayflies (13 percent). Dipteran midge larvae was the most dominant organism in 1992 (28 percent), followed by the Asian clam Corbicula (20 percent) and caddisflies (14 percent). Regulated stream flows and cold water releases from Appalachia Powerhouse stress warmwater benthic communities in the river.

Fish Community Assessment—No meaningful change was seen in the fish community as ratings for both 1993 and 1992 were good with Index of Biotic Integrity (IBI) score 48 each year. Limited deficiencies in number of native species, numbers of darter and sunfish species, proportion of fish as specialized insectivores, and fish density indicated less than optimum conditions. Problems found in the fish community may be partially attributed to altered flows due to releases from Apalachia Powerhouse.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected in 1993.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth was collected during summer and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations. The only analyte high enough to be noteworthy was PCBs in carp with a slightly elevated concentration of 0.6 μg/g.

WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

Watts Bar Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, surface water temperatures ranged from a minimum of 18.3°C in April to a maximum of 30.2°C in July in the forebay; and from 16.7°C to 29.8°C (for the same months) at the transition zone. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Values for DO at the 1.5m depth ranged from a low of 6.5 mg/l in September to a high of 12.6 mg/l in April at the forebay, and from 7.1 mg/l to 11.3 mg/l (for the same months) at the transition zone. At the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir (i.e. the tailrace of Fort Loudoun dam) a minimum DO of 3.9 mg/l was recorded in September. At the inflow sampling site on the Clinch River arm of Watts Bar Reservoir (i.e., the tailrace of Melton Hill dam) a minimum DO of 6.3 mg/l was recorded in March. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993. For the period April through August, monthly surface to bottom temperature differentials (ΔT's) were: 5.2°C, 5.5°C, 7.4° C, 7.3°C, and 4.0°C at the forebay; and 2.3°C, 2.6°C, 3.9°C, 6.2°C, and 2.2°C at the transition zone.

DO versus depth data show that a rather strong oxycline also developed in Watts Bar Reservoir, particularly from June through August. During these three months, surface to bottom differences in DO were: 9.2 mg/l, 9.2 mg/l, and 5.8 mg/l at the forebay; and 7.2 mg/l, 5.8 mg/l, and 3.1 mg/l at the transition zone. At the forebay, near bottom DO concentrations in the hypolimnion were less than 2 mg/l in June and July. In addition, the proportion of the hypolimnion with low DO's (i.e. less than 2 mg/l) averaged about 13 percent of the total cross sectional area, higher than in any other Tennessee River reservoir. The minimum observed DO concentration in Watts Bar Reservoir in 1993 was 0.6 mg/l at the bottom of the forebay in July, but DO's were never less than 4 mg/l at the transition zone.

DO ratings used in the overall reservoir ecological health evaluation for Watts Bar Reservoir were poor at the forebay; excellent at the transition zone and at the inflow sampling site on the Clinch River; and fair at the inflow site on the Tennessee River. The low forebay rating was due to the large proportion of the forebay hypolimnion with low DO concentrations (i.e., less than 2 mg/l). The fair rating at the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir was a result of oxygen levels being measured about 1 mg/l, below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Fort Loudoun dam.

Historically, the pH's of water in Watts Bar Reservoir has been higher than other Tennessee River sampling site. This is due to the addition of the cool, clear, well oxygenated, nitrate rich, and hard water of the Clinch River which combines with the Tennessee River (and Watts Bar Reservoir) at TRM 567.9, about seven miles upstream from the transition zone sampling site. In the summer of 1993, values of pH ranged from 6.8 to 9.0 on Watts Bar Reservoir. During much of the April-September sample period, near surface values of pH frequently exceeded 8.5 at both the forebay and the transition zone, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.035 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations in 1993. In addition, the average dissolved ortho phosphorus concentrations of 0.007 mg/l and 0.004 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1993. TN/TP ratios on Watts Bar Reservoir are higher than on any other Tennessee River reservoir. The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly at the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The highest chlorophyll *a* concentrations were measured in August at the forebay (10 µg/l) and in May at the transition zone (11 µg/l). Surface concentrations of chlorophyll *a* averaged about 7 µg/l at the forebay and about 8 µg/l at the transition zone in 1993. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Watts Bar Reservoir were good (i.e., falling in the 3 to 10 µg/l range) at both locations.

Forebay Secchi depth and suspended solids measurements averaged 1.5 m and 6.3 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1993.

Sediment—Chemical analyses of sediments in Watts Bar Reservoir in 1993 indicated elevated levels of un-ionized ammonia (240 µg/l) in the forebay, and the presence of chlordane (18 µg/kg) in the transition zone. Mercury was also detected at the transition zone at a slightly elevated level (0.72 mg/kg), but at a level below sediment quality guidelines for mercury (i.e. 1.0 mg/kg). Toxicity tests detected acute toxicity to daphnids and rotifers (40 percent survival each) in the forebay. The forebay was also toxic to rotifers in 1992. Particle size analysis showed sediments from the forebay were near 100 percent silt and clay; and 98 percent silt and clay from the transition zone.

Sediment quality ratings used in the overall Watts Bar Reservoir ecological health evaluation for 1993 were "poor" at the forebay (acute toxicity to test animals and presence of ammonia); and "good" at the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone fair, and both the Tennessee River and Clinch River inflow sites had poor benthic communities. The forebay on Watts Bar had 805 organisms/m^2 representing 18 taxa; the dominant species were the chironomids Chironomus sp (32 percent) and Coelotanypus tricolor (16 percent). The transition zone had 14 taxa and 1,280 organisms/2 with the snail Musculium transversum (34 percent), the mayfly Hexagenia limbata (27 percent) and the chironomid Chironomus sp (17 percent) as the dominant species present. The Tennessee River inflow site had 314 organisms/m^2 representing 20 taxa; Corbicula fluminea was the dominant species comprising 71 percent of the total organisms. The Clinch River inflow site had 145 organisms/m^2 made up of 16 taxa; Corbicula fluminea (49 percent), Pseudochironomus sp (18 percent) and Tubificidae (18 percent), were the dominant taxa.

The Watts Bar forebay scored well on all metrics except for the paucity of EPT taxa and the preponderance of chironomids. Those two factors kept this site from obtaining an excellent rating. The transition zone exhibited a fair community. Reduced diversity, minimal numbers of long-lived species, above average numbers of chironomids, and unevenness associated with the dominant species all contributed to the fair rating this site received. The Tennessee River and Clinch River inflow sites both had a poor benthic communities because of the lack of diversity, EPT taxa, and long-lived species. The unevenness of dominant taxa also negatively impacted these benthic communities. Interestingly, the percent of the total organisms comprised of tubificids and chironomids, normally considered tolerant organisms, was relatively low at both inflows.

Aquatic Macrophytes—Aquatic plants have declined from about 700 acres in the late 1980's to an estimated 10 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community—Shoreline electrofishing (60 transects) and offshore gill netting (39 net-nights) sampled a total of 5,174 fish represented by 50 species. Three species made up the majority of the overall sample: gizzard shad (37 percent), bluegill (13 percent), and emerald shiners (12 percent). Electrofishing results showed catch rates to be similar in the Clinch River inflow (CPUE=51 per 300m transect), Tennessee River inflow (CPUE=53 per 300m transect), and forebay (CPUE=56 per 300m transect) but much higher at the transition zone (CPUE=129 per 300m transect). The higher catch rate in the transition was attributed mainly to abundance of emerald shiners and bluegill. Threadfin shad YOY catch rates were moderate in all sample zones except the Tennessee River inflow which was considered high. Gill netting catch rates were much the same in all four sample areas.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the transition (RFAI=48), fair in the forebay (RFAI=34) and Tennessee River inflow (RFAI=34), and poor in the Clinch River inflow (RFAI=30). The lower Clinch River inflow rating (compared to the Tennessee River inflow) resulted from slightly fewer numbers of sunfish and intolerant species. The gill netting RFAI rated both the transition zone (RFAI=38) and forebay (RFAI=32) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=33) received a fair rating, followed by the transition (RFAI=43) zones which was rated good. Electrofishing RFAI scores for the Tennessee (RFAI=34) and Clinch River (RFAI=30) inflow zones were rated fair and poor, respectively.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming areas were tested for fecal coliform bacteria 12 times each in 1993. Only one sample at each site was collected within 48 hours of a rainfall of at least one-half inch. Bacteria concentrations were generally higher after rainfall. If the one rainfall sample is excluded, all sites met Tennessee's water quality criteria for geometric mean concentration. However, four sites had one or more concentrations to exceed 1000/100 ml, Tennessee's maximum concentration for one sample. Only three of the fourteen areas had very low geometric mean concentrations for all samples (<20/100 ml), a much lower ratio than the other Tennessee River Reservoirs. All monthly fecal coliform bacteria samples taken at the two Vital Signs locations were <10/100 ml.

Fish Tissue—Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public to avoid eating certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and white bass) were reexamined in autumn in 1992. Average PCB concentrations among sample sites ranged from 0.4 to 1.9 μg/g for channel catfish (five sites), 1.0 to 1.1 μg/g for striped bass (two sites), 0.2 to 0.6 μg/g for sauger (three sites), and the average for white bass at the single location was 0.7 μg/g. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from studies conducted for DOE study. This is also true for additional fish collected for TVA studies in autumn 1993.

Fort Loudoun Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in Fort Loudoun Reservoir which persisted throughout most of the summer (April through September) of 1993. Summer surface water temperatures were warmest in July and coolest in April. They ranged from a maximum of 29.3°C to a minimum of 15.8°C at the forebay; and from 30.4°C to 15.5°C at the transition zone. Surface to bottom temperatures differentials (ΔT's) exceeded 5°C each month from April through August at the forebay and from May through July at the transition zone. Maximum thermal stratification occurred in July when ΔT's were 9.6°C at the forebay, and 10.2°C at the transition zone.

In Fort Loudoun Reservoir in 1993, DO at the 1.5m depth ranged from a high of 14.5 mg/l in May (algal bloom) to a low of 5.4 mg/l in September at the forebay; and from 12.6 mg/l to 5.4 mg/l (for the same months) at the transition zone. The minimum DO observed in Fort Loudoun Reservoir in 1993 was 2.5 mg/l at the bottom of the forebay during September. Maximum surface to bottom dissolved oxygen differentials (DO's) exceeded 5 mg/l each month, May through August, at the forebay; and, exceeded 4 mg/l April through June at the transition zone, with a minimum bottom DO of 4.9 mg/l in September. DO ratings used in the overall reservoir ecological health evaluation for Fort Loudoun Reservoir were excellent at both the forebay and the transition zone.

Summer values of pH ranged from 6.9 to 9.4 in Fort Loudoun Reservoir in 1993. At the forebay, near surface pH values exceeding 8.5 (ranged from 8.8 to 9.3), and DO saturation values exceeding 120 percent (ranged from 121% to 163%) were measured each month from April through August indicating substantial photosynthetic activity. During May, June, and July, a similar pattern of high pH's (range 8.6 to 9.4) and high DO saturations (range 132% to 161%) was observed at the transition zone. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Conductivity ranged from 107 to 221 µmhos/cm, averaging about 185 µmhos/cm at the forebay and 200 µmhos/cm at the transition zone. The slightly lower conductivities measured at the forebay were caused by the mixing of the soft water inflows from the Little Tennessee River, via the Tellico Reservoir canal with the harder water of the Tennessee River. During the summer, the water in the forebay of Tellico Reservoir is often cooler (1993 average summer forebay temperature was 16.5C) than the water in the forebay of Fort Loudoun Reservoir (1993 average summer forebay temperature was 20.6C). During hydro-electric power generation, water from Tellico Reservoir forebay is pulled into Ft Loudoun forebay and being cooler (higher density) flows under the warmer water of Fort Loudoun Reservoir. For example, in Fort Loudoun forebay in September 1993, surface conductivity was approximately 200 µmhos/cm and near bottom conductivity was about 115 µmhos/cm (i.e. lower conductivity because of the addition of cooler, lower conductivity water from Tellico Reservoir). At the same time, this cooler, epilimnetic water from Tellico Reservoir has higher DO's than the bottom water in the forebay of Fort Loudoun Reservoir, resulting in improved hypolimnetic DO's in Fort Loudoun's forebay, and improved DO's in the releases from Fort Loudoun dam.

Nutrient concentrations (total nitrogen and total phosphorus) have historically (1990-1993) been high at both the forebay and the transition zone. The average nitrite plus nitrate-nitrogen concentrations of

0.34 mg/l (forebay) and 0.43 mg/l (transition zone); and the average total nitrogen concentrations of 0.60 mg/l (forebay) and 0.71 mg/l (transition zone) were the highest average concentrations of these nutrients measured in 1993 at any of the Tennessee River Vital Signs Monitoring locations. These high concentrations of nitrogen are due to a combination of the effect of wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad Rivers, which have relatively high nitrogen concentrations.

The transition zone area of Fort Loudoun Reservoir has historically had lower water clarity than any of the other Tennessee River Vital Signs sampling sites. In 1993, total suspended solids (TSS) averaged 13.4 mg/l, while Secchi depths averaged less than 1 meter. One final interesting piece of data was the high fecal coliform concentrations, with no antecedent rainfall, measured at both the forebay and transition zone sampling sites in April (greater than 600 fecal coliform (FC) colonies per 100 ml of water), which may indicate municipal wastewater treatment interruptions in the Knoxville area. On no other occasion throughout the summer did fecal coliform concentrations exceed 5 F°C colonies/100 ml.

The highest chlorophyll *a* concentrations in the forebay occurred in April (24 μg/l) and in the transition zone in May (19 μg/l). Surface concentrations of chlorophyll *a* averaged about 14.7 μg/l and 13.7 μg/l, at the forebay and transition zone, respectively, among the highest measured at Tennessee River sampling sites in 1993. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Fort Loudoun Reservoir were fair (i.e., falling in the 10 to 15 μg/l range), at both locations; just below the level considered poor (i.e. greater than 15 μg/l).

Sediment—As 1990-1992, chemical analyses of sediments in 1993 from Fort Loudoun Reservoir indicated high levels of zinc (300 mg/kg) in both forebay and in transition zone samples. Chlordane was also detected in sediment at both the forebay (12 μg/kg) and the transition zone (27 μg/kg). Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the forebay. Particle size analysis showed sediments from the forebay and the transition zone were 99 percent silt and clay.

Sediment quality ratings used in the overall Fort Loudoun Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane and zinc); and good at the transition zone (presence of chlordane and zinc).

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate sampling showed fair communities in the forebay and transition zone, and a very poor community in the inflow. The forebay benthic community improved and the inflow benthic community declined from 1992. The forebay site on Fort Loudoun had 1,178 organisms/m^2 representing 15 taxa; Chironomus (45 percent) and Tubificidae (26 percent) were the dominant organisms. The transition zone had fewer total organisms (987 organisms/m^2) but greater taxa richness (22 total taxa) than the forebay site. The transition zone benthic community this year was more diverse and abundant than the 1992 community. Tubificidae (27 percent) and the chironomids Chironomus sp (23 percent) and Procladius sp (24 percent) were the most abundant taxa. The inflow macroinvertebrate community had 747 organisms/m^2 and 18 taxa. Polypedilum sp comprised 31 percent of the sample, and Tubificidae and Corbicula fluminea comprised 24 percent of the total each.

The Fort Loudoun forebay benthic community rating was negatively impacted by the abundance of chironomids and the lack of EPT taxa. This was balanced by the positive influence of a diverse assemblage with evenness among the dominant taxa, allowing this site to achieve an overall fair rating. The benthic community at the transition zone was negatively impacted by the shortage of long-lived taxa and the abundance of chironomids. This was off-set by the taxa richness and evenness of dominant species observed at the site, resulting in a fair rating. The inflow site on Fort Loudoun had a very poor benthic community in 1993 because of low diversity, a shortage of EPT and long-lived taxa, and an overabundance of the dominant species.

Aquatic Macrophytes—Aquatic plants on Ft. Loudoun Reservoir were primarily upstream of TRM 635. An estimated 25 acres of aquatic plants were present in 1993. Coverage over the past decade has ranged from 25 to 140 acres, and Eurasian watermilfoil has been the dominant species.

Fish Community—Fish samples from the littoral (45 electrofishing transects) and profundal areas (34 net-nights) of Fort Loudoun Reservoir produced 3,211 individuals, representing 40 species. The most abundant taxa was gizzard shad which accounted for 42 percent of the total number collected. Other abundant species included bluegill (11 percent), yellow bass (10 percent), largemouth bass (9 percent), and carp (7 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (907) and transition zones (1,027). Considerably lower numbers in the inflow zone (420) were due to reduced catch of gizzard shad, bluegill, and largemouth bass. Very high numbers of YOY threadfin shad were collected by electrofishing in both the transition (CPUE=7,775 per 300m transect) and forebay (CPUE=7,953 per 300m transect) zones of Fort Loudoun Reservoir. Gill netting catch rate decreased from 37 fish per net night in the forebay to 30 and 6 in the transition and inflow zones, respectively.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) very poor in the transition zone (RFAI=14) and poor in the forebay (RFAI=24) and inflow zones (RFAI=26). The transition RFAI of 14, which was the lowest score ever observed in TVA reservoirs, resulted from the lowest possible score for all metrics except percent anomalies. The gill netting RFAI rated the transition (RFAI=36) and forebay (RFAI=36) both fair. High metric scores were observed at both areas for percent of tolerant and omnivorous species, and percent anomalies, with low scores for intolerant and lithophilic spawning species. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=30) and transition (RFAI=25) zones and the electrofishing RFAI for the inflow (RFAI=26) were all rated poor, resulting in the poorest fish community conditions in TVA run-of-the-river reservoirs.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—One boat ramp was tested for fecal coliform bacteria in 1993. Fecal coliform concentrations met Tennessee's bacteriological criteria for water contact recreation. The only fecal coliform bacteria concentrations in the monthly Vital Signs monitoring >10/100 ml were the April samples. Concentrations were >600/100 ml at both stations.

Fish Tissue—The sample site for the PCB trend study is near the transition zone at TRM 625. Ten channel catfish were collected there in autumn 1992. Concentrations in 1992 were higher than had been found in 1990 (average of 1.0 g/g and range of 0.3 to 1.9 g/g) but lower than in 1991 (average of 2.5 g/g and range 1.4 to 4.6 g/g). The 1992 samples had an average of 1.8 g/g and ranged from <0.1 to 4.2 g/g).

Melton Hill Reservoir

Summary of 1993 Conditions - Ecological Health

Water—In the summer of 1993, thermal stratification began to develop in May and persisted through September at both the forebay and the transition zone in Melton Hill Reservoir. Temperature differentials (ΔT's) exceeding 10°C between the water surface and the bottom were found each month at the forebay from May through August; and each month at the transition zone from May through July. This fairly strong thermal stratification of Melton Hill Reservoir is enhanced by the upstream release of cool water from Norris Dam, which during the summer flows along the bottom of Melton Hill Reservoir. Surface water temperatures were warmest in July and coolest in April. They ranged from a high of 29.7°C to a low of 11.5°C at the forebay; and from 28.8°C to 10.9°C at the transition zone. In the late summer the release of cool water from Norris Dam into the upstream end of Melton Hill Reservoir and the solar warming as the water moves downstream into the forebay often results in water surface temperatures being 4-5°C cooler at the transition zone than at the forebay. In 1993, the average summer water temperatures in Melton Hill Reservoir (16.7°C at the forebay and 16.5°C at the transition zone) were lower than all other run-of-the-river sampling sites except at Tellico Reservoir forebay.

In spite of the thermal stratification, little oxygen stratification and no hypolimnetic anoxia were found in Melton Hill Reservoir in 1993. Minimum DO's measured in the summer of 1993 were 4.3 mg/l on the bottom at the forebay in July; and 6.5 mg/l on the bottom at the transition zone in September. DO's at the 1.5m depth in Melton Hill Reservoir in the summer of 1993, ranged from a high of 11.5 mg/l in May and June to a low of 9.3 mg/l in September at the forebay; and from 10.8 mg/l in April to 7.6 mg/l in September at the transition zone. Average summer DO's (= 9.1 mg/l) and percent oxygen saturation values (= 92 percent) were higher at the Melton Hill transition zone than any other reservoir Vital Signs sampling site in 1993. DO ratings used in the overall reservoir ecological health evaluation for Melton Hill Reservoir were excellent at both the forebay and the transition zone.

The Clinch River flows through the Valley and Ridge physiographic province, a region underlain by large amounts of limestone and dolomite. Consequently, Melton Hill Reservoir has relatively high pH and conductance; in fact, the highest among the run-of-the-river reservoirs. In the summer of 1993, pH ranged from 7.3 to 8.8 and conductivity ranged from 223 to 272 µmhos/cm and averaged about 255 µmhos/cm in Melton Hill Reservoir. At the forebay, near surface water pH's exceeded 8.5 each month from May through August, coincident with DO super-saturation values (>110%), and indicative of photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average nitrite plus nitrate-nitrogen concentrations were quite high in Melton Hill Reservoir. As in past years, the 1993 average concentration at the transition zone (0.56 mg/l) was the highest nitrite plus nitrate-nitrogen among all Vital Signs locations sampled.

Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only about 0.003-0.004 mg/l at the forebay and transition zone, respectively, among the lowest measured at run-of-the-river sampling sites in 1993. Further, TN/TP ratios were often high (>50) indicating frequent episodes of phosphorus limitation to algal productivity in Melton Hill Reservoir. Consequently, average summer chlorophyll *a* concentrations of 5.3 µg/l at the forebay and 4 µg/l at the transition zone, may reflect a limiting nutrient effect. The highest chlorophyll *a* concentrations measured were 6-7 µg/l at both the transition zone and the forebay. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Melton Hill Reservoir were "good" (i.e., falling in the 3 to 10 µg/l range), at both locations; just above the level considered fair (i.e., less than 3 µg/l).

The water clarity (Secchi depth, suspended solids, color, etc.) of Melton Hill Reservoir was comparatively high and measurements were generally stable throughout the year, being largely influenced by discharges from Norris Dam rather than localized rainfall runoff events.

Sediment—Chemical analyses of sediments in Melton Hill Reservoir in 1993 indicated the presence of chlordane in one of two forebay samples (25 µg/kg) and also in the transition zone (32 µg/kg) sample. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediment in the forebay were 99 percent silt and clay and from the transition zone were 90 percent silt and clay.

Sediment quality ratings used in the overall Melton Hill Reservoir ecological health evaluation for 1993 were "good" at both the forebay and the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The 1993 benthic communities at all three sites on Melton Hill declined from 1992. The forebay and inflow had a poor benthic macroinvertebrate community and the transition zone had a very poor benthic community. Melton Hill forebay had 16 taxa and 363 organisms/m^2, a decrease in both diversity and dominance from 1992. The benthic community was dominated by Chironomus sp (49 percent) and Tubificidae 17 percent. The transition zone had 362 organisms/m^2 representing 21 taxa, predominately Tubificidae (36 percent) and Chironomus (27 percent). The inflow location had the greatest abundance (1,649 organisms/m^2) and diversity (29 taxa) of all locations sampled on Melton Hill. There was a substantial increase in diversity and density in the inflow compared to the previous year. Tubificidae (49 percent) and Paratendipes (17 percent) were the dominant organisms at this site.

Several factors contributed to the poor benthic communities found on Melton Hill Reservoir. Three factors that negatively impacted all three locations were a preponderance of chironomids, and low numbers of EPT and long-lived taxa. The problems were further compounded at the transition and inflow sites because of decreased diversity and inflated numbers of tubificids.

Aquatic Macrophytes—An estimated 240 acres of aquatic macrophytes occurred on Melton Hill Reservoir in 1993. Eurasian watermilfoil was the dominant aquatic plant and was most abundant from CRM 24 to 51. Coverage over the past decade has generally ranged from about 100 to 250 acres.

Fish Community—Electrofishing (45 transects) and gill netting efforts (34 net-nights) on Melton Hill Reservoir produced a total of 2,437 fish representing 42 species. Gizzard shad was the most numerous species (56 percent of the total number of fish sampled), followed in abundance by yellow bass (8 percent), largemouth bass (5 percent), carp (5 percent), and bluegill (4 percent). The threadfin shad YOY catch rate (CPUE=335 per 300m electrofishing transect) was moderate in the forebay zone of Melton Hill Reservoir and insignificant in the transition and inflow areas. Overall fish abundance was much the same in the forebay (1,172) and transition (1,108) zones but substantially less in the inflow (157). Fewer species were also collected from the inflow zone (16) than the forebay (28) or transition zone (36).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition (RFAI=32), poor in the inflow (RFAI=22), and very poor in the forebay (RFAI=18) zones of Melton Hill Reservoir. The very poor rating in the forebay, which represented the lowest RFAI score for all run-of-the-river forebays, resulted from minimum scores for all metrics except number of sucker and intolerant species. The gill netting RFAI rated both the forebay (RFAI=38) and transition (RFAI=40) zones fair. The only extreme difference between the two zones in metric scoring resulted from higher numbers of lithophilic spawning species in the transition. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the transition zone (RFAI=36) fair. The poor RFAI's of 28 and 22 in the forebay and inflow zones, respectively, were the lowest recorded for comparable zones of run-of-the-river reservoirs in 1993. (Note: Results from biomonitoring on Melton Hill Reservoir like Tellico, were compared to results from mainstream reservoirs due to similar operational characteristics. These reservoirs lack deep drawdown which occurs in storage impoundments and have a navigation lock.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation areas in 1993. The April fecal coliform bacteria concentrations at the Vital Signs locations were 113 and 191/100 ml at the forebay and transition zone, respectively. All other concentrations were <20/100 ml.

Fish Tissue—PCB contamination in catfish from Melton Hill Reservoir has been under study for several years. Because of this contamination, the TDEC has advised the public not to eat these catfish. TVA participates on a study team with TDEC, TWRA, and ORNL to investigate PCBs and other contaminants in fish from east Tennessee Reservoirs. In 1992 ORNL collected and analyzed channel catfish from the forebay, while channel catfish from near the transition zone and inflow were collected and analyzed by TVA. Average PCB concentrations from these same locations were 0.8, 1.0, and 0.5 μg/g, respectively, and average chlordane concentrations were 0.07, 0.10, and 0.05 μg/g, respectively.

Emory River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Emory River is soft (average hardness of 24 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 102 percent of saturation.

Of the 12 stations monitored in the Tennessee Valley, the Emory River had the lowest concentrations of nitrate+nitrite-nitrogen (0.10 mg/l), total phosphorus (0.020 mg/l), and dissolved orthophosphate (0.002 mg/l). The low organic nitrogen (0.195 mg/l) and ammonia nitrogen (0.002 mg/l) concentrations were in the lower third of all stations. The good total phosphorus and nitrate+nitrite-nitrogen concentrations, in particular, contributed to a good nutrient rating for the station.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples), dissolved nickel (2 of 6 samples) and zinc were detected. All were within EPA guidelines for the protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate community rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 102 taxa and 4,308 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 77 taxa and 3,137 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years with the exception of a 25 percent increase in total taxa reported in the qualitative sample. Dominant organisms in 1993 were dipteran midge larvae (62 percent), coleopteran riffle beetles (13 percent), and caddisflies (10 percent). Dipteran midge larvae was also the most dominant organism in 1992 (56 percent), followed by caddisflies (14 percent) and mayflies (12 percent). Siltation from coal mining practices in the Emory River watershed are a continuing problem for benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 52, improving from the borderline good (IBI = 46) rated in 1992. The 1993 fish sample contained no hybrids and fewer diseased fish, and had a slightly increased fish density suggesting less stressful conditions for fish since 1992. Minor problems, however, continued to be seen in species composition and trophic structure. A contributing factor of stress on fish at this station is naturally-occurring low flow (usually less than 50 cfs) during mid to late summer. Low flow reduces fish habitat, reduces the river's ability to assimilate pollutants, and generally makes the aquatic fauna more vulnerable to environmental degradation.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on the Emory River in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Mercury was detected in all three samples but at concentrations which would not be considered elevated. Chlordane was detected at low concentrations in two samples, and PCBs were found in all samples (carp 0.4 μg/g; channel catfish 1.2 μg/g; and largemouth bass 0.6 μg/g). Additional catfish and largemouth bass were collected in summer 1993, but results were not available at the time this report was prepared.

CLINCH RIVER AND POWELL RIVER WATERSHED

Norris Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperature ranged, for the months it was measured (April-October), from 12.6°C in April to 29.8°C in July in the forebay, from 14.9°C to 30.0°C for the same months at the Clinch mid-reservoir sampling location, and from 14.6°C to 30.1°C for the same months at the Powell mid-reservoir sampling location. Thermal stratification was evident in Norris Reservoir in 1993. While this stratification was evident in April, when the first measurements for the year were made, it became much stronger beginning in May, due to drastically decreased streamflow combined with solar heating. Maximum surface to bottom water column temperature differentials occurred in July, when the surface temperatures were about 22°C warmer than bottom temperatures in the forebay, and about 19°C at the mid-reservoir sampling locations. The strong thermal stratification in Norris Reservoir persisted through October for the forebay, and through September for the mid-reservoir locations.

Dissolved oxygen at the 1.5m depth ranged from 9.7 mg/l in May to 7.4 mg/l in September at the forebay, from 10.8 mg/l in April to 7.0 mg/l in August at the Clinch mid-reservoir sampling location, and from 10.2 mg/l in May to 6.7 mg/l in October at the Powell mid-reservoir sampling location. During the summer of 1993, (as in past summers) anoxic conditions developed at all three sampling locations on Norris Reservoir. At the mid-reservoir sampling locations, dissolved oxygen concentrations near the bottom were approximately 0 mg/l in July, August, and September. Further, in August this anoxia development resulted in hypolimnetic dissolved oxygen concentrations being less than 1 mg/l over approximately two-thirds of the water column depths in the mid-reservoir sampling locations. For the forebay, anoxic conditions existed at the bottom in September and October.

DO ratings used in the overall reservoir ecological health evaluation for Norris Reservoir were poor at the forebay and very poor at the mid-reservoir sampling locations. The forebay DO rating was poor because approximately 10 percent of the cross-sectional area (six-month summertime average) of the forebay had a dissolved oxygen concentration less than 2.0 mg/l; anoxic bottom conditions existed; and, over 20% of this site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. The mid-reservoir sites both received very poor ratings for dissolved oxygen because of even poorer DO conditions. At both sites over 20 percent of the cross-sectional areas (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l; both had anoxic bottom conditions; and both had over 50 percent of each site's cross-sectional bottom length (six-month summertime average) with dissolved oxygen concentrations less than 2.0 mg/l.

In 1993, values of pH in Norris Reservoir ranged from 7.0 to 8.7 for the three monitoring locations. Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5) at the forebay in August, at the Clinch mid-reservoir location in June, and at the Powell mid-reservoir location in May and June. In each of these cases, dissolved oxygen saturation concentrations were high (>100 percent), which indicates substantial photosynthetic activity. The conductivity of the water in Norris Reservoir is among the highest of all the reservoirs in the Tennessee River drainage. Reservoir-wide, conductivities ranged from 172 to 382 µmhos/cm. They averaged 244 µmhos/cm at the forebay, 277 µmhos/cm at the Clinch mid-reservoir sampling location, and 295 µmhos/cm at the Powell mid-reservoir sampling location.

Concentrations of nutrients were very low, which is typical for Norris Reservoir. Average total phosphorus (TP) and dissolved ortho phosphorus (DOP) were especially low reservoir-wide. At the forebay, both TP and DOP averaged less than 0.002 mg/l and were among the lowest average total phosphorus concentrations measured in 1993. Further, TN/TP ratios for individual samples often exceeded 100 at all Norris sampling sites, which indicates extremely limiting phosphorus conditions on algal productivity in the reservoir.

Concentrations of chlorophyll *a* averaged only 1.7 μg/l at the forebay, 4.1 μg/l at the Clinch mid-reservoir sampling location, and 3.6 μg/l at the Powell location. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Norris Reservoir were fair at the forebay (i.e. less than 3 μg/l) and good (i.e. falling in the 3 to 10 μg/l range), at both mid-reservoir locations; just above the level considered fair (i.e. less than 3 μg/l).

The water of Norris Reservoir, especially in the forebay area has historically been quite clear. However, Norris Reservoir forebay in 1993 was less clear than 1992 with an average Secchi depth of 2.5 meters. The Clinch mid-reservoir Secchi depth was slightly clearer than in 1992, averaging 2.5 meters, and the Powell was about the same, averaging 2.2 meters.

Sediment—As in 1990-92, chemical analyses of sediments in Norris Reservoir in 1993 found high levels of lead (76 mg/kg) in the forebay, and elevated levels of un-ionized ammonia in both the Clinch (375 μg/l) and Powell (370 μg/l) mid-reservoir regions. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay; from the Clinch mid-reservoir were about 95 percent silt and clay; and from the Powell mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall Norris Reservoir ecological health evaluation for 1993 were good at the forebay (presence of lead); and good at both of the mid-reservoir sites (presence of ammonia).

Benthic Macroinvertebrates—Among the three reservoir monitoring locations on Norris Reservoir, the Powell River mid-reservoir site had the highest number of benthic taxa (23) and greatest density (1,887 organisms/m^2), and received the best overall benthic rating of good. The dominant taxa were Tubificidae (39 percent), Limnodrilus sp (21 percent) and Chironomus sp (22 percent). The forebay and Clinch River mid-reservoir site both had fair benthic communities. The forebay site had 16 taxa and 751 organisms/m^2; Tubificidae, the dominant taxon, comprised 56 percent of the total, followed by Corbicula fluminea (26 percent). The Clinch River mid-reservoir location had 1,214 organisms/m^2 representing 17 taxa and was dominated by Tubificidae (52 percent) and Chironomus sp (36 percent).

The Norris forebay could have achieved a good rating had it not been for the abundance of tubificids and the dearth of EPT taxa. These negative influences were offset by the abundance of long-lived taxa and low numbers of chironomids. The Powell River site, which received a good rating, scored well because of its diversity and evenness of the dominant taxa. All other metrics evaluated were fair. The Clinch River site had an average benthic community primarily because all metrics evaluated received only a fair score. The only metric that rated very low was the dominance metric; in this instance, Tubificidae comprised an overwhelmingly large percentage of the total organisms collected.

Fish Assemblage—The fish samples from the littoral (45 electrofishing transects) and profundal areas (36 net-nights) of Norris Reservoir produced a total of 1,602 individuals representing 29 species. Highest concentrations of fish were found in the Clinch River transition zone (43 percent of total fish sampled) due to the abundance of walleye in the gill netting sample (10 per net night) and black basses (smallmouth, spotted, and largemouth) in the electrofishing sample (9 per 300m transect). The forebay electrofishing catch rate (CPUE=15 per 300m transect) was the lowest recorded among all tributary reservoir forebays. The forebay gill netting catch rate (CPUE=7 per net night) was the second lowest recorded (Parksville forebay was the lowest). Twenty-five species were collected at both transition zones and 16 in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the Powell River transition (RFAI=46) zone and fair in both the Clinch River transition (RFAI=40) and forebay (RFAI=34) zones. The higher RFAI in the Powell River transition zone was influenced by maximum metric scores for diversity, number of piscivore, sucker, intolerant, and lithophilic spawning species, percent tolerant species and dominance by a single species. Both the Powell and Clinch rivers received gill netting RFAI values of 50 classifying them good. The forebay (RFAI=28) was poor; only one metric (percent anomalies) had a maximum score in the forebay of Norris; all other scores were either minimum or midrange. Combined electrofishing and gill netting RFAI scores for both the Clinch (RFAI=45) and Powell (RFAI=48) river transitions were rated good, followed by a fair rating in the forebay (RFAI=31).

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, and one site upstream and another downstream of the Jacksboro sewage treatment plant were tested for fecal coliform bacteria twelve times each in 1993. Two samples at each site were collected within 48-hours of rainfall of at least one-half inch. Bacteria concentrations at all five sites were very low (geometric mean <20/100 ml).

Fish Tissue—Fish tissue samples for screening studies were collected on Norris Reservoir in autumn 1992. All analytes were low except for PCBs, which were highest at the forebay where the concentration was 0.9 µg/g. Concentrations at the other two locations were low. Screening samples were collected again in autumn 1993 to further evaluate PCB concentrations but results were not available at the time this report was prepared.

Clinch River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Clinch River is moderately hard (average hardness of 147 mg/l) and alkaline (average total alkalinity of 120 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 81 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Clinch River ranked among the lowest in average concentrations of ammonia nitrogen (0.015 mg/l) and dissolved orthophosphate (0.003 mg/l). It ranked just below the median in average concentrations of organic nitrogen (0.198 mg/l), nitrate+nitrite-nitrogen (0.30 mg/l), and total phosphorus (0.020 mg/l). The low concentrations of total phosphorus and nitrate+nitrite-nitrogen yielded a good nutrients rating for the station.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples, but did not exceed the EPA guidelines for the protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 53, with 83 taxa and 2,726 organisms/m^2. Conditions in 1992 also rated good (MBIBI score 50) with 85 taxa and 3,326 organisms/m^2. The Clinch River is rated the best among the 12 stream monitoring sites. The benthic fauna in 1993 was composed mostly of river snails (33 percent), nutrient tolerant oligochaeta worms (16 percent), and mayflies (14 percent). Mayflies were the dominant organism in 1992 (46 percent), followed by river snails (13 percent) and coleopteran riffle beetles (9 percent). Overall, conditions remain unchanged between sampling years.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) of 50 in 1993, showing no change since 1992. Minor problems were seen in species composition, trophic structure, and fish condition. The fish assemblage was basically intact with a good number of native species and a healthy compliment of darter, sucker, and intolerant species. Trophic structure was good at the lower levels, as most fish found were specialized insectivores. Fish density was also at a normal level. Detrimental conditions observed at this station included occasional bank erosion and siltation.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The weir downstream of Norris Dam and the canoe launch site downstream of the weir were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48 hours of rainfall of at least one-half inch. The geometric mean of fecal coliform bacteria concentrations were very low (<20/100 ml)at both sites.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Powell River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Powell River is moderately hard to hard (average hardness of 150 mg/l) and alkaline (average total alkalinity of 125 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 105 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Powell River ranked in the lower half in concentrations of nutrients. The average ammonia nitrogen concentration (0.013 mg/l) was the lowest for the network. The good average total phosphorus (0.035 mg/l) and nitrate+nitrite-nitrogen (0.47 mg/l), in particular, yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples) and dissolved nickel (1 of 6 samples) were detected. Neither metal exceeded the EPA guidelines for the protection of aquatic life or human health. Additional metals analyses included total and dissolved forms of iron and manganese. Total iron exceeded the EPA guideline for combined consumption of fish and water in one sample. Total manganese was detected in 4 of 6 samples, but none exceeded EPA guidelines.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate community rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 94 taxa and 2,586 organisms/m^2. Conditions in 1992 rated fair (MBIBI score 42) with 66 taxa and 2,167 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (27 percent), river snails (24 percent), and coleopteran riffle beetles (16 percent). River snails were the most dominant group in 1992 (43 percent), followed by dipteran midge larvae (24 percent) and the Asian clam Corbicula (10 percent). Overall, conditions improved from fair to good over the previous year.

Fish Community Assessment—Meaningful improvement was seen in the fish community in 1993. Ratings of good were found for both 1993 and 1992, however the Index of Biotic Integrity (IBI), on which the ratings are based, increased from 48 in 1992 to 56 in 1993 and was approaching an excellent rating. Improvement was seen in species richness and composition, trophic structure, and fish density. Only slight deficiencies in number of darter species and proportion of piscivorous fish prevented a higher rating. Accumulations of sand, coal, and gravel were observed in some pool areas, but apparently were not a major problem for the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected and analyzed above the stream monitoring site.

Fish Tissue—A five fish composite each of freshwater drum, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

LITTLE TENNESSEE RIVER WATERSHED

Tellico Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Fairly strong thermal stratification persisted from April through September 1993 at both the forebay and transition zone. From June through August, temperature differentials between the water surface and bottom equaled or exceeded 11°C at the forebay and 10°C at the transition zone. These differentials were due to a combination of atmospheric warming of surface water—intensified by the low streamflows in April and May and the intrusion of surface waters from Fort Loudoun forebay—contrasted with the inflow of cool bottom water from the releases of Chilhowee Dam upstream. Surface water temperatures ranged from lows in April to highs in July (i.e. from 16.1°C to 28.0°C at the forebay and from 16.3°C to 29.5°C at the transition zone). Water in Tellico Reservoir was relatively cool, particularly at the transition zone which was influenced by the releases from Chilhowee Dam. Summer temperatures averaged 16.5°C and 17.5°C at the forebay and transition zone, respectively, among the lowest temperatures for run-of-the-river Vital Signs sampling sites in 1993.

DO at the 1.5m depth ranged from a high of 11.4 mg/l in April to a low of 6.8 mg/l in September at the forebay; and from 10.6 mg/l to 8.1 mg/l (for the same months) at the transition zone. From June through September a persistent oxycline was present in the forebay. Differences between surface and bottom DO concentrations were 5 to 9 mg/l, and near bottom concentrations were less than 1 mg/l in August and September. This near bottom, cool, low DO water was very low in conductivity (<50 μmhos/cm). This suggests that cool water, which is fairly high in DO when it is released from Chilhowee Dam, becomes trapped in the hypolimnion of Tellico Reservoir and is slowly depleted of oxygen content during the summer. The minimum DO was 4.1 mg/l in July, on the bottom at the transition zone. DO ratings used in the overall reservoir ecological health evaluation for Tellico Reservoir were fair at the forebay (due to the hypolimnetic anoxia in August and September) and excellent at the transition zone.

The Little Tennessee River drains through the Blue Ridge physiographic province—a mountainous, largely forested region underlain, for the most part, by crystalline rocks. The upper slopes of the watershed have generally thin soils and weathered rock. In addition, the underlying rocks, broadly speaking are siliceous and not easily dissolved. Surface drainage is rapid, and consequently, the water of the Little Tennessee River (and Tellico Reservoir) are quite soft, low in pH and conductivity, and low in nutrients.

In 1993, Tellico Reservoir pH values ranged from 6.0 to 8.9. Near surface pH's exceeded 8.5 at the forebay in June and July and at the transition zone in July, coincident with DO super-saturation values indicative of photosynthetic activity. Values of pH in Tellico Reservoir were the lowest of any of the run-of-the-river Vital Signs reservoirs, averaging 7.0 at both the forebay and transition zone. Values of pH below the Tennessee minimum criterion of 6.5 for fish and aquatic life were observed in the hypolimnion of Tellico Reservoir at both the forebay and transition zone in 1993.

The conductivity of water in Tellico Reservoir was also quite low, averaging about 35 μmhos/cm at the transition zone and 65 μmhos/cm at the forebay. Mixing of forebay surface waters between Fort Loudoun and Tellico reservoirs via the inter-reservoir canal influences water quality and causes the higher measured conductivity at Tellico forebay compared with Tellico transition zone.

Total nitrogen concentrations were low and averaged only 0.33 mg/l at the forebay and 0.22 mg/l at the transition zone. Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) were also quite low, averaging only 0.003 mg/l at the forebay and transition zone. Together, these nutrient concentrations were among the lowest measured concentrations at Vital Signs Monitoring locations in 1993; and consequently, primary productivity could be expected to be limited much of the time.

Average summer chlorophyll *a* concentrations were 7 µg/l at the forebay and 3 µg/l at the transition zone. The highest single sample chlorophyll *a* concentrations measured in 1993 were 9 µg/l at the forebay and only 6 µg/l at the transition zone. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Tellico Reservoir were good (i.e. falling in the 3 to 10 µg/l range), at both locations; just above the level considered fair (i.e. less than 3 µg/l).

Water clarity data (as measured by Secchi depth, suspended solids, color, etc.) was comparatively high with little relative variation throughout the year. This is because inflows to Tellico Reservoir are primarily a result of Chilhowee Dam discharges which are of high clarity and low color, rather than rainfall runoff events.

Sediment—Samples for toxicity testing and chemical analyses were collected at three sites in Tellico Reservoir in 1993: the forebay (LTRM 1.0); and two transition zone locations (LTRM 15.0, downstream of the confluence of the Tellico River, and LTRM 21.0, upstream of the confluence of the Tellico River). Chemical analyses of sediments in Tellico Reservoir in 1993 indicated the presence of chlordane in the forebay (21 µg/kg) and in one of two transition zone (LTRM 15.0) samples (16 µg/kg). Toxicity tests detected acute toxicity to daphnids (0 percent survival) at all sampling sites tested; however, for the first time since 1990, toxicity to rotifers was not detected. Particle size analysis showed sediments from the forebay were about 97 percent silt and clay; from LTRM 15.0 transition zone were 91 percent silt and clay; and from LTRM 21.0 transition zone were about 66 percent silt and clay, 34 percent sand.

Sediment quality ratings used in the overall Tellico Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane); poor at the transition zone site-LTRM 15.0 (acute toxicity to test animals and presence of chlordane). Information from the transition zone site at LTRM 21.0 was not included in the overall ecological health rating.

Benthic Macroinvertebrates—The benthic community in Tellico Reservoir in 1993 rated poor at both the forebay and transition zone. The forebay zone had 17 taxa and 433 organisms/m^2 dominated by Tubificidae (65 percent of the total), which is very similar to the benthic community observed the previous year. The transition zone had 13 taxa and 320 organisms/m^2. As in 1992, Tubificidae was the dominant taxon (28 percent) and the chironomid <u>Zalutschia</u> <u>zalutschicoia</u> was the second most abundant (18 percent).

Reduced diversity, few EPT taxa, and an abundance of tubificids resulted in the forebay and transition zone communities receiving poor ratings were . The transition zone was further impacted because relatively few long-lived taxa were present.

Aquatic Macrophytes—The 246 acres of aquatic macrophytes on Tellico Reservoir were most abundant in the Tellico River portion (between miles 1 and 13) of the reservoir and along the Little

Tennessee River portion from LTRM 9 to 15. Eurasian watermilfoil was the dominant submersed macrophyte on Tellico Reservoir.

Fish Assemblage—Electrofishing (30 transects) and gill netting samples (24 net-nights) in the transition zone and forebay produced 1,498 individuals of 36 species. More fish (66 percent) as well as more species (31 compared to 29) were found in the forebay than in the transition zone. Gizzard shad comprised 37 percent of the total sample, followed by spotfin shiners, bluegill, and the black basses (smallmouth, spotted, and largemouth) all at 9 percent. Electrofishing and gill netting results indicated most species were present in higher numbers in the forebay than the transition zone. Walleye and sauger were more numerous in 1993 than in previous years, which may be of interest to sport anglers in the future.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in both the forebay (RFAI=34) and transition (RFAI=38) zones. All metric scores for both zones were identical with the exception of percent tolerant and omnivorous species which received higher scores in the transition. Gill netting RFAI's rated the forebay (RFAI=34) fair and the transition (RFAI=22) poor, due primarily to lower scores for the number of species, number of sucker, intolerant, lithophilic spawning species, and percent anomalies and dominance by a single species. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=34) fair and the transition (RFAI=30) zone poor. The RFAI rating of poor in the transition resulted from a low gill netting RFAI (22) which was the lowest score observed for run-of-the-river reservoirs in 1993. (Note: Results from biomonitoring on Tellico Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs in storage impoundments and the presence of a navigation lock allowing recruitment of fish species.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in 1993. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the Vital Signs stations. The highest individual concentrations were April samples, 114 and 54/100 ml, at the forebay and transition zone, respectively.

Fish Tissue—An advisory not to eat catfish from Tellico Reservoir has been in effect for several years. Documentation of the PCB problem in what was thought to be a background study in 1985 came as a surprise because there was basically no industrial development in the watershed. Subsequently, more intensive studies supported the initial results and showed very little change in concentrations during the late 1980s. Several attempts at locating potential sources were fruitless and the source remains unknown. A less intensive sampling effort was begun in autumn 1990. Since then one composite of five channel catfish has been collected annually from the forebay and one from an area about 10 miles upstream (several miles downstream of the transition zone) to continue examination of the temporal trend in PCB concentrations.

Channel catfish samples collected in autumn 1992 had relatively high PCB concentrations - 2.7 μg/g at the forebay and 1.9 μg/g at the mid-reservoir location. Chlordane concentrations were also relatively high - 0.22 and 0.20 μg/g, respectively. Other organics were either not detected or found in very low concentrations. Arsenic, cadmium, lead, and selenium were not detected in either sample. Mercury concentrations were relatively high - 0.65 and 0.36 μg/g at the forebay and mid-reservoir locations. Due to these high concentrations of mercury, largemouth bass were collected along with channel catfish in autumn 1993; results were not available at the time this report was prepared.

Fontana Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fontana Reservoir in 1993 was about 107 percent of normal, with an average residence time of 174 days. Fontana Reservoir was strongly stratified, with a maximum temperature difference in the water column at the forebay of 21.8°C in July, and remaining 14.3°C in October. Due to the fall drawdown, the two mid-reservoir sampling locations were weakly stratified in September and mixed in October. Maximum surface temperatures were 27.8°C at the forebay, 29.8°C at the Little Tennessee River mid-reservoir station, and 29.0°C at the Tuckasegee River mid-reservoir station. The maximum temperatures were in July. North Carolina's standard for maximum temperature of Class°C waters is 29°C. Depleted DO (<2.0 mg/l) only developed at the forebay at depths of over 100 meters in September and October. Depleted DO conditions also occurred at the Tuckasegee River mid-reservoir station in August and September, but not in the Little Tennessee River mid-reservoir station. The DO rating in the reservoir ecological health index was good for the forebay and Little Tennessee River mid-reservoir sites and poor for the Tuckasegee site.

Conductivities were generally in the 20 to 30 μmhos/cm range, the second lowest of the tributary reservoirs, with little stratification except for late summer when a maximum conductivity of 39 μmhos/cm occurred. The minimum pH was 6.0 at all three sites, the maximum was 8.8 in June at the Little Tennessee River mid-reservoir station.

Total nitrogen concentrations at the three stations were the third, fourth, and fifth lowest concentrations of the 33 tributary reservoir stations. Total nitrogen concentrations at the three sites averaged 0.21 mg/l in April, mostly as nitrates, and 0.07 mg/l in August, mostly as organic nitrogen. Total phosphorus concentrations were 0.01 mg/l at both mid-reservoir locations and 0.003 mg/l at the forebay in April, and dropped to an average of 0.003 mg/l at the three locations in August. Total phosphorus concentrations at the forebay were the lowest concentrations of the tributary reservoir stations. Total organic carbon concentrations averaged 0.8 mg/l in April and 1.4 mg/l in August, with little variation between locations. Chlorophyll *a* concentrations averaged 1.4 μg/l at the forebay, and 2.7 and 2.4 μg/l at the Little Tennessee and Tuckasegee River mid-reservoir locations, respectively. These were the fourth, fifth, and sixth lowest concentrations of the tributary reservoir stations, and were within the range considered fair. Secchi depths at the mid-reservoir stations varied from 2.1 meters in April to 4.9 meters in June, both in the Tuckasegee River. The water at the forebay was the clearest of all tributary reservoir stations, ranging from 5.1 meters in September to 8.1 meters in June.

Sediment—Chemical analyses and toxicity testing of sediments were conducted on sediment samples collected at three locations in Fontana Reservoir in 1993: a forebay site (LTRM 62.0); a mid-reservoir site on the Tuckasegee River (TkRM 3.0) arm; and, a mid-reservoir site on the Little Tennessee River (LTRM 81.5) arm. The presence of chlordane was detected in the forebay (12 μg/kg) and in the Tuckasegee River mid-reservoir region (14 μg/kg). Toxicity tests detected acute toxicity to daphnids (60 percent survival) and rotifers (55 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 75 percent silt and clay, 25 percent sand; in the Little Tennessee River mid-reservoir were 94 percent silt and clay; and in the Tuckasegee River mid-reservoir were 76 percent silt and clay, 24 percent sand.

Sediment quality ratings used in the overall Fontana Reservoir ecological health evaluation for 1993 were poor at the forebay (presence of chlordane and toxicity to test animals); good at the Tuckasegee mid-reservoir site (presence of chlordane); and excellent at the Little Tennessee mid-reservoir site.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Fontana Reservoir was 1993. The benthic community at the forebay site rated very poor, the Tuckasegee River mid-reservoir site rated poor, and the Little Tennessee River mid-reservoir site rated fair. The forebay had 1,040 organisms/m^2 representing 4 taxa. The Tuckasegee site had 15 taxa and by far the greatest density of all three sites sampled (6,328 organisms/m^2). The Little Tennessee mid-reservoir site had the greatest diversity of the three sites, with 23 taxa and 3,753 organisms/m^2. The dominant taxon at all three sites was Tubificidae, accounting for 90 percent of the total at the forebay and Tuskasegee inflow, and 77 percent of the total at the Little Tennessee River inflow.

The three sites sampled on Fontana Reservoir had several common problems: an absence of long-lived taxa, an absence of EPT taxa, and an abundance of tubificids. It is also worthy to note that a common observation at all three locations on Fontana was low numbers of chironomids. In addition to the above elements, the forebay benthic community was further impacted by very low diversity. The Little Tennessee mid-reservoir site had greater diversity and fewer tubificids than the other two sites which allowed it to receive the best overall benthic rating.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore experimental gill netting (36 net-nights) yielded 1782 individuals with 22 species represented. Green sunfish and smallmouth bass were the most abundant species collected, comprising 39 and 16 percent of the total sample, respectively. Bluegill (7 percent) and white bass (7 percent) were also frequently encountered. Catch rates for both gill netting and electrofishing were approximately the same for all three sample areas (forebay, Little Tennessee River transition, and the Tuckasegee River transition).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) poor in all three sample areas (forebay RFAI=28, Little Tennessee River transition RFAI=28, and Tuckasegee River transition RFAI=22) of Fontana Reservoir. All electrofishing metrics received low to moderate scores except for percent omnivores and insectivores. Gill netting RFAI results rated the forebay zone (RFAI=36) fair, and both the Little Tennessee River transition (RFAI=42) and the Tuckasegee River transition (RFAI=48) zones good. Combined electrofishing and gill netting RFAI scores rated all three zones of Fontana Reservoir fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on Fontana Reservoir in 1993.

Fish Tissue—Five channel catfish were collected in autumn 1992 from both the forebay and mid-reservoir site on the Little Tennessee River. Fillets were composited by area and analyzed for selected metals, pesticides, and PCBs on EPA's priority pollutant list. Most analytes were not detected or had low concentrations. Exceptions to this were mercury at both locations (0.40 μg/g at the forebay and 0.53 μg/g at the mid-reservoir site), and PCBs at the forebay (1.1 μg/g). PCBs were not detected in the sample from the mid-reservoir site. Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

Little Tennessee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Little Tennessee River is soft (average hardness of 7 mg/l) and slightly alkaline (average total alkalinity of 10 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 95 to 110 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Little Tennessee River ranked among the lowest in average concentrations of organic nitrogen (0.188 mg/l), nitrate+nitrite-nitrogen (0.14 mg/l), total phosphorus (0.030 mg/l), and dissolved orthophosphate (0.006 mg/l). The highest average concentration of ammonia nitrogen (0.138 mg/l) was found at this site. The good total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Three of the samples exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline for chronic toxicity. Dissolved lead exceeded the guideline for chronic toxicity. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites. As seen below, there was no acute toxicity testing apparent in these samples.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 44, with 92 taxa and 11,086 organisms/m^2. Conditions in 1992 also rated good (MBIBI score 46) with 84 taxa and 9,079 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (54 percent), nutrient tolerant oligochaete worms (15 percent), and caddisflies (9 percent). Mayflies were the most dominant group in 1992 (27 percent), followed by dipteran midge larvae (23 percent) and caddisflies (19 percent). Conditions have essentially remained unchanged between sampling years; however, an increase was noted in the numbers of silt and nutrient tolerant organisms.

Fish Community Assessment—The fish community rated excellent with an Index of Biotic Integrity (IBI) of 58 and showed little change since rating borderline good (IBI = 56) in 1992. With the exception of low fish density (catch rate), measures of the fish community indicated nearly optimum conditions. Siltation, however, was conspicuous and is suspected of effecting low fish density at this station.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No studies conducted in 1993.

Fish Tissue—A five fish composite each of river redhorse, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

FRENCH BROAD RIVER WATERSHED

Douglas Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, surface water temperatures ranged from 13.4°C in April to 28.5°C in July at the forebay, and from 15.4°C to 30.2°C (for the same months) at the mid-reservoir sampling location. Some thermal stratification was observed beginning in May at both the forebay and mid-reservoir locations, and was strongest in July when the temperature differentials between the bottom and the surface were 15.1°C at the forebay, and 12.1°C at the mid-reservoir location. This stratification existed through August at the mid-reservoir location, and through September at the forebay.

Dissolved oxygen at the 1.5m depth ranged from 12.5 mg/l in May to 4.6 mg/l in October at the forebay, and from 11.8 mg/l in May to 5.5 mg/l in September at the mid-reservoir location. (The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5 mg/l, at the 1.5m depth.) Anoxic conditions near the bottom existed from June through September at the forebay, and from June through August at mid-reservoir. This hypolimnetic anoxia peaked at the forebay in August and at the mid-reservoir in July. In each case, about two-thirds of the water column had dissolved oxygen concentrations of less than 1 mg/l. The forebay and mid-reservoir sampling sites had, respectively, about 30% and 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l; and, over 60% of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above (and the low surface concentration in October at the forebay, 4.6 mg/l), DO ratings used in the overall reservoir ecological health evaluation for Douglas Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

Values of pH ranged from 6.6 to 9.4 for both locations in Douglas Reservoir in 1993. In April through August at the forebay, and May through August at the mid-reservoir location, near surface pH's equal to or exceeding 8.5 were observed. In almost all of these cases, when the pH was above 8.5, surface dissolved oxygen saturation values exceeded 100 percent, indicating high levels of photosynthesis.

In 1993, the average concentrations of total phosphorus (average 0.035 mg/l at the forebay and 0.040 mg/l at the mid-reservoir) were higher in Douglas Reservoir than any of the other tributary Vital Signs reservoirs; and, at the mid-reservoir sampling location the dissolved ortho phosphorus (average 0.013 mg/l) was also higher than any of the other tributary reservoirs. The Douglas mid-reservoir sampling site historically has had the lowest average TN/TP ratios of all the tributary reservoirs.

In 1993, concentrations of chlorophyll *a* averaged 6.6 µg/l at the forebay and 10.3 µg/l at the mid-reservoir site. These concentrations are somewhat lower than those measured in 1992, when they were among the highest of the Vital Signs reservoirs. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Douglas Reservoir were good at the forebay (i.e. falling in the 3 to 10 µg/l range); and fair at the mid-reservoir location (i.e. falling in the 10 to 15 µg/l range).

The water of Douglas Reservoir, especially in the mid-reservoir area has historically had low water clarity. In 1993, the Secchi depth averaged only 1.2 m, the lowest of all the tributary reservoir sampling locations.

Sediment—Chemical analyses of sediments in Douglas Reservoir in 1993 indicated the presence of chlordane (18 µg/kg) at the mid-reservoir site. Toxicity tests detected acute toxicity to rotifers (55 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 83 percent silt and clay, 17 percent sand.

Sediment quality ratings used in the overall Douglas Reservoir ecological health evaluation for 1993 were excellent at the forebay; and poor at the mid-reservoir site (presence of chlordane and toxicity to rotifers).

Benthic Macroinvertebrates—The forebay on Douglas Reservoir did not change significantly from the previous year. Only 265 organisms/m^2 representing 6 taxa were found, similar to the number of taxa (7) and density (282 organisms/m^2) found in 1992. The dominant taxa were Chironomus (50 percent) and Tubificidae (31 percent). The benthic macroinvertebrate community at this site was poor primarily because of the absence of long-lived and EPT taxa, and because of the abundance of chironomids. The benthic community structure observed at the forebay is indicative of low near-bottom dissolved oxygen concentrations.

The inflow site on Douglas Reservoir was not evaluated in 1993 because it was determined that 90 percent of the samples taken at that site were above the average winter pool level.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore/deep netting (24 net-nights) samples collected 2,679 fish of 29 species. The most abundant species were gizzard shad (29 percent), followed by white bass (20 percent), and largemouth bass (13 percent). The crappie species (black and white) represented 10 percent of the total sample. Electrofishing results indicated fish abundance in the transition (1,075) was twice that of the forebay (533) due mainly to much higher numbers of white bass, largemouth bass, and white crappie. Gill netting efforts showed a similar pattern, with the transition catch (884) considerably higher than the forebay (187). The only species that were more abundant in the forebay samples were smallmouth buffalo and black crappie.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data showed the forebay (RFAI=42) zone to be good and the transition (RFAI=36) fair. Maximum metric scores were recorded at both sample areas for species diversity, number of sucker species, and dominance by a single species, and minimum scores for percent insectivores. The gill netting RFAI rated the transition zone (RFAI=50) good and the forebay (RFAI=30) poor. Transition zone scores were midrange or maximum (3's or 5's) for all metrics except for number of intolerant species. Combined electrofishing and gill netting RFAI scores indicated good fish community conditions in the transition (RFAI=43) zone and fair in the forebay (RFAI=36).

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach and two boat ramps were tested for fecal coliform bacteria twelve times in 1993. Two samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at every site.

Fish Tissue—TVA worked with the Tennessee Department of Environment and Conservation in 1992 to conduct fish tissue studies on Douglas Reservoir. TVA collected the fish samples and provided fillets to TDEC for analysis. Results were not available at the time this report was prepared.

French Broad River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the French Broad River is soft (average hardness of 18 mg/l) and only slightly alkaline (average total alkalinity of 20 mg/l), reflecting the underlying geology of the area. The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 99 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the French Broad River station ranked among the highest in mean concentrations of total phosphorus (0.122 mg/l), dissolved orthophosphate (0.087 mg/l), and nitrate+nitrite-nitrogen (0.56 mg/l). Average concentrations of 0.220 mg/l and 0.030 mg/l for organic nitrogen and ammonia nitrogen placed the site near median for these variables. The high average total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. Three of those exceeded the EPA criterion for chronic toxicity to freshwater aquatic life. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites. However, the acute toxicity test data is consistent with the water chemistry. See "Sediment" for additional information on toxicity testing results.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 77 taxa and 12,121 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 35) with 81 taxa and 10,961 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years. Dominant organisms in 1993 were dipteran midge larvae (67 percent), caddisflies (15 percent), and dipteran black-fly larvae (6 percent). Dipteran black-fly larvae was the most dominant organism in 1992 (49 percent), followed by dipteran midge larvae (36 percent) and caddisflies (5 percent). The French Broad River consistently ranks the poorest of the 12 stream monitoring sites. Siltation from agricultural land usage along the river severely affects benthic communities at this site.

Fish Community Assessment—The fish community continued to be depressed rating borderline poor with an Index of Biotic Integrity (IBI) score of 38 in 1993 and borderline poor (IBI = 36) in 1992. Serious problems were found in species richness and composition, and in fish density, indicating poor conditions. Forty to 60 native species were expected to occur at this station, but only 30 were found. Diversity was low among darters, sunfish, suckers, and intolerant species. The proportion of tolerant fish was excessive representing approximately 41 percent of the fish found, and fish density was among the lowest found at the 11 stations sampled in 1993. Turbidity, siltation, and nutrient enrichment were evident and probably played some part in the disorder exhibited by the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Nolichucky River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Nolichucky River is moderately hard (average hardness of 79 mg/l) and moderately alkaline (average total alkalinity of 67 mg/l). The median pH for the stream monitoring site was 7.8. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Nolichucky River station ranked just above the median concentrations for average organic nitrogen (0.223 mg/l), nitrate+nitrite-nitrogen (0.56 mg/l), total phosphorus (0.075 mg/l), and dissolved orthophosphate (0.024 mg/l). An average concentration of ammonia nitrogen of 0.022 mg/l placed the site among the best for the variable. The moderately high average total phosphorus concentration yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. Dissolved lead was detected in 2 of 6 samples. Neither metal exceeded the EPA criteria for protection of aquatic life or human health. Additional metals analyses included both total and dissolved forms of manganese and iron. Total iron exceeded the chronic toxicity criterion for freshwater aquatic life in one sample and the criterion for combined consumption of fish and water in 4 samples. Total manganese was detected in 5 of 6 samples, although only one sample exceeded an EPA criterion value (for combined consumption of fish and water).

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 39, with 81 taxa and 5,543 organisms/m^2. Conditions in 1992 were also rated fair (MBIBI score 39) with 91 taxa and 6,195 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (32 percent), caddisflies (24 percent), and mayflies (19 percent). Dipteran midge larvae were also the most dominant group in 1992 (46 percent), followed by dipteran black-fly larvae (18 percent) and caddisflies (14 percent). Conditions have essentially remained unchanged between sampling years. Siltation from agricultural land usage along the river and mica and mica and feldspar mining in the watershed adversely affect benthic communities at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving considerably from the borderline fair (IBI = 38) rated in 1992. Improvement included a lower proportion of tolerant fish, a higher proportion of piscivorous fish, increased fish density, and absence of hybrids. Deficiencies in number of native species and in numbers of darter, sunfish, and intolerant species continued to indicate poor conditions. Excessive turbidity and heavy siltation have been observed at this station during all sampling trips, 1990-93.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Bacteriological studies were not conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

HOLSTON RIVER WATERSHED

Cherokee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Summer surface water temperatures ranged from 12.2°C in April to 29.8°C in July at the forebay, and from 14.4°C to 30.9°C for the same months at the mid-reservoir sampling location (Tennessee's maximum temperature criterion for the protection of fish and aquatic life is 30.5C). Thermal stratification was evident in Cherokee Reservoir in 1993. Stratification was strongest in June, when the temperature difference between the surface and the bottom of the reservoir was about 20°C at the forebay and about 18°C at the mid-reservoir location. Thermal stratification persisted through September at the forebay and through August at the mid-reservoir site.

Dissolved oxygen at the 1.5m depth ranged from 15.2 mg/l (algal bloom) in April to 5.2 mg/l in September at the forebay, and from 14.2 mg/l (algal bloom) in April to 5.6 mg/l in July at the mid-reservoir sampling location. Anoxic conditions in the hypolimnion developed in the forebay in July and existed through October. In July and August, dissolved oxygen concentrations were less than 1 mg/l for about three-fourths of the water column. Dissolved oxygen gradients (DO's) were high in the forebay (about 7 mg/l) in June, July, and August. The gradients were not as high in September and October because of the low surface dissolved oxygen. Similar conditions existed at the mid-reservoir sampling location where hypolimnetic anoxia existed near the bottom in July and August. In July in the mid-reservoir location, three-fourths of the water column contained less than 1 mg/l dissolved oxygen. Dissolved oxygen gradients of 9.4 mg/l and 7.6 mg/l were observed in June and August, respectively. Such a high gradient did not exist in July because of the low surface dissolved oxygen for that month. The forebay and mid-reservoir sampling sites both had over 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l; and, over 40 percent of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above, DO ratings used in the overall reservoir ecological health evaluation for Cherokee Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

In 1993, values of pH in Cherokee Reservoir ranged from 6.9 to 8.8 for both monitoring locations. Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criterion for the protection of fish and aquatic life is 8.5) at the forebay in April through August, and at the mid-reservoir location in May through August. In each of these cases, with the exception of July at the mid-reservoir section, high dissolved oxygen saturation values coincided with the high pH's, sometimes up to 140 percent, indicating substantial photosynthetic activity.

Historically, the mid-reservoir sampling site has had the highest nutrient concentrations among all reservoir Vital Signs sampling locations. Average nutrient concentrations at the mid-reservoir location in 1993 were observed to be only about half of 1992 concentrations. In 1993, the average total nitrogen concentration was 0.45 mg/l and the average total phosphorus concentration was 0.030 mg/l. Lower nutrient concentrations at the forebay as well as higher TN/TP ratios indicate a higher productivity potential at the mid-reservoir sampling site than at the forebay sampling site.

Concentrations of chlorophyll *a* support this hypothesis where chlorophyll *a* averaged 7.6 μg/l at the forebay and 9.4 μg/l at the mid-reservoir site. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Cherokee Reservoir were good (i.e. falling in the 3 to 10 µg/l range), at both the forebay and the mid-reservoir locations.

Sediment—Chemical analyses of sediments in Cherokee Reservoir in 1993 indicated high levels of copper (57 mg/kg) from the mid-reservoir and elevated levels of un-ionized ammonia from both the forebay (390 µg/l) and mid-reservoir (290 µg/l). Toxicity tests detected acute toxicity to rotifers (75 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Cherokee Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); and poor at the mid-reservoir site (presence of copper and ammonia and toxicity to rotifers).

Benthic Macroinvertebrates—In 1993, the overall condition of the benthic macroinvertebrate community in the forebay of Cherokee Reservoir remained approximately the same as in 1992. However, there was a slight increase in taxa (14) and decrease in density (510 organisms/m^2). As in 1992, Tubificidae (45 percent) and Chironomus sp (26 percent) were the dominant taxa.

The forebay had a fair macroinvertebrate benthic community; problem characteristics were numbers of long-lived species and the abundance of chironomids. On a more positive note, this site exhibited excellent species diversity. The Cherokee inflow benthic macroinvertebrate community improved substantially since last year, resulting in an excellent rating. The only factor that kept this site from receiving a perfect score for the benthic component was a slightly elevated number of chironomids in the sample. The abundance of mayfly Hexagenia limbata, considered to be an intolerant, long-lived species, greatly improved the benthic community rating at the inflow.

Fish Assemblage—Fish sampling in shoreline (45 electrofishing transects) and offshore/deep areas (34 net-nights) of Cherokee Reservoir produced a total of 4,086 individuals including 33 species. The most numerous species was gizzard shad (35 percent), followed by bluegill (20 percent), and largemouth bass (14 percent). Species richness ranged from 24 in the transition , 25 in the forebay, to 27 in the inflow. Electrofishing results indicated higher abundance in the inflow (1,458), where gizzard shad and largemouth bass were most numerous, and in the forebay (1,104) where bluegill numbers were very high. Gill netting catch rates were progressively higher from inflow to forebay areas due largely to abundance of gizzard shad, quillback carpsuckers, and striped bass.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data determined the quality of the littoral fish communities of the forebay (RFAI=32) and inflow (RFAI=34) zones to be fair and the transition (RFAI=30) to be poor. All three reservoir sample areas were rated fair based on gill netting RFAI's. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=36), transition (RFAI=34), and inflow (RFAI=35) zones of Cherokee Reservoir were all rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach, seven boat ramps, and the head of one small embayment were tested for fecal coliform bacteria twelve times in 1993. Two samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the swimming beach and at six of the boat ramps. At the Malinda Bridge boat ramp and at the head of Spring Creek Embayment, the geometric mean fecal coliform concentrations were between 20 and 50/100 ml, well below the Tennessee criterion for recreation.

Fish Tissue—Channel catfish were collected from Cherokee Reservoir as part of screening studies in autumn 1992. Results indicated low or nondetectable concentrations of metals. Mercury, known to be a problem in the North Fork Holston River, was 0.29 μg/g at the forebay with lower concentrations at the other two locations. The only organics found were PCBs and chlordane. Chlordane concentrations were low (maximum 0.07 μg/g) and PCB concentrations were generally similar to those in past years - 0.8, 0.5, and 0.5 μg/g at the forebay, transition zone, and inflow, respectively.

Fort Patrick Henry Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fort Patrick Henry Reservoir in 1993 was about 91 percent of normal. It is only stratified due to the continual release of cold water from the three upstream dams. The maximum temperature difference in the water column was 12.5°C in July. The maximum surface temperature was 27.8°C in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. Low DO (<5.0 mg/l) conditions developed in July, August, and October, but DO never dropped below 2.2 mg/l. Absence of DO <2.0 mg/l gave Fort Patrick Henry Reservoir a good rating for DO in the reservoir ecological health index.

Conductivities varied widely from month to month and in the water column, but averaged the fourth highest of the 19 tributary reservoirs. The minimum was 150 μmhos/cm at the bottom of the water column in May, and the maximum was 216 μmhos/cm in September, also at the bottom of the water column. Surface pH reached or exceeded 9.0 in July, August, and September, while bottom pH never fell below 7.1.

Relatively high nutrient concentrations were found: the total nitrogen concentration in April was 1.08 mg/l, 72 percent as nitrates, and 0.63 mg/l in August, 62 percent as organic nitrogen. Total phosphorus concentrations were 0.02 mg/l in both surveys. Total organic concentrations were 2.0 mg/l in April and 2.8 mg/l in August. Chlorophyll *a* concentrations tied for the fourth highest of the 33 tributary reservoir stations, averaging 10.3 μg/l. This chlorophyll concentration was considered fair in the reservoir ecological health index. Water clarity was low. Secchi depths ranged from 1.3 meters in September to 1.7 meters in July and August.

Sediment—Chemical analyses of sediments from the forebay of Fort Patrick Henry Reservoir in 1993 indicated slightly elevated levels of un-ionized ammonia (210 μg/l). Toxicity tests detected no toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were 99 percent silt and clay.

The sediment quality rating used in the overall Fort Patrick Henry Reservoir ecological health evaluation for 1993 was good at the forebay (presence of ammonia).

Benthic Macroinvertebrates—The first year that the benthic community in this tributary reservoir was evaluated was 1993. The forebay, the only sample location, had a fair benthic macroinvertebrate community with 11 taxa, 438 organisms/m^2, and Tubificidae as the dominant taxa (63 percent). The absence of EPT taxa and the abundance of tubificids negatively impacted the benthic community. An average representation of the long-lived species Corbicula fluminea, average taxa richness, and low numbers of chironomids were all positive attributes of the benthic community.

Fish Assemblage—Only the forebay zone was sampled on Fort Patrick Henry Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,251 individuals represented by 22 species. Fifty-one percent of the total catch consisted of spotfin shiners, followed by gizzard shad (23 percent), bluegill (7 percent), carp (6 percent), and largemouth bass (5 percent).

Fish community conditions were rated fair for both electrofishing (RFAI=38) and gill netting (RFAI=34) in the forebay zone of Fort Patrick Henry Reservoir. The overall RFAI of 36 also rated the reservoir forebay as fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The boat ramp at Warriors Path State Park was tested for fecal coliform bacteria in 1993. The geometric mean concentration was 94/100 ml, well within Tennessee's Criterion for water contact recreation.

Fish Tissue—Autumn 1993 was the first time TVA had conducted fish tissue samples from Fort Patrick Henry Reservoir. Results were not available at the time this report was prepared.

Boone Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Boone Reservoir in 1993 was about 97 percent of normal, with an average residence time of 38.5 days. Boone Reservoir has two large arms, the South Fork Holston River and Watauga River, their confluence is slightly more than one mile upstream of Boone Dam. Both arms receive cold water releases from the deep impoundments upstream. Consequently, Boone Reservoir remains stratified throughout the sampling period, with a maximum temperature difference in the water column at the forebay of 16.3°C in July. The maximum surface temperature was 28.9°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) at the forebay and in the South Fork Holston River arm was limited to the metalimnion from July through October. In the Watauga arm, DO depletion occurred at the bottom in September. The limited amount of DO depletion gave the forebay a good rating and both mid-reservoir stations fair ratings for DO in the reservoir ecological health index.

Conductivities varied widely by month and depth. In the Watauga arm, conductivities ranged from 74 μmhos/cm at the bottom in May to 236 μmhos/cm in the metalimnion in September. In the South Fork Holston River arm, conductivities varied from 177 μmhos/cm at the surface to 264 μmhos/cm in the metalimnion in July. Conductivities in the forebay reflected the mixing of these two rivers. The minimum pH was 6.7 in the Watauga arm in September, while pH reached 9.1 in both the forebay and Watauga arm in the summer.

Total nitrogen concentrations on South Fork Holston River were the third highest of the 33 tributary reservoir stations. Total nitrogen concentrations in April ranged from 0.76 mg/l on the Watauga River to 1.07 mg/l on South Fork Holston River. About 60 percent of the total nitrogen was nitrates at each site. Nitrate concentrations had dropped by August to 0.03 mg/l or less at each station, bringing the average total nitrogen concentration to 0.41 mg/l, slightly higher at the mid-reservoir stations than at the forebay. Total phosphorus concentrations were 0.01 mg/l on the Watauga River and 0.02 mg/l at the other two sites in April. Total phosphorus concentrations dropped at the forebay from April to August to 0.008 mg/l, remained constant in the South Fork Holston River, and increased in the Watauga River to 0.03 mg/l. Dissolved ortho phosphorus concentrations were 0.003 mg/l in the Watauga River both months and at the forebay in April, and <0.002 for the other three samples. The TN/TP ratios were high, 50:1 at the forebay and higher at the other two stations. Total organic carbon concentrations were high, ranging from 1.8 mg/l in the Watauga River to 2.7 mg/l in the forebay in April, and 3.8 mg/l at both mid-reservoir stations to 4.5 mg/l at the forebay in August. The forebay concentrations of total organic carbon were the fourth highest of the tributary reservoir locations.

The two mid-reservoir stations had the second and third highest chlorophyll concentrations of the tributary reservoir stations. Average chlorophyll *a* concentrations were 8.7 μg/l at the forebay, 11.9 μg/l in the South Fork Holston River, and 10.4 μg/l in the Watauga River. These concentrations are in the ranges considered good for the forebay and fair for the two mid-reservoir locations in the reservoir ecological health index. Water clarity was low at the mid-reservoir stations, Secchi depths varied from 1.0 meter in the South Fork Holston River in June to 1.5 meters at both stations in October. The South Fork Holston

River mid-reservoir station had the second lowest water clarity of the tributary reservoir stations. At the forebay, Secchi depths varied from 1.3 meters in May to 2.2 meters in October.

Sediment—Chemical analyses of sediments collected from three locations in Boone Reservoir in 1993 indicated very high levels of un-ionized ammonia at all three sites: 790 μg/l at the forebay sampling site; 660 μg/l at the South Fork Holston River (SFHR) mid-reservoir sampling site; and, 990 μg/l at the Watauga River (WR) mid-reservoir sampling site. Chlordane was also detected in sediment at all three sampling sites: 22 μg/kg at the forebay site; 35 μg/kg at the SFHR mid-reservoir site; and, 35 μg/kg at the WR mid-reservoir site. In addition, high levels of copper (58 mg/kg) and zinc (370 mg/kg) were found at the Watauga River mid-reservoir sampling site. However, no acute toxicity to daphnids nor rotifers was found at any of the three sampling sites. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay; in the S. F. Holston River mid-reservoir were 99 percent silt and clay; and in the Watauga River mid-reservoir were 86 percent silt and clay, 14 percent sand.

Sediment quality ratings used in the overall Boone Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent because ammonia was elevated; good at the SFHR mid-reservoir site (presence of ammonia); and fair at the WR mid-reservoir site (presence of copper, zinc, and ammonia).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Boone Reservoir was 1993. The forebay site had a poor benthic community, with 1,107 organisms representing a mere 10 taxa; Tubificidae (58 percent) and the tubificid Limnodrilus hoffmeisteri (38 percent) were the dominant taxa. The South Fork Holston River and the Watauga River mid-reservoir sites both had poor benthic communities. Both had only 11 taxa, but the South Fork Holston inflow had a lower density (615 organisms/m^2) than the Watauga inflow (267). The tubificids Limnodrilus sp and Tubificidae were the dominant taxa at both mid-reservoir sites comprising 91 percent of the total at the South Fork Holston site and 96 percent of the total at the Watauga site.

The forebay and both inflows were negatively impacted by the absence of long-lived and EPT taxa, and the abundance of tubificids. If not for the relatively low proportion of chironomids, all sites would have received a "very poor" benthic rating.

Fish Assemblage—Electrofishing (45 transects) and gill netting (34 net-nights) results from Boone Reservoir yielded 2,439 individuals of 23 species. Bluegill were the most abundant species, comprising 29 percent of the total number of fish sampled. Other species making up a significant portion of the reservoir sample included gizzard shad (21 percent), spotfin shiners (21 percent), and carp (9 percent). Fish abundance was greater in the Watauga River transition zone (1,414), followed by the South Fork Holston River transition (632) and the forebay (393). Both electrofishing and gill netting total catch rates followed the same pattern as abundance.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) fair in the Holston River transition (RFAI=32) and poor in both the Watauga River transition (RFAI=28) and forebay zones (RFAI=26). Minimum metric scores for diversity, and number of intolerant and lithophilic spawning species were recorded for all stations. The gill netting RFAI followed the same pattern as electrofishing, rating the Holston River transition (RFAI=36) fair, and both the Watauga River transition (RFAI=28) and forebay (RFAI=26) zones poor. Scoring at all zones revealed scattered values for most metrics with the exception of maximum scores (5) for percent anomalies, and minimum scores (1) for percent tolerant and omnivorous species.

Combined electrofishing and gill netting RFAI scores for both the forebay (RFAI=26) and Watauga River transition (RFAI=28, which was the lowest tributary transition RFAI recorded in 1993) rated poor and the Holston River transition zone (RFAI=34) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—Two swimming areas and four boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Bacteria concentrations were very low (geometric mean <20/100 ml) at the four boat ramps. The geometric mean fecal coliform concentration at the swimming beaches were 106 and 51/100 ml, well within Tennessee's criterion of 200/100 ml for water contact recreation. One sample at the Boone Dam recreation area exceeded Tennessee's maximum concentration criterion for one sample of 1000/100 ml.

Fish Tissue—Past studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. Fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

South Holston Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through South Holston Reservoir in 1993 was near normal with an average residence time of about 341 days. The reservoir was strongly stratified, with a maximum temperature difference in the forebay water column of 21.9°C in July. The maximum surface temperature was 28.3°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) occurred in both the metalimnion and at the bottom of the water column. Areas of DO depletion began in July at mid-reservoir and August at mid-reservoir. Because the water was clearer at the forebay than at mid-reservoir and the photic zone was deeper, metalimnetic DO depletion occurred at deeper depths in the forebay than at mid-reservoir and the area of low DO was not mixed as the surface cooled in October as was the case at mid-reservoir. For the reservoir ecological health index, DO was considered fair at the forebay and poor at mid-reservoir.

Conductivities varied widely by month and depth, from a minimum of 72 µmhos/cm in May near the bottom at the forebay to 270 µmhos/cm at the mid-reservoir bottom in September. Surface pH was between 8.5 and 9.0 at both stations each month except for April at the forebay. The minimum pH was 7.1 at mid-reservoir in September.

Total nitrogen concentrations were 0.75 and 1.08 mg/l in April at the forebay and mid-reservoir, respectively, about three-fourths as nitrates. In August, the total nitrogen concentration had dropped to 0.36 mg/l at both stations, primarily due to a decline in nitrates. The mid-reservoir total nitrogen concentrations were the fourth highest of the 33 tributary reservoir stations. In April, total and dissolved ortho phosphorus concentrations were 0.01 and 0.003 mg/l at the forebay and 0.02 and 0.003 mg/l at mid-reservoir. In August, total phosphorus was <0.002 mg/l at the forebay and 0.003 at mid-reservoir. TN/TP ratios were very high, over 50 in April and over 100 in August. Total organic carbon concentrations varied only from 1.7 mg/l in April to 2.7 mg/l in August, both concentrations at mid-reservoir.

Average chlorophyll *a* concentrations were 3.4 µg/l at the forebay and 7.0 µg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 2.3 m in September and October at mid-reservoir and from 2.0 m in May to 5.75 m in June at the forebay. The forebay had the fourth clearest water of the 19 tributary reservoir forebays.

Sediment—Chemical analyses of sediments in South Holston Reservoir in 1993 indicated the presence of chlordane (12 µg/kg) and un-ionized ammonia (310 µg/l) in the mid-reservoir. Toxicity tests detected no acute toxicity to daphnids or rotifers, however survival of daphnids (75 percent survival) was reduced in the forebay. Particle size analysis showed sediment in the forebay were 99 percent silt and clay, and in the mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall South Holston Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent due to reduced survival of daphnids) and good at the mid-reservoir site (presence of ammonia and chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on the South Holston Reservoir was 1993. The forebay site had a very poor community, with only 3 taxa, 98 organisms/m^2, and the tolerant Tubificidae comprising 97 percent of the total. The inflow site rated somewhat better with 13 taxa and 354 organisms/m^2, dominated by Tubificidae (69 percent).

The forebay site had very poor benthic community structure as indicated by low diversity, the absence of EPT and long-lived taxa, and the preponderance of tubificids; a low number of chironomids was the only metric that kept this site from receiving the lowest possible score. The inflow site had a fair benthic representation, but an absence of EPT taxa and an abundance of tubificids were negative attributes of the community. As was the case at the forebay, a low number of chironomids found at the site was a considered a positive indicator. Diversity and the presence of long-lived species allowed the inflow site to receive a better rating than the forebay site.

Fish Assemblage—Fish samples taken in the shoreline areas (30 electrofishing transects) and offshore/deep areas (24 net-nights) of South Holston Reservoir produced a total of 2,160 individuals represented by 27 species. Fish density and diversity was similar between the forebay (1,246 individuals of 20 taxa) and transition zone (914 individuals of 23 taxa). No inflow zone sample was collected from South Holston Reservoir. The three most abundant species were spotfin shiner (46 percent), gizzard shad (10 percent), and bluegill (8 percent). Other abundant species included black crappie and walleye at six percent, and white bass at five percent of the total catch. Gill netting results indicated an increase from 1992 estimates in black crappie numbers in both forebay and transition zones.

RFAI analysis of electrofishing data determined the quality of the littoral fish community in the transition zone (RFAI=40) and forebay (RFAI=38) to be fair. Gill netting RFAI rated the transition (RFAI=32) fair and forebay (RFAI=50) good. Forebay scores for all metrics were maximum except for number of sunfish and sucker species, and percent insectivores. The forebay score of 50 represented a substantial improvement from the previous sample season (1992 RFAI=28). Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=44) zone good and the transition (RFAI=36) fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One informal swimming area and three boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all four sites.

Fish Tissue—There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples are for fish collected in autumn 1991. The single composite of channel catfish from the forebay had low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury). The mercury concentration was 0.42 µg/g, just high enough to be of interest. Additional fish tissue samples were collected from the forebay in autumn 1993, but results were not available at the time this report was prepared.

Watauga Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Watauga Reservoir in 1993 was near normal with an average residence time of about 404 days. Watauga Reservoir was strongly stratified with a maximum temperature difference in the forebay water column of 21.3°C in July. The maximum surface temperature was 28.8°C at mid-reservoir in July, less than Tennessee's maximum temperature criterion for aquatic life of 30.5°C. At the forebay, the area of DO depletion (DO < 2.0 mg/l) was limited to the bottom of the water column in October. At mid-reservoir, areas of DO depletion developed in both the metalimnion and at the bottom of the reservoir in September and October. The limited amount of DO depletion gave the forebay a rating of good and mid-reservoir a rating of fair for DO in the reservoir ecological health index.

The maximum conductivity was 101 µmhos/cm at the forebay and 96 µmhos/cm at mid-reservoir, both at the bottom of the water column in September. At both stations pH reached 9.0 near the surface, the minimum pH was 6.5 in the mid-reservoir metalimnion in September.

Total nitrogen concentrations in April were 0.80 mg/l at mid-reservoir and 0.61 mg/l at the forebay, about three-fourths of the total at each site as nitrates. The total nitrogen concentration in August was about half the April total with the reduction due to a decline in nitrate concentrations as organic nitrogen concentrations rose slightly. Total phosphorus concentrations in April were 0.02 mg/l at mid-reservoir and 0.01 mg/l at the forebay. August concentrations were about half of the April total. TN/TP ratios were 40 or higher for each sample. Dissolved ortho phosphorus concentrations were at or below the detection limit of 0.002 mg/l for all four samples. Total organic carbon concentrations at mid-reservoir were 1.8 and 3.2 mg/l in April and August, respectively, and 2.1 mg/l at the forebay in August.

The average chlorophyll *a* concentration was 4.1 µg/l at the forebay and 5.9 µg/l at mid-reservoir. These concentrations are in the good range for the reservoir ecological health index. Secchi depths varied at the forebay from 1.3 m in April to 3.9 m in May, and at mid-reservoir from 1.7 m in April to 4.2 m in September.

Sediment—Chemical analyses of sediments in Watauga Reservoir in 1993 indicated the presence of chlordane in both forebay (22 µg/kg) and in the mid-reservoir (36 µg/kg). Elevated levels of un-ionized ammonia (260 µg/l) were found in the forebay. Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (5 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay, and in the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Watauga Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to daphnids and rotifers and presence of chlordane and ammonia); and good at the mid-reservoir site (presence of chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Watauga Reservoir was 1993. The forebay and mid-reservoir sites both had very poor benthic communities with only 7 and 9 taxa, respectively, and 158 and 60 organisms/m^2, respectively. The forebay was dominated by Tubificidae (79 percent of the total) and the inflow was dominated by the chironomid Einfeldia sp (53 percent).

Scores at both sites were negatively influenced by three common factors: low diversity, the absence of EPT taxa, and the absence of long-lived taxa. An interesting difference was observed between the forebay and inflow sites on Watauga: the forebay site was overwhelmingly dominated by the tubificids which negatively impacted the community rating, but very few chironomids were found, whereas the inflow site was overwhelmingly dominated by chironomids which negatively impacted the rating at that site, but very few tubificids were found.

Fish Assemblage—Combined fish samples in shoreline electrofishing (30 transects) and offshore gill netting (24 net-nights) produced a total of 1,102 individuals including 20 species in the transition and forebay zones of Watauga Reservoir. No sampling was conducted in the inflow zone. Fish were more abundant in the transition zone (63 percent of total) but diversity was similar in both sample areas (14 taxa in the forebay and 17 in the transition). The three dominant species by number were bluegill (23 percent), gizzard shad (20 percent), and walleye (16 percent). Other common species were spotfin shiners (11 percent), and rockbass (9 percent).

Analysis of shoreline electrofishing data identified a very poor littoral fish community in the forebay zone (RFAI=20) of Watauga Reservoir. In fact, the forebay score of 20 was the lowest observed (in both 1992 and 1993) in comparable areas of other tributary reservoirs that were sampled. The low forebay RFAI resulted from minimum scores in eight of the twelve metrics used for evaluation. Although the transition zone (RFAI=40) fish community rated only fair, it did receive maximum scores in five of the twelve metrics. Gill netting RFAI evaluations rated the transition zone (RFAI=34) fair and forebay (RFAI=30) poor. The slightly lower forebay rating resulted from minimum scores for six of the twelve metrics.

Combined electrofishing and gill netting RFAI score of 25 indicated a poor rating for the forebay (only Parksville Reservoir had a lower forebay score). The transition zone (RFAI=37) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Shook Branch Recreation Area and an informal swimming area at Watauga Point and three boat ramps were tested for fecal coliform bacteria twelve times each in 1993. No sample was collected within 48-hours of a rainfall of one-half inch or greater. Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all five sites.

Fish Tissue—There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury) were low or not detected in the single channel catfish composite from the forebay. The mercury concentration was 0.53 μg/g. Additional fish tissue screening samples were collected in autumn 1993, but results were not available at the time this report was prepared.

Holston River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Holston River is moderately hard (average hardness of 113 mg/l) and moderately alkaline (average total alkalinity of 94 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Holston River station ranked among the highest in average nitrate+nitrite-nitrogen (0.67 mg/l) and just above the median for average total phosphorus (0.112 mg/l), dissolved orthophosphate (0.057 mg/l), and ammonia nitrogen (0.038 mg/l). The average concentration of organic nitrogen (0.185 mg/l) was among the lowest recorded. The high average total phosphorus and average nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Dissolved nickel was detected in 1 of 6 samples. Neither metal exceeded EPA criteria for protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed. No PCBs or pesticides exceeding the EPA guidelines. However, copper was detected at a level slightly above the EPA guideline for copper in sediment. This was an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 59 taxa and 4,673 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 50 taxa and 3,311 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (30 percent), dipteran black-fly larvae (25 percent), and river snails (10 percent). River snails were the most dominant group in 1992 (43 percent), followed by coleopteran riffle beetles (10 percent) and caddisflies (7 percent). Siltation from agricultural land usage along the river and pollution from industries located upstream have a major impact on benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving from a rating of fair (IBI = 44) in 1992. Improvement was seen mainly in decreased proportions of both tolerant fish and omnivorous fish suggesting some relief from chronic nutrient enrichment of the river. Other problems for the fish community continued to be reflected by low numbers of darter, sunfish, sucker, and other native species, and low proportions of piscivorous fish. Adverse conditions observed were nutrient enrichment (evident in the abundance of aquatic vegetation), and alteration of flow by releases from Fort Patrick Henry Dam.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Seven sites on South Fork Holston River were tested twelve times each for fecal coliform bacteria in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Six sites were located between South Holston Dam and Boone Reservoir. Thomas and Beidleman Creeks were sampled near their confluence with South Fork Holston River. The geometric mean concentration of fecal coliforms on both streams were about 250/100 ml, a little higher than Tennessee's water quality criterion for recreation of 200/100 ml. The other sites were on South Fork Holston River. The two sites between the South Holston Weir and the confluence with Thomas Creek and the site downstream of Thomas Creek but upstream of Beidleman Creek all had very low fecal coliform bacteria concentrations (geometric mean <20/100 ml). The site downstream of Beidleman Creek had a geometric mean concentration of 31/100 ml, and the site downstream of Boone Dam at Fordtown Bridge had a geometric mean concentration of 52/100 ml. Three sites on South Fork Holston River are boat launching sites. Samples at the other sites were taken from the middle of the stream off a bridge, including a footbridge at the most upstream site.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.57 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

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Tennessee Valley Authority
Water Management

Aquatic Ecological Health Determinations for TVA Reservoirs--1994
An Informal Summary of 1994 Vital Signs Monitoring Results and Ecological Health Determination Methods

April 1995

Tennessee Valley Authority

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An Informal Summary of 1994 Vital Signs Monitoring Results
and Ecological Health Determination Methods

Prepared by Monitoring Team

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AQUATIC ECOLOGICAL HEALTH DETERMINATIONS
FOR TVA RESERVOIRS--1994

Contents

Section 1. Reservoir Monitoring -- Overview of Approach, Methods, and 1994 Results

Introduction

The Tennessee Valley Authority (TVA) began its Stream Monitoring Program in 1986 to evaluate major tributaries of the Tennessee River. A parallel program, Reservoir Monitoring, was begun in 1990. The combined Stream and Reservoir Monitoring efforts consolidated these newly-developed activities with existing activities to form an integrated program that is part of TVA's comprehensive Clean Water Initiative.

Objectives of TVA's monitoring efforts are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee River tributaries and reservoirs and to provide screening level information for describing how well these water resources meet the "fishable" and "swimmable" goals of the Clean Water Act. Vital Signs monitoring activities provide the necessary information from key physical, chemical, and biological indicators to evaluate the ecological health of each stream or reservoir and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions. Periodic monitoring of toxic contaminants in fish and bacteriological sampling at recreation areas provides information for evaluating whether Tennessee Valley waters are fishable and swimmable.

This paper focuses on how TVA performs the overall ecological health rating for reservoirs. It summarizes 1994 data as an example of the mechanics and index values resulting from the rating system.

Study Design Considerations

Several fundamental premises or assumptions were formulated to aid the study design process. These included:

1. Ecological health evaluations must be based on information on physical, chemical, and biological components of the ecosystem;

2. Monitoring program design must be considered dynamic and flexible, rather than rigid and static, and must allow adoption of new environmental monitoring techniques as they develop to meet specific needs;

3. Monitoring methods must provide current, useful information to resource managers;

4. Monitoring must be sustained for several years to document the status of the river/reservoir system, determine its year-to-year variability, and track results of water quality improvement efforts; and

5. Addressing specific cause/effect mechanisms is not the primary purpose of monitoring. While monitoring may provide information to identify cause/effect relationships, more detailed assessment investigations usually are required.

With these premises in mind, TVA's challenge has been to develop a sustainable monitoring effort that collects the right kinds of physical, chemical, and biological data to provide enough information to reliably characterize ecological health. Study design must carefully consider selection of important ecological indicators, representative sampling locations, and frequency of sampling, all in light of available resources. Following are some the basic study design decisions TVA made in developing this program. The four main activities of the program focus on (1)physical/chemical characteristics of water; (2)acute toxicity and physical/chemical characteristics of sediment; (3)benthic macroinvertebrate community sampling; and (4) fish assemblage sampling.

Ecological Indicators-- Physical, chemical, and biological indicators were selected to provide information from various habitats or ecological compartments on the health of that particular habitat or compartment. For example, in reservoirs the open water or pelagic area was represented by physical and chemical characteristics of water (including chlorophyll) in midchannel. The shoreline or littoral area was evaluated by sampling the fish community. The bottom or benthic compartment was evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments and acute toxicity testing of pore water); and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

Sampling Locations--Three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam. Overbanks, basically the floodplain which was inundated when the dam was built, were included in transition zone and forebay areas. Another important reservoir area, embayments, also was considered. Previous studies (Meinert, Butkus, and McDonough, 1992) have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with little influence from the main body of the reservoir. Although these are important areas, monitoring the ecological health of hundreds of embayments is beyond the scope of this program. As a result, only four, large embayments (all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres) were included in the Vital Signs Monitoring Program.

Sampling Frequency--Sampling frequencies (indexing periods) must consider the expected temporal variation for each indicator. Physical and chemical components vary significantly in the short term so they are monitored monthly from spring to fall. Biological indicators better integrate long-term variations and are sampled once each year. Fish assemblage sampling is conducted in autumn (September-November). From 1990 through 1994 benthic macroinvertebrate sampling was conducted in early spring (February-April) to avoid aquatic insect emergence. Beginning in 1995, sampling will be conducted in late autumn/early winter (November and December). The problem with spring sampling is that results are reflective of conditions from the previous year. This caused evaluations for this indicator to be out of synch with those from the other indicators. This change is more thoroughly discussed in Section 4 "Benthic Macroinvertebrate Community."

Data Evaluation Considerations

Selection of data evaluation techniques is also of primary importance in study design considerations. Like most evaluations, results for ecological integrity studies must be compared to some reference or yard stick to determine if monitoring results are indicative of good, fair, or poor conditions. In streams this is usually accomplished by studying a site that has had little or preferably no alterations due to human activities. Observations at that site provide the reference conditions or expectations of what represents a site with good/excellent ecological health. Given that reservoirs are not natural systems, this approach is not possible. Developing reference conditions for reservoirs represents a more difficult task and requires special attention. Tied closely to development of reference conditions is the issue of classification--grouping only those waterbodies which are expected to have similar characteristics and thus correctly allow an "apples to apples" comparison. In streams, important considerations include comparable stream size, gradient, ecoregion, etc. Similar considerations apply to reservoirs but the list is longer because reservoirs are managed or controlled systems and those objectives must be taken into consideration.

Reference Conditions--It is not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to determine characteristics or expectations of a "natural" reservoir because reservoirs are manmade systems. Other approaches must be used such as: historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. Preimpoundment conditions are inappropriate because of significant habitat alterations. For the most part, models are of limited value for a large variety of indicators because of such great spatial and temporal variations within and between reservoirs. Spatial variation exists within in the multiple zones (e.g., forebay, transition zone, inflow, and embayments) of a reservoir. Further, each zone responds differently to different stimuli. Temporal variations are introduced because reservoirs are controlled systems with planned annual drawdowns in elevations ranging from only a few feet to several hundred feet. This leaves best observed conditions or professional judgment as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment is the best approach. Use of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

Reservoir Classification -- Implications of reservoir classification issues to environmental indicator evaluation had to be considered in developing the study design. This was accomplished by examining the following fundamental question separately for each indicator--Should reservoir ecological health evaluations be based on:

(1) ideal conditions (for example, a very low DO concentration is an unacceptable ecological condition); or

(2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir (for example, very low DO concentrations are acceptable in many tributary reservoirs because of water management practices, withdrawal schemes, stratification, etc.)?

The answer to this question was the same for some indicators but differed for others. For DO and Sediment Quality, ideal conditions should be expected. That is, poor DO is unacceptable regardless of type of reservoir or dam operation. Sediments should not have high concentrations of metals, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota. In this situation, there is no need for classification because the same conditions are desired for all reservoirs. For chlorophyll, benthos, and fish the latter approach was used. As such, reservoirs must be grouped or stratified because the same conditions do not exist for all reservoirs. The classification scheme that has evolved for chlorophyll is actually a combination of the two approaches--examination of the "natural" nutrient level in the watershed and then a conceptual/subjective decision made as to the concentrations indicative of good, fair, and poor conditions. Two classes of reservoirs were developed -- reservoirs in watersheds draining nutrient poor soils, primarily those in the Blue Ridge Ecoregion (i.e., expected oligotrophic reservoirs); and reservoirs in watersheds draining soils which are not nutrient poor (i.e., expected mesotrophic reservoirs).

For the benthic macroinvertebrate and fish communities, reservoirs were divided into four classes. The reservoirs on the Tennessee River plus two navigable reservoirs on tributaries to the Tennessee River. This group of reservoirs has relatively short retention times and little winter drawdown. The remaining tributary reservoirs were separated by ecoregion into three classes: those in the Blue Ridge Ecoregion, those in the Ridge and Valley Ecoregion, and those on the Interior Plateau Ecoregion.

Reservoir classification issues are further discussed in subsequent sections as they apply to specific environmental indicators.

Ecological Health Rating Methods

There are no official or universally accepted guidelines or criteria upon which to base an evaluation of the health or integrity of the aquatic ecosystem within reservoirs. Consequently, an evaluation methodology had to be developed to assess overall ecological health or condition of reservoirs included in TVA's Vital Signs program. The ecological health evaluation system combines both biological and physical/chemical information to examine reservoir and stream health. Five aquatic ecosystem indicators are used -- dissolved oxygen, chlorophyll-a, sediment quality, benthic macroinvertebrates, and fish community.

Detailed descriptions of scoring criteria for each environmental indicator are provided in other sections. A brief overview is provided here to assist in understanding how individual ratings contribute to the overall ecological health score for a reservoir. Dissolved oxygen scoring criteria attempt a multidimensional approach that includes considering dissolved oxygen levels both in the water column and near the bottom of the reservoir. The DO scoring criteria necessarily are complicated because of the combined effects of flow regulation and the potential for oxygen depletion in the hypolimnion.

Chlorophyll scoring criteria were developed separately for each of the two classes of reservoirs based on geologic and soil characteristics and professional experience with reservoirs in the TVA region. Reservoirs expected to be oligotrophic received highest ratings at low chlorophyll concentrations. Reservoirs expected to be mesotrophic received highest ratings for a range of concentrations. Experience has shown that below a threshold level of chlorophyll (about 2-3 ug/l), primary production may be insufficient to support an active, biologically healthy food chain. In addition, chlorophyll concentrations above a higher threshold (about 10 ug/l) result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment.

The sediment quality scoring criteria uses a combination of two characteristics: sediment toxicity to test organisms; and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs.

For the benthic macroinvertebrate and fish community indicators, scoring criteria were developed from the existing data base on TVA reservoirs. Appropriate community characteristics or metrics were selected for each community (8 metrics for benthic macroinvertebrates and 12 metrics for fish). Data for each metric/community characteristic (e.g., number of taxa, abundance, etc.) were ranked and divided into good, fair, and poor groupings. Data for the current year of monitoring (e.g., 1994) were then compared to these criteria and scored accordingly. Scores for each metric were then summed to obtain a score for that community. This approach is valid if the data base is sufficiently large and if it can be safely assumed that the data base covers the full spectrum of good to poor conditions.

The first step in determining an overall reservoir health score is to sum the ratings for all indicators (ranging from 1-poor to 5-excellent) at a sample site. The number of indicators monitored at each site varies. Generally, all five indicators are included; however, this is not always the case. For example, chlorophyll and sediment quality are not monitored at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. The number of sites per reservoir also varies from one (the forebay) in small tributary reservoirs to four (forebay, transition zone, inflow, and embayment) in selected run-of-the-river reservoirs. As a result, the number of individual ratings vary from five to 18 for the 30 reservoirs monitored in 1994. Specific information on what indicators were sampled in each reservoir is in Table 1.

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum potential ratings for that reservoir, and expressed as a percentage. For example, a small reservoir with only one sample site, the minimum health evaluation would be 20 percent (all five indicators rated poor-1 for a total score of 5 divided by the maximum possible total of 25) and the maximum would be 100 percent (all five indicators rated good-5). This same range of 20 to 100 percent applies to all reservoirs regardless of the number of sample sites, and the same calculation process is used.

The next step is to divide the 20-100 percent scoring range into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results are plotted and examined for apparent groupings.

2. Groupings are compared to known, a priori conditions (focusing on reservoirs with known poor conditions), and good-fair and fair-poor boundaries were established subjectively.

3. The groupings are compared to a trisection of the overall scoring range. A scoring range is adjusted up or down a few percentage points to ensure a reservoir with known conditions falls within the appropriate category. This is done only in circumstances where a nominal adjustment is necessary.

These methods have been in use for four years. Each year slight modifications are made in the original evaluation process and the numerical scoring criteria for each of the five ecological health indicators based on experience gained from working with this process, review of the evaluation scheme by other state and federal professionals, and results of another year of monitoring,

As a result, scoring ranges have changed slightly over the years as outlined below

	Run-of-the-river reservoirs			Tributary, storage reservoirs		
	Poor	Fair	Good	Poor	Fair	Good
1991	<53	53-72	>72	<57	57-72	>72
1992	<53	53-72	>72	<57	57-72	>72
1993	<52	52-71	>71	<57	57-71	>71
1994	<52	52-72	>72	<57	57-72	>72

The difference in the poor scoring range between the two types of reservoirs is due to the fact that two storage reservoirs with known poor conditions rated slightly higher than the boundary for the lower (poor) grouping on the run-of-the-river reservoirs. Hence, the high end of the lower scoring range for storage reservoirs was shifted upward from 52 to 56 percent to accommodate these reservoirs with known poor conditions.

An example that illustrates the overall reservoir health evaluation methodology is presented in Table 2. Wilson Reservoir, the example used, has five aquatic health indicators at one location and three indicators at another location.

Ecological Health Ratings--1994 Results

Experience has shown rainfall and runoff have a significant impact on the ecological conditions in TVA reservoirs. Both were above the long-term average for the Tennessee Valley in 1994 (Figures 1 and 2, respectively). Figure 3 shows the relative contribution of each of the major tributary rivers to flow rates in Tennessee River reservoirs.

Physical and operational characteristics of reservoirs and the dams that control them are also important in evaluating ecological condition. Table 3 summarizes a number of attributes of the reservoirs included in the Vital Signs Monitoring program.

A brief summary of Vital Signs Monitoring results for each reservoir in 1994 is provided in Appendix A. Differences between 1994 and 1993 results are discussed and explained to the extent possible. Appendix A also includes ecological health scores for all years for which Vital Signs Monitoring data exist. Scores are provided as reported (calculated based on the methods in use at that time) and based on the 1994 scoring methods. These scores are also listed for each reservoir in Table 4.

The ecological score for each reservoir in 1994 is presented by classification unit in Figure 4. Run-of-river reservoirs clearly scored higher than any other class. Six fell in the "good" category, four in the upper end of the "fair" range, one in the middle of the "fair" range, and none "poor". For the tributary reservoirs, scores tended to be higher for reservoirs in the Blue Ridge Ecoregion--two were "good", three "fair", and one "poor". Tributary reservoirs in the Ridge and Valley Ecoregion had no "good" scores--six were in the "fair" range and one in the "poor" range. One reservoir in the Interior Plateau Ecoregion was "good", three "fair", and two "poor".

The relative contribution of each environmental indicator to the overall score in 1994 for a reservoir is given for the run-of-river reservoirs in Figure 5 and for tributary reservoirs in Figure 6. Low ratings for certain indicators are obvious. In the run-of-river reservoirs low ratings for the benthic macroinvertebrate community are obvious for Ft. Loudoun, Melton Hill, and Tellico Reservoirs. Low rating for DO are apparent for several tributary reservoirs, especially those in the Interior Plateau

Ecoregion. Minimal DO ratings (i.e., a rating of 1 for all sample locations) occurred in Norris and Cherokee Reservoirs in the Ridge and Valley Ecoregion and for all six reservoirs in the Interior Plateau Ecoregion. None of the reservoirs in the Blue Ridge Ecoregion had minimal DO ratings. Probably low primary productivity rates due to naturally low nutrient levels account for better DO conditions in the latter group of reservoirs. As would be expected based on this line of logic, the reservoir with the highest chlorophyll concentrations among reservoirs in the Blue Ridge Ecoregion (Nottely Reservoir) had the poorest DO conditions.

Figures 7 - 11 further examine the influence of each environmental indicator on overall reservoir scores. Each figure plots the overall reservoir score based on all five indicators and the score with one indicator deleted. These scores were also tested with a Paired T-test to quantitatively test for differences between overall scores based on all five indicators and scores with one indicator deleted. Tests were conducted separately for each ecoregion. Test results should be used only as an indication of possible statistical significance because these are proportional ratings, not actual data, and because no transformation was used prior to testing. Results are summarized below and on Figures 7-11:

Indicator Deleted	Mean Difference In Reservoir Scores With All Five Indicators Vs Score With One Deleted			
	Run-of-River Reservoirs	Ridge and Valley Reservoirs	Blue Ridge Reservoirs	Interior Plateau Reservoirs
DO	-4.3***	4.1	-1.6	10.9***
Chlorophyll	0.6	-1.1	-4.5*	-4.9*
Sediment Qual.	-1.5**	-4.6**	1.1	-4.5*
Benthic Macro.	3.7*	3.6**	6.6***	0.9
Fish	1.3	-1.3	-1.6	-2.4

* Significant at $\alpha = 0.1$; ** Significant at $\alpha = 0.05$; *** Significant at $\alpha = 0.01$

Figure 7 plots these total scores on 1994 data with DO deleted. The previously discussed influence of DO on overall scores for reservoirs in the Interior Plateau Ecoregion is readily apparent. Scores for all six reservoirs in that ecoregion would be almost 10 percentage points higher if DO were excluded. The opposite is the case for the Run-of-River reservoirs -- most reservoir scores would decrease slightly. Scores for most tributary reservoirs in the Ridge and Valley Ecoregion would be higher if DO were excluded. It is not possible to fully explain the consistency of very poor DO conditions in the Interior Plateau tributary reservoirs. One important consideration is that 5 of the 6 reservoirs are water storage projects; only Tims Ford has hydroelectric generators. This affects water retention time and withdrawal depth, both have significant implications to DO conditions.

Figure 8 plots total scores with Chlorophyll deleted. Trends are not obvious. This is possibly due to the importance of localized conditions of land use and nutrient enrichment on individual reservoirs over riding natural regional conditions.

Figure 9 plots scores with Sediment Quality deleted. A listing of these changes is in Table 5. It is important to consider implications of these changes because plans at the time this text was prepared were to exclude Sediment Quality testing in 1995 due to budget constraints. Although small in most cases, scores for 23 of the 30 reservoirs monitored would be lower if Sediment Quality were excluded. Six of these 23 would decrease by 5 or more percentage points. The greatest decrease (11%) would be for Beech Reservoir which had mostly poor or fair ratings, so excluding sediments would cause the score to drop substantially. Only four reservoirs would have a higher score if Sediment Quality were excluded. Two of these (Parksvile and Fontana) would decrease by 5 or more percentage point. Parksville would have the greatest improvement (+15%). Sediment Quality problems there include very high concentrations of several metals, high concentrations of PCBs, and toxicity to test animals. Problems in Fontana Reservoir were high chlordane and toxicity.

Figure 10 plots total reservoir scores with Benthic Macroinvertebrates deleted. Tributary reservoirs in the Blue Ridge and Ridge and Valley Ecoregions, as well as the upper most Run-of-River reservoirs, would have mostly higher scores if benthos were excluded. Benthos ratings were mostly low in these reservoirs, so excluding them would result in a higher overall score. There is no obvious reason for this trend. There is a great variety of reservoir depths, substrate types, drawdown depths, and dam management strategies among these reservoirs.

Figure 11 plots overall scores with and without Fish ratings. Few substantial differences are apparent.

References

Meinert, DL., S.R. Buttus, and T.A. McDonough. 1992. Chickamauga Reservoir Embayment Study - 1990. TVA/WR-92/28

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

			Reservoir Vital Signs Monitoring Tools				
Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a.

BCM - Bear Creek Mile	BRM - Beech River Mile	CCM Cedar Creek Mile
CRM - Clinch River Mile	DRM - Duck River Mile	ERM - Elk River Mile
FBRM - French Broad River	HiRM - Hiwassee River Mile	HRM - Holston River Mile
LBCM - Little Bear Creek Mile	LTRM - Little Tennessee River Mile	NRM - Nottely River Mile
ORM - Ocoee River Mile	PRM - Powell River Mile	SFHR - So Fork Holston River Mile
TRM - Tennessee River Mile	ToRM - Toccoa River Mile	TkRM - Tuckaseegee River Mile
WRM - Watauga River Mile	PRM - Powell River Mile	

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone cholrophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near shore fish community, during autumn.

Table 2 Computational Method For Evaluation of Reservoir Health

Wilson Reservoir - 1994 (Run-of-the-river reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:		No Samples	Tailrace DOs	3.5	No Rating	5
Less Than 2 mg/L (Summer Avg.)				(fair)		(good)
% of X-Sectional Area	0.4 (5)	-	-			
% of X-Sectional Bottom Length	10.7 (2)*	-	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	-	No			
Chlorophyll-a, µg/L:		No Samples	No Samples	3	No Rating	No Rating
Summertime Average	13.5	-	-	(fair)		
Maximum Concentration	30.0	-	-			
Sediment Quality:		No Samples	No Samples	3.0	No Rating	No Rating
Toxicity	Rating = 1			(fair)		
Ceriodaphnia Survival	Yes-0% sur.	-	-			
Rotifer Survival	Yes-30% sur.	-	-			
Chemistry	Rating = 5					
Metals/NH3/pesticides	None	-	-			
Benthic Community:		No Samples		2	No Rating	5
Dominance	1		5	(poor)		(excellent)
Tubificidae	5		3			
Chironomidae	1		5			
EPT	1		3			
Long-lived	1		5			
Taxa richness	1		5			
Zero in sample	5		5			
Non-tolerant density	1		3			
Total	20	-	34			
Fish Community:		No Samples		4	No Rating	3
RFAI	45		40	(good)		(fair)
Rating	4	-	3			
		Sampling Location Sum		15.5 of 25	--	13 of 15
		Reservoir Sum		28.5 of 40 [71%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
- Less than 52% - poor (red)
- 52% to 72% - fair (yellow)
- Greater than 72% - good (green)

(tables93.wpf, page 24)

Table 3

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1994[a] (days)	Average CY 1994 Reservoir Flow (cfs)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	16.6	86,463
Pickwick	32,820	52.7	43.1	84	924	6	54,900	5.9	79,148
Wilson	30,750	15.5	15.5	108	634	3	51,500	4.2	76,182
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	7.3	72,927
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	8.3	61,766
Nickajack	21,870	46.3	10.4	60	241	0	35,900	2.3	52,487
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	6.2	50,663
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	12.6	40,393
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	6.5	28,147
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	8.1	7,451
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	24.2	8,638[d]
Tributary River Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	165.6	6,211
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	78.8	9,009
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	117.9	6,335
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	4.3	3,189
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	30.2	3,151
South Holston	703	23.7	7.6	239	658	33	976	264.1	1,256
Watauga	468	16.3	6.4	274	569	26	714	345.2	831
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	130.0	5,509
Hiwassee	968	22.2	6.1	255	422	45	2,020	74.5	2,855
Chatuge	189	13.0	7.0	124	234	10	459	217.7	542
Nottely	214	20.2	4.2	167	170	24	416	183.1	468
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	26.9	1,592
Blue Ridge	232	11.0	3.3	156	193	36	614	171.0	569
Tims Ford	529	34.2	10.6	143	530	12	940	194.1	1,377
Bear Creek	232	16.0	0.7	74	10	11[e]	380	9.8	513
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	121.8	389
Little Bear Creek	61	7.1	1.6	82	45	12[e]	101	170.6	133
Normandy	195	17.0	3.2	83	110	11	320	116.3	477
Beech	16	5.3	0.9	32	11	1[e]	14	--	--

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a. Estimates based on normal maximum summer pool.
b. *Tennessee River and Reservoir System Operation and Planning Review,* Final EIS, TVA/RDG/EQS--91/1, 1990.
c. Major/minor arms of reservoir.
d. Estimated flow based on releases from Chilhowee Dam (POR avg.= 4770cfs), and adjusted based on the additional drainage area between Chilhowee Dam (1977 sq miles) and Tellico Dam (2627 sq miles).
e. Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

Data Source: Hydrologic Data Management (Knoxville, TN), Systems Engineering, TVA, 1994.

(vs-res94.tbl)

Table 4. Reservoir Ecological Health Scores 1991 - 1994

Watershed/	Area	Eco Health Rating, as reported				Eco Health on 1994 Criteria				Three-yr
Reservoir	(Acres)	1991	1992	1993	1994	1991	1992	1993	1994	Average
Kentucky Res. Watershed										
Kentucky Reservoir	160,300	77	88	75	71	76	88	76	71	78
Beech Reservoir	900	N/A	N/A	65	56	N/A	N/A	70	56	63
Duck River Watershed										
Normandy Reservoir	3,200	N/A	N/A	56	68	N/A	N/A	56	68	62
Pickwick/Wilson Watershed										
Pickwick Reservoir	43,100	77	75	73	84	74	78	71	84	78
Wilson Reservoir	15,500	60	68	71	71	60	68	74	71	71
Bear Creek Resrvoir	700	N/A	N/A	60	56	N/A	N/A	56	56	56
Little Bear Creek Res.	1,600	N/A	N/A	64	64	N/A	N/A	64	64	64
Cedar Creek Reservoir	4,200	N/A	N/A	56	80	N/A	N/A	60	80	70
Wheeler/Elk Watershed										
Wheeler Reservoir	67,100	89	80	72	75	70	78	74	75	76
Tims Ford Reservoir	10,600	N/A	60	58	58	N/A	58	56	58	57
Guntersville/Sequatchie WS										
Guntersville Reservoir	67,900	66	83	78	83	81	85	81	83	83
Nickajack/Chickamauga										
Nickajack Reservoir	10,400	89	83	88	90	85	83	88	90	87
Chickamauga Res.	35,400	90	73	83	87	88	81	86	87	85
Hiwassee River Watershed										
Hiwassee Reservoir	6,100	82	69	58	68	70	73	65	68	69
Chatuge Reservoir	7,100	60	56	67	77	60	80	75	77	77
Nottely Reservoir	4,200	60	60	64	56	60	53	62	56	57
Blue Ridge Reservoir	3,300	87	73	72	86	80	83	80	86	83
Ocoee No. 1 Reservoir	1,900	47	53	52	60	70	70	68	60	66

Table 4. cont. Reservoir Ecological Health Score 1991 - 1994

Watershed/ Reservoir	Area (Acres)	Eco Health Rating, as reported 1991	1992	1993	1994	Eco Health on 1994 Criteria 1991	1992	1993	1994	Three-yr Average
Watts Bar/Ft. Loud./Mel. Hill										
Watts Bar Reservoir	39,000	69	71	68	79	71	76	74	79	76
Fort Loudoun Reservoir	14600	60	53	58	61	63	59	60	61	60
Melton Hill Reserovir	5700	80	67	68	72	72	66	69	72	69
Clinch/Powell Watershed										
Norris Reservoir	34200	57	67	67	69	73	76	71	69	72
L' Tenn. River Watershed										
Tellico Reservoir	15,900	48	48	63	71	54	48	57	71	59
Fontana Reservoir	10,600	N/A	N/A	64	67	N/A	N/A	71	67	69
French Broad River WS										
Douglas Reservoir	30,400	42	56	58	64	60	52	58	64	58
Holston River Watershed										
Cherokee Reservoir	30300	50	53	64	53	62	60	64	53	59
Fort Pat. Henry Res.	900	N/A	N/A	72	60	N/A	N/A	80	60	70
Boone Reservior	4300	51	64	59	59	52	63	61	59	61
South Holston Res.	7600	60	57	65	66	63	63	69	66	66
Watauga Reservor	6,400	80	57	61	65	77	72	63	65	67

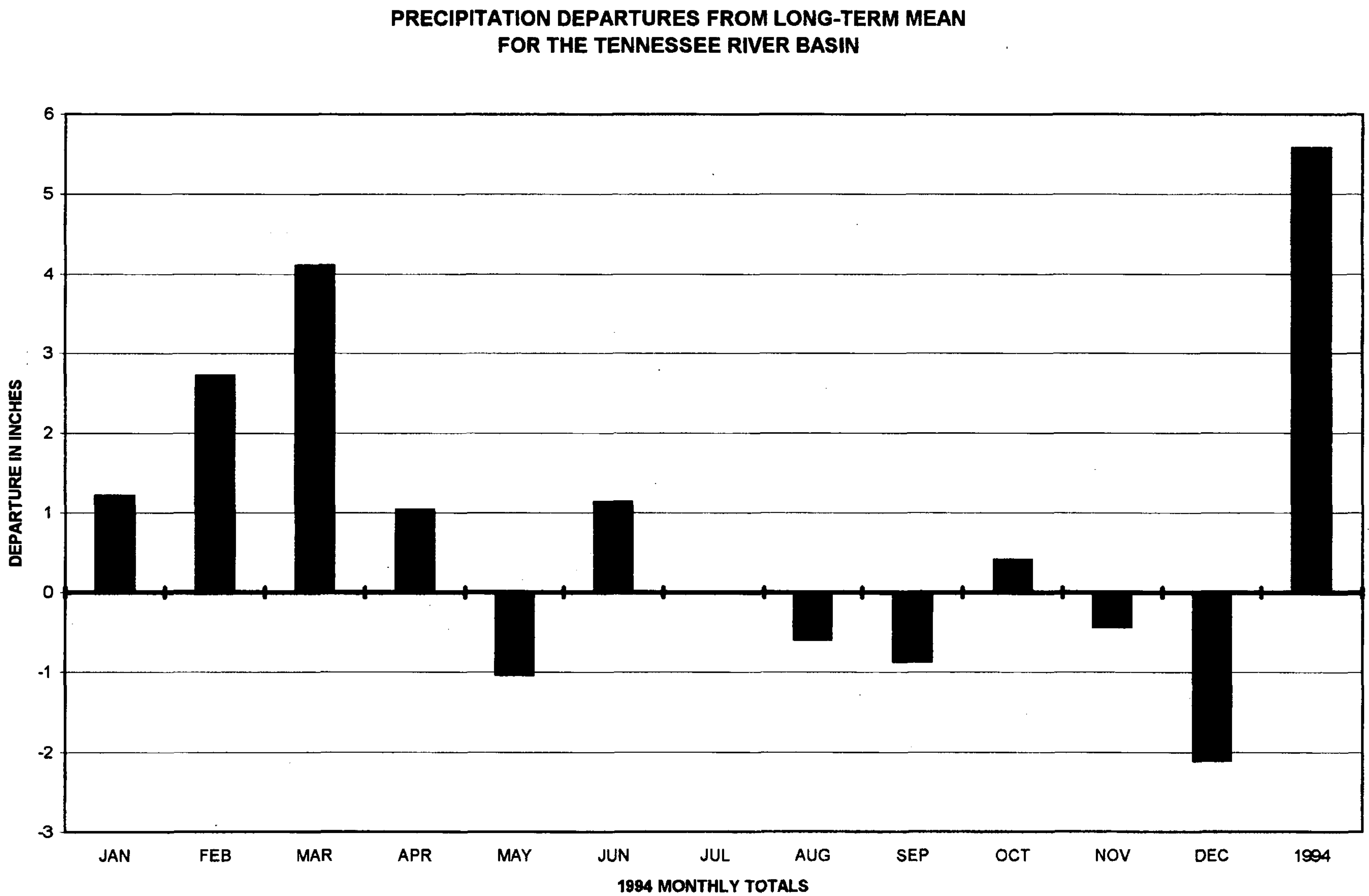
Table 5. Reservoir Ecological Health Scores for 1994--With and Without Sediment Quality

Reservoir	1994 Rating/Score	1994 Rating/Score Without Sediment	Difference
Kentucky	Fair - 71	Fair - 69	-2 pts
Pickwick	Good - 84	Good - 81	-3 pts
Wilson	Fair - 71	Good - 73	+2 pts
Wheeler	Good - 75	Good - 73	-2 pts
Guntersville	Good - 83	Good - 82	-1 pt
Nickajack	Good - 90	Good - 89	-1 pt
Chickamauga	Good - 87	Good - 87	0
Watts Bar	Good - 79	Good - 79	0
Fort Loudoun	Fair - 61	Fair - 57	-4 pts
Melton Hill	Fair - 72	Fair - 68	-4 pts
Tellico	Fair - 71	Fair - 71	0
Norris	Fair - 69	Fair - 65	-4 pts
Douglas	Fair - 64	Fair - 63	-1 pt
Cherokee	Poor - 53	Poor - 43	-10 pts
Fort Patrick Henry	Fair - 60	Poor - 55	-5 pts
Boone	Fair - 59	Fair - 58	-1 pt
South Holston	Fair - 66	Fair - 58	-8 pts
Watauga	Fair - 65	Fair - 64	-1 pt
Fontana	Fair - 67	Good - 75	+8 pts
Hiwassee	Fair - 68	Fair - 60	-8 pts
Chatuge	Good - 77	Good - 76	-1 pt
Nottely	Poor - 56	Poor - 53	-3 pts

Table 5. Cont.'

Reservoir	1994 Rating/Score	1994 Rating/Score Without Sediment	Difference
Blue Ridge	Good - 86	Good - 83	-3 pts
Parksville	Fair - 60	Good - 75	+15 pts
Tims Ford	Fair - 58	Poor - 55	-3 pts
Normandy	Fair - 68	Fair - 60	-8 pts
Bear Creek	Poor - 56	Poor - 55	-1 pt
Little Bear	Fair - 64	Fair - 65	+1 pt
Cedar Creek	Good - 80	Good - 75	-5 pts
Beech	Poor - 56	Poor - 45	-11 pts

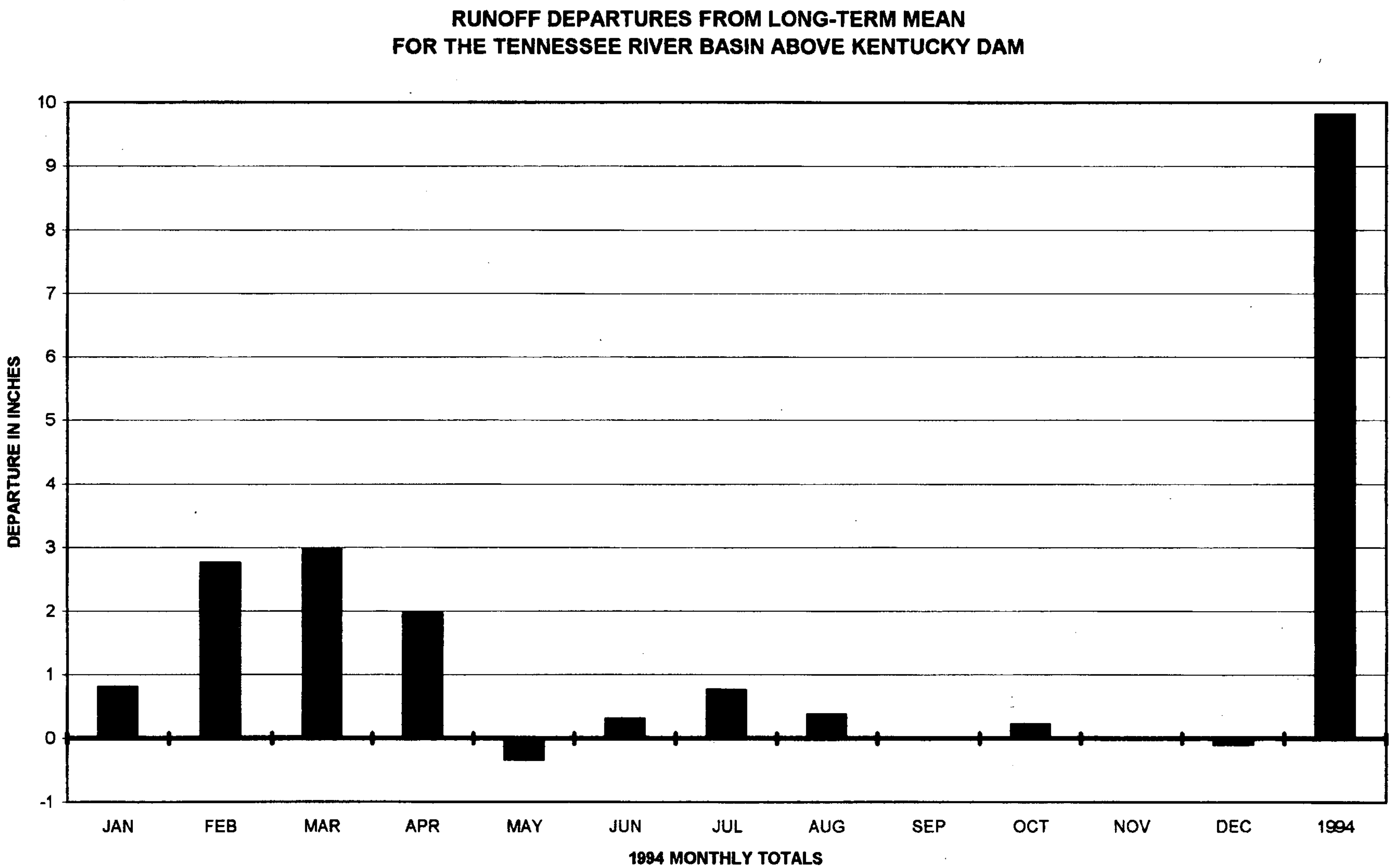
FIGURE 1



RAIN_RUN.XLS,Chart17

Prepared by Edward A. Thornton 1/23/95

FIGURE 2



RAIN_RUN.XLS,Chart19

Prepared by Edward A. Thornton 1/23/95

Figure 3. Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

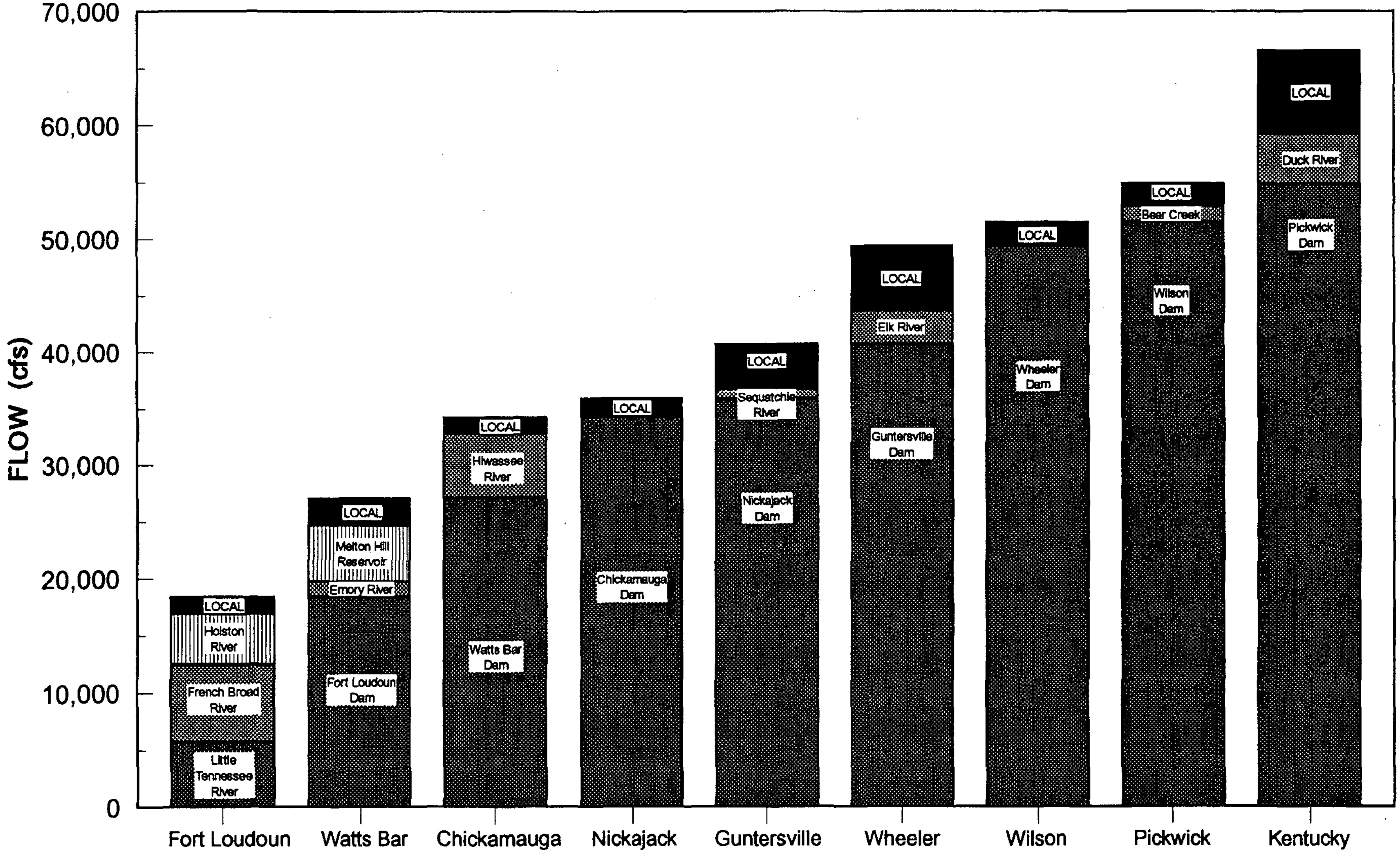
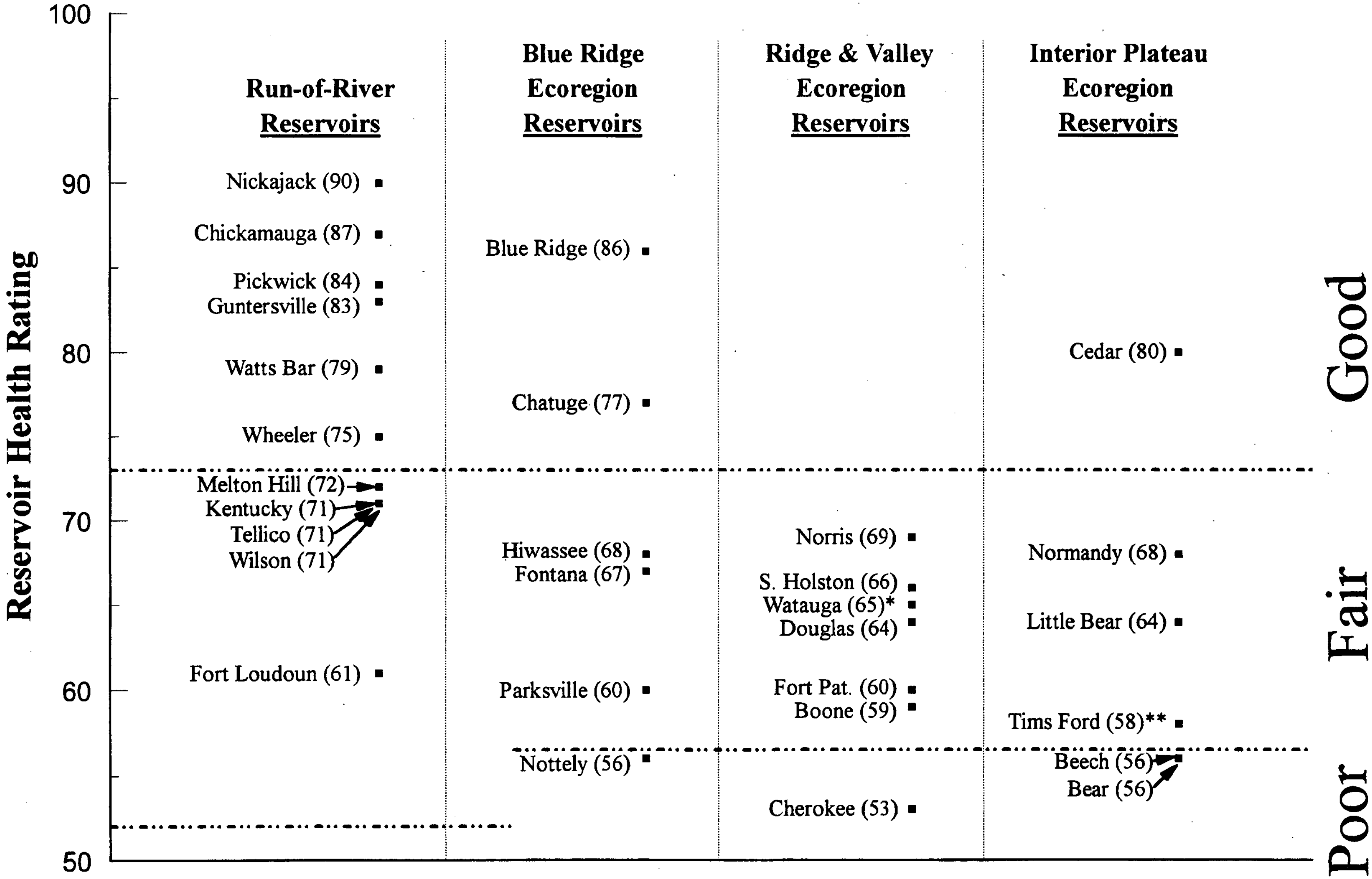


Figure 4. 1994 Ecological Health Summary



* Benthos & Fish compared to Blue Ridge Ecoregion resrevoirs although Watauga physically within Ridge & Valley Ecoregion.

** Benthos & Fish compared to Ridge & Valley Ecoregion reservoirs although Tims Ford physically within Interior Plateau Ecoregion.

Figure 5. Overall Ecological Health of Run-of-the-River Reservoirs in the Tennessee Valley in 1994. (Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

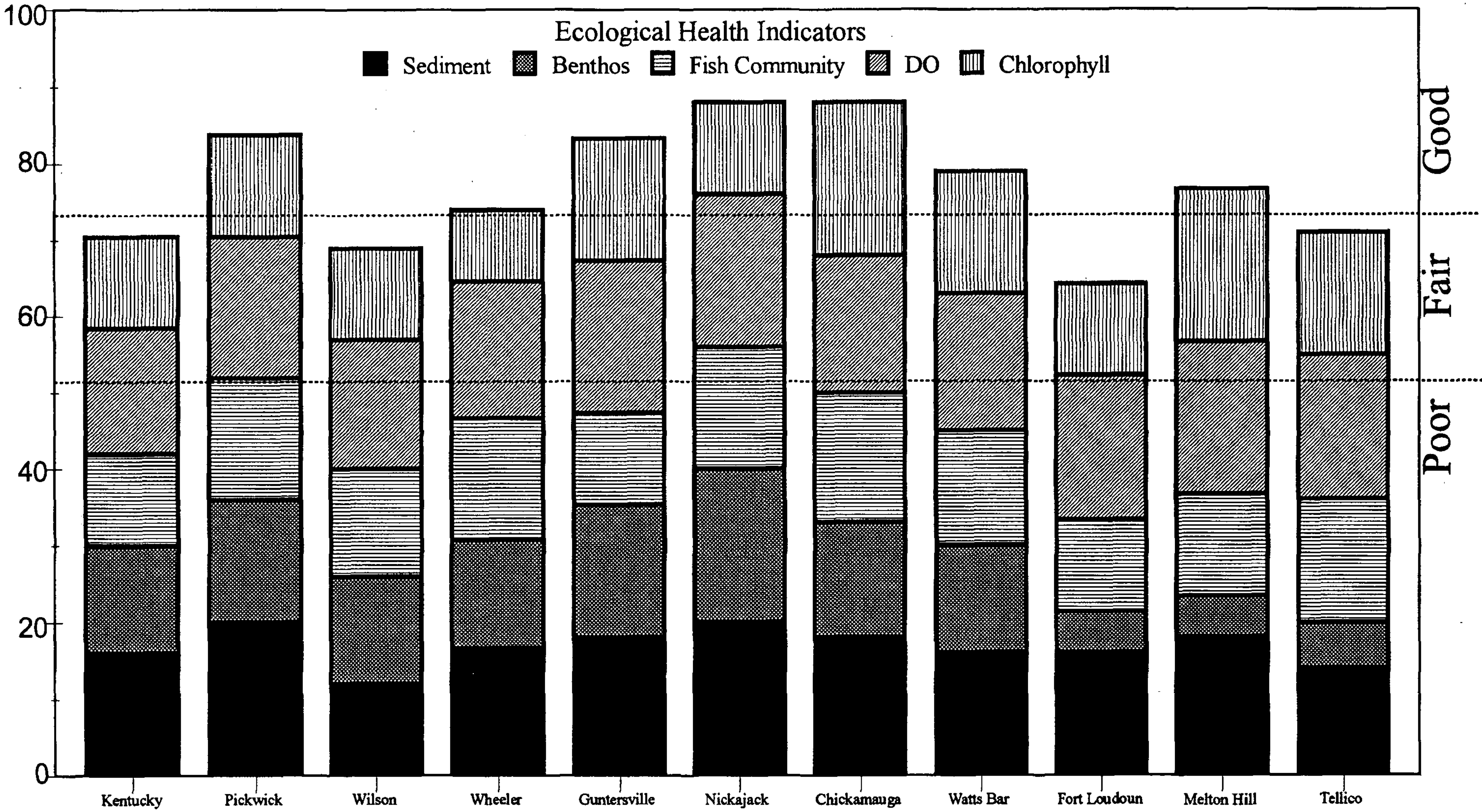


Figure 6. Overall Ecological Health of Tributary Reservoirs in the Tennessee Valley in 1994.

(Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

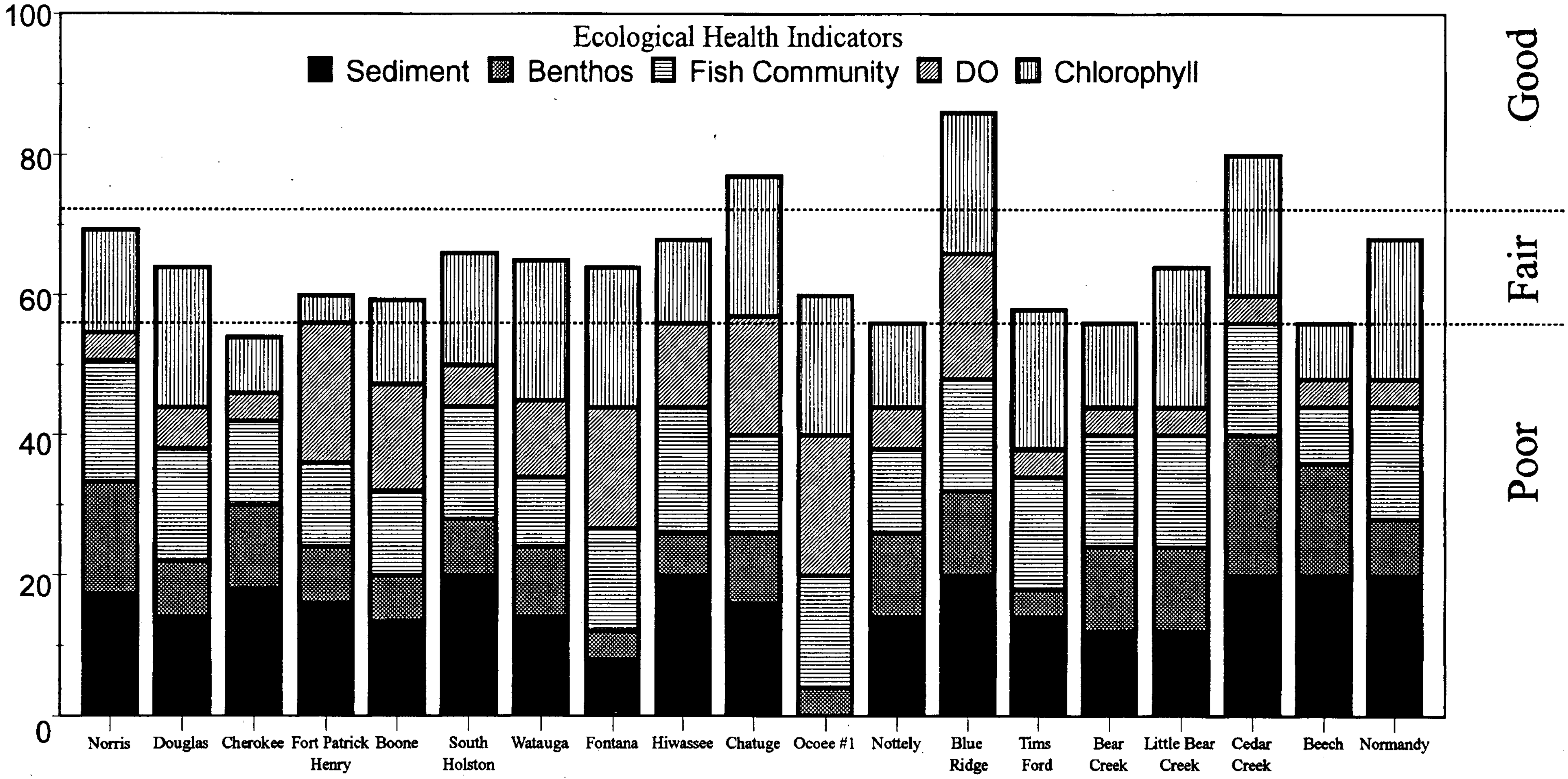
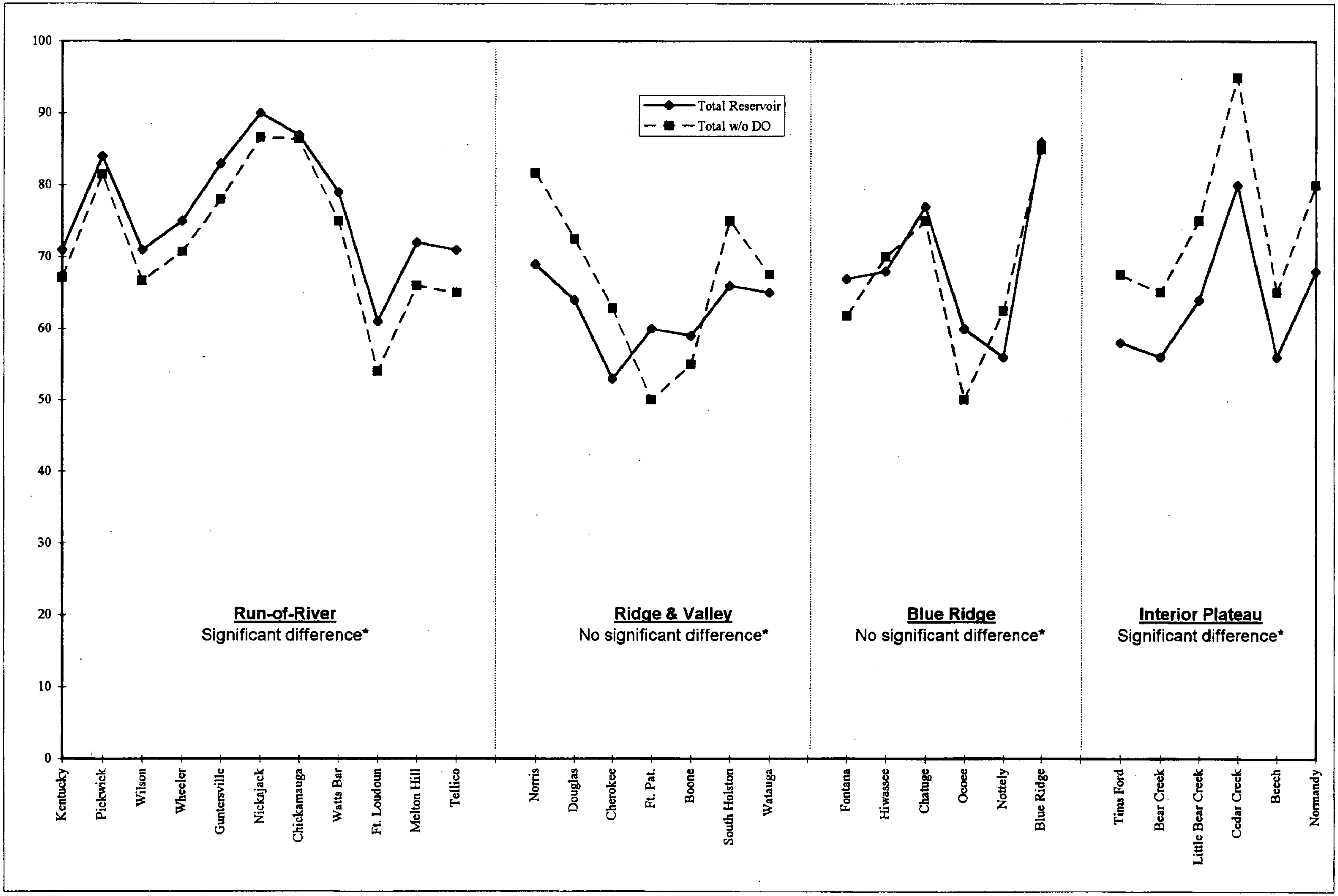
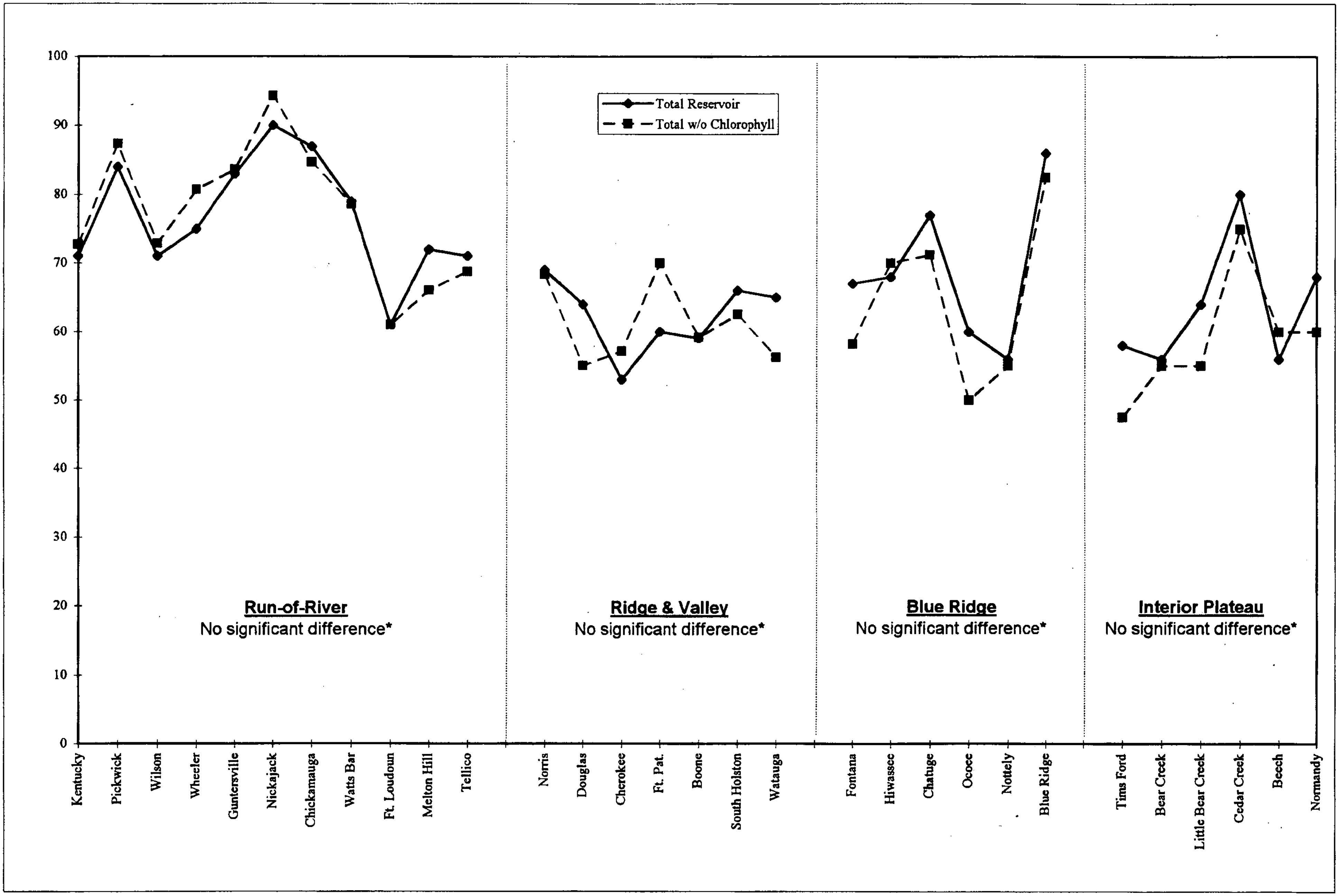


Figure 7. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Dissolved Oxygen Ratings - 1994 Results



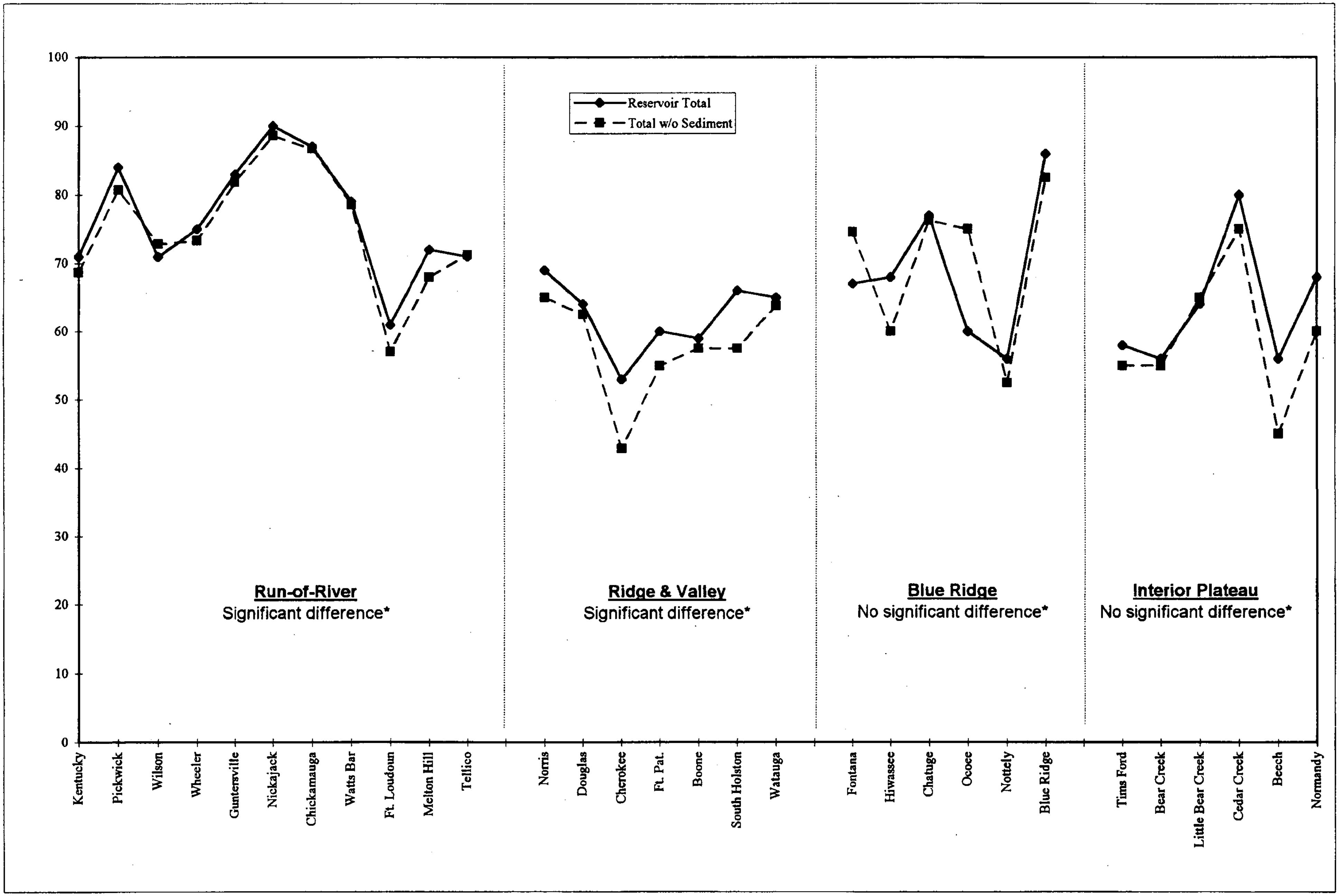
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 8. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Chlorophyll Ratings - 1994 Results



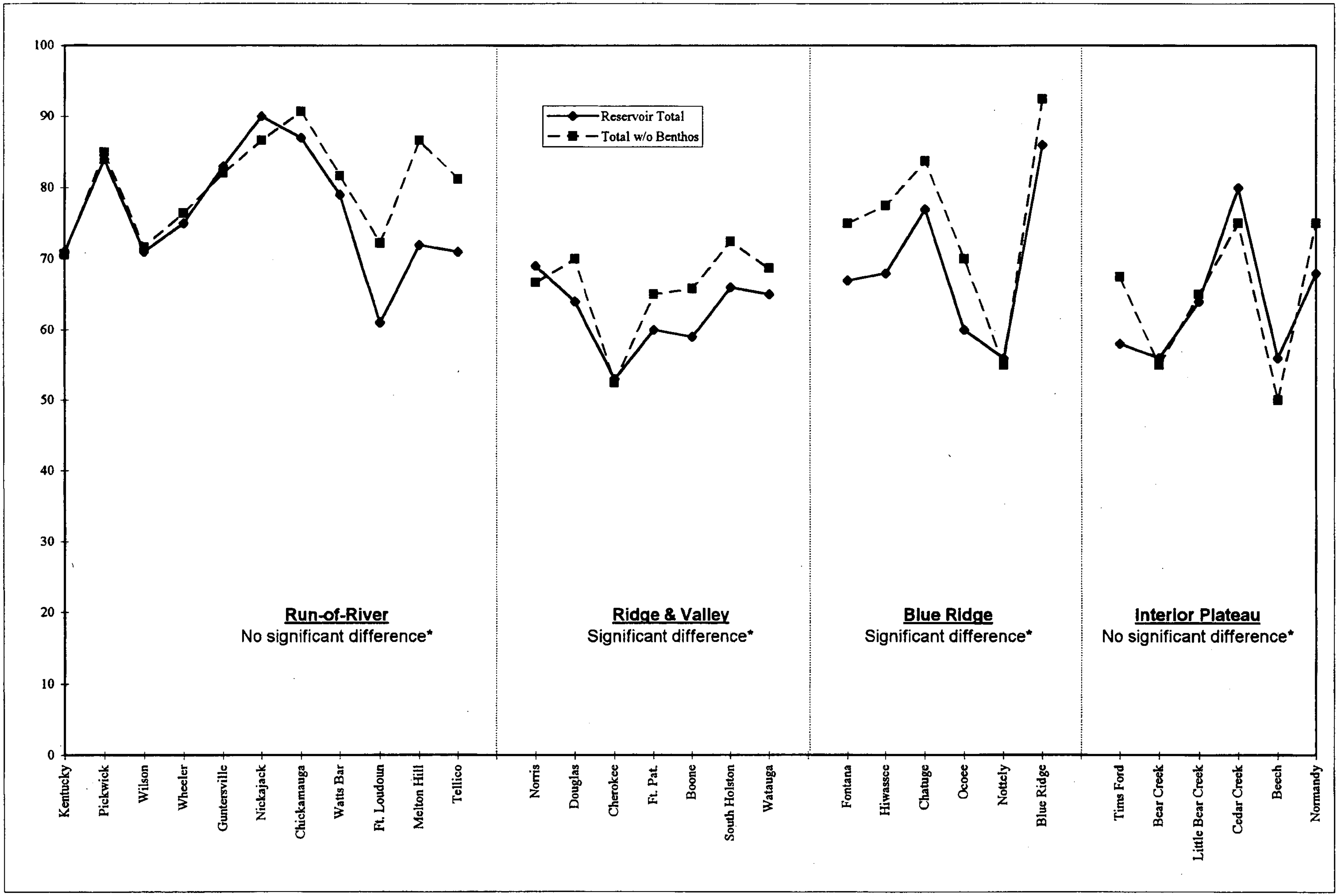
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 9. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Sediment Ratings - 1994 Results



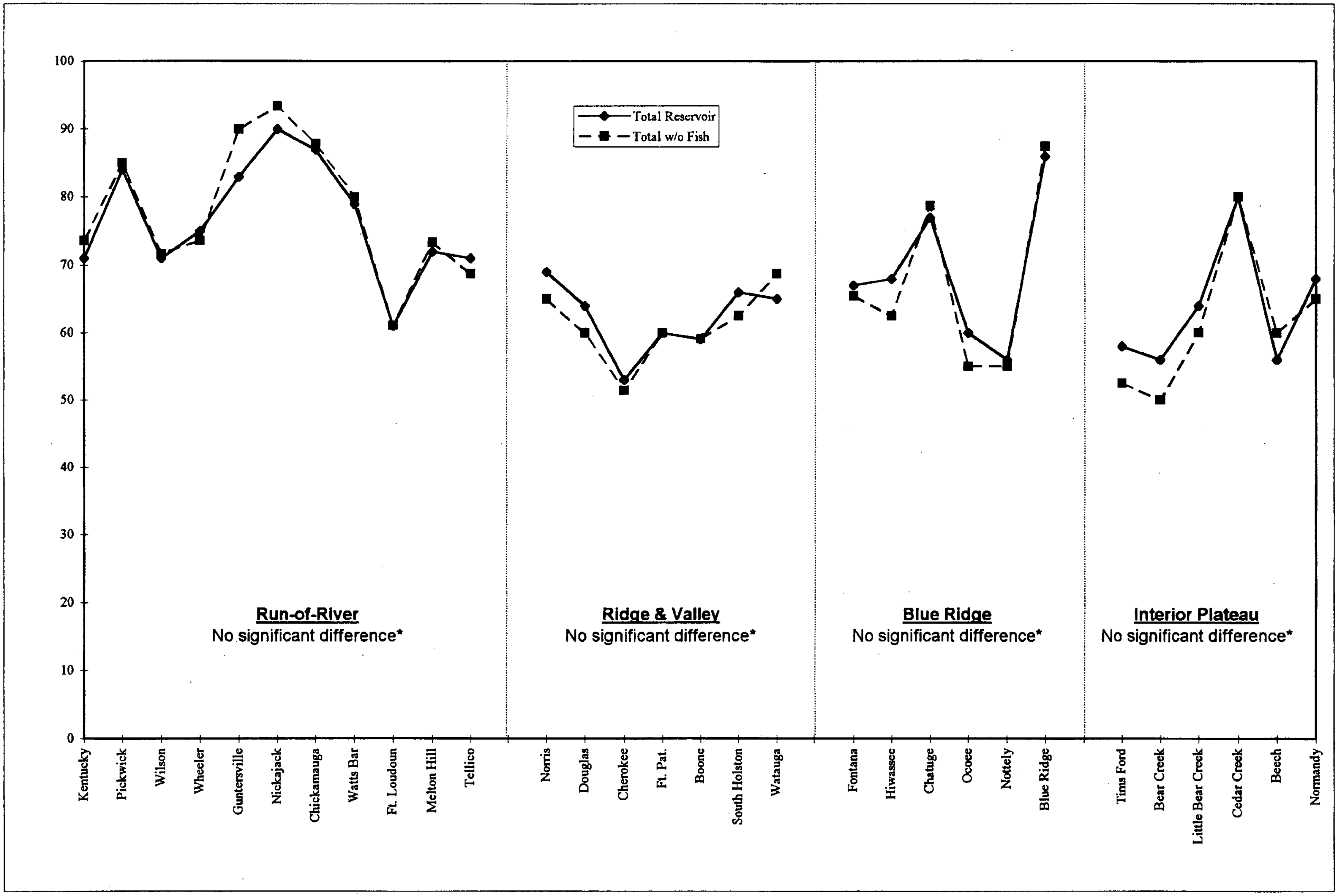
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 10. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Benthic Ratings - 1994 Results



* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 11. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Fish Ratings - 1994 Results



* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Section 2. Dissolved Oxygen (DO) and Chlorophyll

Dissolved Oxygen

Philosophical Approach/Background

Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about the nature of a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are below saturation in the metalimnion and hypolimnion of a reservoir or lake. This hypolimnetic and metalimnetic oxygen depletion is a common, but undesirable, occurrence in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia not only promotes the biochemical release of phosphorus which affects trophic conditions, but also promotes the release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, many of these reduced chemicals can cause chronic or acute toxicity to benthos.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions exist. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish growth and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

A question fundamental to reservoir ecological health evaluation as well as reservoir classification issues is -- should reservoir ecological health evaluations be based on (1) ideal conditions, for example, very low DO concentrations represent an unacceptable ecological condition; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir, for example, very low DO concentrations are acceptable in many tributary reservoirs because of withdrawal schemes, stratification, etc. The approach selected for this program is -- poor DO is unacceptable regardless of type of reservoir or dam operation. Hence, reservoirs were not separated into classes for DO evaluations/expectations because the expectation was the same for all reservoirs.

<u>Data Collection Methods</u>

DO data were collected concurrently with chlorophyll and other physical/chemical samples. Collection methods for these efforts are described in the subsection entitled Data Collection Methods--Physical/Chemical Characteristics of Water (following the subsection on Chlorophyll Rating Scheme).

<u>DO Rating Scheme</u>

A conceptual model was developed for dissolved oxygen rating criteria. The rating criteria represent a multidimensional approach that includes dissolved oxygen levels both throughout the water column (WC_{DO}) and near the bottom (B_{DO}) of the reservoir. The DO rating at each sampling location (ranging from 1 "poor" to 5 "good") is based on monthly summer water column and bottom water DO concentrations. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.) The final DO rating is the average of the water column DO rating and the bottom DO rating:

$$\textbf{DO Rating} = 0.5\ (\textbf{WC}_{DO}\ \textbf{rating} + \textbf{B}_{DO}\ \textbf{rating}),\ \text{where:}$$

<u>WC_{DO} (Water Column DO) Rating</u>--a six-month average of the percent of the reservoir cross-sectional area (at the location where the sampling was conducted) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L.

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location*
<5%	5 (good);
≥5% but ≤10%	3 (fair);
>10%	1 (poor).

*Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows.

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length* (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

*The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Results from 1994 Monitoring

Table 2 summarizes DO and chlorophyll results for each location monitored in 1994. The summary of DO results includes information on water column and bottom DO measurements and the final DO rating.

Isopleths for dissolved oxygen and temperature are provided in Appendix A for each sample location during the 1994 sampling season.

Chlorophyll

Philosophical Approach/Background

Algae are the base of the aquatic food chain; consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977).

Generally, lower chlorophyll concentrations in the oligotrophic range are thought of being indicative of good water quality conditions. Conversely, high chlorophyll concentrations are usually considered indicative of cultural eutrophication. However, care must be taken not to over generalize. For example, it would be inappropriate to expect all reservoirs in the Tennessee Valley to have low chlorophyll concentrations because some reservoirs are in watersheds which have nutrient rich, easily erodable soils. Most watersheds in the Tennessee Valley provide sufficient nutrients to expect chlorophyll concentrations in the mesotrophic range, even in absence of cultural etrophication. However, two watersheds in the Tennessee Valley have soils (and consequently waters) with naturally low nutrient levels--the Little Tennessee and Hiwassee. The streams and rivers in these watersheds drain the Blue Ridge Ecoregion which is largely characterized by thin soils and is underlain mostly with hard crystalline and metasedimentary rocks.

Obviously, development of appropriate expectations is a critical step in evaluating implications of chlorophyll concentrations on the ecological health of a reservoir. The range of concentrations which are considered indicative of good, fair, and poor conditions must be tailored to reservoirs within each watershed based on knowledge of background or natural conditions. This leads to separating reservoirs into classes based upon these conditions.

The classification scheme used to develop expectations for chlorophyll in Tennessee Valley reservoirs was based on the "natural" nutrient level in a watershed. Professional judgment was used to select concentrations considered indicative of good, fair, and poor conditions. Based on this approach, reservoirs were placed into one of two classes for chlorophyll expectations -- those expected to be oligotrophic because they are in watersheds with naturally low nutrient concentrations and those expected to be mesotrophic because the are in watersheds which naturally have greater nutrient availability. The reservoirs expected to be ologotrophic are those in the Blue Ridge Ecoregion. Included in this group are those in the Hiwassee River drainage--Hiwassee, Chatuge, Nottely, Blue Ridge, and Parksville reservoirs and those in the Little Tennessee River drainage--Tellico and Fontana.

The remaining reservoirs, both mainstream reservoirs and tributary reservoirs, are expected to be mesotrophic.

The range of concentrations selected to represent good, fair, and poor conditions obviously will be much lower for reservoirs in nutrient-poor watersheds. In reservoirs with naturally low nutrient levels, the primary concern is early identification of cultural eutrophication so appropriate actions can be taken to prevent a shift to a higher trophic state. For reservoirs expected to be mesotrophic, the concern is that chlorophyll levels not become too great because of the associated undesirable conditions--occasional dense algal blooms, poor water clarity, low DOs, and the predominance of noxious bluegreen algae. In mesotrophic reservoirs where sufficient nutrients are available but chlorophyll concentrations remain low, there is likely something inhibiting this natural process, such as excessive turbidity, toxicity, etc. Consequently, the rating for chlorophyll-a is lowered when such conditions are found.

Data Collection Methods

Chlorophyll samples were collected concurrently with DO and other physical/chemical samples. Data collection methods for these efforts are described below following the section on Chlorophyll Rating Scheme.

Chlorophyll Rating Scheme

Chlorophyll ratings at each sampling location were based on the average summer concentration of monthly, photic zone chlorophyll-a samples (corrected) collected from April through September (or October), as shown below. If triplicate samples were collected at a sampling location (for QA purposes), the median value of the triplicate was used in calculating the summer average and the maximum.

	Average Chlorophyll-a Concentration	Sampling Location Chlorophyll Rating
Oligotrophic Reservoirs	Less than 4 μg/L	5 (good)
	4 to 7 μg/L	3 (fair)
	Greater that 7 μg/L	1 (poor)
Mesotrophic Reservoirs	Less than 3 μg/L	3 (fair);**
	3 to 10 μg/L	5 (good);
	10.1 to 15 μg/L	3 (fair);
	Greater than 15 μg/L	1 (poor).

* If any single chlorophyll-a sample exceeds 30 μg/L, the value is not included in calculating the average, but the rating is decreased one unit, (i.e., 5 to 4, or 4 to 3, etc.) for each sample that exceeded 30 μg/L.

** If nutrients are present (e.g., nitrate+nitrite greater than 0.05 mg/L and total phosphorus greater than 0.01 mg/L) but chlorophyll-a concentrations are generally low (e.g., ≤ 2 μg/L), another/other limiting or inhibiting factors such as toxicity, turbidity, etc. is likely. When these conditions exist, chlorophyll is rated 2 (poor).

Results from 1994 Monitoring

Table 2 summarizes DO and chlorophyll results for each location monitored in 1994. The summary of chlorophyll results includes the average chlorophyll concentration for the monitoring season, the maximum observed chlorophyll concentration, and the Final Chlorophyll-a Rating.

References

Carlson, R.E., 1977. "A Trophic State Index for Lakes." Limnology and Oceanography, 22:361-369.

Hutchinson, G. Evelyn, 1975. A Treatise on Limnology, Volume 1, Part 2 - Chemistry of Lakes, J. Wiley and Sons, New York.

Masters, A., and T.A. McDonough, April 1993. TVA Water Management, Chattanooga, Tennessee, Personal Communication.

Data Collection Methods--Physical/Chemical Characteristics of Water

In 1994, physical/chemical water quality variables were measured at a total of 57 sampling locations on 30 reservoirs. Three specific QA/QC measures were incorporated in the reservoir physical/chemical water sampling activities. These included: (1) collection and analysis of triplicate sets of water samples once during the year at all forebay sampling locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling.

The water quality monitoring activities on the Vital Signs reservoirs followed a "basic" (11 run-of-the-river reservoirs) or a "limited" (19 tributary reservoirs) sampling strategy (Table 1). Physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system.

Basic--Monitoring on the run-of-the-river reservoirs included monthly water quality surveys (April through September) at forebays and transition zones. Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone (defined as twice the Secchi depth) composite chlorophyll-a samples; and photic zone composite and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids. Physical/chemical water quality sampling was not conducted at most run-of-the-river reservoir inflows because most of these locations are tailwater areas of upstream dams; water quality characteristics there are more representative of processes in the upstream reservoir.

Limited--Tributary storage reservoirs were sampled monthly (April through October) for a smaller list of parameters. The approach was the same as for the run-of-the-river reservoirs, except that no fecal coliform, color, or suspended solids samples were collected, and only photic zone composites for nutrients and organic carbon samples were collected and only in April and August. The April and August nutrient samplings were designed to provide information on nutrient concentrations available at the beginning of the growing season, then near the end of the growing season. Forebays were sampled on all these reservoirs, and mid-reservoir locations were sampled on all but the smaller reservoirs.

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools				
			Water Quality[c]	Sediment Quality[d]		Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
				Toxicity	Phy/Chem		
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a. BCM - Bear Creek Mile; BRM - Beech River Mile; CCM Cedar Creek Mile; CRM - Clinch River Mile; DRM - Duck River Mile; ERM - Elk River Mile; FBRM - French Broad River; HiRM - Hiwassee River Mile; HRM - Holston River Mile; LBCM - Little Bear Creek Mile; LTRM - Little Tennessee River Mile; NRM - Nottely River Mile; ORM - Ocoee River Mile; PRM - Powell River Mile; SFHR - So Fork Holston River Mile; TRM - Tennessee River Mile; ToRM - Toccoa River Mile; TkRM - Tuckaseegee River Mile; WRM - Watauga River Mile; PRM - Powell River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone cholrophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near shore fish community, during autumn.

TABLE 2

1994 Vital Signs Monitoring Data (using average minimum winter pool elevations)

Reservoir	Dissolved Oxygen: Water Column DO: Less than 5.0 mg/l ? (@ 1.5 meters)	Dissolved Oxygen: Water Column DO: Percent of X−Section < 2.0 mg/l	Dissolved Oxygen: Water Column DO: Rating	Dissolved Oxygen: Bottom DO: Bottom DO 0 mg/l ?	Dissolved Oxygen: Bottom DO: Percent of B−L @ MP < 2.0 mg/l	Dissolved Oxygen: Bottom DO: Rating	Final DO Rating	Chlorophyll−a: Average	Chlorophyll−a: Maximum	Final Chlor−a Rating	Comments
RUN−OF−THE−RIVER RESERVOIRS											
Kentucky											
Tailrace(TRM 22.3)	No	–	5	–	–	–	5	–	–	–	
Forebay(TRM 23.0)	No	0.9	5	No	2.8	4	4.5	10.5	18	3	
T−Zone(TRM 85.0)	No	0	5	No	0	5	5	7.3	13	5	
Inflow(TRM 200−206)	No	–	5	–	–	–	5	–	–	–	
Embay(BSRM 7.4)	No	8.2	3	Yes	21.3	1	2	19.4	33	1	
Pickwick											
Forebay(TRM 207.3)	No	0	5	No	0	5	5	11.2	31	2	
T−Zone(TRM 230.0)	No	0	5	No	0	5	5	7.7	22	5	
Inflow(TRM 253−259)	Yes 4.8	–	4	–	–	–	4	–	–	–	
Embay(BCM 8.4)	No	0.8	5	No	1.6	4	4.5	13.3	20	3	
Wilson											
Forebay(TRM 260.8)	No	0.4	5	Yes	10.7	2	3.5	13.5	30	3	
Inflow(TRM 273−274)	No	–	5	–	–	–	5	–	–	–	
Wheeler											
Forebay(TRM 277.0)	No	0	5	No	0	5	5	14.8	24	3	
T−Zone(TRM 295.9)	No	0	5	No	0	5	5	2.2	3	3	
Inflow(TRM 347−348)	No	–	5	–	–	–	5	–	–	–	
Embay(ERM 6.0)	No	6.3	3	No	20.0	3	3	19.0	35	1*	*[Rating lowered to 1, 2 values above 30ug/l]
Guntersville											
Forebay(TRM 350.0)	No	0	5	No	0	5	5	6.7	15	5	
T−Zone(TRM 375.2)	No	0	5	No	0	5	5	2.7	5	3	
Inflow(TRM 420−424)	No	–	5	–	–	–	5	–	–	–	
Nickajack											
Forebay(TRM 425.5)	No	0	5	No	0	5	5	2.7	3	3	
Inflow(TRM 469−470)	No	–	5	–	–	–	5	–	–	–	
Chickamauga											
Forebay(TRM 472.3)	No	0	5	No	0	5	5	8.2	13	5	
T−Zone(TRM 490.5)	No	0	5	No	0	5	5	5.3	10	5	
Inflow(TRM 518−529)	Yes 3.7	–	3	–	–	–	3	–	–	–	
Embay(HRM 8.5)	No	0	5	No	0	5	5	3.2	4	5	
Watts Bar											
Forebay(TRM 531.0)	No	2.7	5	Yes	8.9	3	4	11.0	19	3	
T−Zone(TRM 560.8)	No	0	5	No	0	5	5	9.3	14	5	
Inflow(TRM 600−601)	Yes 4.7	–	4	–	–	–	4	–	–	–	
Inflow(CRM 19−22)	No	–	5	–	–	–	5	–	–	–	

TABLE 2 (Cont'd)

1994

Reservoir	Dissolved Oxygen: Water Column DO: Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section < 2.0 mg/l	Rating	Bottom DO: Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	Final DO Rating	Chlorophyll-a: Average	Maximum	Final Chlor-a Rating	Comments
RUN-OF-THE-RIVER RESERVOIRS (continued)											
Fort Loudoun											
Forebay(TRM 605.5)	No	0.6	5	No	7.6	4	4.5	10.8	16	3	
T-Zone(TRM 624.6)	No	0	5	No	0	5	5	10.3	16	3	
Tellico								[Nutrient limited watershed]			
Forebay(LTRM 1.0)	No	2.5	5	No	9.2	4	4.5	5.0	8	3	
T-Zone(LTRM 15.0)	No	0	5	No	0	5	5	3.8	6	5	
Melton Hill											
Forebay(CRM 24.0)	No	0	5	No	0	5	5	7.8	13	5	
T-Zone(CRM 45.0)	No	0	5	No	0	5	5	4.2	9	5	
TRIBUTARY RESERVOIRS											
Norris											
Forebay(CRM 80.0)	No	20.3	1	No	42.0	1	1	2.3	5	3	
CRM 125.0	No	27.0	1	Yes	63.8	1	1	2.7	6	3	
PRM 30.0	No	21.4	1	Yes	54.1	1	1	3.3	7	5	
Cherokee											
Forebay(HRM 53.0)	No	23.8	1	Yes	49.5	1	1	11.6	17	3	
HRM 76.0	No	30.6	1	Yes	62.7	1	1	16.7	26	1	
Douglas											
Forebay(FBRM 33.0)	Yes 4.8	26.8	1	Yes	61.3	1	1	7.6	18	5	
FBRM 51.0	No	6.1	3	No	171.7	1	2	9.9	15	5	
Ft. Patrick Henry											
Forebay(SFHRM 8.7)	No	0	5	No	0	5	5	15.9	25	1	
Inflow(SFHRM 18.5)	Yes 3.8	–	3	–	–	–	3	–	–	–	
Boone											
Forebay(SFHRM 19.0)	No	3.2	5	No	4.5	4	4.5	8.7	11	5	
SFHRM 27.0	No	16.5	1	No	12.8	3	2	16.7	29	1	
WRM 6.5	No	0	5	No	0	5	5	13.3	24	3	
South Holston											
Forebay(SFHRM 51.0)	No	9.8	3	No	32.5	1	2	2.9	5	3	
SFHRM 62.5	No	25.2	1	Yes	61.7	1	1	7.3	12	5	
Watauga											
Forebay(WRM 37.4)	No	2.5	5	No	18.6	3	4	4.7	7	5	
WRM 45.5	No	13.4	1	No	20.8	2	1.5	6.3	8	5	

1994

TABLE 2 (Cont'd)

Reservoir	Dissolved Oxygen: Water Column DO: Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section < 2.0 mg/l	Rating	Bottom DO: Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	Final DO Rating	Chlorophyll-a: Average	Maximum	Final Chlor-a Rating	Comments
TRIBUTARY RESERVOIRS (continued)											
Fontana								[Nutrient limited watershed]			
Forebay(LTRM 62.0)	No	1.0	5	No	6.5	4	4.5	2.1	4	5	
LTRM 81.5	No	0	5	No	0	5	5	3.6	7	5	
TkRM 3.0	No	2.2	5	No	23.4	2	3.5	3.0	5	5	
Blue Ridge								[Nutrient limited watershed]			
Forebay(ToRM 54.1)	No	0.1	5	No	1.2	4	4.5	2.6	4	5	
Hiwassee								[Nutrient limited watershed]			
Forebay(HiRM 77.0)	No	8.9	3	Yes	46.8	1	2	6.0	22	3	
HIRM 85.0	No	1.0	5	No	15.1	3	4	5.0	9	3	
Nottely								[Nutrient limited watershed]			
Forebay(NRM 23.5)	No	26.0	1	No	59.7	1	1	5.4	13	3	
NRM 31.0	No	7.4	3	Yes	46.3	1	2	6.7	13	3	
Chatuge								[Nutrient limited watershed]			
Forebay(HiRM 122.0)	No	3.8	5	No	9.9	4	4.5	2.4	3	5	
Shooting Cr 1.5	No	2.7	5	No	15.2	3	4	2.4	4	5	
Ocoee #1								[Nutrient limited watershed]			
Forebay(ORM12.5)	No	0	5	No	0	5	5	2.0	3	5	
Tims Ford											
Forebay(ERM 135.0)	No	46.0	1	Yes	76.3	1	1	6.4	11	5	
ERM 150.0	No	39.4	1	Yes	70.9	1	1	6.3	11	5	
Normandy											
Forebay(DRM 249.5)	No	47.2	1	Yes	88.9	1	1	5.9	8	5	
Bear Creek											
Forebay(BCM 75.0)	No	23.5	1	Yes	66.4	1	1	12.1	24	3	
Little Bear Creek											
Forebay(LBCM 12.5)	No	42.1	1	Yes	83.1	1	1	6.9	14	5	
Cedar Creek											
Forebay(25.2)	No	33.0	1	Yes	78.6	1	1	3.7	7	5	
Beech											
Forebay(BRM 36.0)	No	46.4	1	No	77.6	1	1	12.8	72	2	

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(1-5-95)

TABLE 2 (Cont'd)

1994--River Performance Report – Quality of the Water Resource

Dissolved Oxygen Rating – The Dissolved Oxygen (DO) rating at each sampling location is based on both summer water column and bottom water DO concentrations. (The summer time period is April through September for the 11 Run-of-the-River reservoirs, and May through October for the 19 Tributary reservoirs.) The Final DO Rating is the average of the the water column DO rating and the bottom DO rating:

Final DO Rating = 0.5 (Water Column DO rating + Bottom DO rating)

-- The Water Column DO rating is based on a six month summertime average of the percent of the reservoir cross-sectional area (at the location where sampling is conducted) that has a DO concentration less than 2.0 mg/l, as follow:

Average Cross-Sectional Area (DO less than 2mg/L)	Sampling Location Water Column Rating
< 5 %	(good) – 5
5-10 %	(fair) – 3
> 10 %	(poor) – 1

+ In addition, if the DO is ever less than 5 mg/L at the 1.5 meter depth, the location's water column DO rating is decreased as follows:

Minimum DO at 1.5 meter depth	Sampling Location DO Rating Change
4-4.9 mg/L	Lower 1 unit (e.g., 5 to 4)
3-3.9 mg/L	Lower 2 units (e.g., 5 to 3)
2-2.9 mg/L	Lower 3 units (e.g., 5 to 2)
etc.	etc.

-- The Bottom DO rating is based on a six month summertime average of the percent of the reservoir cross-sectional bottom length (at the location where sampling is conducted), that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length (DO less than 2mg/L)	Sampling Location Bottom Water Rating
0 %	(good) – 5
0-10 %	– 4
10-20 %	(fair) – 3
20-30 %	– 2
> 30 %	(poor) – 1

+ The average percent X-sectional length is computed on the basis of the total X-sectional length at average minimum winter pool elevation. In addition, if anoxic conditions (i.e., 0 mg/l DO) are observed at the bottom, the bottom DO rating is decreased one unit, with a minimum rating of 1.

Ratings – 94
<3 Red
3 to 4 Yellow
>4 green
Chl-a, DO, Sediment

Chlorophyll-a Rating – The chlorophyll-a rating at each sampling location is based on the average summer concentration, as shown below. (If triplicate samples are collected at a sampling location, only the median value of the triplicate is used in the calculation of the summer average and the maximum.) If a monthly chlorophyll-a sample has a concentration that exceeds 30 ug/l, the value is not included in the calculation of the summer average, however, the final chlorophyll-a rating is decreased one unit, (i.e. 5 to 4, or 4 to 3, etc.) for each sample that exceeds 30 ug/l.

Average Summer Chlorophyll-a Concentration	Rating	Average Summer Chlorophyll-a Concentration (Nutrient Limited Watersheds)	Rating
< 3 ug/L*	(fair) – 3		
3 – 10 ug/L	(good) – 5	< 4 ug/L	(good) – 5
10 – 15 ug/L	(fair) – 3	4 – 7 ug/L	(fair) – 3
> 15 ug/L	(poor) – 1	> 7 ug/L	(poor) – 1

* If nutrients are present (e.g. total phosphorus greater than about 0.01 mg/L and nitrate+nitrite-nitrogen greater than about 0.05 mg/L) but chlorophyll-a concentrations are generally low (e.g. < 3ug/L), other limiting or inhibiting factors (e.g., high streamflows, turbidity, toxicity, etc.) must be considered. When these conditions exist, chlorophyll-a is rated 2 (poor).

Section 3.0. Sediment Quality

Philosophical Approach/Background

Contaminated bottom sediments can have direct adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. There are many sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). TVA's approach combines two sediment assessment methods--one biological, the other chemical--to evaluate sediment quality.

A fundamental question concerning implications of sediment quality on overall reservoir ecological health is essentially a classification issue -- should reservoir ecological health evaluations be based on: (1) ideal conditions; for example, sediments should not have high concentrations of metals compared to background, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir; for example, high concentrations of reduced metals are acceptable in tributary reservoirs due to anoxic conditions resulting from long retention times and thermal stratification. The approach taken for these studies accepts only ideal conditions. That is, metal concentrations should not be elevated, pesticides should not be present, and there should be no toxicity. In this situation, there is no need for classification because the same conditions are desired for all reservoirs.

Sediment Collection and Toxicity Testing Methods

Annual sediment samples and near-bottom water samples were collected during the summer of 1994 from 57 locations, i.e., the forebays and transition zones (or mid-reservoir) of the 11 mainstream reservoirs and 19 tributary reservoirs as shown in Table 1. In addition, ten of the 57 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the ten sites. Replicate samples were handled and processed independently. Results from these ten sets of replicates were used to assess field methods consistency, variations in laboratory toxicity and physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment and Kemmerer or Isco water samplers were used to collect the near-bottom water. Each sediment sample was a composite of at least three subsamples independently collected at each sampling location from the original stream channel bed. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency, and split into two fractions: one fraction for acute toxicity testing, and one fraction for physical/chemical analyses. Samples were placed on ice immediately after collection, compositing, and splitting, and were shipped or carried to the appropriate laboratory. One split from each sampling location and the sample of near-bottom water were shipped to the Toxicity Testing Laboratory (TTL) for toxicity testing; the other split at each sampling location was shipped or carried to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute Toxicity Testing--Within 36 hours of collection, all sediment samples were screened for toxicity using Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. Organisms were exposed to undiluted interstitial (pore) water from the sediment and near bottom water. Interstitial water was obtained by refrigerated centrifugation of sediment. Control water consisted of Moderately Hard Reconstituted Water, MHRW (TVA, 1992), (hardness of 80-100 mg/L as $CaCO_3$) enriched with 10 percent Tennessee River water from TTL's experimental channels for the daphnid test and MHRW adjusted to pH=7.5 using HCl for the rotifer test. All samples were aerated to bring dissolved oxygen levels to near saturation (8.4 mg/L at 25°C) before testing. Water chemistry (temperature, DO, pH, conductivity, alkalinity, and hardness) was measured for all samples and controls. After centrifugation of the sediment, pore water samples were collected and preserved and sent to the Environmental Chemistry Laboratory for un-ionized ammonia analysis. Four replicates of five individuals each were used in both tests. Rotifer (24-hr) and daphnid (48-hr) acute toxicity was reported if average survival in the four replicates was significantly reduced (95 percent probability) from the control.

Physical/Chemical Characteristics--Splits of the same sediment samples used in the toxicity testing were analyzed for 13 metals, un-ionized ammonia (in pore water), total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs, Table 2).

Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in TVA technical report (Moses, Simbeck, and Wade, 1995).

Sediment Rating Scheme

TVA's scoring criterion is based on ratings for the toxicity of sediment pore water (S_{TOX}) to test organisms, and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia. The final sediment quality score or rating is the average of these two ratings:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating), where:

S_{TOX} (Sediment Toxicity) Rating--Sediment toxicity is evaluated using both Rotox® (rotifer Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. The acute toxicity evaluations entail the exposure of these organisms (zooplankton) to interstitial pore water from sediment. The survival rates of the organisms are based on the average survival in four replicates of five individuals each, compared to a control. If average survival is significantly reduced (95 percent probability) from the control, the sample is considered to be toxic. Sampling locations are rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good)	Survival not significantly different than control and greater than or equal to 80 percent for both species, (i.e., no significant toxicity);
3 (fair)	Survival not significantly different from control, but less than 80 percent survival for either species; or
1 (poor)	Survival of either organism significantly less than control, (i.e., significant toxicity).

S_{CHM} (Sediment Chemistry) Rating--Splits of the same sediment used in the sediment toxicity testing are analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings are based on:
(a) concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (Table 2); (b) detectable amounts of PCBs or pesticides; and (c) concentrations of un-ionized ammonia in pore water above 200 $\mu g\ NH_3/L$.
Each sampling location is rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

* Analytes (i.e., heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in Table 2.

Results from 1994 Monitoring

Table 3 provides sediment chemistry rating, sediment toxicity rating, and Final Sediment Quality Rating for each location examined in 1994. Table 4 summarizes sediment toxicity data which resulted in the sediment toxicity rating for each location. Table 5 sediment chemistry data which resulted in the sediment chemistry rating for each location.

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TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
			Reservoir Vital Signs Monitoring Tools				
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

			Reservoir Vital Signs Monitoring Tools				
Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a.

BCM - Bear Creek Mile	BRM - Beech River Mile	CCM Cedar Creek Mile
CRM - Clinch River Mile	DRM - Duck River Mile	ERM - Elk River Mile
FBRM - French Broad River	HiRM - Hiwassee River Mile	HRM - Holston River Mile
LBCM - Little Bear Creek Mile	LTRM - Little Tennessee River Mile	NRM - Nottely River Mile
ORM - Ocoee River Mile	PRM - Powell River Mile	SFHR - So Fork Holston River Mile
TRM - Tennessee River Mile	ToRM - Toccoa River Mile	TkRM - Tuckaseegee River Mile
WRM - Watauga River Mile	PRM - Powell River Mile	

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone cholrophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near shore fish community, during autumn.

Table 2
Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Metals and Ammonia		
Aluminum, mg/g	1 mg/g	--
Arsenic, mg/kg	1 mg/kg	15 ~~8~~ mg/kg[b]
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/g	0.5 mg/g	--
Chromium, mg/kg	10 mg/kg	75 mg/kg[b]
Copper, mg/kg	2 mg/kg	50 mg/kg[b]
Iron, mg/g	1 mg/g	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/g	0.5 mg/g	--
Manganese, mg/g	0.1 mg/g	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	10 mg/kg	300 mg/kg
Un-ionized Ammonia (in pore water), μg NH_3/l	10 μg/l	200 μg/l
Solids		
Total solids, %	0.1%	--
Total volatile solids, %	0.1%	--
Particle size, <0.062 mm diameter, %	0.1%	--
Particle size, <0.125 mm diameter, %	0.1%	--
Particle size, <0.50 mm diameter, %	0.1%	--
Particle size, <2.0 mm diameter, %	0.1%	--
Organochlorine Pesticides and PCB's		
Aldrin, μg/kg	10 μg/kg	10 μg/kg
α-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
β-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
γ-Benzene Hexachloride (Lindane), μg/kg	10 μg/kg	10 μg/kg
δ-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
Chlordane, μg/kg	10 μg/kg	10 μg/kg
Dieldrin, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDT, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDD, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDE, μg/kg	10 μg/kg	10 μg/kg

Correct Guideline = 15 mg/kg (DLD 1-24-200?)

Table 2.3 (continued)

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Organochlorine Pesticides and PCB's (continued)		
α-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
ß-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
Endosulfan Sulfate, μg/kg	10 μg/kg	10 μg/kg
Endrin, μg/kg	10 μg/kg	10 μg/kg
Endrin Aldehyde, μg/kg	10 μg/kg	10 μg/kg
Heptachlor, μg/kg	10 μg/kg	10 μg/kg
Heptachlor Epoxide, μg/kg	10 μg/kg	10 μg/kg
Methoxychlor, μg/kg	10 μg/kg	10 μg/kg
PCB-1221, μg/kg	100 μg/kg	100 μg/kg
PCB-1232, μg/kg	100 μg/kg	100 μg/kg
PCB-1242, μg/kg	100 μg/kg	100 μg/kg
PCB-1248, μg/kg	100 μg/kg	100 μg/kg
PCB-1254, μg/kg	100 μg/kg	100 μg/kg
PCB-1260, μg/kg	100 μg/kg	100 μg/kg
PCB-1016, μg/kg	100 μg/kg	100 μg/kg
PCBs, Total, μg/kg	100 μg/kg	100 μg/kg
Toxaphene, μg/kg	500 μg/kg	500 μg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

TABLE 3

SEDIMENT RATINGS
1994 RESERVOIR VITAL SIGNS DATA

Chemistry
5 – no analytes
3 – 1 or 2 analytes
1 – 3 or more analytes

Toxicity
5 – no toxicity
3 – some toxicity
1 – significant toxicity

SEDIMENT QUALITY = 0.5(CHEMISTRY + TOXICITY)

Reservoir	Mile	Comment	Collection Date yy	mm	dd		CHEMISTRY RATING		TOXICITY RATING	SEDIMENT QUALITY RATING
Kentucky	TRM 23.0	Dup–1	94	7	25	5	5	1	3	4.0
		Dup–2	94	7	25	5		5		
Kentucky	TRM 85.0		94	7	25		5		5	5.0
Kentucky	BSRM 7.4		94	7	26		5		1	3.0
Pickwick	TRM 207.3		94	8	3		5		5	5.0
Pickwick	TRM 230.0	Dup–1	94	8	3	5	5	5	5	5.0
		Dup–2	94	8	3	5		5		
Pickwick	BCM 8.4		94	8	3		5		5	5.0
Wilson	TRM 260.8		94	7	26		5		1	3.0
Wheeler	TRM 277.0	Dup–1	94	6	27	5	5	3	2	3.5
		Dup–2	94	6	27	5		1		
Wheeler	TRM 295.9	Dup–1	94	6	27	3	3	5	5	4.0
		Dup–2	94	6	27	3		5		
Wheeler	ERM 6.0		94	7	26		5		5	5.0
Guntersville	TRM 350.0		94	8	29		3		5	4.0
Guntersville	TRM 375.2		94	8	29		5		5	5.0
Nickajack	TRM 425.5		94	6	7		5		5	5.0
Chickamauga	TRM 472.3	Dup–1	94	5	25	3	2	5	5	3.5
		Dup–2	94	5	25	1		5		
Chickamauga	TRM 490.5		94	5	25		5		5	5.0
Chickamauga	HiRM 8.5		94	5	25		5		5	5.0
Watts Bar	TRM 531.0		94	6	1		3		5	4.0
Watts Bar	TRM 560.8	Dup–1	94	6	1	3	3	5	5	4.0
		Dup–2	94	6	1	3		5		
Fort Loudoun	TRM 605.5		94	6	20		3		5	4.0
Fort Loudoun	TRM 624.6	Dup–1	94	6	20	3	3	5	5	4.0
		Dup–2	94	6	20	3		5		
Tellico	LTRM 1.0		94	7	13		5		1	3.0
Tellico	LTRM 15.0	Dup–1	94	7	13	5	5	5	3	4.0
		Dup–2	94	7	13	5		1		
Melton Hill	CRM 24.0	Dup–1	94	8	29	5	5	5	5	5.0
		Dup–2	94	8	29	5		5		
Melton Hill	CRM 45.0		94	8	29		3		5	4.0
Norris	CRM 80.0		94	6	6		3		5	4.0
Norris	CRM 125.0		94	6	7		5		5	5.0
Norris	PRM 30.0		94	6	7		3		5	4.0
Douglas	FBRM 33.0		94	6	21		5		5	5.0
Douglas	FBRM 51.0		94	6	21		3		1	2.0

TABLE 3 (Cont'd)

SEDIMENT RATINGS
1994 RESERVOIR VITAL SIGNS DATA

Chemistry
5 – no analytes
3 – 1 or 2 analytes
1 – 3 or more analytes

Toxicity
5 – no toxicity
3 – some toxicity
1 – significant toxicity

SEDIMENT QUALITY =
0.5(CHEMISTRY + TOXICITY)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	CHEMISTRY RATING	TOXICITY RATING	SEDIMENT QUALITY RATING
Cherokee	HRM 53.0	Dup–1	94	7	18	5 5	5 5	5.0
		Dup–2	94	7	18	5	5	
Cherokee	HRM 76.0		94	7	18	3	5	4.0
Ft Pat Henry	SFHRM 8.7		94	6	22	3	5	4.0
Boone	SFHRM 19.0		94	6	22	3	3	3.0
Boone	SFHRM 27.0		94	6	22	3	5	4.0
Boone	WRM 6.5		94	6	22	1	5	3.0
South Holston	SFHRM 51.0		94	7	12	5	5	5.0
South Holston	SFHRM 62.5		94	7	12	5	5	5.0
Watauga	WRM 37.4		94	8	22	5	1	3.0
Watauga	WRM 45.5		94	8	22	3	5	4.0
Fontana	LTRM 62.0		94	8	22	3	1	2.0
Fontana	LTRM 81.5		94	8	22	3	1	2.0
Fontana	TkRM 3.0		94	8	22	3	1	2.0
Hiwassee	HiRM 77.0		94	7	12	5	5	5.0
Hiwassee	HiRM 85.0		94	7	12	5	5	5.0
Chatuge	HiRM 122.0		94	5	24	3	5	4.0
Chatuge	SCM 1.5		94	5	24	3	5	4.0
Nottely	NRM 23.5		94	8	17	5	3	4.0
Nottely	NRM 31.0		94	8	17	5	1	3.0
Ocoee #1	ORM 12.5		94	6	6	1	1	1.0
Blue Ridge	ToRM 54.1		94	6	20	5	5	5.0
Tims Ford	ERM 135.0		94	8	23	3	1	2.0
Tims Ford	ERM 150.0		94	8	23	~~3~~ 5	5	~~4.0~~ 5
Normandy	DRM 249.5		94	8	23	5	5	5.0
Bear Creek	BCM 75.0		94	8	17	5	1	3.0
L. Bear Creek	LBCM 12.5		94	8	17	5	1	3.0
Cedar Creek	CCM 25.2		94	8	17	5	5	5.0
Beech	BRM 36.0		94	5	31	5	5	5.0

(sedrat94.wk1–1/19/95)

1994 SEDIMENT QUALITY RATINGS/EVALUSTIONS

Sediment Quality - Ratings for reservoir sediment quality were based both on biological toxicity testing (S_{TOX}) and chemical analysis of sediment for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia (S_{CHM}). The final sediment quality rating at each sampling location was the average of these two ratings, as follows:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating

* *Sediment Toxicity (S_{TOX}) Rating* -- Reservoir sediment toxicity was evaluated with both Ceriodaphnia dubia and Branchionus calyciflorus by examining these organisms survival rates (compared to a control) when exposed to sediment interstitial pore water. Each sampling location was rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good) --	Survival of both organisms not significantly different than control and greater than or equal to 80% for both species *(i.e. no significant toxicity).
3 (fair) --	Survival of both organism not significantly different from control, but less than 80% survival for either species; or
1 (poor) --	Survival of either organism significantly less than control, (i.e. significant toxicity);

* *Sediment Chemistry (S_{CHM}) Rating* -- Splits of the same sediment used in the sediment toxicity testing were analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings were based on: (a.) concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines; (b.) detectable amounts of pesticides or PCBs; and (c.) concentrations of un-ionized ammonia in pore water above 200 ug NH_3/L. Each sampling location was rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceeding guidelines;
3 (fair)	One or two analytes exceeding guidelines;
1 (poor)	Three or more exceeding guidelines.

* Analytes (i.e. heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in table 1.

TABLE 4

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
BASIC					
Kentucky	TRM 23.0 (A)	FB	1	Toxicity to dapnids	3
	TRM 23.0 (B)	FB	5	No toxicity	
	TRM 85.0	TZ	5	No toxicity	5
	BSRM 7.4	EMB	1	Toxicity to dapnids	1
Pickwick	TRM 207.3	FB	5	No toxicity	5
	TRM 230.0 (A)	FB	5	No toxicity	5
	TRM 230.0 (B)	TZ	5	No toxicity	
	BCM 8.4	EMB	5	No toxicity	5
Wilson	TRM 260.8	FB	1	Toxicity to both species	1
Wheeler	TRM 277.0 (A)	FB	3	Rotifer survival 60%	2
	TRM 277.0 (B)	FB	1	Toxicity to both species	
	TRM 295.9 (A)	TZ	5	No toxicity	5
	TRM 295.9 (B)	TZ	5	No toxicity	
	ElRM 6.0	EMB	5	No toxicity	5
Guntersville	TRM 350.0	FB	5	No toxicity	5
	TRM 375.2	TZ	5	No toxicity	5
Nickajack	TRM 425.5	FB	5	No toxicity	5
Chickamauga	TRM 472.3 (A)	FB	5	No toxicity	5
	TRM 472.3 (B)	FB	5	No toxicity	
	TRM 490.5	TZ	5	No toxicity	5
	HiRM 8.5	EMB	5	No toxicity	5
Watts Bar	TRM 531.0	FB	5	No toxicity	5
	TRM 560.8 (A)	TZ	5	No toxicity	5
	TRM 560.8 (B)	TZ	5	No toxicity	

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
Ft. Loudoun	TRM 605.5	FB	5	No toxicity	5
	TRM 624.6 (A)	TZ	5	No toxicity	5
	TRM 624.6 (B)	TZ	5	No toxicity	
Melton Hill	CRM 24.0 (A)	FB	5	No toxicity	5
	CRM 24.0 (B)	FB	5	No toxicity	
	CRM 45.0	TZ	5	No toxicity	5
Tellico	LTRM 1.0	FB	1	Toxicity to both species	1
	LTRM 15.0 (A)	TZ	5	No toxicity	3
	LTRM 15.0 (B)	TZ	1	Toxicity to daphnids	
TRIBUTARY					
Norris	CRM 80.0	FB	5	No toxicity	5
	CRM 125.0	TZ	5	No toxicity	5
	PRM 30.0	TZ	5	No toxicity	5
Cherokee	HoRM 53.0 (A)	FB	5	No toxicity	5
	HoRM 53.0 (B)	FB	5	No toxicity	
	HoRM 76.0	TZ	5	No toxicity	5
Douglas	FBRM 33.0	FB	5	No toxicity	5
	FBRM 51.0	TZ	1	Toxcity to rotifers	1
Fort Pat Henry	SFHRM 8.7	FB	5	No toxicity	5
Boone	SFHRM 19.0	FB	3	Rotifer survival 75%	3
	SFHRM 27.0	TZ	5	No toxicity	5
	WRM 6.5	TZ	5	No toxicity	5

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
S. Holston	SFHRM 51.0	FB	5	No toxicity	5
	SFHRM 62.5	TZ	5	No toxicity	5
Watauga	WRM 37.4	FB	1	Toxicity to both species	1
	WRM 45.5	FB	5	No toxicity	5
Fontana	LTRM 62.0	FB	1	Toxicity to both species	1
	LTRM 81.5	TZ	1	Toxicity to daphnids	1
	TkRM 3.0	TZ	1	Toxicity to daphnids	1
Hiwassee	HiRM 77.0	FB	5	No toxicity	5
	HiRM 85.0	TZ	5	No toxicity	5
Chatuge	HiRM 122.0	FB	5	No toxicity	5
	SCM 1.5	FB	5	No toxicity	5
Nottely	NoRM 23.5	FB	3	Daphnid survival 60%	3
	NoRM 31.0	TZ	1	Toxicity to rotifers	1
Ocoee No. 1	ORM 12.5	FB	1	Toxicity to dapnids	1
Blue Ridge	ToRM 54.1	FB	5	No toxicity	5
Tims Ford	EIRM 135.0	FB	1	Toxicity to both species	1
	EIRM 150.0	TZ	5	No toxicity	5
Bear Creek	BCM 75.0	FB	1	Toxicity to both species	1
Cedar Creek	CCM 25.2	FB	5	No toxicity	5

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
L. Bear Creek	LBCM 12.5	FB	1	Toxicity to daphnids	1
Beech	BRM 36.0	FB	5	No toxicity	5
Normandy	DRM 249.5	FB	5	No toxicity	5

Good = 5 (No toxicity to either species, survival for both species ≥ 80%)
Fair = 3 (No toxicity to either species, however survival of at least one species < 80%)
Poor = 1 (Toxicity to at least one species)

TABLE 5

SEDIMENT CHEMISTRY
1994 RESERVOIR VITAL SIGNS DATA

Reservoir	Mile	Comment	Collection Date yy	mm	dd	Metals, mg/kg (dry weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	ZINC	AMMONIA (ug/l)	CHLORDANE (ug/kg)	DDT (ug/kg)	TOTAL PCB (ug/kg)
Kentucky	TRM 23.0	Dup−1	94	7	25	7.6	0.5 K	28	14	18	0.18	20	110	36	10 K	10 K	25 K
		Dup−2	94	7	25	7.0	0.5 K	30	12	18	0.17	21	110	34	10 K	10 K	25 K
		Precision	94	7	25	7.2	0.5 K	28	12	20	0.17	19	100		10 K	10 K	25 K
Kentucky	TRM 85.0		94	7	25	9.0	0.5 K	26	10	16	0.17	16	93	14	10 K	10 K	25 K
Kentucky	BSRM 7.4		94	7	26	12.0	0.5 K	25	8	22	0.12	17	78	26	10 K	10 K	25 K
Pickwick	TRM 207.3		94	8	3	7.2	0.5 K	36	26	35	0.75	26	150	15	10 K	10 K	25 K
Pickwick	TRM 230.0	Dup−1	94	8	3	7.6	0.5 K	22	10	21	0.74	11	90	14	10 K	10 K	25 K
		Dup−2	94	8	3	6.8	0.5 K	19	10	19	0.72	10	88	25	10 K	10 K	25 K
Pickwick	BCM 8.4		94	8	3	8.9	0.5 K	26	6	20	0.10 K	16	82	15	10 K	10 K	25 K
Wilson	TRM 260.8		94	7	26	8.7	0.5 K	38	22	37	0.15	30	160	43	10 K	10 K	25 K
Wheeler	TRM 277.0	Dup−1	94	6	27	7.6	0.5 K	31	24	30	0.16	29	160	50	10 K	10 K	25 K
		Dup−2	94	6	27	7.0	0.6	32	25	28	0.15	30	160	39	10 K	10 K	25 K
Wheeler	TRM 295.9	Dup−1	94	6	27	3.9	0.5 K	22	17	16	0.13	18	110	23	10 K	50	25 K
		Dup−2	94	6	27	4.8	0.5 K	26	20	21	0.14	20	130	24	10 K	50	25 K
Wheeler	ERM 6.0		94	7	26	5.0	0.5 K	23	5	20	0.10	22	68	26	10 K	10 K	25 K
Guntersville	TRM 350.0		94	8	29	8.2	0.6	45	29	54	0.62	34	320	34	10 K	10 K	60
Guntersville	TRM 375.2		94	8	29	4.8	0.5 K	20	12	26	0.23	21	160	21	10 K	10 K	25 K
		Precision	94	8	29	4.6	0.5 K	23	11	28	0.24	20	150		10 K	10 K	25 K
Nickajack	TRM 425.5		94	6	7	7.0	0.6	32	38	56	0.25	26	250	23	10 K	10 K	25 K
Chickamauga	TRM 472.3	Dup−1	94	5	25	7.8	0.5 K	33	58	46	0.38	31	280	1	10 K	10 K	25 K
		Dup−2	94	5	25	8.5	0.6	31	63	50	0.38	30	320	1	10 K	10 K	50
		Precision	94	5	25	7.4	0.5	33	62	52	0.37	30	320		10 K	10 K	25 K
Chickamauga	TRM 490.5		94	5	25	6.0	0.5 K	28	30	33	0.25	22	240	1	10 K	10 K	25 K
Chickamauga	HiRM 8.5		94	5	25	2.7	0.5 K	28	46	16	0.10 K	16	200	2	10 K	10 K	25 K
Watts Bar	TRM 531.0		94	6	1	12.0	0.5 K	36	34	34	0.43	30	200	31	10 K	10 K	60
Watts Bar	TRM 560.8	Dup−1	94	6	1	8.4	0.6	24	27	28	0.53	21	160	16	10 K	10 K	40
		Dup−2	94	6	1	8.8	0.6	30	32	33	0.57	27	190	12	10 K	10 K	30
Fort Loudoun	TRM 605.5		94	6	20	8.1	0.7	33	30	38	0.11	24	280	82	10 K	10 K	40
		Precision	94	6	20	7.8	0.6	35	29	36	0.11	26	270		10 K	10 K	40
Fort Loudoun	TRM 624.6	Dup−1	94	6	20	5.6	1.0	28	29	34	0.12	20	310	78	10 K	10 K	40
		Dup−2	94	6	20	5.7	0.9	29	30	36	0.12	22	300	66	10 K	10 K	40
Tellico	LTRM 1.0		94	7	13	10.0	0.5 K	32	23	29	0.12	22	130	50	10 K	10 K	25 K
Tellico	LTRM 15.0	Dup−1	94	7	13	7.0	0.5 K	25	22	22	0.13	16	110	22	10 K	10 K	25 K
		Dup−2	94	7	13	7.0	0.5 K	24	18	22	0.12	14	94	13	10 K	10 K	25 K
Melton Hill	CRM 24.0	Dup−1	94	8	29	11.0	0.5 K	27	31	44	0.12	26	130	120	10 K	10 K	25 K
		Dup−2	94	8	29	12.0	0.6	27	31	44	0.13	26	130	110	10 K	10 K	25 K
Melton Hill	CRM 45.0		94	8	29	6.8	0.5 K	20	26	38	0.10	21	120	62	10 K	10 K	40
Norris	CRM 80.0		94	6	6	27.0	1.2	28	36	94	0.12	30	150	41	10 K	10 K	25 K
Norris	CRM 125.0		94	6	7	6.3	0.5	28	28	39	0.10 K	27	130	39	10 K	10 K	25 K
Norris	PRM 30.0		94	6	7	8.8	0.5	24	28	52	0.10 K	26	160	39	10	10 K	25 K
		Precision	94	6	7	8.8	0.5	24	27	52	0.10 K	27	160		10 K	10 K	25 K
Douglas	FBRM 33.0		94	6	21	6.3	0.5 K	32	24	33	0.10 K	16	110	12	10 K	10 K	25 K
Douglas	FBRM 51.0		94	6	21	2.7	0.6	33	28	33	0.10 K	18	160	37	20	10 K	25 K
Cherokee	HRM 53.0	Dup−1	94	7	18	9.3	0.5 K	35	40	38	0.18	27	150	65	10 K	10 K	25 K
		Dup−2	94	7	18	9.8	0.5 K	36	44	38	0.20	29	160	49	10 K	10 K	25 K
Cherokee	HRM 76.0		94	7	18	7.3	0.5 K	32	54	38	0.42	26	150	92	10 K	10 K	25 K

TABLE 5 (Cont'd)

SEDIMENT CHEMISTRY
1994 RESERVOIR VITAL SIGNS DATA

Reservoir	Mile	Comment	Collection Date yy	mm	dd	Metals, mg/kg (dry weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	ZINC	AMMONIA (ug/l)	CHLORDANE (ug/kg)	DDT (ug/kg)	PCB (ug/kg)
Ft Pat Henry	SFHRM 8.7		94	6	22	7.0	0.5 K	30	45	35	0.10 K	18	200	120	30	10 K	30
Boone	SFHRM 19.0		94	6	22	8.1	0.5 K	34	39	44	0.10	21	170	96	30	10 K	40
Boone	SFHRM 27.0		94	6	22	5.0	0.5 K	27	30	38	0.11	16	110	140	40	10 K	25 K
Boone	WRM 6.5		94	6	22	5.8	0.5	33	54	55	0.13	20	280	71	30	10 K	50
South Holston	SFHRM 51.0		94	7	12	7.6	0.5 K	26	29	40	0.10 K	16	78	27	10 K	10 K	25 K
South Holston	SFHRM 62.5		94	7	12	5.8	0.5 K	29	23	38	0.12	18	96	29	10 K	10 K	25 K
		Precision	94	7	12	5.1	0.5 K	31	23	37	0.12	19	100		10 K	10 K	25 K
Watauga	WRM 37.4		94	8	22	7.6	0.5 K	27	28	38	0.10 K	28	98	37	10 K	10 K	25 K
Watauga	WRM 45.5		94	8	22	5.2	0.5 K	29	25	38	0.10 K	26	140	12	20	10 K	25 K
Fontana	LTRM 62.0		94	8	22	5.0	0.5 K	40	40	36	0.10 K	34	140	20	20	10 K	25 K
Fontana	LTRM 81.5		94	8	22	2.0	0.5 K	50	42	30	0.10 K	34	150	8	30	10 K	25 K
Fontana	TkRM 3.0		94	8	22	2.1	0.5 K	47	24	17	0.10 K	32	120	9	30	10 K	25 K
Hiwassee	HiRM 77.0		94	7	12	4.8	0.5 K	41	40	40	0.10	23	120	29	10 K	10 K	25 K
Hiwassee	HiRM 85.0		94	7	12	3.0	0.5 K	38	36	34	0.10	22	120	19	10 K	10 K	25 K
Chatuge	HiRM 122.0		94	5	24	2.8	0.5 K	60	50	24	0.10 K	27	80	8	10 K	10 K	25 K
Chatuge	SCM 1.5		94	5	24	3.0	0.5 K	81	58	32	0.10 K	45	84	12	10 K	10 K	25 K
Nottely	NRM 23.5		94	8	17	2.4	0.5 K	37	33	21	0.10 K	20	96	14	10 K	10 K	25 K
Nottely	NRM 31.0		94	8	17	3.0	0.5 K	47	38	26	0.10 K	26	120	25	10 K	10 K	25 K
Ocoee #1	ORM 12.5		94	6	6	38.0	3.5	40	1700	1200	0.23	18	1300	8	10 K	10 K	240
Blue Ridge	ToRM 54.1		94	6	20	3.4	0.5 K	42	43	44	0.10 K	19	110	1	10 K	10 K	25 K
Tims Ford	ERM 135.0		94	8	23	11.0	0.5 K	20	17	33	0.10 K	56	77	68	10 K	10 K	25 K
		Precision	94	8	23	11.0	0.5 K	22	18	31	0.10 K	62	84		10 K	10 K	25 K
Tims Ford	ERM 150.0		94	8	23	9.8	0.5 K	33	16	34	0.10 K	32	90	46	10 K	10 K	25 K
Normandy	DRM 249.5		94	8	23	8.0	0.5 K	20	21	34	0.10 K	33	76	36	10 K	10 K	25 K
Bear Creek	BCM 75.0		94	8	17	6.8	0.5 K	29	16	22	0.10 K	26	80	100	10 K	10 K	25 K
L. Bear Creek	LBCM 12.5		94	8	17	9.8	0.5 K	38	14	28	0.11	28	120	61	10 K	10 K	25 K
Cedar Creek	CCM 25.2		94	8	17	8.3	0.5 K	25	10	17	0.10 K	20	68	35	10 K	10 K	25 K
Beech	BRM 36.0		94	5	31	12.0	0.6	28	20	35	0.10 K	16	70	5	10 K	10 K	25 K
		Number				74	74	74	74	74	74	74	74	67	74	74	74
		Max				38.0	3.5	81	1700	1200	0.75	62	1300	140	40	50	240
		Min				2.0	0.5 K	19	5	16	0.10 K	10	68	1	10 K	10 K	25 K
		Mean				7.7	0.6 K	32	51	49	0.19 K	24	163	38	12 K	11 K	31 K

(sedchem94.wk1)

Section 4. Benthic Macroinvertebrate Community

Philosophical Approach/Background

Benthic macroinvertebrates are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have limited capability of movement thereby preventing them from avoiding undesirable conditions. The macroinvertebrate community in a reservoir is expected to be vastly different from that in the river in the preimpoundment state. Also, substantial differences are expected along a longitudinal gradient with a more riverine community expected at the upper end or inflow of a reservoir and a more lake like community expected in the pool near the dam. Other factors to consider in evaluating this community in reservoirs include reservoir operational characteristics (e.g., depth of withdrawal for discharge, water depth, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability) and physical/chemical features owing to geological characteristics of different ecoregions.

All these factors, plus the fact that a reservoir is an artificial system, must be considered in selecting community characteristics or expectations that will be used to represent good, fair, and poor conditions. Given that reservoirs are artificial systems, it not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using references site to determine characteristics or expectations of a reservoir unaffected by human impacts. Other approaches must be used such as: historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. The state of the science of benthic macroinvertebrate communities in reservoirs simply is insufficient for predictive models to be effective. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for this community in reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment is the best approach.. Use of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 30 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics.

Run-of-the-River
Reservoirs
- Kentucky
- Pickwick
- Wilson
- Wheeler
- Guntersville
- Nickajack
- Chickamauga
- Watts Bar
- Melton Hill
- Tellico
- Fort Loudon

Tributary Reservoirs:
Interior Plateau Ecoregion
- Bear Creek
- Cedar Creek
- Little Bear
- Normandy
- Beech

Tributary Reservoirs:
Ridge and Valley Ecoregion
- Cherokee
- Fort Patrick Henry*
- Boone
- South Holston
- Norris
- Douglas
- Tims Ford**

Tributary Reservoirs:
Blue Ridge Ecoregion
- Fontana
- Hiwassee
- Chatuge
- Nottely
- Parksville***
- Blue Ridge
- Watauga

* Fort Patrick Henry Reservoir was included in this class because it is in the Ridge and Valley Ecoregion, but results were excluded in developing scoring ranges for this class because the shallow drawdown and short retention are uncharacteristic of the other reservoirs in this class.
** Tims Ford is in the Interior Plateau ecoregion but due to operational and morphological characteristics was considered more similar to and classified with Ridge and Valley reservoirs.
***Results for Parksville Reservoir were excluded from developing reference conditions because of known poor sediments conditions (very high metal concentrations), which would be expected to cause a degraded benthic macroinvertebrate community.

Once reservoirs have been appropriately classified, scoring criteria (i.e., those values for each metric which will be considered good, fair, or poor) must be developed. When using best observed conditions, a database must exist and decisions made as to how best separate data for each metric into the three scoring ranges of good, fair, and poor. The approach taken by TVA is, for each metric, first omit outliners (defined as more than three standard deviations from the mean), then trisect the range of the remaining values. Cutoff points are examined closely and adjusted if appropriate based on professional judgment. These three ranges represent good, fair, and poor conditions and form the reference conditions or expectations for each metric. More details of TVA's approach to developing scoring ranges are provided under the Benthic Community Scoring Scheme below.

<u>Sample Collection Methods</u>

Benthic macroinvertebrate community samples were collected in the spring (March and April) of 1994 at 69 locations on 30 TVA reservoirs (Table 1). At each sample location, a line-of-sight transect was established across the width of the reservoir, and one Ponar grab sample collected at 10 equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Care was taken to collect samples only from the permanently wetted bottom portion of the reservoir (i.e., below the elevation of the minimum winter pool level). Samples were washed in the field, transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution. Samples were sent to the laboratory where they were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request

To assess the reproducibility of benthic macroinvertebrate sampling results, replicate samples were collected at 13 of the 69 sampling locations in 1994, with all types of reservoir locations (i.e., forebay, transition zone, embayment, and inflow) included. At each of the replicate sampling locations, the sampling protocol involved collection of a first set of 10 samples, leaving the sampling location, and then returning as near as possible to the original transect site (on the same day) and repeating the collection of a second (replicate) set of 10 samples. The results from sets of replicate samples were then evaluated for reproducibility.

Note: Beginning in 1995, benthic macroinvertebrate sampling will be conducted in late fall/early winter rather than late winter/early spring as in 1990 -1994. The problem with late winter/early spring time frame is that results are reflective of conditions the previous year. This has the undesirable effect of causing results for benthic macroinvertebrates to be out of synch with the rest of the monitoring data. This period was initially selected because late fall/early winter was thought unfeasible because the required reporting date of mid-January would not allow processing time in the laboratory. Also, there was concern that insect instars would be so small that they could pass through the collection screen and/or be difficult to identify. Thorough evaluation of the 1993 - 1994 results showed late fall/early winter collection and use of field identification to the family and order levels would negate problems resulting from early spring sampling and would not impact the contribution of this important community to the overall evaluation. Appendix A documents the basis of this change.

<u>Benthic Community Rating Scheme</u>

Eight community characteristics (or metrics), were selected to evaluate the benthic community.

1. **Taxa richness**—The average total number of taxa per sample at each site. An increase taxa richness indicates better conditions than low taxa richness.
2. **EPT**—The average total number of Ephemeroptera, Plecoptera, and Trichoptera per sample at each site. Higher diversity of these taxa indicate good water quality and other habitat conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.
3. **Long-lived species**—The percent of samples with at least one long-lived organism (<u>Corbicula</u>, <u>Hexagenia</u>, mussels, and snails) present. The presence of long-lived taxa is indicative of conditions which allow long-term survival.
4. **Proportion as Chironomidae**—The average proportion of chironomids in each sample at each site. A higher proportion indicates poor water quality.
5. **Proportion as Tubificidae**—The average proportion of tubificids in each sample at each site.
A higher proportion indicates poor water quality.
6. **Proportion as dominant taxa**—The average proportion of the two dominant families in each sample even if the dominant taxon differed among the samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples a site. This metric is used as an evenness indicator. Dominance of one or two families indicates poor conditions.
7. **Total abundance excluding Chironomidae and Tubificidae**—The average number of organisms excluding chironomids and tubificids per sample at each site. This metric examines the community excluding families which often dominate under adverse conditions. A higher abundance of non-chironomids and tubificids indicates good water quality conditions.
8. **Percentage of samples with no organisms present**—Percentage of samples with no organisms present. "Zero-samples" indicate living conditions unsuitable to support aquatic life (i.e. toxicity, unsuitable substrate, etc.). Any site having one or more empty samples was assigned a score of one. Sites with no empty samples were assigned a score of five.

Scoring Criteria for each of the eight metrics were developed using the five years of Vital Signs monitoring data (1990 - 1994). Scoring ranges were developed as follows:

- Individual criteria were developed for each type of sampling location (forebay, transition zone/mid-reservoir, embayment and inflow) for each of the four classes of reservoirs.
- Results from the 10 samples along a transect for each sample year were combined (averaged for most metrics) and outliers deleted.
- The range of average values was then trisected with the third of the range representing desirable conditions assigned a value of 5 (good), the middle one-third assigned a 3 (fair), and the third representing undesirable conditions was assigned a 1 (poor).

Professional judgment along with supplementary statistical analyses were used to adjust the cutoffs for each range as appropriate. Scoring Criteria resulting from these efforts are detailed for each metric in Table 2. Separate tables are provided for each class of reservoir.

Sample results at each site were compared with these criteria for each metric and assigned the rating described above--5 (good) 3 (fair), 1(poor) if they fell within the top, middle, or bottom group, respectively. Numerical ratings for the eight metric were then summed. This resulted in a minimum score of 8 if all metrics at a site were poor, and a maximum score of 40 if all metrics were good.

The resulting score has two uses. One is to evaluate the condition of the benthic macroinvertebrate itself. The other is to help establish the overall ecological health of a reservoir. In the latter case, the benthic macroinvertebrate community is one of five equally weighted indicators which are summed to arrive at an overall Ecological Health Index for a reservoir.

To arrive at an evaluation of the condition of the benthic macroinvertebrate community at a sample location, scores were evaluated as follows:

Benthic Community Score	8-15	16-21	22-27	28-33	34-40
Community Condition	Very Poor	Poor	Fair	Good	Excellent

The contribution of the benthic macroinvertebrate results for each sample site to the overall reservoir Ecological Health Index was as follows:

Benthic Community Score	8-15	16-21	22-27	28-33	34-40
Contribution to Reservoir Ecological Health Index	1	2	3	4	5

One further use of these results is for TVA's report to the public on the conditions of Tennessee Valley reservoirs. In this publication, titled *Riverpulse,* results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good), yellow (fair), or red (poor). This necessitated dividing the benthic macroinvertebrate scores into three ranges as follows:

Benthic Community Score	8-18	19-29	30-40
Color (Rating) in *RiverPulse*	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1994 Monitoring

Results from 1994 monitoring activities are summarized by reservoir class and type of location for each metric in the Table 3. Also included with the 1994 results are results from all previous years. Abbreviations for metrics in the table are those provided above each metric is defined. Appendix B provides mean density for each species at each location in 1994.

Results of Quality Control samples are identified in the table with a "Q". Approximately 20 percent of all the benthic sampling stations were revisited for Quality Control purposes. All together, 13 randomly selected sites were revisited, usually on the same day as the first sample set. The desired maximum difference between the score for the original sample and the QA sample was 6. A difference greater than this would cause the rating to change 2 categories (e.g., very poor to fair, fair to good), which was deemed unacceptable. Results for each set of repeat samples are provided below.

Run-of-the-River Reservoirs	Original Score	QA/QC Score	Difference
Forebays			
Chickamauga	28 (Good)	34 (Excellent)	6
Nickajack	34 (Excellent)	30 (Good)	4
Transition Zones			
Chickamauga	38 (Excellent)	38 (Excellent)	0
Kentucky	32 (Good)	34 (Excellent)	2
Inflows			
Nickajack	34 (Excellent)	38 (Excellent)	4
Pickwick	30 (Good)	32 (Good)	2
Embayments			
Hiwassee	24 (Fair)	22 (Fair)	2
Tributary Reservoirs			
Forebays			
Parksville	12 (Very Poor)	8 (Very Poor)	4
Blue Ridge	22 (Fair)	28 (Good)	6
Little Bear	24 (Fair)	28 (Good)	4
Upper			
Watauga	22 (Fair)	16 (Poor)	6
Hiwassee	18 (Poor)	18 (Poor)	0
Nottely	28 (Good)	34 (Excellent)	6

The maximum observed difference was 6 (4 sets of samples) and the minimum was 0 (2 sets of samples). A greater difference generally was found for the tributary reservoirs than for the run-of-the-river reserves. The mean difference for all reservoirs was 3.54. The 95% confidence interval around the mean would be 2.17 to 4.9, well below the desired level of 6.

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

			Reservoir Vital Signs Monitoring Tools				
				Sediment Quality[d]			Fish Community[f]
Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a.
BCM - Bear Creek Mile	BRM - Beech River Mile	CCM Cedar Creek Mile
CRM - Clinch River Mile	DRM - Duck River Mile	ERM - Elk River Mile
FBRM - French Broad River	HiRM - Hiwassee River Mile	HRM - Holston River Mile
LBCM - Little Bear Creek Mile	LTRM - Little Tennessee River Mile	NRM - Nottely River Mile
ORM - Ocoee River Mile	PRM - Powell River Mile	SFHR - So Fork Holston River Mile
TRM - Tennessee River Mile	ToRM - Toccoa River Mile	TkRM - Tuckaseegee River Mile
WRM - Watauga River Mile	PRM - Powell River Mile	

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone cholrophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near shore fish community, during autumn.

Table 2. Scoring Criteria for Benthic Macroinvertebrate Community
1994 Reservoir Vital Signs Monitoring

Run-of-the-River Reservoirs									
Benthic Community Metrics	**Forebay**			**Transition**			**Inflow**		
	1	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
Taxa Richness	≤4.6	4.6-6.9	≥7	≤6	6.1-8.9	≥9	≤5	5.1-7.9	≥8
EPT	≤.5	.6-.9	≥1	≤.5	.6-1.4	≥1.5	≤.8	.9-1.9	≥2
Long-lived	≤.5	.6-.8	≥.9	≤.5	.6-.9	≥1	≤.5	.6-.8	≥.9
Percent Chironomids	≥60.0	45.1-59.9	≤40.0	≥60.0	35.1-59.9	≤35.0	≥40.0	10.1-39.9	≤10.0
Percent Tubificids	≥30.0	15.1-29.9	≤15.0	≥30.0	15.1-29.9	≤15.0	≥30.0	15.1-29.9	≤15.0
Dominance	≥90.0	80.1-89.9	≤80.0	≥85.0	75.1-84.9	≤75.0	≥85.0	70.1-84.9	≤70.0
Non-tolerant Density	≤250	250.1-324.9	≥325	**≤300**	300.1-699.9	≥700	≤500	500.1-999.9	≥1000
Zero Samples	≥1	-	0	≥1	0	0	≥1	-	0

Blue Ridge Tributary Reservoirs									
Benthic Community Metrics	**Forebay**						**Upper**		
	1	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
Taxa Richness	≤2	2.1-3.9	≥4	-	-	-	≤3	3.1-3.9	≥4
EPT	≤.1	.11-.39	≥.4	-	-	-	≤.1	.11-.59	≥.6
Long-lived	≤.1	.11-.49	≥.5	-	-	-	≤.1	.11-.49	≥.5
Percent Chironomids	≥45.0	30.1-44.9	≤30.0	-	-	-	≥60.0	30.1-59.9	≤30.0
Percent Tubificids	≥65.0	40.1-64.9	≤40.0	-	-	-	≥65.0	35.1-64.9	≤35.0
Dominance	≥95.0	90.1-94.9	≤90.0	-	-	-	≥96.0	92.1-95.9	≤92.0
Non Chi. and Tub. Density	≤100.0	100.1-199.9	≥200.0	-	-	-	≤25.0	25.1-49.9	≥50.0
Zero Samples	1	-	0	-	-	-	1	-	0

Table 2. Cont', Scoring Criteria for Benthic Macroinvertebrate Community
1994 ReservoirVital Signs Monitoring

Interior Plateau Tributary Reservoirs									
Benthic Community Metrics	**Forebay**			**Transition**			**Inflow**		
	1	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
Taxa Richness	≤2.5	2.6-3.9	≥4	-	-	-	-	-	-
EPT	≤.1	.11-.59	≥.6	-	-	-	-	-	-
Long-lived	≤.1	.11-.49	≥.5	-	-	-	-	-	-
Percent Chironomids	≥60.0	30.1-59.9	≤30.0	-	-	-	-	-	-
Percent Tubificids	≥96.0	92.1-95.9	≤92.0	-	-	-	-	-	-
Dominance	≥95.0	90.1-94.9	≤90.0	-	-	-	-	-	-
Non Chi. and Tub. Density	≤30.0	30.1-59.9	≥60.0	-	-	-	-	-	-
Zero Samples	0	-	1	-	-	-	-	-	-

Ridge and Valley Tributary Reservoirs									
Benthic Community Metrics	**Forebay**			**Transition**			**Upper**		
	1	**3**	**5**	**1**	**3**	**5**	**1**	**3**	**5**
Taxa Richness	≤1.5	1.6-2.9	≥3	-	-	-	≤3	3.1-4.9	≥5
EPT	0	.1-.19	≥.2	-	-	-	0	.1-.19	≥.2
Long-lived	≤.1	.11-.49	≥.5	-	-	-	≤.2	.21-.69	≥.7
Percent Chironomids	≥50.0	25.1-49.9	≤25.0	-	-	-	≥65.0	35.1-64.9	≤35.0
Percent Tubificids	≥80.0	50.1-79.9	≤50.0	-	-	-	≥60.0	40.1-59.9	≤40.0
Dominance	≥98.0	94.1-97.9	≤94.0	-	-	-	≥98.0	94.1-97.9	≤94.0
Non Chi. and Tub. Density	≤1.5	1.4-2.9	≥3.0	-	-	-	≤25.0	25.1-49.9	≥50.0
Zero Samples	0	-	1	-	-	-	0	-	1

Table 3. Results and Ratings for Individual Metrics and Final Benthos Score. Separated by Reservoir Class and Type of Sample Location

Run-of-River Reservoirs--Forebays

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		472.3	91	30	5.8	3	1.0	5	0.9	3	54.4	3	6.7	5	84.3	3	280.0	3	0.0	5
CHICKAMAUGA		472.3	92	38	5.9	3	1.0	5	1.1	5	38.6	5	9.3	5	74.4	5	501.7	5	0.0	5
CHICKAMAUGA		472.3	93	36	7.2	5	1.0	5	0.9	3	41.6	5	17.8	3	75.1	5	348.3	5	0.0	5
CHICKAMAUGA	Q *	472.3	93	34	6.7	3	1.0	5	1.0	5	43.9	5	19.4	3	73.6	5	308.3	3	0.0	5
CHICKAMAUGA		472.3	94	28	6.5	3	1.0	5	1.3	5	61.8	1	14.2	5	85.4	3	198.3	1	0.0	5
CHICKAMAUGA	Q	472.3	94	34	7.4	5	1.0	5	1.0	5	48.7	3	23.1	3	85.1	3	378.3	5	0.0	5
FORT LOUDOUN		603.2	91	16	3.5	1	0.4	1	0.0	1	36.1	5	44.6	1	99.9	1	33.5	1	0.0	5
FORT LOUDOUN		605.5	92	10	2.1	1	0.4	1	0.2	1	72.5	1	25.3	3	100.0	1	6.8	1	0.1	1
FORT LOUDOUN		603.2	92	14	3.0	1	0.3	1	0.1	1	67.4	1	27.0	3	99.1	1	12.7	1	0.0	5
FORT LOUDOUN		605.5	93	14	5.2	3	0.5	1	0.3	1	63.6	1	33.5	1	97.1	1	22.7	1	0.0	5
FORT LOUDOUN		605.5	94	14	4.5	1	0.4	1	0.2	1	65.1	1	22.8	3	99.3	1	17.4	1	0.0	5
GUNTERSVILLE		350.0	91	36	7.2	5	1.0	5	1.1	5	58.9	3	11.7	5	80.0	5	318.3	3	0.0	5
GUNTERSVILLE		350.0	92	32	5.9	3	1.0	5	0.8	3	43.4	5	15.8	3	77.4	5	313.3	3	0.0	5
GUNTERSVILLE		350.0	93	30	6.8	3	0.9	5	0.8	3	50.8	3	13.9	5	80.2	3	316.7	3	0.0	5
GUNTERSVILLE		350.0	94	28	6.9	3	1.0	5	1.0	5	54.1	3	15.2	3	82.0	3	220.0	1	0.0	5
KENTUCKY		23.0	91	28	5.4	3	1.0	5	0.6	3	52.9	3	11.4	5	84.4	3	221.7	1	0.0	5
KENTUCKY		23.0	92	32	5.4	3	1.0	5	0.4	1	39.2	5	18.6	3	78.3	5	371.7	5	0.0	5
KENTUCKY		7.4#	93	32	8.7	5	1.0	5	0.6	3	71.8	1	3.4	5	87.2	3	360.0	5	0.0	5
KENTUCKY		23.0	93	36	7.5	5	1.0	5	0.6	3	42.2	5	13.0	5	85.2	3	708.3	5	0.0	5
KENTUCKY		7.4#	94	22	8.7	5	0.8	3	0.4	1	77.1	1	10.8	5	90.1	1	138.3	1	0.0	5
KENTUCKY		23.0	94	26	5.9	3	1.0	5	0.4	1	50.0	3	23.3	3	83.6	3	283.3	3	0.0	5
MELTON HILL		24.0	91	16	3.9	1	0.7	3	0.4	1	68.4	1	16.9	3	96.3	1	31.7	1	0.0	5
MELTON HILL		24.0	92	22	6.7	3	0.7	3	0.6	3	54.1	3	30.1	1	87.1	3	143.5	1	0.0	5
MELTON HILL		24.0	93	14	4.1	1	0.3	1	0.1	1	65.9	1	16.2	3	94.4	1	25.0	1	0.0	5
MELTON HILL		24.0	94	16	5.7	3	0.3	1	0.5	1	67.7	1	25.3	3	93.9	1	33.3	1	0.0	5
NICKAJACK		425.5	91	36	6.1	3	1.0	5	1.0	5	25.6	5	3.4	5	84.7	3	543.3	5	0.0	5
NICKAJACK		425.5	92	38	6.8	3	1.0	5	1.0	5	23.7	5	9.4	5	74.0	5	521.7	5	0.0	5
NICKAJACK		425.5	93	36	7.3	5	1.0	5	1.3	5	37.6	5	11.4	5	81.6	3	270.0	3	0.0	5
NICKAJACK	Q	425.5	93	40	7.2	5	1.0	5	1.0	5	37.4	5	7.1	5	77.8	5	358.3	5	0.0	5
NICKAJACK		425.5	94	34	8.2	5	1.0	5	1.9	5	51.7	3	10.1	5	78.0	5	235.0	1	0.0	5
NICKAJACK	Q	425.5	94	30	6.0	3	0.9	5	1.4	5	49.2	3	12.8	5	81.2	3	170.0	1	0.0	5
PICKWICK		207.3	91	18	4.8	3	0.8	3	0.8	3	63.2	1	16.1	3	88.8	3	208.3	1	0.1	1
PICKWICK		207.3	92	34	6.1	3	0.9	5	0.8	3	39.2	5	9.5	5	76.8	5	290.0	3	0.0	5
PICKWICK		8.4#	93	16	6.5	3	0.7	3	0.4	1	62.8	1	33.4	1	96.6	1	40.0	1	0.0	5
PICKWICK		207.3	93	32	6.3	3	1.0	5	0.9	3	30.7	5	16.9	3	75.8	5	290.0	3	0.0	5
PICKWICK		8.4#	94	16	6.5	3	0.2	1	0.0	1	71.5	1	26.9	3	98.4	1	20.0	1	0.0	5
PICKWICK		207.3	94	38	8.0	5	0.9	5	1.2	5	41.2	5	19.6	3	77.1	5	625.0	5	0.0	5
TELLICO		1.0	91	12	1.7	1	0.1	1	0.0	1	38.5	5	73.5	1	100.0	1	6.7	1	0.2	1
TELLICO		1.0	92	16	2.7	1	0.3	1	0.1	1	17.2	5	59.8	1	99.2	1	8.9	1	0.0	5
TELLICO		1.0	93	16	3.6	1	0.5	1	0.2	1	20.3	5	67.9	1	92.0	1	25.0	1	0.0	5
TELLICO	Q	1.0	93	12	2.7	1	0.1	1	0.1	1	30.5	5	78.7	1	99.2	1	5.0	1	0.1	1
TELLICO		1.0	94	16	2.8	1	0.5	1	0.1	1	18.8	5	61.2	1	95.7	1	28.3	1	0.0	5
WATTS BAR		531.0	91	22	3.8	1	0.9	5	0.4	1	58.0	3	2.1	5	96.0	1	98.3	1	0.0	5
WATTS BAR		531.0	92	22	5.8	3	0.9	5	0.6	3	49.8	3	36.7	1	95.9	1	67.6	1	0.0	5
WATTS BAR		531.0	93	26	6.4	3	1.0	5	0.9	3	68.0	1	4.2	5	87.5	3	170.0	1	0.0	5
WATTS BAR		531.0	94	22	4.9	3	0.8	3	0.6	3	56.1	3	18.9	3	90.2	1	53.3	1	0.0	5
WHEELER		277.0	91	20	5.4	3	0.8	3	0.3	1	77.9	1	9.2	5	95.1	1	50.0	1	0.0	5
WHEELER		277.0	92	16	4.4	1	0.7	3	0.3	1	64.2	1	20.2	3	93.9	1	61.7	1	0.0	5
WHEELER		277.0	93	22	4.9	3	0.9	5	0.3	1	83.4	1	2.8	5	94.8	1	100.0	1	0.0	5
WHEELER		277.0	94	20	6.1	3	0.8	3	0.1	1	65.0	1	18.8	3	87.9	3	101.7	1	0.0	5
WILSON		260.8	91	18	5.2	3	0.7	3	0.0	1	66.7	1	25.4	3	93.3	1	73.3	1	0.0	5
WILSON		260.8	92	14	4.2	1	0.6	3	0.1	1	61.7	1	33.7	1	95.3	1	41.7	1	0.0	5
WILSON		260.8	93	22	6.5	3	0.8	3	0.4	1	74.0	1	13.6	5	89.4	3	131.7	1	0.0	5
WILSON		260.8	94	16	4.1	1	0.3	1	0.0	1	75.4	1	12.2	5	93.8	1	91.7	1	0.0	5

*Q = Identifies results from a replicate set of samples for QA purposes

\# = Identifies an embayment sample location; included with forebays because habitat (sediment substrate and reservoir flow) in these embayments was similar to forebay habitat

Table 3 (Cont'd)

Run-of-River Reservoirs--Transition Zones

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		490.5	91	34	5.9	1	1.0	5	1.1	3	21.6	5	7.9	5	74.9	5	913.3	5	0.0	5
CHICKAMAUGA		490.5	92	36	6.4	3	1.0	5	1.0	3	23.4	5	9.2	5	74.7	5	908.3	5	0.0	5
CHICKAMAUGA		8.5 #	93	32	12.2	5	1.0	5	1.3	3	19.3	5	40.7	1	76.4	3	825.0	5	0.0	5
CHICKAMAUGA		490.5	93	34	8.4	3	1.0	5	1.1	3	29.2	5	14.9	5	75.0	5	466.7	3	0.0	5
CHICKAMAUGA	Q*	490.5	93	32	7.8	3	1.0	5	1.0	3	28.3	5	15.4	3	70.3	5	490.0	3	0.0	5
CHICKAMAUGA		8.5 #	94	24	6.0	1	0.8	3	1.2	3	17.2	5	33.6	1	75.3	3	380.0	3	0.0	5
CHICKAMAUGA		490.5	94	38	8.9	3	1.0	5	2.1	5	28.5	5	14.6	5	67.3	5	735.0	5	0.0	5
CHICKAMAUGA	Q	8.5 #	94	22	4.9	1	0.9	3	0.9	3	8.1	5	38.6	1	83.7	3	211.7	1	0.0	5
CHICKAMAUGA	Q	490.5	94	38	8.3	3	1.0	5	2.0	5	33.2	5	11.8	5	70.7	5	715.0	5	0.0	5
FORT LOUDOUN		624.6	91	14	4.7	1	0.4	1	0.4	1	49.3	3	42.5	1	97.0	1	51.7	1	0.0	5
FORT LOUDOUN		624.6	92	18	5.9	1	0.7	3	0.5	1	55.7	3	26.7	3	90.4	1	90.0	1	0.0	5
FORT LOUDOUN		624.6	93	20	7.7	3	0.8	3	0.7	3	53.0	3	31.2	1	85.2	1	140.0	1	0.0	5
FORT LOUDOUN		624.6	94	16	5.9	1	0.6	3	0.4	1	70.2	1	18.7	3	94.3	1	80.0	1	0.0	5
GUNTERSVILLE		375.2	92	34	6.5	3	1.0	5	0.8	3	22.1	5	6.4	5	83.3	3	906.7	5	0.0	5
GUNTERSVILLE		375.2	93	40	10.8	5	1.0	5	1.5	5	27.6	5	11.2	5	65.0	5	775.0	5	0.0	5
GUNTERSVILLE		375.2	94	38	9.8	5	1.0	5	1.3	3	22.7	5	5.6	5	73.7	5	915.0	5	0.0	5
KENTUCKY		85.0	92	34	7.8	3	1.0	5	0.8	3	16.6	5	12.0	5	79.2	3	871.7	5	0.0	5
KENTUCKY		85.0	93	34	9.1	5	1.0	5	1.1	3	23.6	5	23.8	3	72.6	5	606.7	3	0.0	5
KENTUCKY		85.0	94	32	7.8	3	1.0	5	1.6	5	23.2	5	16.6	3	76.1	3	606.7	3	0.0	5
KENTUCKY	Q	85.0	94	34	8.1	3	1.0	5	1.7	5	27.4	5	19.7	3	71.0	5	426.7	3	0.0	5
MELTON HILL		45.0	91	18	5.6	1	0.8	3	0.8	3	62.1	1	24.8	3	91.0	1	45.0	1	0.0	5
MELTON HILL		45.0	92	16	5.5	1	0.9	3	0.4	1	43.3	3	42.8	1	87.1	1	35.2	1	0.0	5
MELTON HILL		45.0	93	18	4.9	1	0.7	3	0.2	1	51.0	3	29.5	3	91.8	1	35.0	1	0.0	5
MELTON HILL		45.0	94	14	7.1	3	0.5	1	0.4	1	60.4	1	31.8	1	92.1	1	36.7	1	0.0	5
NICKAJACK		433.0	91	24	5.5	1	0.9	3	1.1	3	19.2	5	25.3	3	79.4	3	300.0	1	0.0	5
PICKWICK		230.0	91	28	4.6	1	1.0	5	0.7	3	31.0	5	4.6	5	82.2	3	263.3	1	0.0	5
PICKWICK		230.0	92	34	7.2	3	1.0	5	1.0	3	24.7	5	12.2	5	69.6	5	417.3	3	0.0	5
PICKWICK		230.0	93	32	7.0	3	0.9	3	1.0	3	27.7	5	14.9	5	72.8	5	511.7	3	0.0	5
PICKWICK		230.0	94	34	9.4	5	1.0	5	2.2	5	41.5	3	17.6	3	73.1	5	442.4	3	0.0	5
TELLICO		15.0	93	12	5.0	1	0.3	1	0.1	1	64.1	1	31.9	1	98.8	1	10.0	1	0.0	5
TELLICO		15.0	94	14	4.2	1	0.4	1	0.4	1	76.2	1	16.9	3	98.4	1	13.3	1	0.0	5
WATTS BAR		560.8	91	28	6.7	3	1.0	5	0.9	3	51.4	3	7.5	5	81.3	3	266.7	1	0.0	5
WATTS BAR		560.8	92	30	6.6	3	1.0	5	1.0	3	36.4	3	4.5	5	75.4	3	540.0	3	0.0	5
WATTS BAR		560.8	93	34	7.0	3	1.0	5	1.1	3	33.1	5	1.7	5	80.6	3	786.7	5	0.0	5
WATTS BAR		560.8	94	36	8.9	3	1.0	5	2.0	5	33.8	5	13.2	5	72.4	5	696.7	3	0.0	5
WHEELER		294.1	92	32	6.6	3	1.0	5	0.8	3	30.9	5	12.7	5	78.2	3	416.7	3	0.0	5
WHEELER		6.0 #	93	18	8.4	3	0.9	3	0.3	1	49.6	3	40.5	1	90.1	1	165.0	1	0.0	5
WHEELER		295.9	93	32	7.7	3	1.0	5	1.0	3	18.7	5	9.8	5	78.0	3	643.3	3	0.0	5
WHEELER		6.0 #	94	16	8.4	3	0.5	1	0.3	1	44.1	3	53.6	1	97.6	1	60.0	1	0.0	5
WHEELER		295.9	94	34	8.8	3	1.0	5	1.7	5	35.9	3	12.2	5	74.0	5	395.0	3	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

= Identifies an embay sample location; included with transition zone results because habitat in these embayments was similar to transition zone habitat (sediment substrate and reservoir flow)

Table 3 (Cont'd)

Run-of-River Reservoirs--Inflows

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		518.0	91	24	3.2	1	1.0	5	0.5	1	0.7	5	9.1	5	91.4	1	460.6	1	0.0	5
CHICKAMAUGA		518.0	92	26	3.8	1	1.0	5	0.2	1	4.5	5	11.8	5	92.0	1	884.6	3	0.0	5
CHICKAMAUGA		518.0	93	30	6.6	3	0.9	5	0.7	1	5.4	5	9.5	5	77.4	3	690.9	3	0.0	5
CHICKAMAUGA	Q*	518.0	93	32	6.8	3	1.0	5	0.4	1	3.8	5	8.8	5	82.3	3	1487.3	5	0.0	5
CHICKAMAUGA		518.0	94	22	2.7	1	0.8	3	0.0	1	1.0	5	5.0	5	95.0	1	436.7	1	0.0	5
FORT LOUDOUN		652.0	91	16	1.9	1	0.9	5	0.0	1	14.6	3	28.0	3	95.8	1	381.7	1	0.1	1
FORT LOUDOUN		652.0	92	18	5.0	1	0.9	5	0.1	1	45.7	1	18.2	3	96.0	1	397.4	1	0.0	5
FORT LOUDOUN		652.0	93	14	3.5	1	0.7	3	0.1	1	29.4	3	27.7	3	95.2	1	193.3	1	0.1	1
FORT LOUDOUN		649.5	93	26	5.8	3	1.0	5	0.3	1	17.9	3	7.5	5	93.9	1	572.0	3	0.0	5
FORT LOUDOUN		652.0	94	12	2.9	1	0.8	3	0.3	1	23.8	3	42.0	1	92.9	1	165.5	1	0.2	1
GUNTERSVILLE		420.0	91	26	3.5	1	0.9	5	0.2	1	3.3	5	1.2	5	91.4	1	638.3	3	0.0	5
GUNTERSVILLE		420.0	92	36	9.8	5	1.0	5	1.2	3	4.7	5	14.7	5	79.8	3	1380.5	5	0.0	5
GUNTERSVILLE		420.0	93	30	6.5	3	1.0	5	1.1	3	2.5	5	9.7	5	79.6	3	451.8	1	0.0	5
GUNTERSVILLE	Q	420.0	93	30	7.5	3	0.9	5	1.0	3	4.0	5	13.8	5	71.8	3	463.6	1	0.0	5
GUNTERSVILLE		420.0	94	28	7.0	3	1.0	5	0.5	1	5.3	5	7.4	5	77.7	3	468.2	1	0.0	5
KENTUCKY		200.0	91	14	2.7	1	0.8	3	0.3	1	24.3	3	23.1	3	86.9	1	52.5	1	0.2	1
KENTUCKY		15.0	91	34	9.0	5	1.0	5	1.0	3	7.5	5	7.6	5	84.1	3	659.1	3	0.0	5
KENTUCKY		200.0	92	28	7.6	3	1.0	5	0.7	1	4.5	5	9.5	5	72.8	3	490.0	1	0.0	5
KENTUCKY		15.0	92	36	9.0	5	1.0	5	1.2	3	1.7	5	0.6	5	73.4	3	2732.3	5	0.0	5
KENTUCKY		200.0	93	26	5.4	3	0.9	5	0.8	1	17.0	3	0.0	5	78.2	3	210.9	1	0.0	5
KENTUCKY		15.0	93	36	8.1	5	1.0	5	2.2	5	8.7	5	1.9	5	76.0	3	590.9	3	0.0	5
KENTUCKY		15.0	94	26	5.6	3	1.0	5	0.6	1	10.9	3	5.7	5	82.2	3	301.8	1	0.0	5
KENTUCKY		200.0	94	30	8.3	5	0.9	5	0.4	1	23.7	3	1.3	5	68.3	5	150.9	1	0.0	5
MELTON HILL		58.8	91	8	1.4	1	0.3	1	0.1	1	65.0	1	30.0	1	96.7	1	14.2	1	0.3	1
MELTON HILL		58.8	92	18	8.4	5	0.6	3	0.1	1	44.8	1	46.1	1	91.2	1	71.8	1	0.0	5
MELTON HILL		58.8	93	14	7.4	3	0.4	1	0.3	1	49.3	1	43.8	1	93.1	1	121.1	1	0.0	5
MELTON HILL		58.8	94	12	3.3	1	0.0	1	0.0	1	64.1	1	35.4	1	99.5	1	6.4	1	0.0	5
NICKAJACK		469.0	91	34	6.0	3	1.0	5	2.4	5	9.4	5	0.0	5	68.3	5	284.6	1	0.0	5
NICKAJACK		469.0	92	32	7.4	3	1.0	5	1.6	3	6.1	5	3.7	5	75.0	3	799.1	3	0.0	5
NICKAJACK		469.0	93	40	10.2	5	1.0	5	2.1	5	3.2	5	10.1	5	65.2	5	1061.8	5	0.0	5
NICKAJACK	Q	469.0	93	40	10.7	5	1.0	5	2.3	5	1.6	5	0.4	5	67.2	5	2298.0	5	0.0	5
NICKAJACK		469.0	94	34	6.8	3	1.0	5	1.8	3	0.0	5	0.6	5	73.4	3	1196.4	5	0.0	5
NICKAJACK	Q	469.0	94	38	9.4	5	1.0	5	2.8	5	0.5	5	1.9	5	69.3	5	769.1	3	0.0	5
PICKWICK		253.2	91	14	1.7	1	0.8	3	0.0	1	23.3	3	20.0	3	95.8	1	38.2	1	0.2	1
PICKWICK		253.2	92	26	4.6	1	1.0	5	0.1	1	3.9	5	4.2	5	92.2	1	713.3	3	0.0	5
PICKWICK	Q	253.2	92	26	10.0	5	1.0	5	0.0	1	9.0	5	43.6	1	87.2	1	572.7	3	0.0	5
PICKWICK		253.2	93	36	9.7	5	1.0	5	2.4	5	6.4	5	5.7	5	75.4	3	658.2	3	0.0	5
PICKWICK		253.2	94	30	6.5	3	1.0	5	1.5	3	5.9	5	5.4	5	76.7	3	271.8	1	0.0	5
PICKWICK	Q	253.2	94	32	7.3	3	1.0	5	1.3	3	1.6	5	0.3	5	78.4	3	715.2	3	0.0	5
WATTS BAR		600.0	91	18	3.7	1	0.9	5	0.1	1	34.4	3	10.0	5	97.3	1	369.1	1	0.1	1
WATTS BAR		19.0	91	22	4.4	1	1.0	5	0.8	1	22.4	3	6.1	5	94.2	1	420.2	1	0.0	5
WATTS BAR		19.0	92	20	5.6	3	0.9	3	0.4	1	58.2	1	8.1	5	95.3	1	150.7	1	0.0	5
WATTS BAR		600.0	92	22	5.9	3	0.8	3	0.3	1	23.9	3	4.6	5	91.6	1	390.0	1	0.0	5
WATTS BAR		600.0	93	20	4.4	1	0.7	3	0.3	1	28.7	3	0.2	5	91.3	1	256.4	1	0.0	5
WATTS BAR		19.0	93	22	2.9	1	0.9	5	0.2	1	23.7	3	8.0	5	97.7	1	79.1	1	0.0	5
WATTS BAR	Q	19.0	93	24	5.8	3	0.9	5	0.4	1	28.2	3	13.4	5	89.4	1	196.4	1	0.0	5
WATTS BAR		19.0	94	16	4.0	1	0.7	3	0.7	1	28.2	3	10.0	5	91.2	1	60.0	1	0.1	1
WATTS BAR		600.0	94	28	6.5	3	1.0	5	0.9	3	27.7	3	8.1	5	73.5	3	164.6	1	0.0	5
WHEELER		347.0	91	30	6.7	3	1.0	5	1.0	3	5.6	5	1.5	5	79.6	3	325.5	1	0.0	5
WHEELER		347.0	92	38	9.1	5	1.0	5	2.2	5	6.8	5	0.0	5	68.2	5	593.6	3	0.0	5
WHEELER		347.0	93	38	9.9	5	1.0	5	2.2	5	5.7	5	0.0	5	68.7	5	619.1	3	0.0	5
WHEELER		347.0	94	34	9.9	5	1.0	5	1.9	3	8.6	5	0.0	5	59.8	5	407.3	1	0.0	5
WILSON		273.0	91	30	7.0	3	1.0	5	1.2	3	9.9	5	15.2	3	72.8	3	788.3	3	0.0	5
WILSON		273.0	92	32	9.1	5	1.0	5	1.3	3	7.8	5	24.3	3	74.5	3	780.3	3	0.0	5
WILSON		273.0	93	36	10.6	5	1.0	5	1.7	3	4.5	5	9.7	5	67.2	5	566.8	3	0.0	5
WILSON		273.0	94	34	10.9	5	1.0	5	1.7	3	5.1	5	15.0	3	59.3	5	728.5	3	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

Table 3 (Cont'd)

Blue Ridge Ecoregion Tributary Results--Forebays and Upper Reservoir

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																				
BLUE RIDGE		54.1	93	34	5.1	5	0.9	5	0.4	5	40.6	3	37.3	5	85.1	5	498.3	5	0.1	1
BLUE RIDGE		54.1	94	22	2.3	3	0.5	5	0.2	3	48.7	1	34.9	5	94.7	3	73.3	1	0.2	1
BLUE RIDGE	Q*	54.1	94	28	3.7	3	0.5	5	0.8	5	41.3	3	51.2	3	90.5	3	251.7	5	0.2	1
CHATUGE		1.5	93	28	5.6	5	0.4	3	0.5	5	45.2	1	46.0	3	93.3	3	116.7	3	0.0	5
CHATUGE		122.0	93	32	5.6	5	0.4	3	0.4	5	25.9	5	56.1	3	95.4	1	288.3	5	0.0	5
CHATUGE		1.5	94	24	4.6	5	0.1	1	0.3	3	60.3	1	30.2	5	92.4	3	46.4	1	0.0	5
CHATUGE		122.0	94	20	3.6	3	0.2	3	0.2	3	53.1	1	44.4	3	97.5	1	6.7	1	0.0	5
FONTANA		62.0	93	14	1.2	1	0.2	3	0.0	1	20.0	5	97.6	1	100.0	1	23.3	1	0.2	1
HIWASSEE		77.0	93	12	1.2	1	0.0	1	0.0	1	25.3	5	74.7	1	100.0	1	1.7	1	0.1	1
HIWASSEE		77.0	94	10	1.7	1	0.1	1	0.0	1	37.8	3	74.0	1	96.0	1	15.0	1	0.2	1
NOTTELY		23.5	93	16	3.5	3	0.0	1	0.0	1	46.5	1	52.1	3	98.6	1	10.0	1	0.0	5
NOTTELY		23.5	94	16	3.4	3	0.0	1	0.1	1	49.9	1	48.7	3	98.6	1	5.9	1	0.0	5
OCOEE NO 1		12.5	93	18	2.1	3	0.0	1	0.0	1	9.5	5	81.3	1	96.6	1	18.3	1	0.0	5
OCOEE NO 1		12.5	94	12	1.2	1	0.0	1	0.1	1	21.4	5	80.4	1	96.7	1	8.3	1	0.2	1
OCOEE NO 1	Q	12.5	94	8	0.7	1	0.0	1	0.0	1	50.0	1	79.2	1	100.0	1	5.0	1	0.4	1
WATAUGA		37.4	93	12	1.3	1	0.0	1	0.0	1	25.9	5	87.2	1	99.6	1	11.7	1	0.2	1
WATAUGA		37.4	94	16	1.2	1	0.3	3	0.0	1	26.0	5	55.0	3	100.0	1	4.6	1	0.1	1
UPPER																				
FONTANA		3.0	93	20	3.5	3	0.0	1	0.0	1	4.4	5	94.5	1	98.9	1	26.7	3	0.0	5
FONTANA		81.5	93	26	5.3	5	0.1	1	0.0	1	14.1	5	69.2	1	94.1	3	76.7	5	0.0	5
FONTANA	Q	81.5	93	22	3.8	3	0.0	1	0.1	1	21.0	5	64.6	3	97.6	1	41.2	3	0.0	5
FONTANA		3.0	94	10	2.4	1	0.0	1	0.0	1	47.6	3	72.3	1	99.9	1	3.3	1	0.2	1
FONTANA		81.5	94	14	2.8	1	0.0	1	0.0	1	62.1	1	37.7	3	99.8	1	1.7	1	0.0	5
HIWASSEE		85.0	93	18	3.7	3	0.0	1	0.0	1	12.0	5	86.7	1	98.7	1	13.0	1	0.0	5
HIWASSEE		90.0	93	28	5.0	5	0.4	3	0.4	3	34.9	3	60.4	3	95.4	3	43.3	3	0.0	5
HIWASSEE		85.0	94	18	2.8	1	0.2	3	0.1	1	15.2	5	78.3	1	98.1	1	15.0	1	0.0	5
HIWASSEE		90.0	94	20	3.4	3	0.2	3	0.1	1	69.5	1	29.3	5	98.8	1	6.7	1	0.0	5
HIWASSEE	Q	85.0	94	18	3.0	1	0.3	3	0.1	1	12.1	5	82.1	1	96.5	1	14.4	1	0.0	5
NOTTELY		31.0	93	34	5.2	5	0.6	5	0.6	5	54.9	3	36.5	3	93.4	3	58.3	5	0.0	5
NOTTELY		31.0	94	28	4.7	5	0.4	3	0.5	3	82.4	1	7.1	5	95.2	3	35.5	3	0.0	5
NOTTELY	Q	31.0	94	34	4.3	5	0.5	5	0.8	5	73.8	1	7.2	5	89.0	5	44.6	3	0.0	5
WATAUGA		45.5	93	12	1.7	1	0.0	1	0.0	1	93.8	1	16.2	5	100.0	1	0.0	1	0.1	1
WATAUGA		45.5	94	22	3.3	3	0.1	1	0.1	1	35.1	3	57.0	3	96.0	1	438.3	5	0.0	5
WATAUGA	Q	45.5	94	16	2.2	1	0.1	1	0.0	1	68.2	1	31.1	5	99.3	1	1.7	1	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

Table 3 (Cont'd)

Ridge and Valley Ecoregion Tributary Reservoirs--Forebays and Upper Reservoir

RESVORNA	MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																			
BOONE	19.0	93	22	3.0	5	0.1	1	0.0	1	4.5	5	89.8	1	95.6	3	23.3	1	0.0	5
BOONE	19.0	94	18	2.7	3	0.1	1	0.0	1	7.1	5	91.6	1	98.9	1	5.2	1	0.0	5
CHEROKEE	53.0	91	10	1.5	1	0.0	1	0.0	1	54.6	1	75.4	3	100.0	1	0.0	1	0.3	1
CHEROKEE	53.0	92	22	3.7	5	0.0	1	0.1	3	41.1	3	58.0	3	99.2	1	5.0	1	0.0	5
CHEROKEE	53.0	93	28	3.8	5	0.1	3	0.3	5	50.9	1	46.9	5	97.8	3	12.5	1	0.0	5
CHEROKEE	53.0	94	22	3.5	5	0.1	1	0.1	3	52.3	1	46.2	5	98.6	1	5.0	1	0.0	5
DOUGLAS	33.0	91	16	1.9	3	0.0	1	0.0	1	47.0	3	59.9	3	97.3	3	8.3	1	0.1	1
DOUGLAS	33.0	92	20	2.9	3	0.1	1	0.1	3	53.9	1	39.9	5	98.8	1	5.0	1	0.0	5
DOUGLAS	33.0	93	18	2.2	3	0.0	1	0.0	1	61.5	1	38.6	5	100.0	1	0.0	1	0.0	5
DOUGLAS	33.0	94	18	2.8	3	0.0	1	0.0	1	66.5	1	33.0	5	99.5	1	1.7	1	0.0	5
FORT PATRICK HENRY	8.7	93	28	3.1	5	0.3	3	0.0	1	17.5	5	76.8	3	96.2	3	56.7	3	0.0	5
FORT PATRICK HENRY	8.7	94	20	3.1	5	0.1	1	0.0	1	48.0	3	50.5	3	98.5	1	6.7	1	0.0	5
NORRIS	80.4	91	32	2.9	3	0.6	5	0.1	3	3.1	5	57.9	3	96.7	3	209.9	5	0.0	5
NORRIS	80.4	92	40	6.5	5	1.0	5	0.6	5	15.5	5	24.0	5	87.5	5	406.4	5	0.0	5
NORRIS	80.4	93	34	3.2	5	0.6	5	0.1	3	3.1	5	71.0	3	94.5	3	214.1	5	0.0	5
NORRIS	80.4	94	22	2.0	3	0.3	3	0.0	1	6.4	5	77.9	3	98.2	1	50.0	1	0.0	5
SOUTH HOLSTON	51.0	93	8	0.6	1	0.1	1	0.0	1	51.1	1	88.9	1	100.0	1	1.7	1	0.5	1
SOUTH HOLSTON	51.0	94	24	2.5	3	0.2	3	0.2	5	6.9	5	81.2	1	98.1	1	10.9	1	0.0	5
TIMS FORD	135.0	93	10	0.7	1	0.0	1	0.0	1	30.0	3	100.0	1	100.0	1	0.0	1	0.3	1
TIMS FORD	135.0	94	8	0.5	1	0.0	1	0.0	1	71.7	1	88.3	1	100.0	1	0.0	1	0.6	1
UPPER																			
BOONE	27.0	93	16	2.9	1	0.1	1	0.0	1	11.5	5	87.8	1	99.4	1	8.3	1	0.0	5
BOONE	6.5	93	18	2.4	1	0.1	1	0.0	1	21.9	5	71.2	1	96.7	3	16.7	1	0.0	5
BOONE	27.0	94	14	2.9	1	0.0	1	0.0	1	39.5	3	60.6	1	100.0	1	0.0	1	0.0	5
BOONE	6.5	94	20	3.0	1	0.1	1	0.0	1	31.2	5	58.9	3	98.4	1	28.3	3	0.0	5
DOUGLAS	51.0	94	18	3.4	3	0.0	1	0.0	1	70.4	1	29.6	5	100.0	1	0.0	1	0.0	5
NORRIS	30.0	91	38	5.1	5	0.9	5	0.2	5	31.0	5	53.7	3	92.6	5	73.3	5	0.0	5
NORRIS	125.0	91	28	4.1	3	0.5	3	0.1	3	84.4	1	7.2	5	96.6	3	66.7	5	0.0	5
NORRIS	30.0	92	30	6.0	5	0.5	3	0.1	3	34.9	5	60.9	1	95.8	3	57.6	5	0.0	5
NORRIS	125.0	92	32	5.0	5	0.6	3	0.1	3	49.8	3	40.7	3	91.6	5	50.2	5	0.0	5
NORRIS	30.0	93	34	6.9	5	0.8	5	0.1	3	41.6	3	52.0	3	93.5	5	77.8	5	0.0	5
NORRIS	125.0	93	22	4.4	3	0.4	3	0.1	3	52.4	3	46.2	3	98.6	1	16.1	1	0.0	5
NORRIS	30.0	94	30	4.7	3	0.6	3	0.2	5	48.5	3	46.2	3	94.8	3	63.3	5	0.0	5
NORRIS	125.0	94	36	5.8	5	0.8	5	0.5	5	57.1	3	37.4	5	94.8	3	53.3	5	0.0	5
SOUTH HOLSTON	62.5	93	22	3.1	3	0.2	1	0.0	1	24.1	5	66.5	1	95.7	3	34.9	3	0.0	5
SOUTH HOLSTON	62.5	94	14	2.8	1	0.0	1	0.0	1	36.9	3	63.1	1	100.0	1	0.0	1	0.0	5
TIMS FORD	150.0	93	12	2.1	1	0.1	1	0.1	3	69.6	1	44.6	3	99.1	1	11.7	1	0.3	1
TIMS FORD	150.0	94	12	1.1	1	0.1	1	0.1	3	89.0	1	50.0	3	100.0	1	1.7	1	0.4	1

Table 3 (Cont'd)

Interior Plateau Tributary Reservoirs--Forebays

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																				
BEAR CREEK		75.0	91	16	2.4	1	0.2	3	0.2	3	68.0	1	23.8	5	96.4	1	24.1	1	0.1	1
BEAR CREEK		75.0	93	32	4.6	5	0.5	5	0.4	3	70.6	1	12.4	5	91.3	5	45.9	3	0.0	5
BEAR CREEK		75.0	94	24	3.8	3	0.1	1	0.3	3	75.3	1	9.8	5	95.3	3	33.3	3	0.0	5
BEECH LAKE		36.0	93	30	5.2	5	0.3	3	0.3	3	75.9	1	14.4	5	94.8	3	81.7	5	0.0	5
BEECH LAKE		36.0	94	30	5.1	5	0.3	3	0.3	3	81.1	1	9.5	5	93.7	3	93.3	5	0.0	5
CEDAR CREEK		25.0	91	14	2.4	1	0.3	3	0.3	3	33.2	3	83.0	1	96.2	1	11.7	1	0.2	1
CEDAR CREEK		25.2	93	24	3.0	3	0.2	3	0.2	3	41.3	3	51.6	3	94.4	3	28.3	1	0.0	5
CEDAR CREEK		25.2	94	38	5.0	5	0.6	5	0.7	5	50.0	3	29.7	5	87.2	5	128.3	5	0.0	5
LITTLE BEAR CREEK		12.3	91	24	2.7	3	0.3	3	0.4	3	3.4	5	90.8	1	96.2	1	50.0	3	0.0	5
LITTLE BEAR CREEK		12.5	93	22	2.8	3	0.2	3	0.2	3	11.1	5	85.3	1	97.8	1	11.7	1	0.0	5
LITTLE BEAR CREEK		12.5	94	24	3.2	3	0.4	3	0.5	3	13.9	5	82.0	1	97.0	1	31.7	3	0.0	5
LITTLE BEAR CREEK	Q*	12.5	94	28	3.6	3	0.3	3	0.2	3	7.9	5	86.6	1	94.4	3	70.0	5	0.0	5
NORMANDY		249.5	93	10	1.4	1	0.1	1	0.0	1	46.4	3	80.1	1	99.6	1	5.0	1	0.3	1
NORMANDY		249.5	94	16	2.0	1	0.0	1	0.0	1	34.0	3	62.2	3	99.5	1	3.3	1	0.0	5

Q* = Identifies a replicate set of samples for QA purposes

Section 5. Fish Community

Philosophical Approach/Background

Many of the same considerations discussed for the benthic macroinvertebrate community (Section 4) also apply for the fish community. These are repeated here, as appropriate, in case the reader does not have access to that information.

Fish are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have long a life cycle which allows them to integrate conditions over time. In streams fish community monitoring has often been found to reflect environmental degradation when physical and chemical monitoring have failed to do so. Fish are also important to the public for aesthetic, recreational, and commercial reasons.

Reservoir fish communities are be vastly different from that in the river prior to impoundment due to significant habitat alterations. Also, substantial differences are expected along a longitudinal gradient with a more riverine community expected at the upper end or inflow of a reservoir and a more lacustrine community expected in the pool near the dam. Other factors to consider in evaluating biotic communities in reservoirs include reservoir operational characteristics (e.g., depth of withdrawal for discharge, water depth, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability) and physical/chemical features owing to geological characteristics of different ecoregions.

All these factors, plus the fact that a reservoir is an artificial system, must be considered in selecting community characteristics or expectations that will be used to evaluate aquatic resource conditions. Given that reservoirs are artificial systems, it is not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to determine characteristics or expectations of a reservoir unaffected by human impacts. By definition, IBI specifies reference conditions should be developed from natural, unaltered habitats (Karr and Dudley, 1981 after Frey 1975). Therefore, other approaches must be used; such as, using historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. Like benthic macroinvertebrates, the state of the understanding of fish communities in reservoirs simply is insufficient for models to effectively predict species composition and relative abundance. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment as the best approach. Use of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 30 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics.

Run-of-the-River
<u>Reservoirs</u>
- Kentucky
- Pickwick
- Wilson
- Wheeler
- Guntersville
- Nickajack
- Chickamauga
- Watts Bar
- Melton Hill
- Tellico
- Fort Loudon

Tributary Reservoirs:
<u>Interior Plateau Ecoregion</u>
- Bear Creek
- Cedar Creek
- Little Bear
- Normandy
- Beech
- Tims Ford

Tributary Reservoirs:
<u>Ridge and Valley Ecoregion</u>
- Cherokee
- Fort Patrick Henry
- Boone
- South Holston
- Norris
- Douglas

Tributary Reservoirs:
<u>Blue Ridge Ecoregion</u>
- Fontana
- Hiwassee
- Chatuge
- Nottely
- Parksville
- Blue Ridge
- Watauga

Sample Collection Methods

Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of most reservoirs during autumn (September to mid-November 1994). Only one or two zones were sampled on reservoirs where zones were indistinguishable. No inflow zones were sampled in tributary reservoirs during 1994 because environmental quality of major inflow streams was addressed using Index of Biotic Integrity (IBI) techniques in the free flowing portion upstream of the impoundment. Location of collection sites in 1994 are identified in Table 1

A total of 15 electrofishing transects, each covering 300m of shoreline, was collected from each of the sampled zones. All habitats were sampled in proportion to their occurrence in the zone. Twelve experimental gill nets with five 6.1m panels (mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7cm) were set for one overnight period in forebay and transition zones. Excessive current prevented use of gill nets in mainstream inflow areas limiting sampling to only electrofishing in these locations. Nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets.

Total length (mm) and weight (g) were obtained for all sport species and channel catfish. Remaining species captured were enumerated prior to release. During electrofishing, fish observed but not captured were included if positive identification could be made and counts were estimated when high densities of identifiable fish were encountered. Young-of-year fish were counted separately and, as in stream IBI calculations (Karr 1981), were excluded from proportional and abundance metrics due to sampling inefficiencies. Only fish examined closely as a result of obtaining length and weight measurements were inspected externally for signs of disease, parasites, and anomalies. Other species groups often included several individuals which were observed, but not captured, thus the ratio of diseased, etc. was not obtainable for these groups. Natural hybrids (i.e., those known not to be part of a fisheries management program) were included as an anomaly. Data loggers were used to record all sampling results.

Reservoir Fish Assemblage Index

The current RFAI uses 12 fish community metrics from five general categories (Hickman and McDonough, 1995). The 12 metrics include:

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.
2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.
3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and suitable sediment quality in littoral areas.
4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs.
5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.
6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.
7. **Percentage dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.
9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners spawn over rocky substrate and do not provide parental care. This guild is expected to

be sensitive to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

Fish Health

12. **Percentage individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Establishing scoring criteria (reference conditions) by trisecting observed conditions requires a substantial data base for each class of reservoir and assumes the data base contains reservoirs with conditions ranging from poor to good for each metric. The smaller the number of reservoirs within a class, the less likely these assumptions can be met and the greater the need for sound professional judgment based on extensive knowledge of reservoir communities being studied.

Because some reservoir classes contained relatively few reservoirs, the approach used to develop scoring criteria for RFAI was to include all sampling results from Vital Signs monitoring (1990 - 1994). A slightly different approach was used for species richness metrics than for abundance and proportional metrics. For species richness metrics, a list was made of all species collected from comparable locations within a reservoir class from 1990 - 1994. This species list was adjusted using inferences of experienced biologists knowledgeable of the reservoir system, resident fish species, susceptibility of each species to collection methods being used, and effects of human-induced impacts on these species. This effort resulted in a list of the maximum number of species expected to occur at a sampling location and be captured by collection devices in use. Given that only one collection effort is exerted each year, this maximum number of species would not be expected to be represented in that one collection. Therefore, the range from zero to 95% of the maximum was trisected to provide the three scoring ranges (good, fair, and poor). Although even 95% of the maximum number of species at a site would not be expected to be collected in one sampling event, this "high" expectation was adopted to keep these metrics conservative in light of potential uncertainties introduced by relying heavily on professional judgment.

Scoring criteria for proportional metrics and the abundance metric were determined by trisecting observed ranges after omitting outliers. Next, cutoff points between the three ranges were adjusted based on examination of frequency distributions of observed data for each metric along with professional judgment. In some cases, the narrow range of observed conditions required further adjustment based on knowledge of metric responses to human-induced impacts observed in other reservoir classes. Scoring criteria for the fish health metric are those described by Karr et.al. (1986). Scoring criteria are detailed in Table 2.

To develop metric scores for taxa richness, reproductive composition, and fish health metrics, electrofishing and experimental gill net sampling results were pooled prior to scoring. For abundance and proportional metrics, electrofishing and gill netting results were scored separately, then the two scores averaged to arrive at a final metric value. These scoring criteria separated sites into three categories assumed to represent relative degrees of degradation. Sample results are compared to these reference conditions and assigned a corresponding value: good = 5; fair = 3; and poor = 1.

The sum of the 12 metric ratings constituted the RFAI score. To arrive at an evaluation of the condition of the fish assemblage at a sample location, scores were evaluated as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Community Condition	Very Poor	Poor	Fair	Good	Excellent

The contribution of the fish community results for each sample site to the overall reservoir Ecological Health Index was as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Contribution to Reservoir Ecological Health Index	1	2	3	4	5

One further use of these results is in TVA's annual report to the public on the conditions of Tennessee Valley reservoirs. In this publication, titled *Riverpulse,* results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good), yellow (fair), or red (poor). This necessitated dividing the RFAI scores into three ranges as follows:

RFAI Score	12-28	29-44	45-60
Color (Rating) in *RiverPulse*	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1994 Monitoring

RFAI scores for 1990 through 1994 are summarized by reservoir class and type of location in Table 3. (Note that 10 electrofishing runs were used in 1990 - 1992 rather than the 15 used in 1993 and 1994.) Appendix A summarizes results and ratings for individual metrics and final RFAI scores for each sample location based on 1994 data. Appendix B provides mean catch per effort by species for electrofishing and gill netting efforts at each location in 1994.

Approximately 20 percent of all sampling locations were revisited for Quality Control purposes. All together, 12 randomly selected sites were revisited by a second sample crew several days or weeks after the initial sampling to collect a second set of samples. A RFAI score was developed separately for each of the two sample sets. The desired maximum difference between the RFAI score from the original sample and the QA sample set was 10. A difference greater than this would cause the rating to change 2 categories (e.g., very poor to fair, fair to good), which was deemed unacceptable. Results for each set of repeat samples are provided below.

	Original Score	QA/QC Score	Difference
Run-of-the-River Reservoirs			
Forebays			
Chickamauga	36 (Fair)	36 (Fair)	0
Nickajack	40 (Fair)	38 (Fair)	2
Transition Zones			
Chickamauga	36 (Fair)	46 (Good)	10
Kentucky	40 (Fair)	40 (Fair)	0
Inflows			
Pickwick	42 (Good)	44 (Good)	2
Embayments			
Hiwassee (on Chick. Res.)	42 (Good)	39 (Fair)	3
Tributary Reservoirs			
Forebays			
Parksville	37 (Fair)	33 (Fair)	4
Blue Ridge	36 (Fair)	37 (Fair)	1
Little Bear	46 (Good)	49 (Good)	3
Upper			
Watauga	30 (Poor)	32 (Fair)	2
Hiwassee	34 (Fair)	33 (Fair)	1
Nottely	31 (Poor)	34 (Fair)	3

The maximum observed difference was 10 (1 sets of samples) and the minimum was 0 (2 sets of samples). The mean difference for all reservoirs was 2.58. The 95% confidence interval around the mean would be 0.8 to 4.3, well below the desired level of 10.

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TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
			Reservoir Vital Signs Monitoring Tools				
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools				
			Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone cholrophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. No samples are collected for fecal coliforms, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (Rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near shore fish community, during autumn.

Table 2. Scoring Criteria for Individual Metrics for Each Class of Reservoir

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
all	all	all	12. Percent anomalies	combined	< 0.02	0.02 - 0.05	> 0.05
BLUE RIDGE	all	forbay	1. Number of species	combined	< 8	8 - 15	> 15
BLUE RIDGE	all	forbay	2. Piscivore species	combined	< 3	3 - 5	> 5
BLUE RIDGE	all	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
BLUE RIDGE	all	forbay	4. Sucker species	combined	< 2	2 - 3	> 3
BLUE RIDGE	all	forbay	5. Intolerant species	combined	< 2	2 - 2	> 2
BLUE RIDGE	all	forbay	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15
BLUE RIDGE	all	forbay	6. Percent tolerant species	Gill netting	> .20	.10 - .20	< .10
BLUE RIDGE	all	forbay	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
BLUE RIDGE	all	forbay	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
BLUE RIDGE	all	forbay	8. Percent omnivores	Electrofishing	> .10	.05 - .10	< .05
BLUE RIDGE	all	forbay	8. Percent omnivores	Gill netting	> .30	.15 - .30	< .15
BLUE RIDGE	all	forbay	9. Percent insectivores	Electrofishing	< .75	.75 - .85	> .85
BLUE RIDGE	all	forbay	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
BLUE RIDGE	all	forbay	10. Lithophilic spawning species	combined	< 3	3 - 4	> 4
BLUE RIDGE	all	forbay	11. Average number of individuals	Electrofishing	< 30	30 - 60	> 60
BLUE RIDGE	all	forbay	11. Average number of individuals	Gill netting	< 10	10 - 18	> 18
BLUE RIDGE	all	transition	1. Number of species	combined	< 8	8 - 15	> 15
BLUE RIDGE	all	transition	2. Piscivore species	combined	< 3	3 - 5	> 5
BLUE RIDGE	all	transition	3. Sunfish species	combined	< 2	2 - 3	> 3
BLUE RIDGE	all	transition	4. Sucker species	combined	< 2	2 - 3	> 3
BLUE RIDGE	all	transition	5. Intolerant species	combined	< 2	2 - 2	> 2
BLUE RIDGE	all	transition	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15
BLUE RIDGE	all	transition	6. Percent tolerant species	Gill netting	> .20	.10 - .20	< .10
BLUE RIDGE	all	transition	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
BLUE RIDGE	all	transition	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
BLUE RIDGE	all	transition	8. Percent omnivores	Electrofishing	> .10	.05 - .10	< .05
BLUE RIDGE	all	transition	8. Percent omnivores	Gill netting	> .30	.15 - .30	< .15
BLUE RIDGE	all	transition	9. Percent insectivores	Electrofishing	< .75	.75 - .85	> .85
BLUE RIDGE	all	transition	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
BLUE RIDGE	all	transition	10. Lithophilic spawning species	combined	< 3	3 - 4	> 4
BLUE RIDGE	all	transition	11. Average number of individuals	Electrofishing	< 30	30 - 60	> 60
BLUE RIDGE	all	transition	11. Average number of individuals	Gill netting	< 10	10 - 18	> 18
INTER PLAT	BEAR SYS.	forbay	1. Number of species	combined	< 10	10 - 19	> 19
INTER PLAT	NORMANDY	forbay	1. Number of species	combined	< 8	8 - 17	> 17
INTER PLAT	TIMS FORD	forbay	1. Number of species	combined	< 10	10 - 20	> 20

Table 2 (Cont'd)

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
INTER PLAT	BEAR SYS.	forbay	2. Piscivore species	combined	< 3	3 - 6	> 6
INTER PLAT	NORMANDY	forbay	2. Piscivore species	combined	< 3	3 - 6	> 6
INTER PLAT	TIMS FORD	forbay	2. Piscivore species	combined	< 4	4 - 6	> 6
INTER PLAT	BEAR SYS.	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
INTER PLAT	NORMANDY	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
INTER PLAT	TIMS FORD	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
INTER PLAT	BEAR SYS.	forbay	4. Sucker species	combined	< 3	3 - 5	> 5
INTER PLAT	NORMANDY	forbay	4. Sucker species	combined	< 3	3 - 4	> 4
INTER PLAT	TIMS FORD	forbay	4. Sucker species	combined	< 4	4 - 6	> 6
INTER PLAT	BEAR SYS.	forbay	5. Intolerant species	combined	< 2	2 - 2	> 2
INTER PLAT	NORMANDY	forbay	5. Intolerant species	combined	< 2	2 - 2	> 2
INTER PLAT	TIMS FORD	forbay	5. Intolerant species	combined	< 2	2 - 2	> 2
INTER PLAT	all	forbay	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15
INTER PLAT	all	forbay	6. Percent tolerant species	Gill netting	> .35	.20 - .35	< .20
INTER PLAT	all	forbay	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
INTER PLAT	all	forbay	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
INTER PLAT	all	forbay	8. Percent omnivores	Electrofishing	> .25	.10 - .25	< .10
INTER PLAT	all	forbay	8. Percent omnivores	Gill netting	> .60	.40 - .60	< .40
INTER PLAT	all	forbay	9. Percent insectivores	Electrofishing	< .60	.60 - .80	> .80
INTER PLAT	all	forbay	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
INTER PLAT	BEAR SYS.	forbay	10. Lithophilic spawning species	combined	< 3	3 - 6	> 6
INTER PLAT	NORMANDY	forbay	10. Lithophilic spawning species	combined	< 3	3 - 6	> 6
INTER PLAT	TIMS FORD	forbay	10. Lithophilic spawning species	combined	< 4	4 - 6	> 6
INTER PLAT	all	forbay	11. Average number of individuals	Electrofishing	< 40	40 - 80	> 80
INTER PLAT	all	forbay	11. Average number of individuals	Gill netting	< 10	10 - 18	> 18
INTER PLAT	NORMANDY	transition	1. Number of species	combined	< 8	8 - 17	> 17
INTER PLAT	TIMS FORD	transition	1. Number of species	combined	< 11	11 - 20	> 20
INTER PLAT	NORMANDY	transition	2. Piscivore species	combined	< 3	3 - 6	> 6
INTER PLAT	TIMS FORD	transition	2. Piscivore species	combined	< 4	4 - 6	> 6
INTER PLAT	NORMANDY	transition	3. Sunfish species	combined	< 2	2 - 3	> 3
INTER PLAT	TIMS FORD	transition	3. Sunfish species	combined	< 2	2 - 3	> 3
INTER PLAT	NORMANDY	transition	4. Sucker species	combined	< 2	2 - 2	> 2
INTER PLAT	TIMS FORD	transition	4. Sucker species	combined	< 4	4 - 6	> 6
INTER PLAT	NORMANDY	transition	5. Intolerant species	combined	< 2	2 - 2	> 2
INTER PLAT	TIMS FORD	transition	5. Intolerant species	combined	< 2	2 - 2	> 2
INTER PLAT	all	transition	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15

Table 2 (Cont'd)

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
INTER PLAT	all	transition	6. Percent tolerant species	Gill netting	> .35	.20 - .35	< .20
INTER PLAT	all	transition	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
INTER PLAT	all	transition	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
INTER PLAT	all	transition	8. Percent omnivores	Electrofishing	> .25	.10 - .25	< .10
INTER PLAT	all	transition	8. Percent omnivores	Gill netting	> .60	.40 - .60	< .40
INTER PLAT	all	transition	9. Percent insectivores	Electrofishing	< .50	.50 - .70	> .70
INTER PLAT	all	transition	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
INTER PLAT	NORMANDY	transition	10. Lithophilic spawning species	combined	< 3	3 - 6	> 6
INTER PLAT	TIMS FORD	transition	10. Lithophilic spawning species	combined	< 4	4 - 6	> 6
INTER PLAT	all	transition	11. Average number of individuals	Electrofishing	< 40	40 - 80	> 80
INTER PLAT	all	transition	11. Average number of individuals	Gill netting	< 10	10 - 18	> 18
MAINSTREAM	LOWER MS	forbay	1. Number of species	combined	< 14	14 - 27	> 27
MAINSTREAM	MELTON H	forbay	1. Number of species	combined	< 13	13 - 24	> 24
MAINSTREAM	TELLICO	forbay	1. Number of species	combined	< 13	13 - 24	> 24
MAINSTREAM	UPPER MS	forbay	1. Number of species	combined	< 14	14 - 27	> 27
MAINSTREAM	LOWER MS	forbay	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	forbay	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	TELLICO	forbay	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	UPPER MS	forbay	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	LOWER MS	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
MAINSTREAM	MELTON H	forbay	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	TELLICO	forbay	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	UPPER MS	forbay	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	LOWER MS	forbay	4. Sucker species	combined	< 4	4 - 6	> 6
MAINSTREAM	MELTON H	forbay	4. Sucker species	combined	< 4	4 - 6	> 6
MAINSTREAM	TELLICO	forbay	4. Sucker species	combined	< 4	4 - 6	> 6
MAINSTREAM	UPPER MS	forbay	4. Sucker species	combined	< 4	4 - 7	> 7
MAINSTREAM	LOWER MS	forbay	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	MELTON H	forbay	5. Intolerant species	combined	< 2	2 - 3	> 3
MAINSTREAM	TELLICO	forbay	5. Intolerant species	combined	< 2	2 - 3	> 3
MAINSTREAM	UPPER MS	forbay	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	all	forbay	6. Percent tolerant species	Electrofishing	> .45	.20 - .45	< .20
MAINSTREAM	all	forbay	6. Percent tolerant species	Gill netting	> .40	.20 - .40	< .20
MAINSTREAM	all	forbay	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
MAINSTREAM	all	forbay	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
MAINSTREAM	all	forbay	8. Percent omnivores	Electrofishing	> .45	.20 - .45	< .20

Table 2 (Cont'd)

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
MAINSTREAM	all	forbay	8. Percent omnivores	Gill netting	> .45	.30 - .45	< .30
MAINSTREAM	all	forbay	9. Percent insectivores	Electrofishing	< .35	.35 - .70	> .70
MAINSTREAM	all	forbay	9. Percent insectivores	Gill netting	< .05	.05 - .15	> .15
MAINSTREAM	LOWER MS	forbay	10. Lithophilic spawning species	combined	< 4	4 - 6	> 6
MAINSTREAM	MELTON H	forbay	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	TELLICO	forbay	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	UPPER MS	forbay	10. Lithophilic spawning species	combined	< 3	3 - 6	> 6
MAINSTREAM	all	forbay	11. Average number of individuals	Electrofishing	< 50	50 - 100	> 100
MAINSTREAM	all	forbay	11. Average number of individuals	Gill netting	< 15	15 - 35	> 35
MAINSTREAM	LOWER MS	inflow	1. Number of species	combined	< 14	14 - 27	> 27
MAINSTREAM	MELTON H	inflow	1. Number of species	combined	< 13	13 - 24	> 24
MAINSTREAM	UPPER MS	inflow	1. Number of species	combined	< 14	14 - 27	> 27
MAINSTREAM	LOWER MS	inflow	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	inflow	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	UPPER MS	inflow	2. Piscivore species	combined	< 3	3 - 6	> 6
MAINSTREAM	LOWER MS	inflow	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	MELTON H	inflow	3. Sunfish species	combined	< 3	3 - 4	> 4
MAINSTREAM	UPPER MS	inflow	3. Sunfish species	combined	< 3	3 - 4	> 4
MAINSTREAM	LOWER MS	inflow	4. Sucker species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	inflow	4. Sucker species	combined	< 3	3 - 6	> 6
MAINSTREAM	UPPER MS	inflow	4. Sucker species	combined	< 3	3 - 6	> 6
MAINSTREAM	LOWER MS	inflow	5. Intolerant species	combined	< 3	3 - 6	> 6
MAINSTREAM	MELTON H	inflow	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	UPPER MS	inflow	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	all	inflow	6. Percent tolerant species	Electrofishing	> .55	.30 - .55	< .30
MAINSTREAM	all	inflow	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
MAINSTREAM	all	inflow	8. Percent omnivores	Electrofishing	> .55	.30 - .55	< .30
MAINSTREAM	all	inflow	9. Percent insectivores	Electrofishing	< .25	.25 - .50	> .50
MAINSTREAM	LOWER MS	inflow	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	inflow	10. Lithophilic spawning species	combined	< 3	3 - 5	> 5
MAINSTREAM	UPPER MS	inflow	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	all	inflow	11. Average number of individuals	Electrofishing	< 50	50 - 100	> 100
MAINSTREAM	LOWER MS	transition	1. Number of species	combined	< 16	16 - 30	> 30
MAINSTREAM	MELTON H	transition	1. Number of species	combined	< 13	13 - 26	> 26
MAINSTREAM	TELLICO	transition	1. Number of species	combined	< 13	13 - 26	> 26
MAINSTREAM	UPPER MS	transition	1. Number of species	combined	< 15	15 - 29	> 29

Table 2 (Cont'd)

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
MAINSTREAM	LOWER MS	transition	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	transition	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	TELLICO	transition	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	UPPER MS	transition	2. Piscivore species	combined	< 4	4 - 7	> 7
MAINSTREAM	LOWER MS	transition	3. Sunfish species	combined	< 2	2 - 3	> 3
MAINSTREAM	MELTON H	transition	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	TELLICO	transition	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	UPPER MS	transition	3. Sunfish species	combined	< 2	2 - 4	> 4
MAINSTREAM	LOWER MS	transition	4. Sucker species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	transition	4. Sucker species	combined	< 4	4 - 6	> 6
MAINSTREAM	TELLICO	transition	4. Sucker species	combined	< 4	4 - 6	> 6
MAINSTREAM	UPPER MS	transition	4. Sucker species	combined	< 4	4 - 7	> 7
MAINSTREAM	LOWER MS	transition	5. Intolerant species	combined	< 3	3 - 4	> 4
MAINSTREAM	MELTON H	transition	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	TELLICO	transition	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	UPPER MS	transition	5. Intolerant species	combined	< 2	2 - 4	> 4
MAINSTREAM	all	transition	6. Percent tolerant species	Electrofishing	> .50	.25 - .50	< .25
MAINSTREAM	all	transition	6. Percent tolerant species	Gill netting	> .40	.20 - .40	< .20
MAINSTREAM	all	transition	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
MAINSTREAM	all	transition	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
MAINSTREAM	all	transition	8. Percent omnivores	Electrofishing	> .50	.25 - .50	< .25
MAINSTREAM	all	transition	8. Percent omnivores	Gill netting	> .45	.30 - .45	< .30
MAINSTREAM	all	transition	9. Percent insectivores	Electrofishing	< .30	.30 - .60	> .60
MAINSTREAM	all	transition	9. Percent insectivores	Gill netting	< .07	.07 - .15	> .15
MAINSTREAM	LOWER MS	transition	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	MELTON H	transition	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	TELLICO	transition	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	UPPER MS	transition	10. Lithophilic spawning species	combined	< 4	4 - 7	> 7
MAINSTREAM	all	transition	11. Average number of individuals	Electrofishing	< 50	50 - 100	> 100
MAINSTREAM	all	transition	11. Average number of individuals	Gill netting	< 15	15 - 35	> 35
RID & VALL	all	forbay	1. Number of species	combined	< 10	10 - 19	> 19
RID & VALL	all	forbay	2. Piscivore species	combined	< 3	3 - 6	> 6
RID & VALL	all	forbay	3. Sunfish species	combined	< 2	2 - 3	> 3
RID & VALL	all	forbay	4. Sucker species	combined	< 3	3 - 5	> 5
RID & VALL	all	forbay	5. Intolerant species	combined	< 2	2 - 2	> 2
RID & VALL	all	forbay	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15

Table 2 (Cont'd)

Reservoir Group	Reservoir Subgroup	STATION	METRIC	GEAR	ONE	THREE	FIVE
RID & VALL	all	forbay	6. Percent tolerant species	Gill netting	> .50	.30 - .50	< .30
RID & VALL	all	forbay	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
RID & VALL	all	forbay	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
RID & VALL	all	forbay	8. Percent omnivores	Electrofishing	> .25	.10 - .25	< .10
RID & VALL	all	forbay	8. Percent omnivores	Gill netting	> .60	.40 - .60	< .40
RID & VALL	all	forbay	9. Percent insectivores	Electrofishing	< .60	.60 - .80	> .80
RID & VALL	all	forbay	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
RID & VALL	all	forbay	10. Lithophilic spawning species	combined	< 2	2 - 4	> 4
RID & VALL	all	forbay	11. Average number of individuals	Electrofishing	< 40	40 - 80	> 80
RID & VALL	all	forbay	11. Average number of individuals	Gill netting	< 15	15 - 30	> 30
RID & VALL	all	transition	1. Number of species	combined	< 11	11 - 20	> 20
RID & VALL	all	transition	2. Piscivore species	combined	< 4	4 - 6	> 6
RID & VALL	all	transition	3. Sunfish species	combined	< 2	2 - 3	> 3
RID & VALL	all	transition	4. Sucker species	combined	< 3	3 - 6	> 6
RID & VALL	all	transition	5. Intolerant species	combined	< 2	2 - 2	> 2
RID & VALL	all	transition	6. Percent tolerant species	Electrofishing	> .30	.15 - .30	< .15
RID & VALL	all	transition	6. Percent tolerant species	Gill netting	> .50	.30 - .50	< .30
RID & VALL	all	transition	7. Dominance(% composition of most abundant species)	Electrofishing	> 60	40 - 60	< 40
RID & VALL	all	transition	7. Dominance(% composition of most abundant species)	Gill netting	> 50	30 - 50	< 30
RID & VALL	all	transition	8. Percent omnivores	Electrofishing	> .25	.10 - .25	< .10
RID & VALL	all	transition	8. Percent omnivores	Gill netting	> .60	.40 - .60	< .40
RID & VALL	all	transition	9. Percent insectivores	Electrofishing	< .50	.50 - .70	> .70
RID & VALL	all	transition	9. Percent insectivores	Gill netting	< .03	.03 - .06	> .06
RID & VALL	all	transition	10. Lithophilic spawning species	combined	< 3	3 - 6	> 6
RID & VALL	all	transition	11. Average number of individuals	Electrofishing	< 40	40 - 80	> 80
RID & VALL	all	transition	11. Average number of individuals	Gill netting	< 15	15 - 30	> 30

Table 3. Summary of RFAI Scores for 1990-1994 Based on 1994 Scoring Methods

		1991	1992	1993	1994
Beach Lake	Forebay	.	.	.	29
Bear Creek	Forebay	.	47	45	44
Blue Ridge	Forebay	40	37	39	42
Boone	Transition South Fork of The Holston	41	30	36	36
	Transition Watauga	34	34	34	37
	Forebay	30	35	24	34
Cedar Creek	Forebay	.	42	41	50
Chatuge	Forebay	35	43	40	43
	Shooting Creek	.	.	40	39
Cherokee	Transition	36	34	38	38
	Forebay	42	35	42	38
Chickamauga	Inflow	48	42	56	52
	Transition	45	41	51	41
	Forebay	44	46	45	41
	Embayment	.	.	48	42
Douglas	Transition	42	38	43	44
	Forebay	33	39	40	42
Fontana	Transition Little Tennessee	.	.	44	42
	Transition Tuckasegee	.	.	40	40
	Forebay	.	.	42	43
Fort Loudoun	Inflow	32	24	34	36
	Transition	33	33	34	38
	Forebay	35	41	41	37
Fort Patrick Henry	Forebay	.	.	46	33
Guntersville	Inflow	46	40	38	42
	Transition	33	40	38	35
	Forebay	46	39	46	30
Hiwassee	Transition	49	40	47	43
	Forebay	42	39	48	52
Kentucky	Inflow	46	36	38	34
	Transition	44	49	44	43
	Forebay	44	38	42	38
	Embayment	.	.	31	31
Little Bear Creek	Forebay	.	42	45	46
Melton Hill	Inflow	20	18	22	28
	Transition	36	30	43	43
	Forebay	42	31	40	49
Nickajack	Inflow	48	48	58	50
	Transition	40	.	.	.
	Forebay	45	36	49	45
Normandy	Transition	.	51	.	.
	Forebay	.	41	53	48
Norris	Transition Clinch	40	43	47	51
	Transition Powell	48	44	48	52
	Forebay	34	34	34	43
Nottely	Transition	.	.	40	37
	Forebay	37	35	37	38
Parksville - ocoee no 1	Forebay	32	36	34	42
Pickwick	Inflow	44	42	50	46
	Transition	45	40	47	47
	Forebay	40	34	50	43
	Embayment	.	.	42	44
South Holston	Transition	41	40	44	44

Table 3 (Cont'd)

	Forebay	34	39	51	43
Tellico	Transition	31	31	41	44
	Forebay	38	36	36	47
Tims Ford	Transition	.	48	51	47
	Forebay	.	40	46	50
Upper Bear Creek	Forebay	.	31	34	.
Watauga	Transition	32	31	42	35
	Forebay	33	29	30	31
Watts Bar	Inflow Clinch	40	34	44	40
	Inflow Tennessee	40	42	38	46
	Transition	46	44	53	46
	Forebay	42	35	39	43
Wheeler	Inflow	44	40	44	48
	Transition	36	31	47	43
	Forebay	43	40	49	41
	Embayment	.	.	41	50
Wilson	Inflow	38	46	54	40
	Forebay	44	39	44	45

Section 1

Reservoir Monitoring -- Overview of Approach,

Methods, and 1994 Results

Appendix A.

Watershed and Reservoir Physical Description Including Summary of Ecological Health Results for Each Reservoir in 1994

Kentucky Reservoir Watershed

Duck River Watershed

Pickwick Reservoir - Wilson Reservoir Watershed

Wheeler Reservoir - Elk River Watershed

Guntersville Reservoir - Sequatchie River Watershed

Nickajack Reservoir - Chickamauga Reservoir Watershed

Hiwassee River Watershed

Watts Bar Reservoir, Fort Loudoun Reservoir, and Melton Hill Reservoir Watershed

Clinch River and Powell River Watershed

Little Tennessee River Watershed

French Broad River Watershed

Holston River Watershed

KENTUCKY RESERVOIR WATERSHED

The Kentucky Reservoir watershed area includes all streams flowing into the Tennessee River downstream of Pickwick Landing Dam at Tennessee River mile (TRM) 206.7 to the confluence of the Tennessee River with the Ohio River. The one exception is the Duck River which is considered a separate watershed. The Kentucky Reservoir watershed area is relatively large (4590 square miles) and has an average annual discharge of about 66,600 cfs. Of that, about 82 percent (54,000 cfs) comes into Kentucky Reservoir from Pickwick Landing Dam. The Duck River supplies about 6 percent (4075 cfs), with the remaining 11 percent coming from local inflows.

Kentucky Reservoir is the dominant feature of this watershed. There are four monitoring sites on Kentucky Reservoir--forebay, transition zone, inflow, and Big Sandy River embayment.

The watershed also includes the seven small reservoirs on the Beech River. The largest, Beech Reservoir, is the only one included in Vital Signs monitoring. Given its small size, the forebay is the only site monitored.

Kentucky Reservoir

Kentucky Reservoir is the largest reservoir on the Tennessee River. The dam is located at Tennessee River Mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2280 miles. Average annual discharge is about 66,600 cfs, which provides an average hydraulic retention time of about 22 days.

The Duck River, a major tributary to the Tennessee River (and Kentucky Reservoir), provides about 6 percent of the total flow through Kentucky Reservoir. The confluence of the Duck River with the Tennessee River is at TRM 110.7.

The transition zone sample location was moved prior to the 1992 sample season from TRM 112.0 to TRM 85.0. Results for 1990 and 1991 at TRM 112.0 indicated that location was more representative of a riverine environment than a transition environment. The 1992, 1993 and 1994 results indicate the new transition zone site is correctly located.

Vital Signs monitoring was expanded in 1993 to include a sample site in four of the largest embayments in the Tennessee Valley. One, the Big Sandy River embayment on Kentucky Reservoir, is the largest embayment in the Tennessee Valley. It covers 15,238 surface acres and has over 93 miles of shoreline. Because its watershed is only 629 square miles, there is very little water exchange.

Beech Reservoir

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir is only 5.3 miles long and averages only about 12 feet deep. It has no hydropower generating facilities, but is the primary source of water for the city of Lexington. The reservoir is an urban lake with considerable residential lakefront development. Consequently, it receives a large amount of recreational use relative to its small size (about 900 acres). Discharge from Beech Dam averages only about 14 cfs per day, resulting in a long hydraulic residence times of 300 to 400 days.

Reservoir: Kentucky 1994 Score: 71%

	Prevoius Scores		
	Reported	1994 Criteria	1994 Criteria w/o Big Sandy
1991	77	76	76 (FB and Inf only)
1992	88	88	76 (FB, TZ, and Inf)
1993	75	76	83 (FB, TZ, and Inf)
1994	71	71	81 (FB, TZ and Inf)

Effect of method change between 1993 and 1994: very little as reflected in 1993 scores; 1993 results on 1993 criteria = 75% and 1993 results on 1994 criteria = 76%

Impact of special case scores (i.e., ex/include embayments / TZ moved): Like 1993, inclusion of Big Sandy results had significant influence on overall score; reduction of 10% in 1994 and 8% in 1993 (see special case scores)

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3	5	1	na	9		0	0	0		0
DO	4.5	5	2	5	16.5		0.5	0	-2.5	1	-1
Sediment	4	5	3	na	12		-1	0	1		0
Benthos	3	4	3	4	14		-2	-1	-1	1	-3
Fish	3	4	2	3	12		-1	0	0	0	-1
Total	17.5	23	11	12	63.5	Net	-3.5	-1	-2.5	2	-5

Explanation/discussion of differences: Between 1993 and 1994 biggest single changes were: (1). **Benthos** in forebay (FB) decrease of -2 (5 of 8 metrics lower; general community decrease) -- possible cause was DO related. In 1992 all DO was good in FB, in 1993 FB had some anoxia (DO's = 0 ppm) and about six weeks of DO ≤ 2 ppm.; and (2). **DO** decrease of -2.5 in Big Sandy embayment (all DO measures were lower in 1994 than in 1993). Hypothesis -- 1993 was an irregular flow year and the pulsing and surcharging of Kentucky reservoir in 93 (to help control flooding on the Ohio-Mississippi rivers) may have caused an exchange of water between the embayment and the main reservoir, i.e. pulled out poor, low DO water from Big Sandy. This did not happen in 1994, resulting in lower DO's in Big Sandy in '94.

Overall story for 1994: Kentucky still basically a "good reservoir"; biggest single influence on overall reservoir score is the lower scores in Big Sandy embayment (all yellows or reds). Kentucky Reservoir overall score is in the 80's if Big Sandy is excluded. Other important issures were: (1) benthos worse in 1994 than 1993 at all locations but the inflow; probably due to poor DO in summer of 1993 (which would reflect on 1994 benthos -- good benthos in '93 likely a relection of good DO in 1992); (2) DO in Big Sandy was <2 ppm near bottom for about 4-5 months. DO was measured <0.2 ppm in June, July, & September of 1994 in Big Sandy. See hypothesis in (2) above for explanation. Low DO in 1994 may be more typical in Big Sandy than the unusual events (and higher DO) of 1993; (3) Overall DO's were better in 1994 at FB and transition zone (TZ) and inflow -- due to higher summertime flows in Tennessee River in 1994; and (4) very high summer chlorophylls caused "red" rating in Big Sandy embayment in 1994.

Macrophytes - Aquatic plants were estimated to covered only about 415 acres of Kentucky Reservoir in 1994, a significant decline from 1993 when plants covered about 3500 acres. Most of the aquatic plants were found downstream of the Duck River in shallow water areas around islands and in shallow embayments.

Reservoir: Beech **1994 Score: 56%**

	Previous Scores	
	Reported	1994 Criteria Special Case/1994 Criteria
1991	NA	27 (chloro, DO, fish)
1992	NA	40 (chloro, DO)
1993	65	70 (chloro, DO, sed, benthos)
1994	56	56 (chloro, DO sed,benthos, fish)

Effect of method change between 1993 and 1994: Overall score for '93 results on '93 criteria was 65%; '93 results on '94 criteria = 70. Change of 5% due to new methods for benthos, which increase the benthos contribution to total score 1 pt (1 pt change = 5% for Beech because only one sample location).

	1994 Results					Differences between 1993 and 1994			
	FB	TZ	Inf	Total		FB	TZ	Inf	Net
Chlorophyll	2			2		-3			-3
DO	1			1		0			0
Sediment	5			5		1			1
Benthos	4			4		0			0
Fish	2			2		NA (no fish in '93)			NA
Total	14			14	Net	-2			-2

Explanation/discussion of differences: between 1993 and 1994: Biggest change was for chlorophyll (-3 pts). In '93 mean chlorophyll was 9 and maximum was 14 (a mean below 10 is good, green, and above is fair, yellow). In '94 mean was 13 and maximum was 72 (mean above 10 would cause fair rating but very high maximum caused rating to be downgraded to poor, red). Sediment improved (+1) in '94 (no problems of any kind) compared to '93 (slight toxicity was found).

Overall story for 1994: Beech Reservir was relatively poor in '94. Biggest contributors to low overall rating were: (1). Chlorophyll--much higher in '94 (see above explanation) causing RP color change from green in '93 to red in '94. Higher flows in '94 probably boosted chlorophyll in Beech instead of lowering it like in the mainstream reservoirs. Beech has a long retention time in both wet and dry years. Wet years actually increase chlorophyll production because more nutrients are washed into the lake by the higher runoff. In dry years little new nutrients are washed in and nutrients present are depleted resulting in less chlorophyll. (2). DO was very poor in Beech again in '94 (RP red in both '93 and '94). Much of the water column had DO < 2 ppm and much of that water had no DO at all. (3). Fish will appear as yellow in RP in '94 but it is important to note that the actual fish score was only one point from being red. Poor characteristics were too many tolerant species, many omnivores, few insectivores--bascially poor community balance).

Note (Other color changes in RP for '94 compared to '93 RP): Sediment change color from yellow to green (see above explanation). Benthos change color from yellow to green, but this is totally due to a change in methods ('93 would have been green if '94 methods used). A good benthos in a reservoir with such poor DO would not be expected. One important consideration is that the new methods compare Beech only to similar reservoirs in the same geographical area (Bear, Little Bear, Cedar, and Normandy). A green rating means Beach has a good benthos community compared to this group of rerservoirs. Basically, you don't expect a lot so it doesn't take a lot to be good.

(beeres94)

DUCK RIVER WATERSHED

The Duck River Watershed includes all streams flowing into the Duck River. It has an area of 3500 square miles and an average annual discharge of 4075 cfs to Kentucky Reservoir on the Tennessee River. The Duck River basin is underlain almost entirely by limestone, or phosphatic limestone; consequently, waters in the streams draining this basin are fairly hard and contain large concentrations of minerals. Large deposits of phosphate ores permit phosphate mining and refining operations in the basin. Phosphate concentrations in surface and groundwater are significantly higher than in most of the Tennessee Valley. The soils are thin with limestone outcrops at the surface in many places, and sinkholes are common throughout the watershed.

Normandy Reservoir is the only reservoir in this watershed. This is a relatively small reservoir and only the forebay is included in the Vital Signs monitoring program. There is one stream monitoring site on the Duck River at mile 26..

Normandy Reservoir

Normandy Reservoir is formed by Normandy Dam at Duck River mile (DRM) 248.6. Normandy Reservoir, constructed primarily for flood control and water supply, has a drainage area of 195 square miles and no electric power generation capacity. One of TVA's smaller reservoirs, Normandy at full pool elevation has about 3200 surface acres, 73 miles of shoreline, and about 17 miles of impounded backwater. The reservoir has an average depth of about 35 feet and an average annual drawdown of about 11 feet. The average annual discharge from Normandy Dam is about 320 cfs, providing an average annual retention time of about 175 days.

Reservoir: Normandy 1994 Score: 68%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	NR	NR	NA
1992	NR	NR	NA
1993	56	56	NA
1994	68	68	NA

Effect of method change between 1993 and 1994: None

Impact of special case scores (i.e., ex/include embayments / TZ moved): NA

	1994 Results					Diff. between '93/'94			
	FB	TZ	Inf	Total		FB	TZ	Inf	Net
Chloro	5					0			0
DO	1					0			0
Sediment	5					3			3
Benthos	2					1			1
Fish	4					-1			-1
Total	17					3			3

Explanation/discussion of differences: between 1993 and 1994: Big improvement in **sediment quaity**. No problems in '94 so sediment rated good (green); in '93 had toxicity and ammonia so rated poor (red). **Benthos** had slightly higher score in '94 than '93 but not enough to move another color range (red both years). The same was true for **fish**, just in the opposite direction--slight decrease in score but not enough to move to a lower color range (green both years). Note: **D0** was very poor both years--anoxic and much of water column had low (<2) DO. Normandy had the poorest DO conditions in 1994 of all 30 reservoirs mointored.

Overall story for 1994: Ecological health in Normandy improved over that in 1993. This was primarily due to improvements in sediment quality--no problems found in 1994. Sediment quality added 3 points to overall rating creating an increase of 12 % to overall reservoir score. RP color for sediments changed red in '93 to green in '94. Normandy continued to have very poor DO conditions. Also benthos poor again, although slight improvements were seen.

nomres94

PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir and Wilson Reservoir on the Tennessee River are the most notable features of this drainage area. Only a small part of the flow leaving this watershed actually originates within the watershed itself. The average annual discharge from Pickwick Dam is 54,900 cfs. Of that, 49,500 cfs (90 percent) is the discharge from Wheeler Dam into Wilson Reservoir. About 2100 cfs enters Wilson Reservoir through local tributaries and about 3400 cfs originates in tributaries to Pickwick Reservoir. The streams within this watershed drain an area of about 3230 square miles. The largest tributaries are Bear Creek, a tributary to Pickwick Reservoir with a drainage area of about 945 square miles, and Shoal Creek, a tributary to Wilson Reservoir, with a drainage area of about 445 square miles.

Four small reservoirs were built on Bear Creek in the late 1970s and early 1980s for flood control and recreation. These are Bear Creek, Little Bear Creek, Cedar Creek, and Upper Bear Creek Reservoirs.

Reservoir monitoring activities occur at the forebay, transition zone, and inflow on Pickwick Reservoir and at the forebay and inflow on Wilson Reservoir. Wilson is relatively short and has no definable transition zone. Because of their smaller size, only the forebays of Bear Creek, Little Bear Creek, and Cedar Creek Reservoirs are monitored. No monitoring activities are conducted on Upper Bear Creek because of TVA's program to destratify and oxygenate water in the forebay. The only stream monitoring site is on Bear Creek at Bear Creek mile 27.3.

Pickwick Reservoir

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream, run-of-the-river reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is about 55,000 cfs, which provides an average hydraulic retention time of about eight days.

A major tributary, Bear Creek, joins the Tennessee River in Pickwick Reservoir at about mile 225. Bear Creek provides, on the average, about 2.5 percent of the flow through Pickwick Reservoir.

Reservoir Monitoring activities were expanded on Pickwick Reservoir in 1993 to include a Vital Signs monitoring site in Bear Creek embayment. This rather large embayment (7200 acres) extends from the mouth of Bear Creek upstream about 17 miles to the point where flow is not affected by backwater from Pickwick Dam.

Wilson Reservoir

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short, deep pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 51,500 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

Bear Creek Reservoir

With a surface of only 700 acres, Bear Creek is one of the smallest reservoirs in the TVA system. It is relatively long (16 miles), narrow, and deep (74 feet at the dam). The average annual discharge is 380 cfs providing an average hydraulic retention time of about 13 days. Average annual drawdown is about 11 feet. Bear Creek Reservoir stratifies in the summer and develops hypolimnetic anoxia. Another water quality concern is abandoned strip mines in the watershed.

Little Bear Creek Reservoir

Little Bear Creek Reservoir is relatively short (7.1 miles long) and deep (84 feet at the dam). It has a surface area of 1600 acres. With an average annual discharge of 101 cfs, the hydraulic retention time is 225 days. Compared to Bear Creek Reservoir, the lower flow into the reservoir and larger reservoir volume make the retention time much longer in Little Bear Creek Reservoir. Average annual drawdown is about 12 feet.

Cedar Creek Reservoir

Like the other reservoirs in the Bear Creek watershed, Cedar Creek Reservoir is small (only nine miles long and 4200 acres surface area) and deep (79 feet at the dam). The low average annual discharge from the dam (282 cfs) creates a relatively long average retention time (168 days). This combination of physical features lead to thermal stratification and hypolimnetic anoxia in the summer. Average annual drawdown is about 14 feet.

Reservoir:Pickwick **1994 Score: 84%**

	Prevoius Scores		
	Reported	1994 Criteria	1994 Criteria w/o Bear Cr
1991	77	74	74
1992	75	78	78
1993	73	71	77
1994	84	84	88

Effect of method change between 1993 and 1994: Virtually no effect as reflected in total scores for 93 (71 vs 73)

Impact of special case scores (i.e., ex/include embayments / TZ moved): Like 1993, inclusion of Bear Creek embayment lowered overall reservoir rating about 4 % points.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	2	5	3	na	10		-1	2	2		3
DO	5	5	4.5	4	18.5		1	1	1	1	4
Sediment	5	5	5	na	15		1	1	2		4
Benthos	5	5	2	4	16		1	1	0	-1	1
Fish	4	4	4	4	16		0	0	0	0	0
Total	21	24	18.5	12	75.5	Net	2	5	5	0	12

Explanation/discussion of differences: between 1993 and 1994: Biggest changes compared to 1993 were DO and sediment ratings (both +4). Embayment and TZ locations showed most improvement, both with lower chlorophyll concentrations in 1994 than in 1993. DO was better in 1994 at all four locations. At the FB a single high chlorophyll sample (algal bloom) lowered the score. Sediment was better at all three locations in 1994. No toxicity nor high concentrations of metals found in 1994. (In 1993 had some ammonia and slight toxicity at FB and Bear Creek embayment sediments)

Overall story for 1994: Big improvement in 1994 over 1993 (from 73% to 84%). DO improved at all four locations (with three of four yellows changing to green). Average chlorophyll concentrations were improved (i.e. lower) at all three locations (FB, TZ, and Embay) in 1994 compared with 1993. Note-The "red" color rating for chlorophyll at the FB was due to a lowering of the rating from "yellow" because of a single high sample indicating a large (undesirable) algal bloom. These improvements could all be attributed to increased flows in 1994 compared with 1993, especially during the critical summer months. At TZ all five indicators (DO, chlorophyll, sediment, benthos, and fish) change from yellow in 1993 to green in 1994. Sediment improved from yellow in 1993 to green in 1994 at all three locations. No toxicity no high metal concentrations were found (found some ammonia and toxicity in sediment in FB and Bear Creek in 1993).

Note on Benthos-Trend of poorer benthos in 1994 due to low DO's in 1993 not as evident in Pickwick as in Kentucky. Did see lowered score at inflow in 1994 where worse DO conditions were found in 1993. Bear Cr benthos were poor in 1994; they were reported as fair in 1993 but based on new criteria for 1994, the 1993 would rate poor - no change in community characteristics.

picres94

Reservoir: Wilson **1994 Score: 71%.**

	Previous Scores	
	Reported	1994 Criteria
1991	60	60
1992	68	68
1993	71	74
1994	71	71

Effect of method change between 1993 and 1994: Virtually no effect as reflected in total scores for 1993 (71% vs 74%).

Impact of special case scores (i.e., ex/include embayments / TZ moved): N/A

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3			na	3		0				0
DO	3.5			5	8.5		2.5			1	3.5
Sediment	3			na	3		-1.5				-1.5
Benthos	2			5	7		-1			0	-1
Fish	4			3	7		0			-2	-2
Total	15.5			13	28.5	Net	0.0			-1	-1

Explanation/discussion of differences: between 1993 and 1994: (1) **Sediments** -- substantial improvements in DO at both FB (+2.5) and inflow (+1); (2) substantially worsened sediments -- toxicity to both test organisms in 1994 compared to no toxicity in 1993; (3) **Benthos** in FB scored lower in 94 compared to 93 -- probably due to lower DO's in 1993 impacting benthos in 94; (4) **Fish** assemblage was "fair" in 1993 at inflow -- but when rated using 1994 criteria, 1993 rated good (great) and 1994 fish assemblage rated fair at the inflow (a lower rating than 1993 using an apples-to-apples comparison). RiverPulse (RP) showed a yellow for fish in 1993 at the inflow and will show a yellow for 1994.

Overall story for 1994: Overall score about the same as 1993, improvements in DO offset by declines in sediment and fish DO's much better at FB in 1994 ("red" in 1993 -- almost "green" in 1994), with much less volume of low DO water in Wilson in 1994 than in 1993. Also DO's better in the inflow (discharge from Wheeler dam), change from yellow in 93 to green in 94. All likely due to the higher summertime flows (during the critical time of the year -- less time for stagnation). At the FB, significant sediment toxicity in 1994, little toxicity in 1993. Sediment sampling is difficult because there is a lot of bottom area and we sample only a very small part of the bottom. Given that the bottom is not uniform, substantial differences cam be found between samples (and between years). This is further complicated when floods like the spring of 1994 potentially bring in new sediments which may contain materials harmful to test organisms. Benthos at FB scored lower in 1994 than 1993, probably due to poor DO conditions in summer of 1993.

wilres94

Reservoir: Bear Creek 1994 Score: 56%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	NS	NS	
1992	NS	NS	
1993	60	56	
1994	56	56	

Effect of method change between 1993 and 1994: Decrease of 4 % in total score for '93 (on '94 methods) due to a 1 point difference in benthos.

Impact of special case scores (i.e., ex/include embayments / TZ moved): NA

	1994 Results					Diff. Bet '93 and '94 ('94 Methods)				
	FB	MR-	MR-	Total		FB	MR-	Mr-	Net	
Chloro	3			3		0			0	
DO	1			1		0			0	
Sediment	3			3		1			1	
Benthos	3			3		-1			-1	
Fish	4			4		0			0	
Total	14	0	0	14		0			0	

Explanation/discussion of differences: between 1993 and 1994 (both years on '94 methods): Sediment improved 1 point compared to '93. In '93 found toxicity and ammonia so rated poor (red); in '94 found toxicty again but no ammonia so rated fair (yellow). **Benthos** decreased by 1 point due to decreases in long-lived animals and taxa richness, also less community balance. RP color for benthos change green in '93 to yellow in '94. DO very poor again in '94--5 months anoxic and much of water column with DO <2 during most of summer. Bascially similar to other reservoirs in this class.

Overall story for 1994: Bear Creek similar to '93; although slight change in overall score moved it from the low end of the fair range in '93 to the high end of the poor range in '94. This change was due to benthos--two contributing factors: the community was not as good in '94 as it was in '93 and a change in methods (RP color change from green in '93 to yellow in '94). Sediment Quality improved some --had toxicity in '94, same as in '93, but ammonia found in '93 was not found in '94. This was an improvement from poor (red in '93 RP) to fair (yellow in '94 RP). Fish change green in '93 to yellow in '94 due to a very small change in score ('93 just over the cut-off point to be considered good, and in '94 just under the cut-off). The fish community in '94 had more tolerant species and more omnivores than in '93. DO very poor; represents the most obvious problem in Bear Creek Reservoir.

beasum94

Reservoir: Little Bear Creek 1994 Score: 64%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	NS	NS	
1992	NS	NS	
1993	64	64	
1994	64	64	

Effect of method change between 1993 and 1994: None

Impact of special case scores (i.e., ex/include embayments / TZ moved): NA

	1994 Results					Diff. Bet '93 and '94 ('94 Methods)				
	FB	MR-	MR-	Total		FB	MR-	Mr-	Net	
Chloro	5			5		0			0	
DO	1			1		0			0	
Sediment	3			3		0			0	
Benthos	3			3		0			0	
Fish	4			4		0			0	
Total	16	0	0	16		0			0	

Explanation/discussion of differences: between 1993 and 1994: No change in any indicators between '94 and '93.

Overall story for 1994: Little Bear Creek Reservoir same an in '93--fair. Biggest observation is the very poor DOs--anoxic on bottom and much of water column with low DO (<2.0). Sediments were toxic to one type of test animal causing fair (yellow) rating. Benthos only fair because community made up of mostly tolerant animals. (See last years writeup if more discussion wanted).

lbrsum94

Reservoir: Cedar Creek 1994 Score: 80%

	Reported	Previous Scores 1994 Criteria	Special Case/1994 Criteria
1991	NS	NS	
1992	NS	NS	
1993	56	60	
1994	80	80	

Effect of method change between 1993 and 1994: Change in '93 score on '94 criteria of 4% due to one point change in fish.

Impact of special case scores (i.e., ex/include embayments / TZ moved): N/A

	1994 Results					Diff. Bet '93 and '94 ('94 Methods)				
	FB	MR-	MR-	Total		FB	MR-	Mr-	Net	
Chloro	5			5		2			2	
DO	1			1		0			0	
Sediment	5			5		1			1	
Benthos	5			5		2			2	
Fish	4			4		0			0	
Total	20	0	0	20		5			5	

Explanation/discussion of differences: between 1993 and 1994 (all '94 criteria): Biggest improvements between years was in chlorophyll and benthos (2 points each). **Chlorophyll** improvement was actually a borderline change--mean concentration in '93 (2.8) was just below the level considered good (3.0) so rated fair (yellow in RP in '93); in'94 the mean concentration was slightly higher (3.7) but was within the good range so rated good (green for RP). **Benthos** improved substantially in '94 compared to '93. This was a true community improvement--in '94 with 7 of the 8 metrics improved compared to '93 (remember this is an apples to apples comparision because both years were scored on '94 methods). This was the highest benthos score of all Interior Plateau tributary reservoirs. **Sediment Quality** improved in '94 (no problems found, so green in RP) compared to '93 (ammonia found so yellow in RP). **DO** very poor again in '94. No DO near bottom most of summer and low DO in much of water column most of summer.

Overall story for 1994: Cedar Creek significantly improved in '94 compared to '93. Cedar Creek was a red reservoir in 1993 RP and will be a green in '94 RP. There was a 24% increase in score. A small part of this increase (4%) was due to methods change between years. The rest was due to actual improvements in indicators. Chlorophyll made a borderline change from yellow (3 pts) in '93 to green (5 pts) in '94, which contributed 8 % to the total score. Sediment quality was good in '94 because no problems were found, whereas, in '93 ammonia was found; this added 4% to the total score (RP color change yellow in '93 to green in '94). Benthos showwed significant improvement in essentially all community attributes and added 8 % to the total score (RP color change yellow in '93 to green in '94). Fish score did not change but color changed yellow to green due to methods change('93 fish would have been green if '94 methods were used).

Note: In reservoirs with only one sample site, small changes in metrics cause substantial change in total score (e.g., chlorophyll).

Note: Caution must be excerised in evaluating these results. There are only two years of data for Cedar Creek Reservoir. Each shows vastly different scores. There is no way of knowing which most accurately reflects true environmental conditions.

(cedsum94)

WHEELER RESERVOIR - ELK RIVER WATERSHED

The Wheeler Reservoir - Elk River watershed drains about 5140 square miles in north central Alabama and south central Tennessee. Wheeler Reservoir is the fourth of nine reservoirs on the Tennessee River. About 24,500 square miles of the Tennessee Valley are upstream of this watershed. Wheeler Reservoir receives an average annual inflow of 40,700 cfs from Guntersville Dam. Discharges from Wheeler Dam average 49,400 cfs on an annual basis leaving 8700 cfs which originate within the watershed.

The largest tributary to Wheeler Reservoir is the Elk River, which has a drainage area of about 2250 square miles and contributes about 3000 cfs. The remaining flow enters from tributaries directly to Wheeler Reservoir.

Wheeler Reservoir is the largest reservoir within this watershed followed by Tims Ford Reservoir on the Elk River. There are four Vital Signs monitoring sites on Wheeler Reservoir--forebay, transition zone, inflow, and the Elk River embayment. Two sites are monitored for Vital Signs on Tims Ford Reservoir--forebay and mid-reservoir. Woods Reservoir on the Elk River is not included in this monitoring program because it is property of the Arnold Engineering Development Center, Arnold Air Force Base. The only stream monitoring site within this watershed is on the Elk River at mile 36.5.

Wheeler Reservoir

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is about 49,400 cfs which provides an average hydraulic retention time of about 11 days. Information collected in 1990 and 1991 indicated a more riverine than transition environment at TRM 307.5; consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 295.9. Results for 1992 and 1993 are being evaluated to determine if this new site is suitably located or if it needs to be moved further downstream.

The Elk River joins the Tennessee River in the downstream portion of Wheeler Reservoir at about mile 284 and provides, on the average, about 6 percent of the flow through Wheeler Reservoir.

Vital Signs monitoring activities were expanded in 1993 to include a site in the Elk River embayment. This was one of four embayments added to the Vital Signs program in 1993. The Elk River embayment covers about 4900 acres. Given the relatively high flows in the Elk River (about 3000 cfs annual average), there is substantial water exchange in this embayment.

Tims Ford Reservoir

Tims Ford Reservoir in middle Tennessee is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir is 34 miles long at full pool and has a surface area of 10,600 acres. The depth at the dam is 143 feet and the average depth is about 50 feet. Average annual discharges from Tims Ford Dam are about 940 cfs, resulting in a hydraulic residence time of about 280 days. Tims Ford Reservoir is designed for a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection; however, annual drawdowns average about 18 feet.

Reservoir: Wheeler 1994 Score: 75%

	Reported	Previous Scores 1994 Criteria	1994 Criteria w/o Elk R
1991	89	70	70 (inflow & FB only)
1992	80	78	78 (inflow, TZ & FB)
1993	72	74	83 (inflow, TZ & FB)
1994	75	75	81 (inflow, TZ & FB)

Effect of method change between 1993 and 1994: Very little effect as reflected in total scores for 1993 (72% vs 74%).

Impact of special case scores (i.e., ex/include embayments / TZ moved): Inclusion of Elk River embayment lowered scores (9% points in 1993 and 6% points in 1994) -- considerably poorer quality in Elk River embayment than reservoir as a whole.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3	3	1	na	7		0	-2	0		-2
DO	5	5	3	5	18		3	0	1	0	4
Sediment	3.5	4	5	na	12.5		-1.5	-1	1		-1.5
Benthos	2	5	2	5	14		-1	1	0	0	0
Fish	4	4	4	4	16		0	0	0	0	0
Total	17.5	21	15	14	67.5	Net	0.5	-2	2	0	0.5

Explanation/discussion of differences: between 1993 and 1994: Biggest changes compared to 1993 were: (1) a large improvement in **DO** at FB, +3, (no anoxia and all DO's > 2 ppm in 1994) resulting in change from "red" in 1993 to "green" in 1994 -- and at Elk River, +1, change from "red" in 1993 to "yellow" in 1994; (2) **Chlorophyll** at TZ changed from just "5", green, (x=4.0) in 1993 to "3", yellow, (x=2.2) in 1994 -- probably flow related (TZ pushed further downstream); (3) **Sediments** -- toxicity to test organisms at FB in 1994, no toxicity in 1993 -- and DDT detected in 1994 at TZ, none found in 1993 (sediments at both FB and TZ change from green in 1993 to yellow in 1994); (4) sediments in Elk R. improved from 4 in 1993 to 5 (yellow to green) in 1994, no ammonia found in 1994 as was found in 1993.

Note -- very high chlorophyll concentrations found in Elk R., highest of Vital Signs monitoring stations. Related to naturally high conc of nutrients in Elk River watershed.

Overall story for 1994: Good, with slight improvement over 1993; inclusion of Elk R. pulls reservoir score down (75% w/ compared to a 81% w/o). Important to note Elk R. improved over 1993 with better DO (red in 93 to yellow in 94), fish (yellow in 93 to green in 94), and sediment (yellow in 93 to green in 94). DO and sediment (no ammonia) improvements due to higher flows in 1994; fish may be higher due to better living conditions?? Chlorophyll in Elk R. still quite high and benthos poor. Biggest observation for reservoir in 1994 was significant improvement of DO at the FB -- changed from red in 1993 to green in 1994 -- again due to increased flows through the river system. Several changes in sediment quality: DDT found at TZ in 1994, not found previously (green in 93 to yellow in 94); toxicity at FB in 1994 not found in 1993 (green in 93 to yellow in 94); and an improvement at Elk R (no ammonia) in 1994 (yellow in 93 to green in 94).

Macrophytes - No estimates of aquatic plants were made for Wheeler Lake in 1994. Aquatic plants covered about 6600 acres on Wheeler Lake in 1993.

Reservoir: Tims Ford 1994 Score: 58%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	NR	60 (DO and Chlorophyll only)	
1992	60	63 (DO, Chlorophyll, and Fish)	
1993	58	58 (all 5 indicators)	
1994	58	58 (all 5 indicators)	

Effect of method change between 1993 and 1994: No net change.

Impact of special case scores (i.e., ex/include embayments / TZ moved): Data for all 5 indicators for 1993 and 1994 only.

	1994 Results					Diff. Bet '93 and '94 ('94 Methods)				
	FB	MR-	MR-	Total		FB	MR-	Mr-	Net	
Chloro	5	5		10		0	0		0	
DO	1	1		2		0	0		0	
Sediment	2	5		7		-2	3		1	
Benthos	1	1		2		0	0		0	
Fish	4	4		8		0	-1		-1	
Total	13	16	0	29		-2	2		0	

<u>Explanation/discussion of differences: between 1993 and 1994</u> (both years on '94 methods): No net change; Sediment Quality changed substantially by station and fish made a border-line change. **Sediment Quality** at FB in '94 had significant toxicity to both species and had elevated Ni so rated poor (red in RP). In '93 had Ni and ammonia but no toxicity so rated fair (yellow in '93 RP). At Mid-Res in '94 did not find any problems (no toxicity or elevated chemicals) so rated good (green). In '93 found toxicity and ammonia so rated poor (red in '93 RP). We do not have a good explanation for this shift. **Fish** community scores at FB slightly higher in '94 than in '93 but not enough to move to another category. However, RP color will change from yellow in '93 to green in '94 due to a methods change ('93 would have been green if '94 methods had been used).

<u>Overall story for 1994</u>: Tims Ford Reservoir changed little in overall health from '93 to '94--low end of fair range both years. Biggest contributors to relatively low score were poor DO and benthos. DO problems were anoxia in summer and much of water column with low DO (<2) during summer; typical of this type of reservoir. Benthos rated very poor both years, comprised of only chironomids and tubificids--only scored 8 in '94, the lowest possibe score. Sediment Quality rated good (green) at Mid-Res in '94. This was an improvement over '93 when sediments rated poor (red) due to toxicity and high ammonia. Sediment Quality at FB rated poor (red) in '94 due to significant toxicity and high nickel. This was lower than in '93 when sediments rated fair (yellow) due to high ammonia and nickel (no toxicity found in '93). Fish community color change at FB from yellow in '93 to green in '94 was mainly due to a change in methods. Fish score at Mid-Res in '94 was a little lower than in '93 but not enough to cause a color change (green both years).

timsum94

GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

This watershed includes Guntersville Reservoir and all tributaries draining directly to Guntersville Reservoir. As with the other watershed areas on the mainstem of the Tennessee River, most of the water leaving the watershed through Guntersville Dam enters the watershed area through discharges from the upstream dam (Nickajack). About 35,900 cfs enter from Nickajack Dam and about 40,700 cfs is discharged from Guntersville Dam on an annual average basis. The remaining 4800 cfs originates with the Guntersville Reservoir-Sequatchie River watershed area. The largest contributor of this flow is the Sequatchie River (about 800 cfs). The total watershed area is 2669 square miles. The area drained by the Sequatchie River is about 600 square miles.

Guntersville Reservoir is the dominant characteristic of this watershed. There are three Vital Signs monitoring site on Guntersville Reservoir: forebay, transition zone, and inflow. There is a stream monitoring site on the Sequatchie River at mile 6.3.

Guntersville Reservoir

Guntersville Dam, located at TRM 349.0, creates a 76 mile long reservoir with a surface area of 67,900 acres and a shoreline of 949 miles at full pool. Average annual discharge is about 40,700 cfs, corresponding to an average hydraulic retention time of about 13 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics, but it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. This is due to the shallow nature of Guntersville Reservoir at the inflow area and extensive shallow overbank areas. As a result, winter drawdown on Guntersville Reservoir is nominal to maintain navigation. The shallow drawdown allows the large overbank areas to be permanently wetted creating good habitat for aquatic macrophytes. Guntersville has the greatest area coverage of aquatic plants of any TVA reservoir.

The Sequatchie River joins the Tennessee River at about TRM 423, in the upstream portion of Guntersville Reservoir, just downstream from Nickajack Dam. On the average the Sequatchie River contributes less than 2 percent to the total flow of the Tennessee River through Guntersville Reservoir.

Data collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 396.8. Consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 375.2. Results from the new site are being reviewed to determine if it is suitably located.

Reservoir: Guntersville 1994 Score: 83%

	Reported	Previous Scores 1994 Criteria	1994 Criteria
1991	66	81	81 (no TZ)
1992	83	85	85 (FB, TZ, Inf)
1993	78	81	81 (" " ")
1994	83	83	83 (" " ")

Effect of method change between 1993 and 1994: very little, '93 = 78% on '93 criteria and 81 % on '94 criteria

Impact of special case scores (i.e., ex/include embayments / TZ moved): All years are apples to apples except '91 - no TZ data because TZ moved in '92.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	5	3	NA	NA	8		0	-2	NA	NA	-2
DO	5	5	NA	5	15		0.5	0	NA	4	4.5
Sediment	4	5	NA	NA	9		0	0	NA	NA	0
Benthos	4	5	NA	4	13		0	0	NA	0	0
Fish	2	3	NA	4	9		-2	0	NA	1	-1
Total	20	21		13	54	Net	-1.5	-2		5	1.5

Explanation/discussion of differences: between 1993 and 1994: (1) **DO** biggest change, primarily at inflow, concentrations very low in 1993 (1.8 ppm) but much higher in 1994 (all >5.0). Improvement was due to higher flows in 1994. (2) **Chlorophyll** at TZ changed from just "5" (x = 4.0) in 1993 to just "3" (x = 2.7) in 1994. Higher flows in '94 pushed the actual TZ downstream from our collection site. (3) No reduction seen in **benthos** in 1994; this differed from other reservoirs which were poorer in '94 due to poor DO's in '93. This was because G'ville DO's in '93 were good except at inflow (which were poor); should have seen reduction there in '94 but didn't?? (4) FB **fish** dropped 2 points (high yellow to low yellow for RP)--'94 assemblage had low abundance, no suckers, and high anomalies. (5) **Sediment** - no change in score--in 1993 chlordane at FB and '94 found PCBs.

Overall story for 1994: Still good! Biggest change was improved DO ('93 red and '94 green for RP) at inflow (see #1 above); this was off-set somewhat by lower chlorophylls at TZ, which was also a flow effect -- we sample at fixed sites but the actual TZ is not fixed, under higher flows it will be pushed downstream, sometimes below where we sample - such was probably the case in 1994. Increased turbidity which limits light penetration and hinders algal growth is also related to high flows. Benthos at forebay changed color for RP from green in '93 to yellow in '94--this was a "borderline" change; '93 was "just" over the scoring line and '94 was "just" under it.

Macrophytes - Almost 9600 acres of aquatic plants ocurred on Guntersville Reservoir in 1994, reflecting the steady increase over the last few years. Aquatic plants covered about 7600 acres in 1993, 6000 acres in 1992, and 5200 acres in 1991. Guntersville has more aquatic plants than any other lake in the Tennessee Valley, almost half of the combined plant acreages in all the Tennessee Valley lakes.

gunres94

NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack and Chickamauga Reservoirs are primary features of this watershed. The Hiwassee River is the only sizeable tributary which merges with the Tennessee River within the watershed area. The drainage basin of the Hiwassee River is large enough to be designated a separate watershed. The remaining area drained by tributaries to these two reservoirs is 1780 square miles. On an annual average basis, about 3200 cfs is contributed to the Tennessee River from streams within this watershed. This compares to 27,100 cfs entering the upper end of Chickamauga Reservoir from Watts Bar Dam and 5600 cfs from the Hiwassee River, for a total average annual discharge from Nickajack Dam of 35,900 cfs.

There are two Vital Signs monitoring sites on Nickajack Reservoir, one at the forebay and one at the inflow. There is no transition zone site on Nickajack because the reservoir is short and water exchange is quite rapid. This causes conditions at the location that might be considered the transition zone to be similar to those at the forebay. Chickamauga Reservoir has four Vital Signs monitoring sites--the forebay, the transition zone, the inflow, and a new site established in 1993 in the Hiwassee River embayment.

Nickajack Reservoir

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is approximately 35,900 cfs which provides an average hydraulic retention time of only about three or four days, the shortest retention time among the reservoirs monitored in this program.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sampling sites had quite similar water quality. This was expected since the two sites are relatively close together (separated by only 7.5 river miles), and Nickajack is a well-mixed, run-of-the-river reservoir. Therefore, sampling at the transition zone in Nickajack Reservoir was discontinued in 1992.

Chickamauga Reservoir

Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is approximately 34,200 cfs which provides an average hydraulic retention of nine to ten days.

The Hiwassee River, a major tributary to the Tennessee River, flows into the middle portion of Chickamauga Reservoir at about TRM 499. The flow from the entire Hiwassee River watershed contributes approximately 16.5 percent of the flow through Chickamauga Reservoir. About 10 percent of the 16.5 percent is from the Ocoee River and tributaries in the lower end of the Hiwassee watershed (i.e., downstream of Apalachia Dam).

Vital Signs monitoring activities were expanded in 1993 to include a site in the Hiwassee River embayment, which covers about 6500 acres. Given the relatively high flows in the Hiwassee River (about 5600 cfs annual average), there is substantial water exchange in this embayment, much greater than in any of the other three embayments monitored.

Reservoir: Nickajack   1994 Score: 90%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	89	85	NA
1992	83	83	NA
1993	88	88	NA
1994	90	90	NA

Effect of method change between 1993 and 1994: no change in total score for '93; 88 using '93 criteria or '94 criteria

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3			NA	3		-2			NA	-2
DO	5			5	10		0			3	3
Sediment	5			NA	5		1			NA	1
Benthos	5			5	10		0			0	0
Fish	4			4	8		0			-1	-1
Total	22			14	36	Net	-1			2	1

Explanation/discussion of differences: between 1993 and 1994: Biggest difference was in **DO** scores at inflow (+3 points). All inflow DO measurements good (>5ppm) in 1994 compared to low (2.2 ppm) DO concentrations in 1993. Improved DO result of increased flows in 1994. Another large change was for **chlorophyll** (-2 pts). Mean concentration at FB changed from 6 (good, score = 5) in '93 to 2.7 (fair, score = 3) in '94 (mean of 3.0 is cut-off). This was most likely due to higher flows in '94 reducing retention time in Nickajack to point it was essentially a flow-through reservoir, not allowing time even in FB for algae to "set-up house keeping". **Sediment** improved slightly in 1994; found chlordane in 1993, found nothing in 1994. Fish score decreased at inflow by 1 pt due to change/improvement in scoring criteria - no color change in RP; at forebay score changed very little but RP color changed yellow to green due to method change.

Overall story for 1994: Very good again, still one of best in system (highest score observed in 1994 = 90% as it was in 1993 = 88%). Biggest story to note was improved DO at inflow--changed from red in '93 to green in '94 (see above for detail). As with other mainstream reservoirs, this resulted from increased flows in '94. These high flows negatively impacted chlorophyll levels at FB causing levels to be just below that needed to maintain good fish populations. Sediments at FB rated better in 1994 (chlordane found in '93 but not '94) color change yellow to green. No true change in fish at FB, color change due to a change in the wasy data were evaluated.

Macrophytes - No estimates of aquatic plants were made Nickajack Lake in 1994. Aquatic plants covered about 1000 acres on Nickajack Lake in 1993.

nicres94

Reservoir: Chickamauga **1994 Score: 87%**

	Previous Scores		
	Reported	1994 Criteria	1994 Criteria w/o Hiwassee Embay
1991	90	88	88 (inflow, TZ, FB)
1992	73	81	81 (inflow, TZ, FB)
1993	83	86	85 (inflow, TZ, FB)
1994	87	87	87 (inflow, TZ, FB)

Effect of method change between 1993 and 1994: Had small effect as reflected in total scores for 1993 (83% vs 86%)

Impact of special case scores (i.e., ex/include embayments / TZ moved): Inclusion/exclusion of Hiwassee embayment had almost no effect on overall reservoir scores (see above).

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	5	5	5	na	15		0	0	0		0
DO	5	5	5	3	18		1	0.5	0	0	1.5
Sediment	3.5	5	5	na	13.5		0.5	2	1		3.5
Benthos	4	5	3	3	15		-1	0	-1	-1	-3
Fish	4	4	4	5	17		0	-1	0	0	-1
Total	21.5	24	22	11	78.5	Net	0.5	1.5	0	-1	1

Explanation/discussion of differences: between 1993 and 1994: (1) Biggest change was improvement in **sediments** -- TZ in 1993 had slight toxicity and chlordane but in 1994 neither were found resulting in (+2) change; Hiwassee Embay had high copper (>50 ppm) in 1993 but not (<50 ppm) in 1994 (this was a "border-line" change) resulting in a (+1) change; at FB had slight improvement (+0.5), high Cu and Zn (and chlordane) in 1993 vs. high Cu and Zn in 1994 (with PCB in only one of two duplicates) in 1994. (2) **DO** improved at FB (+1) and TZ (+0.5) -- flow related, no anoxia or low DO's observed in 1994. (3) **Benthos** decreased by 1 pt at FB, inflow, and Hiwassee Embay (the FB and inflow had poor DO in 1993). No low DO's at TZ in 93 or 94 and benthos was good at this location in 93 and 94. The decrease of 1 for benthos on Hiwassee Embay is not likely DO related (some other reason?). (4) **Fish** decreased by 1 pt at TZ in 1994, few fish collected and few suckers at TZ.

Overall story for 1994: Chickamauga Reservoir was good again in 1994, slight overall improvement compared to 1993 (87% in 1994 and 83% in 1993). (1) As expected, some improvement in DO was observed -- FB changed from yellow in 1993 to green in 1994 (flow related); TZ and Hiwassee Embay green both years; and inflow yellow both years (low DO releases from Watts Bar). (2) Also, as expected benthos was lower in 1994 at FB, inflow, and Hiwassee Embay (due largely to lower 1993 DO's impacting 1994 benthos particularly at FB and inflow) -- FB and Hiwassee benthos change green to yellow -- while at inflow remains yellow, but score was lower in 1994 compared to 1993). (3) Large change observed in sediments. TZ sediments change from yellow to green (copper just above cutoff in 1993 and just below in 1994). At FB continued to measure high concentrations of zinc and copper as in past years (yellow, again). (4) Fish at TZ changed from green in 1993 to yellow in 1994 - not many fish collected (especially by electrofishing) and few sucker species (indicators of habitat condition, i.e. more = better conditions).

Macrophytes - No estimates of aquatic plants were made on Chickamauga in 1994. Aquatic plants covered about 1200 acres Chickamauga Lake in 1993.

HIWASSEE RIVER WATERSHED

The headwaters of the Hiwassee River extend into the Blue Ridge Mountains in Tennessee, North Carolina, and Georgia. Streams in this watershed have naturally low concentrations of nutrients and dissolved minerals. These streams change from steep gradient, cold water trout streams in the mountains to lower gradient warm water streams in the valley.

The Hiwassee River Watershed has an area of 2700 square miles and an average annual discharge to the Tennessee River of 5640 cfs. The confluence of the Hiwassee River with the Tennessee River is in Chickamauga Reservoir at Tennessee River Mile 499.4. The lower portion of the Hiwassee River is impounded by backwater from Chickamauga Dam. The impounded portion of the Hiwassee River forms a large embayment (about 6500 surface acres) which extends over 20 miles up the Hiwassee River.

The largest tributary to the Hiwassee River is the Ocoee River, with a drainage area of about 640 square miles. Due to past copper mining and industrial activities in the Copperhill area, several streams and reservoirs in the Ocoee River basin have degraded water quality.

There are eight TVA reservoirs in the Hiwassee River. Vital Signs monitoring activities are conducted on the five largest reservoirs: Hiwassee Reservoir (forebay, mid-reservoir, and inflow); Chatuge Reservoir (forebay sites on the Hiwassee River and Shooting Creek arms); Nottely Reservoir (forebay and mid-reservoir); Ocoee Reservoir No. 1 (forebay only); and Blue Ridge Reservoir (forebay only). Apalachia, Ocoee No. 2, and Ocoee No. 3 Reservoirs are not included in this monitoring because of their small size.

There is a stream monitoring site on the Hiwassee River at HiRM 36.9, about 2.5 miles upstream of the confluence of the Ocoee River. A new site was added in 1994 on the Ocoee River at mile 2.5. Vital Signs monitoring also includes a site on the Hiwassee River embayment (at HiRM 10) of Chickamauga Reservoir.

Hiwassee Reservoir

Hiwassee Reservoir, in the southwestern corner of North Carolina, is the second-largest of the five reservoirs in the Hiwassee River watershed included in the Vital Signs monitoring program. Hiwassee Reservoir is impounded by Hiwassee Dam at river mile 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet (with a maximum depth of about 255 feet at the dam). It has an average annual discharge of about 2020 cfs and average residence time of about 105 days. Hiwassee Reservoir has an average annual drawdown of 45 feet.

Chatuge Reservoir

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HiRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 459 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL), however, the annual drawdown averages only ten feet.

Only the forebay of Chatuge Reservoir was monitored prior to 1993. A new monitoring site was added in 1993 in the Shooting Creek arm to further evaluate this rather large part of the lake. Because of its physical features, the Shooting Creek site would be expected to be representative of forebay conditions.

Nottely Reservoir

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 415 cfs which result in an average hydraulic retention time of about 206 days. The annual drawdown averages about 24 feet on Nottely Reservoir.

Blue Ridge Reservoir

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with a average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. The annual drawdown of Blue Ridge Reservoir averages 36 feet.

Ocoee Reservoir No. 1 (Parksville Reservoir)

Ocoee No. 1 Reservoir, also known as Parksville Reservoir, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has a surface area of about 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin, and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet and is about 115 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), its annual drawdown averages about seven feet.

Reservoir: Hiwassee   1994 Score: 68%

	Reported	1994 Criteria	Special Case/1994 Criteria
1991	82 (No Sed/Bug; Incl Inflow)	70 (No Sed/Bug; No Inflow)	70 (No Sed/Bug; No Inflow)
1992	69 (No Sed/Bug; Incl Inflow)	73 (No Sed/Bug; No Inflow)	73 (No Sed/Bug; No Inflow)
1993	58 (Incl Sed/Bug; No Inflow)	65 (Incl Sed/Bug; No Inflow)	85 (No Sed/Bug; No Inflow)
1994	68 (Incl Sed/Bug; No Inflow)	68 (Incl Sed/Bug; No Inflow)	70 (No Sed/Bug; No Inflow)

(Previous Scores)

Effect of method change between 1993 and 1994: New methods in '94 increased '93 score by 7%, mostly due to changes in chlorophyll and fish methods

Impact of special case scores (i.e., ex/include embayments / TZ moved): Special case provides an apples to apples comparision through time.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3	3			6		-2	-2			-4
DO	2	4			6		-1.5	0			-1.5
Sediment	5	5			10		3	3			6
Benthos	1	2			2		0	0			0
Fish	5	4			9		1	0			1
Total	16	18			34	Net	0.5	1			1.5

Explanation/discussion of differences: between 1993 and 1994: There were several substantial shifts in indicators which tended to off-set one another. **Chlorophyll** ratings decreased substantially because of high chlorophyll concentrations at both sampling locations in '94--twice as high as ever seen since monitoring began there in 1991. (Note: "high" concentration is relative to the expectations for a reservoir in the Blue Ridge Ecoregion--good <4; fair 4 - 7; and poor >7). In '94 mean chlorophyll at FB was 6 and Mid-Res was 5 (previously had seen about 3 at FB and 3.5 at Mid-Res. The high mean at the FB was driven by a very high sample (22) collected in April. This wasn't the case for the relatively high level at the Mid-Res--most monthly samples were above the long-term mean. **DO** declined at the FB in '94 compared to '93 but was similar to '91 and '92. Less severe DO conditions in '93 were probably due to special hydro-electric operations (greater discharge) during the very dry summer months and greater draw-down to allow maintenance operations during autumn. **Sediment Quality** improved significantly in '94 compared to '93 (the first year sediments were sampled on Hiwassee). Sediments rated good at both locations in 1994, but in '93 there had been significant toxicity and chlordane at the FB and Mid-Res (both rated poor). **Fish** improved slightly in '94--will be good (green) in RP; in '93 they were reported as fair (yellow) but on '94 methods, '93 is good (green).

Overall story for 1994: Hiwassee rated fair in '94. Most notable observations for '94: (1) Chlorophyll highest ever seen on Hiwassee (see above for details). (2) Improvements in DO seen in '93 (rated fair) were not seen in '94 (rated poor, like in '92) (see above for explanation). (3) Sediments much improved in '94 --rated good, no problems found. In '93 both locations rated poor due to toxicity and chlordane. (Note: chlordane in '93 may have been a 'false positive' due to methods Echem used in '93). (4) Benthos rated poor again (same as in '93) at both locations--7 of 8 metrics received "1" at FB and 5 of 8 received "1" at the Mid-Res. Note: In '94 sampling was discontinued for fish and benthos at the upper/inflow location on the Hiwassee).

Reservoir: Chatuge 1994 Score: 77%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	60	60	60(For all '91-Chloro, DO, Fish, FB only)
1992	56	80	80(For all '92-Chloro, DO, Fish, FB only)
1993	67	75	80(For Special Case-only used above)
1994	77	77	90(For Special Case-only used above)

Effect of method change between 1993 and 1994: Methods change had significant effect. Results from '93 scored 8% higher on '94 menthods than on '93 methods. Main contriibutor was chlorophyll--expections for reservoirs in Blue Ridge Ecoregion changed beginning in '94 (good<4; fair=4-7; and poor>7).

Impact of special case scores (i.e., ex/include embayments / TZ moved): Goal for Special Case is to provide apples to apples comparison. In this case, all years good except '91, which had poor DO rating, not seen in other years. In '91 and '92 only sample site was forebay and only sampled chlorophyll, DO and fish. In '93 added Shooting Creek and sediments and benthos.

	1994 Results						Differences between 1993 and 1994				
	FB	Sh Cr	Emb	Inf	Total		FB	Sh Cr	Emb	Inf	Net
Chlorophyll	5	5			10		0	0			0
DO	4.5	4			8.5		0.5	0.5			1
Sediment	4	4			8		1	1			2
Benthos	2	3			5		-2	-1			-3
Fish	4	3			7		1	0			1
Total	19.5	19			38.5	Net	0.5	0.5			1

Explanation/discussion of differences: between 1993 and 1994: Little overall change between '94 and '93 when '93 results are scored on '94 methods. Several indicators shifted substantially, generally off-setting one another. **DO** rating at FB improved from fair in '93 (anoxic part of summer) to good in '94 (no anoxia found). At Shooting Creek DO improved also but not enough for a change in rating--no anoxia in '94 but x-section >10%, compared to anoxia and x-section >10% in '93. **Sediment** improved at both locations, but not enough for a color change in RP. At FB only problem found in '94 was elevated Cu (rated fair); in '93 found toxicity but no other problems (rated fair). At Shooting Creek found Chromium and Copper in '94 (rated fair); same as in '93 except list in '93 also included Nickel (rated fair). **Benthos** was only indicator to decline in '94 compared to '93. Both locations had much lower abundance in '94 and those animals present were mostly chironomids. Benthos rated fair (yellow) at both locations in '94 compared to good (green) in '93. **Fish** improved slightly at FB but not enough for a color change.

Overall story for 1994: Chatuge had good ecological health in '94. In '93 it had been reported as fair, but it would have been good if '94 methods had been used (see "Effect of Method Change" above). None of the indicators were poor (red) in '94, same as in '93. Sediments improved slightly but the most noteworthy observation on sdeiments is presernce of elevated chromium in Shooting Creek. This is the only reservoir with elevated chromium. Also had high concentrations of Cu and Ni in Shooting Creek in both '93 and '94. For some reason very few benthic organisms collected in '94; we don't know why. Benthos color in RP will be yellow both for sites in '94; both sites green in '93.

Reservoir: Nottely **1994 Score: 56%**

	Reported	1994 Criteria	Special Case/1994 Criteria
	Previous Scores		
1991	60	60	60 (For all '91-Chloro, DO, Fish, FB only)
1992	60	53	53 (For all '92-Chloro, DO, Fish, FB only)
1993	64	62	60 (For Special Case-only used above)
1994	56	56	47 (For Special Case-only used above)

Effect of method change between 1993 and 1994: Very little change over all (only 2%). Chlorophyll method changes tended to lower reservoir score (concentrations too high for a reservoir in Blue Ridge Ecoregion) and benthos changes tended raise score but not quite as much as the chlorophyll reduction.

Impact of special case scores (i.e., ex/include embayments / TZ moved): The goal for Special Case is to provide an apples to apples comparision through time. In '91 and'92 the only sample site was FB and only chlorophyll, DO, and fish were sampled. The Mid-Res site and sediments and benthos were added in '93. For this case, the lower score in '94 (47) was due to chlorophyll being too high.

	1994 Results						Differences between 1993 and 1994				
	FB	Mid-Re	Emb	Inf	Total		FB	Mid-Re	Emb	Inf	Net
Chlorophyll	3	3			6		-2	0			-2
DO	1	2			3		0	1			1
Sediment	4	3			7		1	-2			-1
Benthos	2	4			6		0	-1			-1
Fish	3	3			6		0	0			0
Total	13	15			28	Net	-1	-2			-3

Explanation/discussion of differences: between 1993 and 1994: **Chlorophyll** concentrations were higher in '94 than seen since monitoring began in 1991. The mean at the FB in '94 was 5.4 (rated fair, yellow), compared to means in previous years between 3 and 4. At Mid-Res mean was 6.7 in '94 (rated fair, yellow) compared to means in previous years between 5 and 6. **DO** was slightly improved at Mid-Res in '94--less low DO water, not enough improvement to result in a category shift (still poor as in previous years). **Sediments** improved slightly at FB in '94 (toxicity to one test animal) compared to '93 (toxicity to both test animals). Both years rated fair (yellow in RP). At Mid-Res sediments were highly toxic to one test animal (all killed) in '94 resulting in a fair rating. No problems were seen there in '93 so rated good. **Benthos** at Mid-Res declined slightly in '94 from a very good score in '93 (green) to a slighlty lower score in '94 (high yellow).

Overall story for 1994: Nottely borderline poor in '94; generally reduced from '93. None of the indicators rated good (green) at either location. Chlorophyll was fair (yellow) at both locations in '94 because concentrations were high for a reservoir in the Blue Ridge Ecoregion--higher than seem in any previous year. Low DO still a problem in Nottley--poor (red) at both lcoations in '94 and '93. Benthos at FB was similar in '94 to that in '93, but RP will show a color change from yellow in '93 to red in '94 due to method change (i.e., '93 would have been red if '94 methods had been used). Benthos at Mid-Res rated fair (yellow) in '94; a borderline change from '93 which rated good (green). Fish rated fair because no intolerant species and few suckers were found at both sites and because of numerous abnormalities at the Mid-Res.

Reservoir: Blue Ridge 1994 Score: 86%

	Previous Scores	
	Reported	1994 Criteria
1991	87	80 (only Chl, DO, and fish)
1992	73	83
1993	72	80
1994	86	86

Effect of method change between 1993 and 1994: Results for '93 scored higher on '94 methods due to change in chlorophyll -- beginning with '94 methods -- expectations for chlorophyll accept low concentrations as "good" for reservoirs in Blue Ridge Ecoregion, (see table below).

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	5	na	na	na	5		0	na	na	na	0
DO	4.5	na	na	na	4.5		-0.5	na	na	na	-0.5
Sediment	5	na	na	na	5		2	na	na	na	2
Benthos	3	na	na	na	3		-2	na	na	na	-2
Fish	4	na	na	na	4		2	na	na	na	2
Total	21.5	na	na	na	21.5	Net	1.5	na	na	na	1.5

Explanation/discussion of differences: between 1993 and 1994: (1) **Chlorophyll** concentrations for both '93 and '94 scored good using '94 methods ('93 was fair on previous methods; RP color change yellow in '93 to green in '94). (2) **DO** conditions were not quite as good in '94 as '93 -- a small volume of low DO water with short duration observed in '94, but not enough to reduce rating from good. (3) **Sediment** -- No problems found in '94 (good); in '93 found toxicity (fair). (4) **Benthos** -- '93 benthos in Blue Ridge lake was best for all Blue Ridge Ecoregion reservoirs. In '94 several metrics were reduced -- much fewer animals collected, mostly chironomids, fewer taxa, fewer EPT, some samples had no animals. RP color yellow for '94 (green in '93). (5) **Fish** -- increased diversity (all species groups/metrics) was main contributor to improved score compared to '93; few fish collected in both '93 and '94. Note: RP will not show a color change (yellow in both '93 and '94), but there were improvements in the fish community in '94. This isn't seen in RP because '93 methods scored '93 results fair (yellow), while '94 methods scored '93 results poor (red).

Overall story for 1994: Blue Ridge lake good again in '94. The high score results from both a new way of evaluating chlorophyll (RP color change yellow in '93 to green in '94) and real/true improvements in sediment (no problems in '94 = good) and fish (found greater variety of fish species in '94; Note - still very few fish collected). The overall score for Blue Ridge was the highest of all tributary reservoirs for the last three years. Benthos score decreased in '94 (see above for explanation) compared to '93; RP color change green in '93 to yellow in '94. Note: none of the indicators rated poor for Blue Ridge in '94.

Nutrient Limited Watershed (Blue Ridge Ecoregion):

Chlorophyll Concentrations	Rating
< 4 ug/L	good - 5
4 -.7 ug/l	fair - 3
> 7 ug/l	poor - 1

Reservoir: Parksville 1994 Score: 60%

	Reported	Previous Scores 1994 Criteria
1991	47	70 (only Chl, DO, and fish - assumed poor "1" sediment)
1992	53	70 (only Chl, DO, and fish - assumed poor "1" sediment)
1993	52	68
1994	60	60

Effect of method change between 1993 and 1994: Results for '93 scored higher on '94 methods due to change in chlorophyll. Beginning with '94 methods, expectations for chlorophyll accept low concentrations as "good" for reservoirs in Blue Ridge Ecoregion, (see table below).

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	5	na	na	na	5		0	na	na	na	0
DO	5	na	na	na	5		0	na	na	na	0
Sediment	0	na	na	na	0		-2	na	na	na	-2
Benthos	1	na	na	na	1		-1	na	na	na	-1
Fish	4	na	na	na	4		1	na	na	na	1
Total	15	na	na	na	15	Net	-2	na	na	na	-2

Explanation/discussion of differences: between 1993 and 1994: (1) **Chlorophyll** concentrations for both '93 and '94 scored good using '94 methods ('93 was poor on previous methods; RP color change red in '93 to green in '94). (2) **DO** good in Parksville again -- little oxygen demand. (3) **Sediments** -- chemically, sediments in Parksville are so bad as to be in a class by themselves (high/very high concentrations of arsenic, copper, lead, zinc, cadmium, and PCB's). In '93 sediments rated poor (bad chemically but no pore water toxicity found. In '94 sediments rated very poor (bad chemically and significant toxicity). RP color for sediment is red for both '93 and '94. Sediment score contributed to overall ecological health purposefully reduced from "1" to "0" to acknowledge the very poor chemical status and toxicity for '94. (4) **Benthos** poor in both '93 and '94 (RP color red both years) but was even poorer in '94 than '93 -- 7 of 8 metrics scored "1" for benthos in '94. (5) **Fish** improved over previous years. Most metrics (especially species metrics) improved, more individuals, more insectivores, still no suckers, no abnormalities either year ('93 or '94).

Overall story for 1994: Parksville score in '94 higher than any previously reported score but the '94 score was the lowest among '91, '92, '93, and '94 when all data are evaluated using the same '94 methods. The most significant method change was for chlorophyll. New method accepts low chlorophyll concentrations as good for Blue Ridge Ecoregion reservoirs (naturally low in nutrients). This is an important change for all the Hiwassee Watershed reservoirs. Parksville's biggest problems are sediment quality (see above) and poor benthos -- both red.
Note: There are signs that Parksville is continuing to recover. Over past few years we have seen more fish and a greater variety of fish in Parksville lake.

Nutrient Limited Watershed (Blue Ridge Ecoregion):

Chlorophyll Concentrations	Rating
< 4 ug/L	good - 5
4 - 7 ug/l	fair - 3
> 7 ug/l	poor - 1

WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

This watershed area is relatively small (1370 square miles) and includes three reservoirs: Fort Loudoun and Watts Bar Reservoirs on the Tennessee River and Melton Hill Reservoir on the Clinch River. All three are run-of-the-river reservoirs with relatively short retention times and annual pool drawdowns of only a few feet. The inflow of Fort Loudoun Reservoir is actually the origin of the Tennessee River. The Holston and French Broad Rivers merge at that point to form the Tennessee River. The Little Tennessee River, another major tributary to the Tennessee River, enters Fort Loudoun Reservoir near the forebay. Watts Bar Reservoir is immediately downstream of Fort Loudoun. The Clinch River, another major tributary, merges with the Tennessee River upstream of the transition zone on Watts Bar Reservoir. Melton Hill Dam bounds the upper end of Watts Bar Reservoir on the Clinch River and Fort Loudoun Reservoir bounds it on the Tennessee River.

Like the other watershed areas formed around one or more of the reservoirs on the mainstream of the Tennessee River, very little of the water leaving this watershed area originates from within. The average annual discharge through Watts Bar Reservoir is about 27,000 cfs. Of this, about 25 percent (6800 cfs) enters from the French Broad River, 16 percent (4500 cfs) from the Holston River, 21 percent (5700 cfs) from the Little Tennessee River, and 15 percent (4200 cfs) from the Melton Hill Dam on the Clinch River. Another five percent (1400 cfs) is contributed by the Emory River, a tributary to the Clinch River near the confluence with the Tennessee River. The remaining 18 percent (4800 cfs) originates from streams which drain directly to one of these reservoirs.

Vital Signs monitoring activities are conducted at the forebays, transition zones, and inflows of all three of these reservoirs. Watt Bar Reservoir has two inflow sites, one near Fort Loudoun Dam and one near Melton Hill Dam. There is one stream monitoring site on the Emory River at Emory River Mile 18.3.

Watts Bar Reservoir

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are: Watts Bar Dam located at Tennessee River Mile (TRM) 529.9, Fort Loudoun Dam located at TRM 602.3, and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,000 cfs, providing an average hydraulic retention time of about 19 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone sampling location in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the Tennessee River and Clinch River inflows. Water entering Watts Bar from Melton Hill Reservoir is quite cool due to the hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

The Emory River is a major tributary to the Clinch River arm of Watts Bar Reservoir and supplies about 5 percent of the average annual flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow, and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

Fort Loudoun Reservoir

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 18,400 cfs which provides an average hydraulic retention time of about ten days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments, each having long retention times. Both of these deep storage impoundments become strongly stratified during summer months resulting in the release of cool, low DO, hypolimnetic water during operation of the hydroelectric units. Some warming and reaeration of the water occurs downstream from Cherokee and Douglas Dams, but both temperature and DO levels are sometimes low when the water reaches Fort Loudoun Reservoir.

Fort Loudoun Reservoir also receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. (Since Tellico Dam has no outlet, under most normal conditions, water flows into Fort Loudoun Reservoir from Tellico Reservoir.) Water from Tellico Reservoir (Little Tennessee River) is often cooler and higher in DO, and has a much lower conductivity than water in Fort Loudoun Reservoir (Tennessee River). In 1992, the forebay sampling location on Fort Loudoun Reservoir (originally located at TRM 603.2) was moved upstream to

TRM 605.5. This resulted in a better assessment of the water quality conditions of the Tennessee River in the forebay portion of Fort Loudoun Reservoir by minimizing the effects of the Little Tennessee River and Tellico Reservoir on the data gathered in the forebay of Fort Loudoun Reservoir.

Although Fort Loudoun Reservoir is a mainstream reservoir, its complex set of hydrologic conditions (cool water inflows from the Holston, French Broad, and Little Tennessee Rivers) often causes it to exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than in other mainstream reservoirs.

Melton Hill Reservoir

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream from Melton Hill Dam about 44 miles. Melton Hill Reservoir has about 170 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is about 4900 cfs resulting in an average retention time of approximately 12 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant factor influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and mid-reservoir areas, is the cold water entering from Norris Dam discharges. During summer, water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a re-regulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

Reservoir: Watts Bar　　　1994 Score: 79%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	69	71	
1992	71	76	
1993	68	74	
1994	79	79	

Effect of method change between 1993 and 1994: Created a 6% pt improvement mostly due to scores for fish and benthos being higher using '94 criteria.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Inf- TN	Inf-Clinch	Total		FB	TZ	Inf-TN	Inf-Clinch	Net
Chlorophyll	3	5	na	na	8		-2	0	na	na	-2
DO	4	5	4	5	18		2	0	1	0	3
Sediment	4	4	na	na	8		2	0	na	na	2
Benthos	3	5	4	2	14		0	0	2	-1	1
Fish	4	4	4	3	15		1	-1	1	-1	0
Total	18	23	12	10	63	Net	3	-1	4	-2	4

Explanation/discussion of differences: between 1993 and 1994: (1) Low **DO** water much reduced in '94 compared with '93, however still had some anoxia in '94 at the FB - this is expected given dam characteristics; overall improvement due to higher flows in '94. (2) **Chlorophyll** at FB higher in '94 (x=11) just over cutoff from good to fair -- have seen these higher concentrations before at FB.
(3) **Sediment** score at FB much better -- '93 had significant toxicity and ammonia while in '94 neither found, but did find low levels of PCB's in sediment for first time (improved lab analytical methods lowered detection limit for PCB's in '94). TZ no color change but '93 found chlordane and '94 found PCB's.
(4) **Benthos** -- contrary to other reservoirs, saw no change or improvements at most locations; greatest improvement was at Inf-TN -- gained 2 pts (RP red to yellow). Note that 1993 DO's at Inf-TN were not significantly different from other years, so DO's not as big a factor. Also, note benthos change of 2 pts was borderline -- high "2" in '93 and low "4" in '94. Benthos at FB decreased slightly (RP green in '93 to yellow in '94) and at TZ increased slightly (yellow to green) -- more difficult to discern DO "influences in Watts Bar because the FB typically has at least some DO problems even in good flow years. Also, need to note scoring methods changes may be important -- FB benthos may have been rated too high in '93 -- was green in RP and rated "4" in '93 using '93 criteria, whereas using '94 criteria, 1993 results would be colored yellow and rate "3" -- the reverse situation occurred at TZ.

Overall story for 1994: Overall score improved substantially (1994 = 79%); highest score ever for Watts Bar. Main contributors were: (1) improved scoring methods, especially those for benthos (more significant for Watts Bar than other reservoirs). (2) Higher flows helped improve DO at FB and at Inf-TN (compared to 1993), with RP color change red to yellow at FB. (3) Sediment quality at FB improved (RP red in '93 to yellow in '94), no toxicity found in '94 as was found in '93, but did find low concentrations of PCB's (improved methods lowered detection limit in '94). (4) Benthos community was better at Inf-TN in '94 than any previous year (real change, not due to methods) and RP color will be yellow for first time -- will be interesting to see if we find this again in '95. Other color changes for benthos (FB green to yellow and TZ yellow to green) mostly due to methods change as noted above in # 1). (5) Fish color changes at TZ, RP color will be green for '94 ('93 results using '93 criteria resulted in yellow, but '93 results using '94 criteria would be green, so no real change in fish assemblage). At Inf-TN color change from yellow to green was true improvement in fish assemblage (fewer tolerant species and better community balance).

Reservoir: Fort Loudoun 1994 Score: 61%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	60	63	
1992	53	59	
1993	58	60	
1994	61	61	

Effect of method change between 1993 and 1994: Very little effect (only 2% pts difference in '93 using '93 and '94 criteria)

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3	3	na	na	6		0	0	na	na	0
DO	4.5	5	na	na	9.5		-0.5	0	na	na	-0.5
Sediment	4	4	na	na	8		2	0	na	na	2
Benthos	1	2	na	1	4		0	0	na	0	0
Fish	3	3	na	3	9		-1	0	na	0	-1
Total	15.5	17		4	36.5	Net	0.5	0		0	0.5

Explanation/discussion of differences: between 1993 and 1994: Results for '93 and '94 quite similar; only rating/point changes occurred at FB -- there **sediment** was biggest change from "2" in '93 to "4" in '94 (+2); (i.e. RP color change red to yellow). '93 sediments at FB rated red because of toxicity, high zinc and chlordane. In '94 FB did not show toxicity, but was yellow because of high zinc and PCB's (lowered DL for PCB's in '94). Change of -1 point for **fish** was "border line" change (4 pts in '93 compared with 3 pts in '94, but no color change in RP).

Overall story for 1994: Very little change from previous years. (1) Sediments at FB improved -- color change red to yellow (see above). Note: Sediment at TZ also had PCB's in '94 (lower DL in '94) and had chlordane in '93. (zinc also high both years and color yellow both years at TZ) (2) Benthos poor at all three locations in '94. Color changes between '93 and '94 -- benthos change yellow to red at both FB and TZ (stays red at inflow). At FB, this is totally due to change in scoring methods (should have been red in '93 by new '94 criteria). At TZ, the score was actually a little lower in '94 than '93 (basically changes from low yellow to high red). (3) Fish at TZ and inflow change from red in '93 to yellow in '94. This was due to change in scoring methods (both '93 and '94 score about the same using '94 scoring methods). No change in fish assemblage between the two years at TZ and inflow. (4) Only DO green (and green at both locations FB and TZ) in Fort Loudoun reservoir.

Reservoir: Melton Hill 1994 Score: 72%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	80	72	
1992	67	66	
1993	68	69	
1994	72	72	

Effect of method change between 1993 and 1994: Very small effect overall (1% change from 68% using '93 criteria to 69% using '94 criteria.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	5	5	na	na	10		0	0	na	na	0
DO	5	5	na	na	10		0	0	na	na	0
Sediment	5	4	na	na	9		0.5	0	na	na	0.5
Benthos	2	1	na	1	4		1	-1	na	0	0
Fish	4	4	na	2	10		1	0	na	0	1
Total	21	19	na	3	43	Net	2.5	-1	na	0	1.5

Explanation/discussion of differences: between 1993 and 1994: (1) **Fish** change of +1 pt between '93 and '94 was due to improvements in essentially all metrics; '93 results on '94 criteria would rate fair (score = 3) and '94 results rated good (score = 4). (2) **Benthos** at FB only a borderline change ('93 = high "1" and '94 = low "2" on '94 criteria). RP color changes discussed below. Benthos at TZ declined 1 pt due to borderline change ('93 = low "2" and '94 = high "1").

Overall story for 1994: Similar to previous years, slight improvement. Improvement was mostly due to better fish assemblages at FB in 1994 (most fish metrics improved), need to note that RP color change from red to green was partially influenced by this. The whole story is that '93 should have been yellow rather than red based on '94 scoring methods, beyond that the community looked better in '94 than in '93 (basically, double color change due partly to change in scoring methods and partly to an improved community).

Color change for benthos at FB (yellow to red) was due to scoring methods change ('93 should have been red rather than yellow based on new scoring methods). Although there was slight change in benthos score at TZ, it was not enough to cause RP color change.

Note -- Benthos poor at all locations in '94 - basically very few benthic animals present, and those present were tolerant types; cannot specifically say why so poor, although low water temperature may have been influential.

Note -- Sediment color was yellow in '93 and '94 but there was a change in the cause (chlordane in '93 and PCB's in '94).

CLINCH RIVER AND POWELL RIVER WATERSHED

This long, narrow watershed lies in southwest Virginia and northeast Tennessee. Streams in the watershed have high concentrations of dissolved minerals and generally low concentrations of nutrients.

For management purposes, an artificial ending point of the watershed has been established at Norris Dam, which is near Clinch River mile 80. The remainder of the Clinch River is associated with the Watts Bar, Fort Loudoun, and Melton Hill Reservoir Watershed area. As defined, this watershed drains an area of 2912 square miles and has an average annual discharge of about 4200 cfs. The Clinch and Powell Rivers contribute about 80 percent of this flow.

Norris Reservoir is the only major reservoir in the watershed; essentially all streams upstream from Norris are free flowing. There are three Vital Signs monitoring sites in Norris Reservoir (forebay and mid-reservoir sites on the Clinch and Powell arms) and two stream sites, one each on the Clinch and Powell Rivers.

Norris Reservoir

Norris Reservoir is formed by Norris Dam at Clinch River mile (CRM) 79.8. It is a large, dendritic, tributary storage impoundment of the Clinch and Powell Rivers which flow together about nine miles upstream of the dam. Norris is one of the deeper TVA tributary reservoirs, with depths over 200 feet. Annual drawdown averages about 32 feet. At full pool, the surface area of the reservoir is 34,200 acres, the shoreline is about 800 miles in length, and water is impounded 73 miles upstream on the Clinch River and 53 miles upstream on the Powell River. Norris Reservoir has a long average retention time (about 245 days) and an average annual discharge of approximately 4200 cfs. Due to the great depth and long retention time of Norris Reservoir, significant vertical stratification is expected.

Because of the confluence of the Clinch and Powell Rivers relatively close to the dam, three reservoir sampling locations were established: one forebay site; and two mid-reservoir sites--one on the Clinch River and one on the Powell River.

Reservoir: Norris **1994 Score: 69%**

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	57	73	
1992	67*	73*	(*Benthos excluded in both columns)
1993	67	71	
1994	69	69	

Effect of method change between 1993 and 1994: Increaseof 4 % on '93 (67 versus 71) due to methods change for benthos. In '94 methods Norris was grouped with a smaller number of more similar reservoirs (Ridge and Valley Ecoregion) and benthos was best among this group.

Impact of special case scores: Benthos not reported in '92 so benthos were excluded from calculating '92 score using '94 methods.

	1994 Results					Diff. Bet '93 and '94 ('94 Methods)				
	FB	MR-C	MR-P	Total		FB	MR-C	MR-P	Net	
Chloro	3	3	5	11		0	-2	0	-2	
DO	1	1	1	3		-1	0	0	-1	
Sediment	4	5	4	13		0	1	0	1	
Benthos	3	5	4	12		-2	0	1	-1	
Fish	4	4	5	13		1	0	1	2	
Total	15	18	19	52		-2	-1	2	-1	

Explanation/discussion of differences: between 1993 and 1994: **Chlorophyll** at Mid-Res on Clinch made a border-line change--in '93 mean concentration was 4.1 (good, green) and in '94 it was 2.7 (fair, yellow; 3.0 is cut-off). (Note: this may have been due to higher flows pushing the transition zone further downstream in '94). **DO** at the FB scored lower in '94 than in '93 because the volume of low DO water was much greater in '94 (20% of x-section and 40% of bottom) than in '93 (10% of x-section and 20% of bottom). DO rated poor both years (red in RP both years). **Sediment Quality** improved at Mid-Res on Clinch due to not finding ammonia in '94 that had been found in '93. Note: Still had high concentration of lead in FB--consistently found every year. **Benthos** scored lower at FB in '94 than '93 due to very few animals being collected; of these, there were no EPT and very few long-lived). RP color in '94 will be yellow. Benthos at FB were reported as fair (yellow) in '93 but would have been green if '94 methods used. At Mid-Res on Powell benthos rated good (green) in '94 compared to fair (yellow) in '93 because more animals were collected in '94. At Mid-Res on Clinch benthos also change from yellow in '93 to green in '94; this was a border-line change with very little difference in communities between the two years. **Fish** at FB had an improved score in '94 over '93 but not enough for a color change in RP (basically a low yellow in '93 and a high yellow in '94). Improvements at the FB in '94 occurred in several species metrics and found more lithophilic spawners. Fish at Mid-Res Powell rated good (green) in '94. The score was higher than in '93, which rated good (green) previously.

Overall story for 1994: Norris ecolgical health in '94 was similar to previous years--high end of fair. Although not a color change in RP between '93 and '94 (both red), DO's were much worse in '94 than in '93 at FB (see above). Chlorophyll at Mid-Res Clinch changed color (green in 93 to yellow in '94) due to low concentrations in '94 (just below cut-off for good). Sediment Quality at the Mid-Res on Clinch was good in '94 (no problems found); in '93 had ammonia causing a fair rating then). Benthos improved at both Mid-Res locations (both changing from yellow in '93 to green in '94). Fish at FB improved a little in '94 but not enough to change colors.

LITTLE TENNESSEE RIVER WATERSHED

The Little Tennessee River Watershed encompasses 2672 square miles, mostly in Tennessee and North Carolina with a small area in Georgia. Much of the watershed is forested, with the headwaters in the Blue Ridge Mountains. The basin is underlain mostly by crystalline and metasedimentary rocks of the Blue Ridge province. This watershed is home to a large variety of federally listed threatened and endangered species.

Most of the streams in the watershed are steep gradient and generally have low concentrations of both dissolved minerals and nutrients. The two largest tributaries to the Little Tennessee River are the Tuckasegee River which merges with the Little Tennessee in Fontana Reservoir and the Tellico River which merges with the Little Tennessee in Tellico Reservoir.

There are several reservoirs in the watershed but only Fontana Reservoir in the mountainous area and Tellico Reservoir at the lower end of the watershed are monitored. TVA does not monitor the other reservoirs either because of their small size or because they are owned by the Aluminum Company of America (ALCOA).

Two sites are monitored on Tellico Reservoir (the forebay and transition zone) and three sites on Fontana Reservoir (the forebay and mid-reservoir sites on the Little Tennessee River and Tuckasegee River). There is one stream monitoring site in the watershed, on the Little Tennessee River upstream of Fontana Reservoir. Another stream monitoring site (on the Tuckasegee River) was added in 1994.

Tellico Reservoir

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It is the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of about 16,000 acres at full pool. The average estimated flow through Tellico Reservoir is approximately 5700 cfs which provides an average retention time of about 37 days. Very little of this water is discharged through Tellico Dam. Rather, it is diverted through a navigation canal to Fort Loudoun Reservoir near the dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably. The hydrodynamics and exchange of water via the inter-connecting canal significantly affect water quality within Tellico Reservoir (and Fort Loudoun Reservoir). The canal is only 20-25 feet deep, but the depth of Tellico Reservoir at the forebay is about 80 feet. Thus, water at strata below about 25 feet is essentially trapped and becomes anoxic during much of the summer in the forebay of Tellico Reservoir.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico Rivers. The transition zone site selected for sample collection in 1990, 1991, and 1992 was in the Little Tennessee River, just upstream of the confluence with the Tellico River at Little Tennessee River Mile (LTRM) 21.0. Water conditions at that site are largely controlled by discharges from Chilhowee Dam at LTRM 33.6. This water is cold, nutrient poor, and has a low mineral content, conditions that are not conducive to establishing a diverse, abundant aquatic community. In 1993, the transition zone sampling location in Tellico Reservoir was moved six miles downstream to LTRM 15.0, just below the confluence of the Tellico River--a site more characteristic of a transition environment rather than riverine conditions.

Fontana Reservoir

Fontana Reservoir is located in the Blue Ridge Mountains of western North Carolina. Fontana is the deepest reservoir in the TVA system. At full pool it has a maximum depth of 460 feet, a length of 29 miles, a shoreline of 248 miles, and a surface area of 10,640 acres. Fontana Reservoir has a relatively large drawdown, which averages about 64 feet annually. Every fifth year Fontana is drawn even deeper to allow sluice gate access for maintenance.

Fontana Dam is located at Little Tennessee River Mile 61.0. Average annual discharge is 3840 cfs which provides an average hydraulic retention time in the reservoir of 186 days.

Water in Fontana Reservoir is quite clear due to limited photosynthetic activity and a mostly forested watershed. Water entering the reservoir is low in nutrients and dissolved minerals.

Reservoir: Tellico 1994 Score: 71%

	Reported	1994 Criteria	Special Case/1994 Criteria
		Previous Scores	
1991	48	54 (FB only)	54 (FB only)
1992	48	48 (FB only)	48 (FB only)
1993	63	57	46 (FB only)
1994	71	71	66 (FB only)

Effect of method change between 1993 and 1994: 6% loss (63% using '93 methods vs. 57% using '94 methods) due mostly to change in chlorophyll methods for low nutrient reservoirs-watersheds (inflows from Ft Loudoun may bring higher chlorophylls and nutrients into Tellico forebay). See table below for nutrient limited watersheds and chlorophyll ratings.

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	3	5	na	na	8		2	0	na	na	2
DO	4.5	5	na	na	9.5		1	0	na	na	1
Sediment	3	4	na	na	7		1	2	na	na	3
Benthos	2	1	na	na	3		0	0	na	na	0
Fish	4	4	na	na	8		1	0	na	na	1
Total	16.5	19	na	na	35.5	Net	5	2	na	na	7

Explanation/discussion of differences: between 1993 and 1994: 4 of 5 indicators improved in '94 at FB. **Chlorophyll** (exercise caution with interpretation due to methods change) results for '93 rated good ("5", green) on '93 methods but on '94 methods would rate poor ("1", red). The new methods assume Tellico is a nutrient poor reservoir and low chlorophyll concentrations would be expected. Inflows from Ft Loudoun FB probably bring in nutrients and higher chlorophyll, complicating the evaluation of Tellico FB results. Using '94 criteria, chlorophyll concentrations at FB improved in '94 (x = 5, yellow) compared to '93 (x = 7.2, red-but just above the cutoff). **DO** gained 1 pt at the FB, no anoxia found in '94. **Sediment** improved 1 pt at FB in '94 -- toxicity in both '93 and '94, however chlordane reported in '93 was not found in '94. Also, sediment improved at TZ (+2 pts) due to less significant toxicity in '94 than in '93 and the absence of chlordane in '94. **Fish** improved 1 pt -- fewer tolerant species, better balance in abundance among species, fewer omnivores and more insectivores.

Overall story for 1994: Much improved, highest score ever. Best score ever for DO at the FB (green for first time). We changed the way chlorophyll in Tellico is evaluated, which changed RP color green to yellow at FB (see chlorophyll discussion above). Sediments also improved -- no chlordane at FB or TZ in '94 (note - there may have been false positives for chlordane in '93 per ECHEM). Sediments at FB and TZ change red to yellow. Fish assemblage at FB best ever (first time green) due to improvements in most fish metrics. Benthos at TZ change from yellow to red - this was due to method change (should have been red in '93 if '94 scoring methods used). Benthos at both FB and TZ red for '94 - basically very poor as indicated by most metrics - can't specify exact cause, but cold water, low DO and toxicity probably play important role.

Nutrient Limited Watersheds

Chlorophyll Concentrations	Rating
< 4 ug/L	good - 5
4 - 7 ug/l	fair - 3
> 7 ug/l	poor - 1

Reservoir: Fontana 1994 Score: 67%

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	N/S	N/S	
1992	N/S	N/S	
1993	64 (No FB Bug)	75 (No FB Bug)	
1994	67 (No FB Bug)	67 (No FB Bug)	

Effect of method change between 1993 and 1994: Chlorophyll method change (new expectations for reservoirs in Blue Ridge Ecosystem) accounted for most of the change ('93 results on '93 methods=64; '93 results on '94 methods=75). This added a total of 6 pts (9%) to overall score.

Impact of special case scores (i.e., ex/include embayments / TZ moved): N/A

	1994 Results						Differences between 1993 and 1994				
	FB	MR-L'T	MR-Tu	Inf	Total		FB	MR-LT	MR-Tu	Inf	Net
Chlorophyll	5	5	5		15		0	0	0		0
DO	4.5	5	3.5		13		1	0	1.5		2.5
Sediment	2	2	2		6		0	-3	-2		-5
Benthos	N/S	1	1		2		N/A	-2	-1		-3
Fish	4	4	3		11		0	0	0		0
Total	15.5	17	14.5		47	Net	1	-5	-1.5		-5.5

Explanation/discussion of differences: between 1993 and 1994: **DO** was the only indicator to improve in '94 compared to '93--the volume of low DO water was less and there was no anoxia at both the FB and Mid-Res on Tuckasegee in '94 compared to '93. Both locations had higher rating in '94 compared to '93--FB changed from fair (yellow) in '93 to good (green) and Mid-Res on Tuck changed from poor (red) to fair (yellow). **Sediment Quality** was much poorer in '94 compared to '93 (the first time sediments were sampled on Fontana). Chlordane and significant toxicity were found at all three locations in 1994. In '93 toxicity was found only at the FB and chlordane was found only at the Mid-Res on Tuck and at the FB. As a result of the '94 results, Sediment Quality rated poor (red in RP) at all three locations. **Benthos** (not collected at FB) at Mid-Res on L' T rated much lower in '94 than in '93--species richness and abundance much reduced, no EPT, no long-lived (in either '93 or '94 for long-lived), and a higher proportion of chironomids. This caused benthos rating for Mid-Res on L'T to be poor in '94 compared to fair in '93. At the Mid-Res Tuck location the poor community found in '93 was even poorer in '94 (7 of 8 metrics scored "1").

Overall story for 1994: Ecological health rating for Fontana Reservoir was fair in '94, same as in '93. The overall score for '94 was slightly higher than reported last year. However, in reality (i.e., comparing apples to apples) the ecological health of Fontana was not as good in '94 as in '93. (Note: if '94 methods had been used in '93, Fontana's total score would have been 75 and it would have been rated good overall). The overall decrease was not readily apparent due to several "opposing" influences on '94 score. A change in methods for chlorophyll increased the overall score about 9%. Also, a true improvement in DO caused the overall score to increase about 4 %. However, these contributions to a higher score were more than off-set by true decreases in sediment quality and benthos (see above for details). It is noteworthy that Sediment Quality and benthos rated poor at all locations in '94 and will be red in RP.

FRENCH BROAD RIVER WATERSHED

The French Broad River watershed is one of the largest (5124 square miles) watersheds in the Tennessee Valley. About half the watershed is in Tennessee and half is in North Carolina. The French Broad River and its two large tributaries (Nolichucky and Pigeon Rivers) originate in the Blue Ridge Mountains. All three of these rivers merge at the upper end of Douglas Reservoir, the only sizable reservoir in the watershed. The water in the French Broad River is moderately hard and relatively high in nutrients.

There are two reservoir Vital Signs monitoring sites on Douglas Reservoir and one stream monitoring site each on the French Broad and Nolichucky Rivers. A stream monitoring site on the Pigeon River was added in 1994. All stream monitoring sites are upstream of Douglas Reservoir.

Douglas Reservoir

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston Rivers which form the Tennessee River. Reservoir drawdown during late summer and autumn is rather large, with an annual average of about 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, maximum depth at the dam is 127 feet, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is approximately 6780 cfs, which provides an average hydraulic retention time of about 105 days.

Lengthy retention times and lack of mixing due to their deep nature tend to cause storage impoundments to have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extends from the forebay to the mid-reservoir sampling location.

Reservoir: Douglas **1994 Score: 64%**

	Previous Scores		
	Reported	1994 Criteria	Special Case/1994 Criteria
1991	42	60 (FB only)	60 (Includes original Mid-Res)
1992	56	52 (FB only)	57 (Includes original Mid-Res)
1993	58	58	[Note: Mid-Reservoir relocated in 1993]
1994	64	64	

Effect of method change between 1993 and 1994: None on overall score.

Impact of special case scores (i.e., ex/include embayments / TZ moved): The mid-reservoir site was moved after 1992; including the data from the old site has little effect on reservoir rating.

	1994 Results						Differences between 1993 and 1994				
	FB	M-R	Emb	Inf	Total		FB	M-R	Emb	Inf	Net
Chlorophyll	5	5			10		0	2			2
DO	1	2			3		0	1			1
Sediment	5	2			7		0	0			0
Benthos	2	2			4		0	N/A			0
Fish	4	4			8		1	0			1
Total	17	15			32	Net	1	3			4

Explanation/discussion of differences: between 1993 and 1994: **Chlorophyll** at Mid-Res location made a borderline shift in '94--mean=9.9, just below the maximum end of the good range (10.0). The caused the rating for '94 to be good. In '93 the mean was only slightly higher (10.3) but was above the cutoff so it rated fair. Obviously, not a significant change but it still added 2 points (4%) to the overall score. **DO** at the Mid-Res location improved in '94 compared to '93--volume of low DO water was much less (6% of x-section in '94 and 18% in '93). Both years rated poor (red in RP), but the '94 DO contributed 1 point more to the overall score than in '93. The 1 point change in **fish** between years was due to methods change (i.e., '93 results on '94 criteria scored almost identical to '94 results on '94 criteria). (Note: benthos were not collected at the Mid-Res in '93.)

Overall story for 1994: Douglas Reservoir ecological health rated fair in '94, slightly higher than in previous years. Most of the apparent "improvement" was due to a border-line change at the Mid-Res location in chlorophyll. Although this caused a color change for chlorophyll in RP (yellow in '93 and green in "94), this small change (see above) is easily within sampling variability and shouldn't be used to imply water quality has improved. DO at Mid-Res improved in '94 compared to '93 but it was still sufficiently bad to be poor (red) again in RP.

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HOLSTON RIVER WATERSHED

The Holston River Watershed encompasses 3776 square miles, mostly in upper east Tennessee and southwest Virginia and a small area in North Carolina. The area is relatively highly populated with substantial industrial development.

Much of the area is underlain with limestone and dolomite which results in high concentrations of dissolved minerals in the streams. There is also substantial zinc mining in the watershed.

There are several reservoirs in the watershed with varying size, depth, flow, and water quality characteristics. The largest is Cherokee Reservoir on the Holston River near the lower end of the watershed. The uppermost reservoirs are Watauga Reservoir on the Watauga River and South Holston Reservoir on the South Fork Holston River. Downstream from these reservoirs, the Watauga and South Holston Rivers merge in Boone Reservoir. Immediately downstream from Boone Dam is Fort Patrick Henry Reservoir, the smallest of the five reservoirs in this watershed included in the Vital Signs Monitoring Program. A few miles downstream from Fort Patrick Henry Dam the South Fork and North Fork Holston Rivers merge to form the Holston River.

Vital Signs monitoring activities are conducted at one, two, or three locations depending on reservoir size and characteristics. There is a stream monitoring site on the Holston River upstream of Cherokee Reservoir and one on the North Fork Holston River, which was established in 19940.

The average annual discharge from Cherokee Dam is 4460 cfs. The Holston River merges with the French Broad River at Knoxville to form the Tennessee River.

Cherokee Reservoir

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile (HRM) 52.3. Like Norris and Douglas Reservoirs, it is a large, relatively deep, tributary storage impoundment with a substantial drawdown which begins in late summer. When the water surface is at full pool, maximum depth at the dam is 163 feet and winter drawdown is 53 feet. However, full pool is not reached most years, and the long-term average drawdown is about 28 feet. At full pool, Cherokee Reservoir is 54 miles long, has a surface area of 30,300 acres, and a shoreline of 393 miles. Average annual discharge is about 4500 cfs which provides an average hydraulic retention time (at full pool) of approximately 165 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit on Cherokee is one of the worst of all Vital Signs monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

Fort Patrick Henry Reservoir

Fort Patrick Henry Reservoir is one of the smaller reservoirs included in the Vital Signs Monitoring Program. It is only ten miles long, has a surface area of about 870 acres, and has a shoreline of 37 miles. Although it is a tributary reservoir, it has characteristics of a run-of-river reservoir, rather than a storage reservoir. Annual fluctuation in elevation is only five feet. Also, retention time is short; with an average discharge of 2650 cfs, the hydraulic retention time is only about five days. Maximum depth is about 80 feet. Fort Patrick Henry Dam is located at South Fork Holston River mile 8.2.

This reservoir had not been sampled as part of this monitoring effort prior to 1993. Because of its small size, only the forebay is monitored for Vital Signs.

Boone Reservoir

Boone Dam is located at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, an average depth of 44 feet, and a maximum depth of 129 feet near the dam. Annual average discharge from Boone Dam is about 2500 cfs, which results in an average hydraulic residence time of about 38 days. Annual drawdowns of Boone Reservoir usually average about 25 feet.

Three locations were selected for ecological health monitoring in Boone Reservoir, one at the forebay and two mid-reservoir sampling locations, one on the Watauga River arm and one on the South Fork Holston River arm. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

South Holston Reservoir

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles long, over 230 feet deep near the dam, with an average depth of 86.5 feet and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, the average hydraulic residence time is almost one year (340 days)--one of the longest residence times of any TVA reservoir. Average annual drawdown of South Holston Reservoir is about 33 feet.

Two locations are monitored for Vital Signs--the forebay and mid-reservoir. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Watauga Reservoir

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the second-deepest reservoir sampled as part of TVA's Vital Signs Monitoring Program. With an annual average discharge of about 700 cfs, Watauga Reservoir also has the longest hydraulic residence time of any of the Vital Signs reservoirs (about 400 days). Average annual drawdown of Watauga Reservoir is about 26 feet.

Two locations are monitored on Watauga Reservoir, the forebay and mid-reservoir. Sediment quality and benthic macroinvertebrates were examined for the first time in 1993.

Reservoir: Cherokee **1994 Score: 53%**

	Previous Scores	
	Reported	1994 Criteria
1991	50	62
1992	53	60
1993	64	64
1994	53	53

Effect of method change between 1993 and 1994: None

	1994 Results						Differences between 1993 and 1994				
	FB	MR	Emb	Inf	Total		FB	MR	Emb	Inf	Net
Chlorophyll	3	1	na	na	4		-2	-4	na	na	-6
DO	1	1	na	na	2		0	0	na	na	0
Sediment	5	4	na	na	9		1	2	na	na	3
Benthos	3	ns	na	na	3		-1	ns	na	na	-1
Fish	3	3	na	na	6		-1	0	na	na	-1
Total	15	3	na	na	24	Net	-3	-2	na	na	-5

Explanation/discussion of differences: between 1993 and 1994: Biggest change between '93 and '94 was in chlorophyll -- too much in '94. **Chlorophyll** at FB in '93 - good (x = 7.6) and in '94 - fair (x = 11.6); at MR in '93 - good (x = 9.4) and in '94 - poor (x = 16.7). Higher chlorophyll concentrations in '94 than '93 or previous years cannot be readily explained. It would not be a reservoir flow issue because Cherokee has a long retention time under all flow regimes. The most likely explanation would be increased nutrient loads due to heavy runoff in '94. **Sediment** improved at both the FB and MR. At FB had ammonia in '93 (fair); no ammonia in '94 (good). At MR had copper, ammonia, and toxicity (poor) in '93; only copper found in '94 (fair). **Benthos** (not sampled at MR) at FB scored lower in '94 than in '93 but not enough to cause a color change (both years in fair range). **Fish** at FB same story as benthos - reduced score in '94 but both years in fair range.

Overall story for 1994: Cherokee poor in '94, mostly due to too much chlorophyll at both FB and MR; highest concentrations found in Cherokee lake since this monitoring program began in 1990. RP color for chlorophyll changes green to yellow at FB and green to red at MR (see above for "explanation" of increased chlorophylls). DO very poor at both locations both years. Sediment improved in '94 -- no ammonia at either sample location and no toxicity, only "problem" was elevated copper at MR (elevated copper at MR found in all previous years). RP color changes for sediment -- at FB yellow to green and at MR red to yellow (see above for more detail). Benthos and fish at FB scored slightly lower in '94 than '93 but not enough to result in a color change.

Note: Discontinued sampling at the upper reservoir inflow location on Cherokee (fish and benthos) in '94.

Reservoir: Ft Patrick Henry 1994 Score: 60%

	Previous Scores	
	Reported	1994 Criteria
1991	--	--
1992	--	--
1993	72	80
1994	60	60

Effect of method change between 1993 and 1994: Method change for benthos and fish resulted in each scoring slightly higher when '93 results evaluated on '94 criteria ('93 results on '93 methods = 72% and '93 results on '94 methods = 80%).

	1994 Results						Differences between 1993 and 1994				
	FB	TZ	Emb	Inf	Total		FB	TZ	Emb	Inf	Net
Chlorophyll	1	na	na	na	1		-2	na	na	na	-2
DO	5	na	na	na	5		0	na	na	na	0
Sediment	4	na	na	na	4		0	na	na	na	0
Benthos	2	na	na	na	2		-2	na	na	na	-2
Fish	3	na	na	na	3		-1	na	na	na	-1
Total	15	na	na	na	15	Net	-5	na	na	na	-5

Explanation/discussion of differences: between 1993 and 1994: (1) **Chlorophyll** -- too much in '94; (in '93 x = 10.3, "fair"; in '94 x = 15.9, "poor"). Similar to observations in Cherokee (more chlorophyll in '94 than '93) -- most likely due to high nutrient loading due to heavy runoff in '94. (2) **Benthos** -- community not as good in '94 as in '93 (no EPT, community dominated by tolerant organisms, i.e. Tubificids and Chironomids); benthos score declined from high end of fair range to low end of range so no color change for RP. (3) **Fish** -- same as benthos with poorer community in '94 (fewer fish collected and greater proportion of tolerant individuals) so lower score but not enough to cause color change.

Overall story for 1994: Fort Pat ecological health declined from "good" in '93 to "fair" in '94. Chlorophyll was high in Fort Pat in '93 and rated fair -- in '94 it was even higher and rated "poor". Saw similar increase just downstream in Cherokee. Assumption is that in this nutrient-rich watershed, the increased runoff in spring and summer of '94 flushed added nutrients into Fort Pat, stimulating algal productivity and higher chlorophylls. Benthos and fish both scored lower in '94 than '93 -- but neither was enough to cause a color change in RP -- both were a high "yellow" in '93 and a low "yellow" in '94, so RP colors don't change but overall score is lower. (Special note for fish -- lots of big bass collected). Sediments -- no color change between '93 and '94, but in '93 found ammonia and in '94 found small amounts of PCB's and chlordane. Note: This was the biggest decline in ecological health scores of all reservoirs sampled (between '93 and '94). These results must be evaluated conservatively because there are only two years of data for Fort Pat, and each shows vastly different scores. Without more information, there is no definitive way to know which year most accurately reflects true condition, (or perhaps the answer is somewhere between the two). Another important consideration is that Fort Pat only has one sample location. A small change in a metric (e.g. DO, fish, etc.) can cause a large change in the overall reservoir score (e.g. a 1 pt change for a metric like fish causes a 4% change in the overall reservoir score).

Reservoir: Boone 1994 Score: 59%

	Reported	Previous Scores 1994 Criteria
1991	51	52 (only Chl, DO, and fish)
1992	64	63 (only Chl, DO, and fish)
1993	59	61
1994	59	59

Effect of method change between 1993 and 1994: Little effect of change (59% vs 61%)

	1994 Results						Differences between 1993 and 1994				
	FB	MR-SFH	MR-Wat	Inf	Total		FB	MR-SFH	MR-Wat	Inf	Net
Chlorophyll	5	1	3	na	9		0	-2	0	na	-2
DO	4.5	2	5	na	11.5		1.5	0	1	na	2.5
Sediment	3	4	3	na	10		-1	0	0	na	-1
Benthos	2	1	2	na	5		-1	-1	0	na	-2
Fish	3	3	3	na	9		1	0	0	na	1
Total	17.5	11	16	na	44.5	Net	0.5	-3	1	na	-1.5

Explanation/discussion of differences: between 1993 and 1994: Overall, very little difference, but there were changes for individual indicators/metrics, which essentially off-set one another. (1) **Chlorophyll** -- higher at both MR locations but only at SFH-MR was the average concentration increased enough to effect a change in score and color (from fair to poor). (2) **DO** improved at FB and Watauga-MR (both change fair to good between '93 and '94). At FB only a small volume of low DO existed in '94, and at MR-Watauga no low DO (>2 mg/l) water was observed. (3) **Sediment** -- FB lower in '94 compared to '93 due to some toxicity in '94 and none in '93 (but no color change - fair "yellow" both years). Note for sediments -- chlordane found at all three sampling locations in both '93 and '94; and in '94 also found PCB's at FB and MR-Watauga. (4) **Benthos** -- not too good anywhere in '93. In '94 benthos was worse at FB and MR-SFH (both locations having a borderline change from fair, "yellow" in '93 to poor, "red" in '94). At MR-Watauga there was also a borderline change from poor, "red" in '93 to fair, "yellow" in '94 for the benthos. (5) **Fish** -- improved at FB in '94 from poor (red) to fair (yellow) due to increased species richness, better balance of individuals among species, and more fish. No change in fish at MR-SFH. At MR-Watauga there was little change in the community but there will be a color change in RP (red in '93 to yellow in '94) due to a change in methods ('93 would be yellow if scored using '94 methods).

Overall story for 1994: Very little change in overall score, but several indicators shifted up or down. Most notable change from '93 is the decrease in conditions at MR-SFH site. Chlorophyll and benthos changed from fair in '93 to poor in '94 (yellow to red). DO was poor both years and sediment and fish only fair both years at MR-SFH site. The reduced chlorophyll rating caused by higher summer chlorophyll concentrations is consistent with observations at Ft Pat and Cherokee in '94. On the plus side, DO was generally better (improved at FB and MR-Watauga) and fish community improved at the FB. Sediments containing chlordane and PCB's represent a concern. Benthos communities at all three locations are fair to poor (see above).

Reservoir: South Holston 1994 Score: 66%

	Previous Scores	
	Reported	1994 Criteria
1991	60	63 (only Chl, DO, and fish)
1992	57	63 (only Chl, DO, and fish)
1993	65	69
1994	66	66

Effect of method change between 1993 and 1994: Change in fish methods resulted in a 1 point increase at both FB and MR results in a 4% change in '93 score using '94 criteria.

	1994 Results						Differences between 1993 and 1994				
	FB	MR	Emb	Inf	Total		FB	MR	Emb	Inf	Net
Chlorophyll	3	5	na	na	8		-2	0	na	na	-2
DO	2	1	na	na	3		-0.5	0	na	na	-0.5
Sediment	5	5	na	na	10		1	1	na	na	2
Benthos	3	1	na	na	4		2	-2	na	na	0
Fish	4	4	na	na	8		-1	0	na	na	-1
Total	17	16	na	na	33	Net	-0.5	-1	na	na	-1.5

Explanation/discussion of differences: between 1993 and 1994: (1) **Chlorophyll's** about the same as they were last year. A "borderline" change from x = 3.4 in '93 to x = 2.9 in 94 results in a color change at FB from green to yellow. No "real" difference between years. (2) **DO's** about the same as '93, with about 10% of X-section at FB with low DO (<2 mg/l) and 30% of the X-section at MR with low DO. (3) **Sediment** - no problems in '94. (Had slight toxicity at FB and ammonia and chlordane at MR in '93). (4) **Benthos** improved at FB (poor in '93 to fair in '94) -- all 8 benthos metrics were "1" in '93, but in '94 only 3 were "1". Benthos declined at MR from fair in '94 to poor in '94. (6 of 8 metrics were "1" in '94, compared to 3 of 8 in '93, and in '94 at MR only Tubificids and Chironomids). (5) **Fish** - no color change in RP. Slight decline in fish community at FB in '94 (fewer intolerant species in '94).

Overall story for 1994: About the same as '93. Biggest concerns in South Holston continue to be low DO's near the bottom in summer and poor benthos communities (possibly related?).

Note: Chlorophyll concentrations in '94 not higher (like Boone, Ft Patrick Henry, Cherokee) because South Holston is upstream of major urban areas. Higher runoffs in urban areas will carry proportionally higher concentrations of nutrients (compared to rural/forested areas) and result in greater algal productivity/higher chlorophyll's.

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Reservoir: Watauga 1994 Score: 65%

	Reported	Previous Scores 1994 Criteria
1991	80	77 (only Chl, DO, and fish)
1992	57	72 (only Chl, DO, and fish)
1993	61	63
1994	65	65

Effect of method change between 1993 and 1994: Very little change

	1994 Results						Differences between 1993 and 1994				
	FB	MR	Emb	Inf	Total		FB	MR	Emb	Inf	Net
Chlorophyll	5	5	na	na	10		0	0	na	na	0
DO	4	1.5	na	na	5.5		-0.5	-1.5	na	na	-2
Sediment	3	4	na	na	7		1	0	na	na	1
Benthos	2	3	na	na	5		1	2	na	na	3
Fish	2	3	na	na	5		0	-1	na	na	-1
Total	16	16.5	na	na	32.5	Net	1.5	-0.5	na	na	1

Explanation/discussion of differences: between 1993 and 1994: (1) **DO** conditions slightly worse in '94 than in '93 at the FB. Biggest change at MR where about twice as much low DO water in '94 compared to '93. Both will result in a color change for RP (FB green to yellow and MR yellow to red). (2) **Sediments** improve slightly at FB in '94. FB sediments poor in '93, fair in '94 (in '94 had toxicity just like '93, but didn't find ammonia and chlordane like in '93). At MR found chlordane in '94 and in '93, no other sediment concerns at MR. (3) **Benthos** -- improved at both FB and MR in '94 compared to '93. In '93 very poor benthos at both places. In '94 FB score improved but not enough to result in color change (red in '93 and '94). At MR community improved slightly ('93 - poor and '94 - fair with more taxa and more individuals collected). (4) **Fish** at MR scored slightly lower in '94 than '93 but not enough to result in color change. At FB the community changed very little but the RP color will change from red (in '93) to yellow (in '94). This was totally due to a change in methods ('93 fish would have been yellow if '94 methods used).

Overall story for 1994: Little overall change in ecological health of Watauga (fair both years), possibly slight improvement overall. Big picture = improved benthos scores off-set by reduced DO scores. We don't have an explanation why Watauga DO scores were lower than previous years. (possible explanation -- Higher pool levels and lower discharges result in longer retention times [and more time for hypolimnetic anoxia development] holding back heavy spring and summer rains to diminish downstream flooding as in '94 -vs.- lower pool levels and higher discharges to supplement flows downstream and in the Tennessee River result in shorter retention times [and less time for hypolimnetic anoxia development] during low flow years as in '93.) In past years Watauga has not had as bad of DO problems as the other deep tribs??? Although benthos improved over '93, they were still only fair at one location and poor at the other. One of the problems for benthos in Watauga is the great depth.

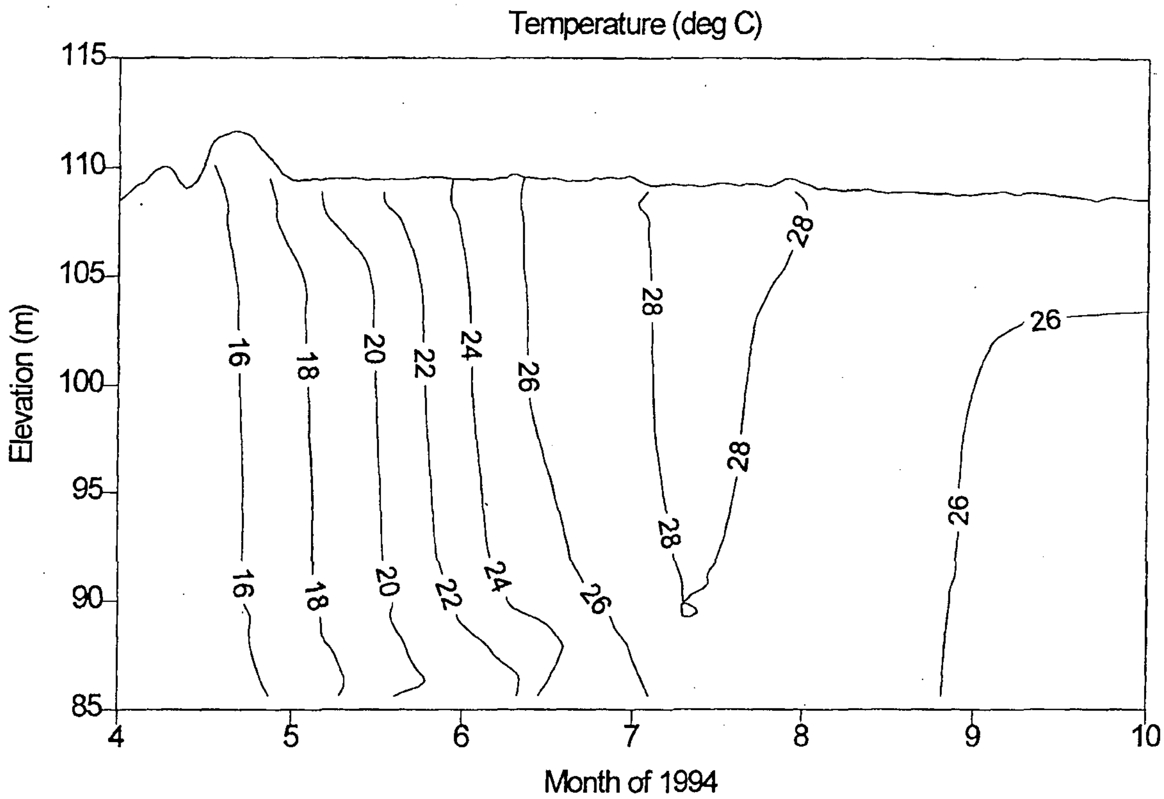
Section 2

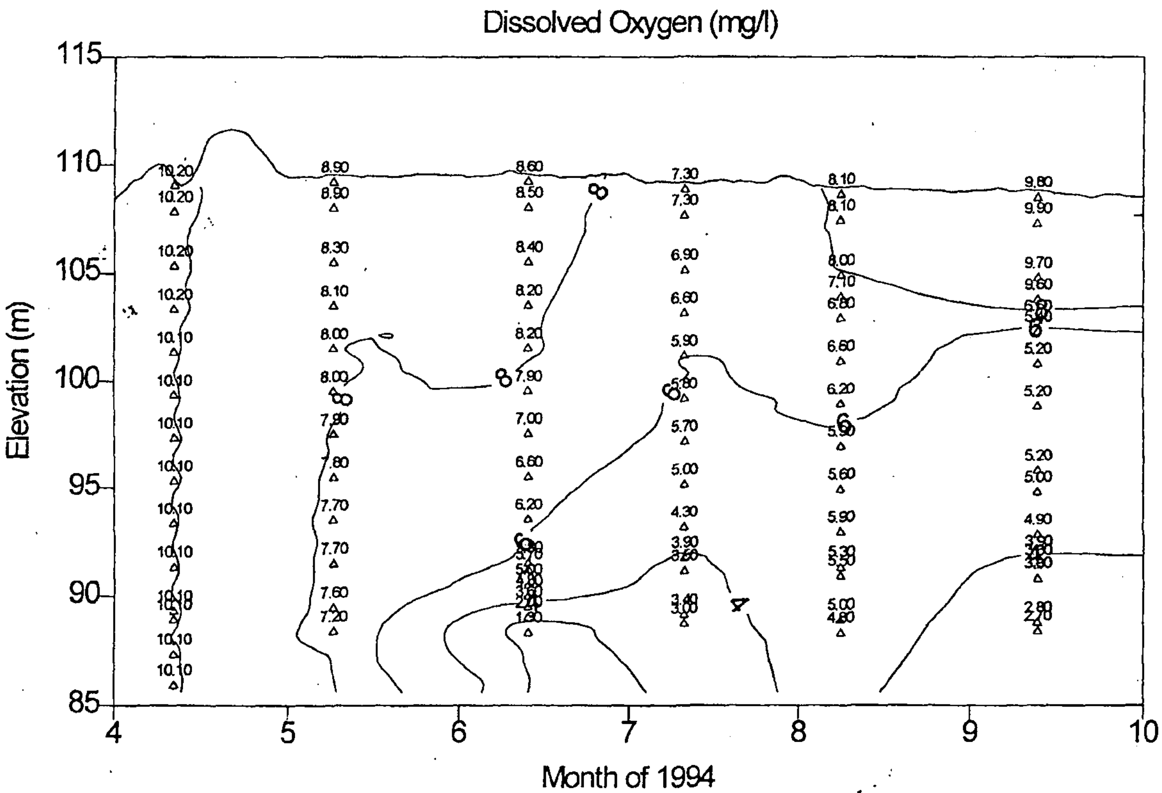
Dissolved Oxygen and Chlorophyll

Appendix A.

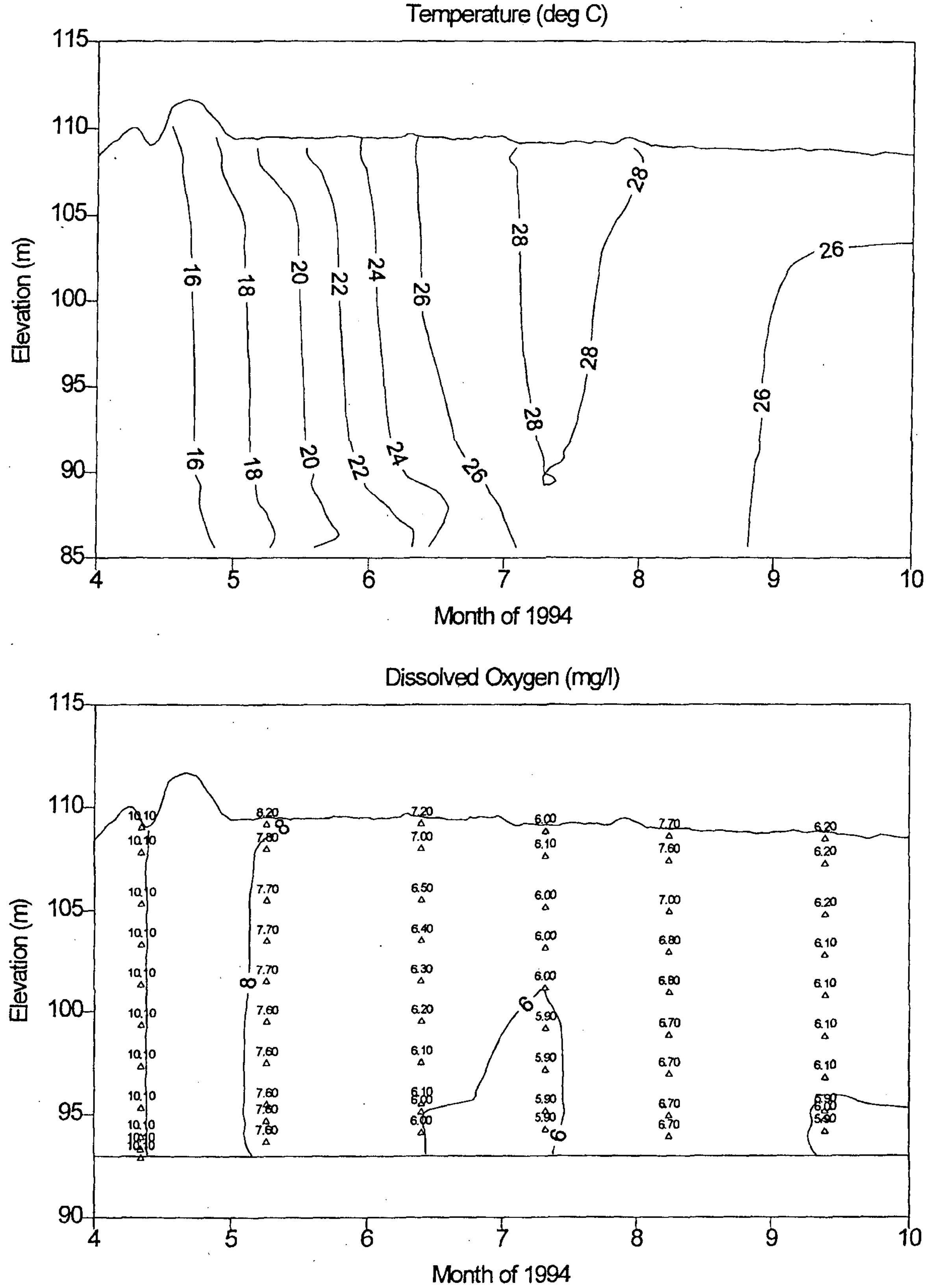
Temperature and Dissolved Oxygen Isopleths for Each Sample Location Throughout the 1994 Monitoring Period

Kentucky Reservoir - TRM 23.0

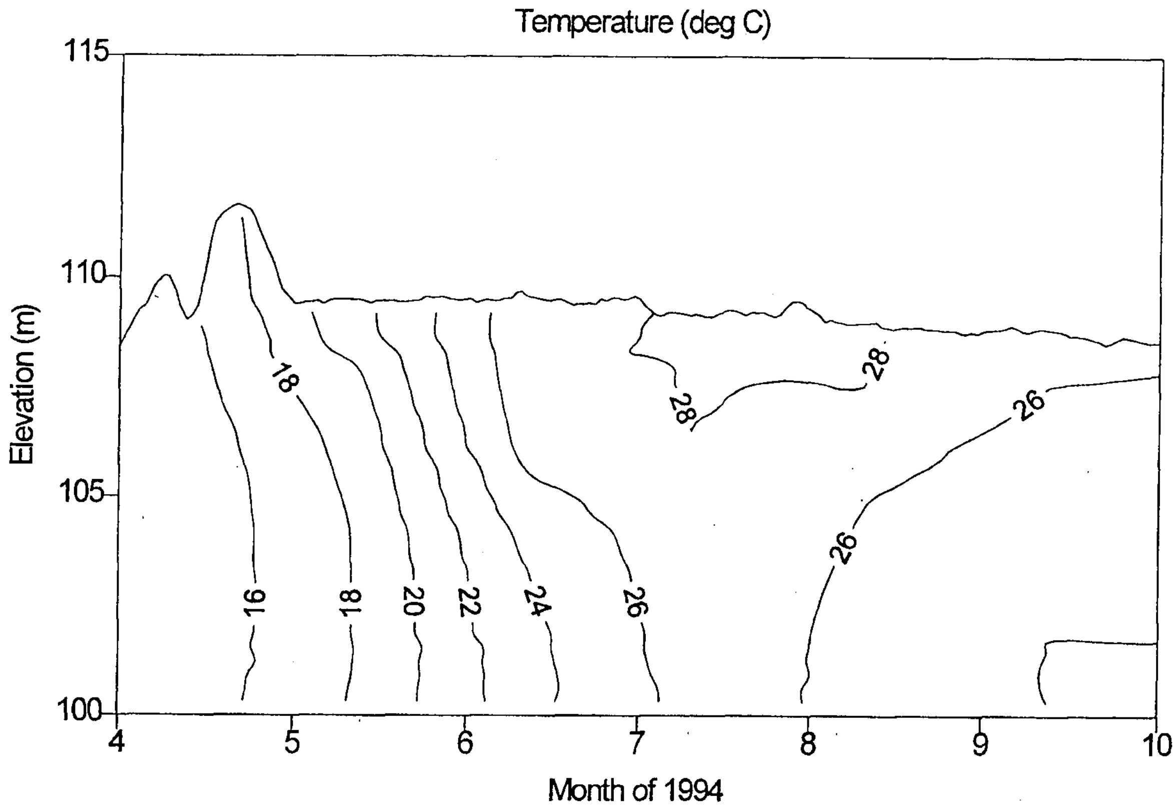


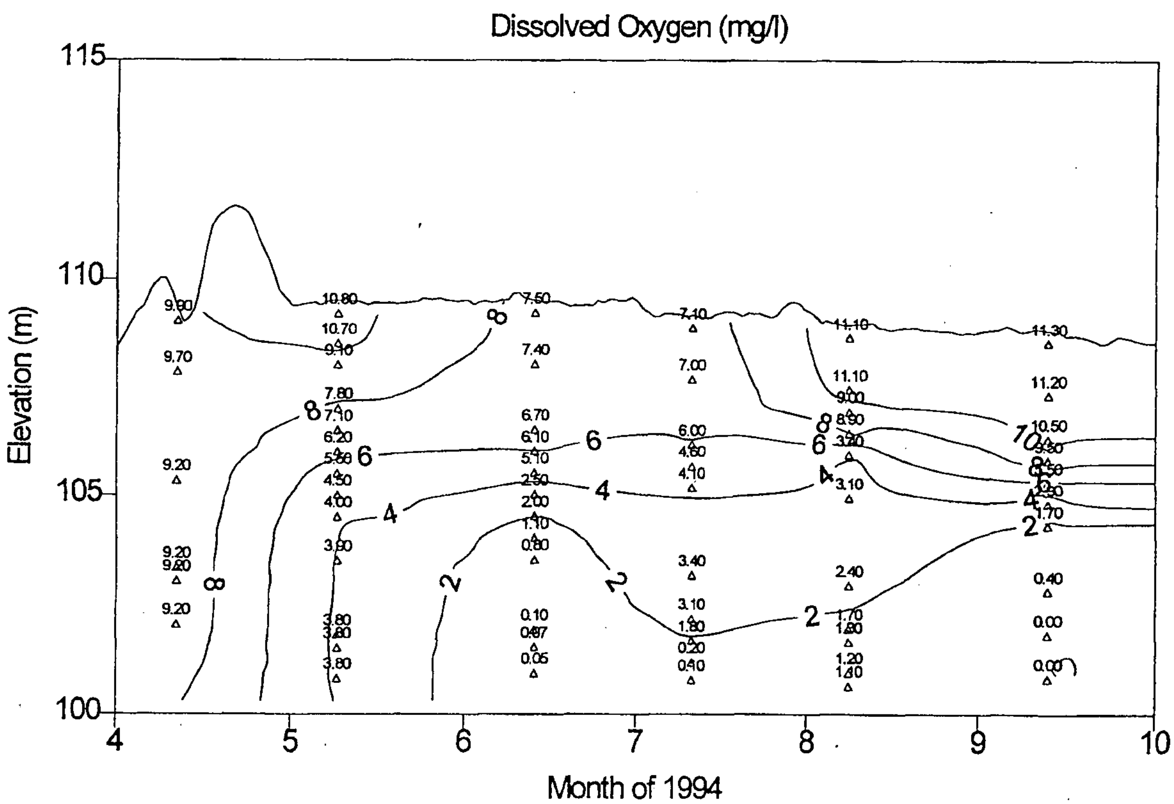


Kentucky Reservoir - TRM 85.0



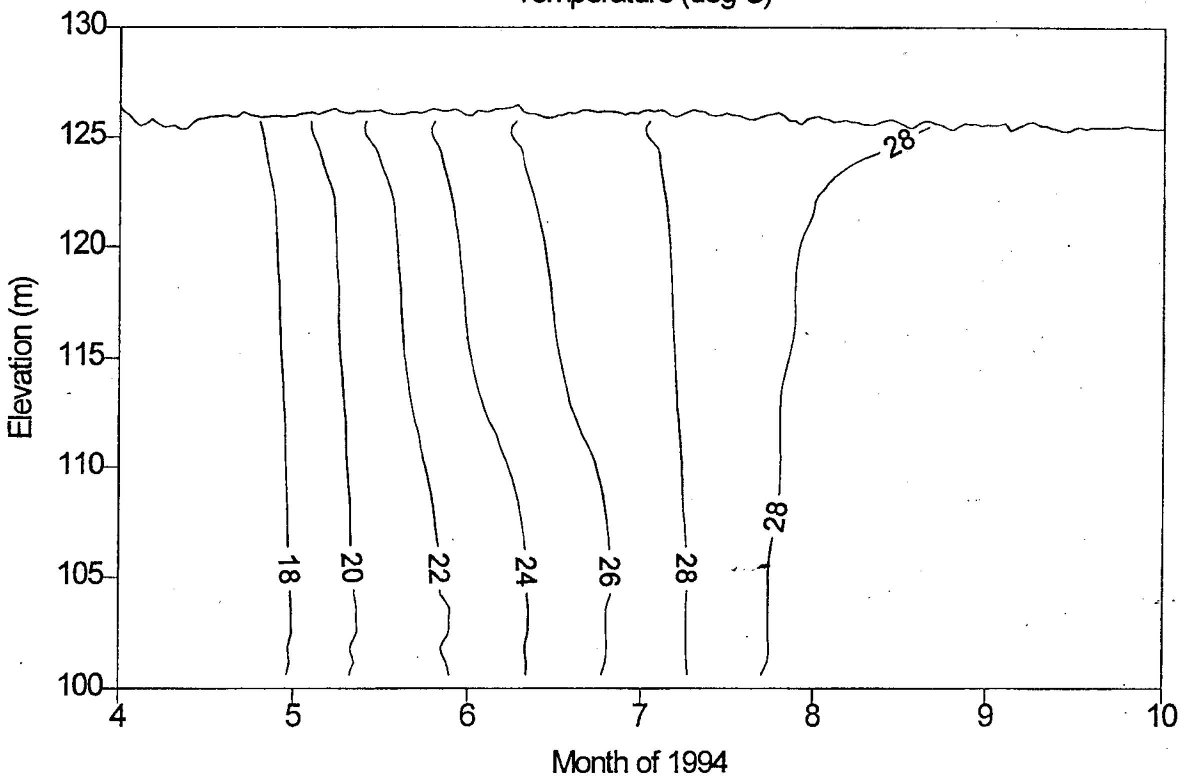
Kentucky Reservoir - Big Sandy River Mile 7.4



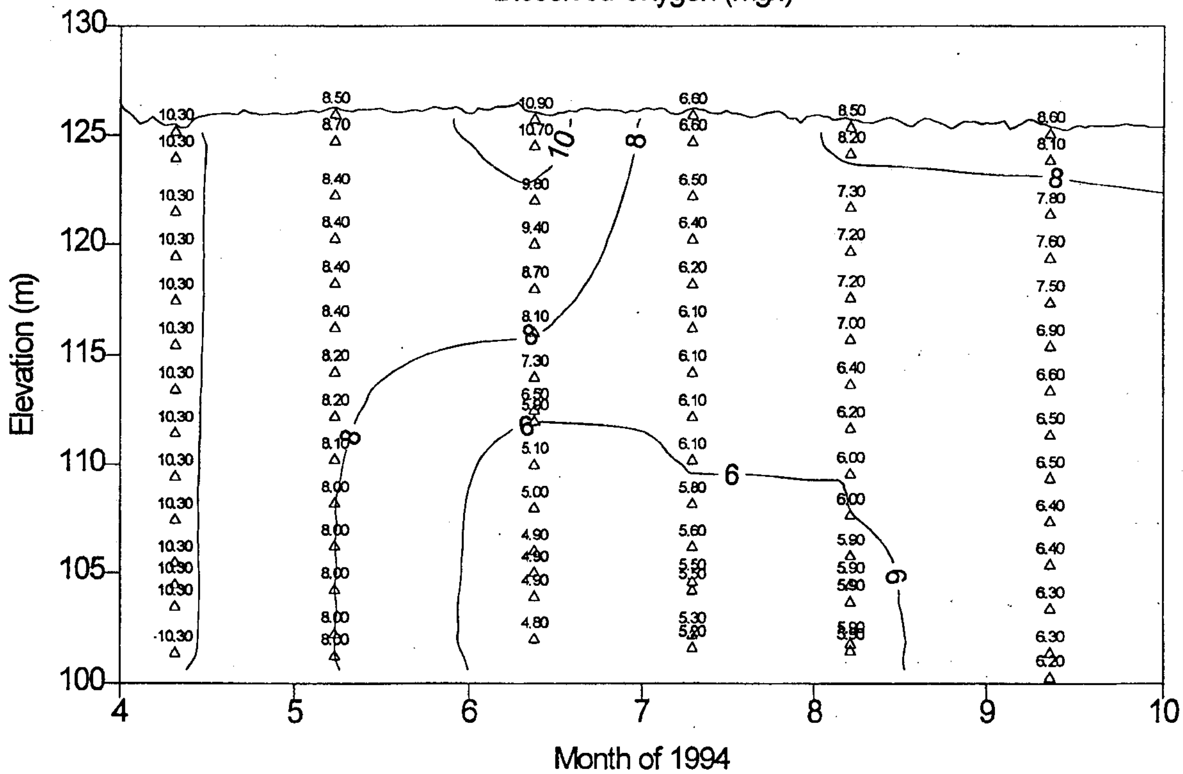


Pickwick Reservoir - TRM 207.3

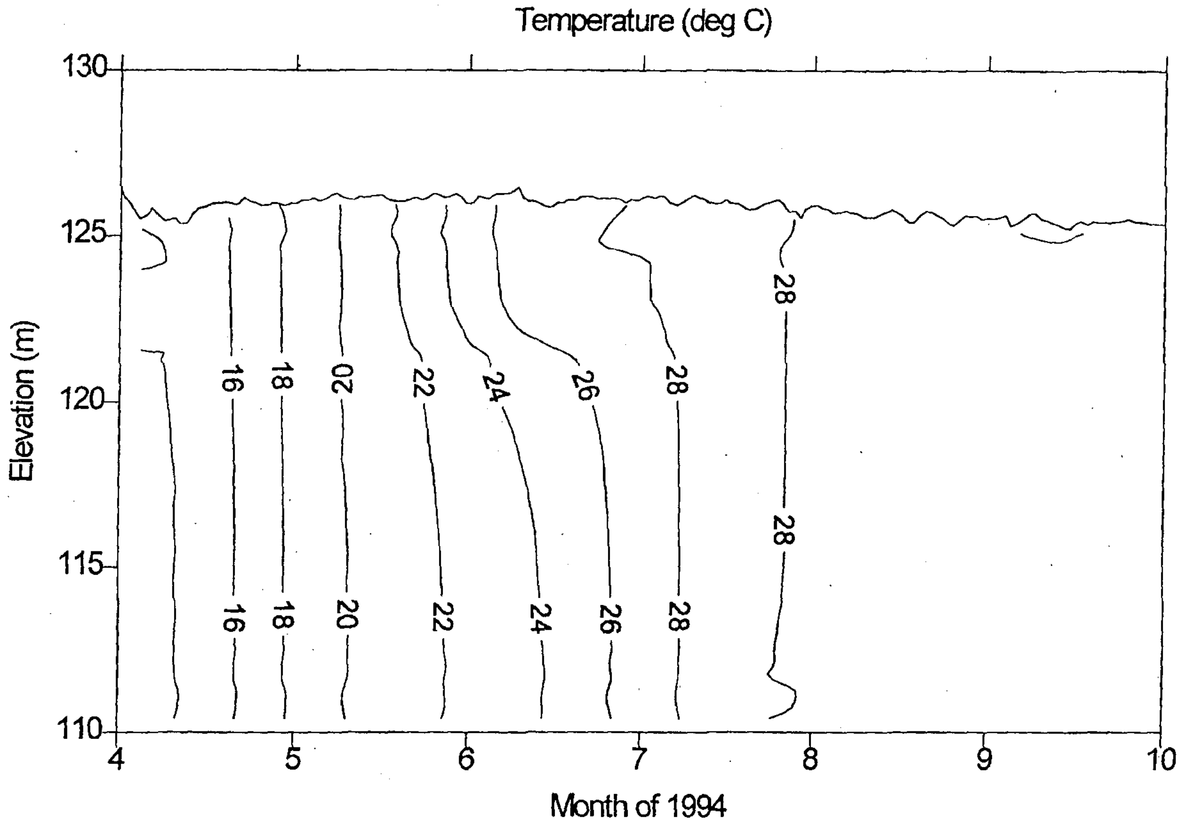
Temperature (deg C)

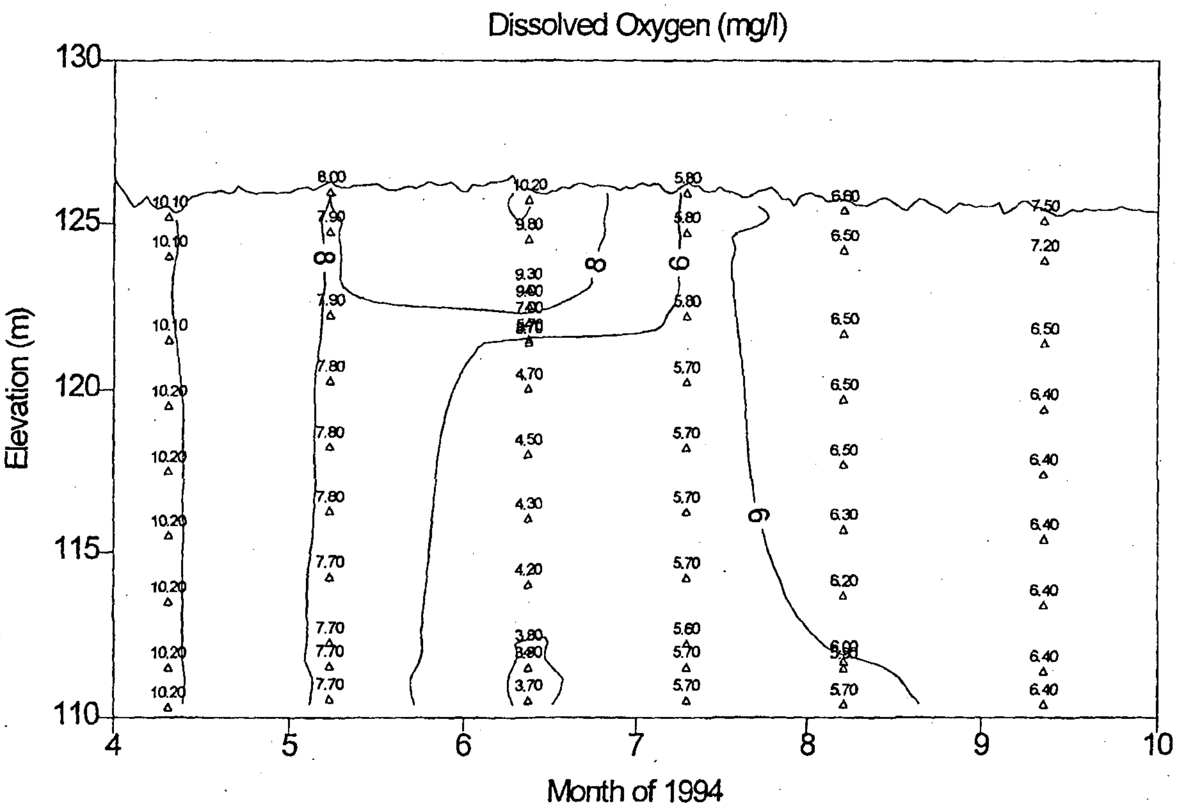


Dissolved Oxygen (mg/l)



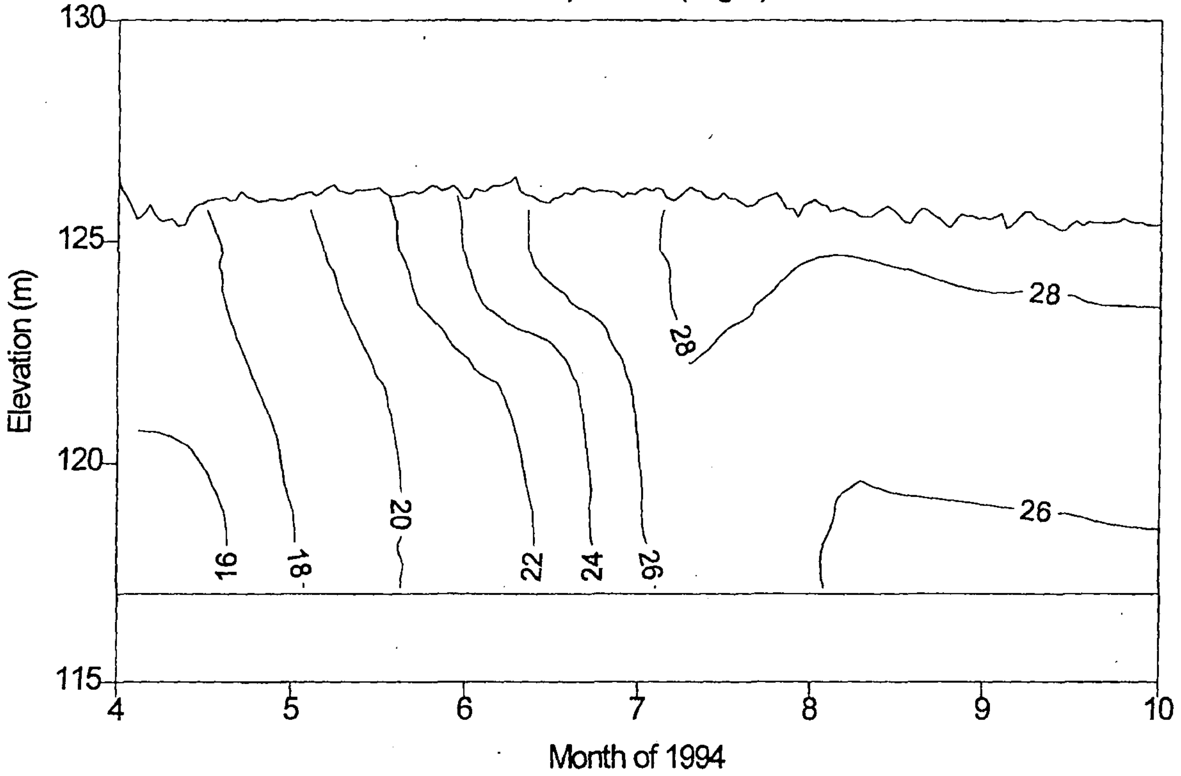
Pickwick Reservoir - TRM 230.3



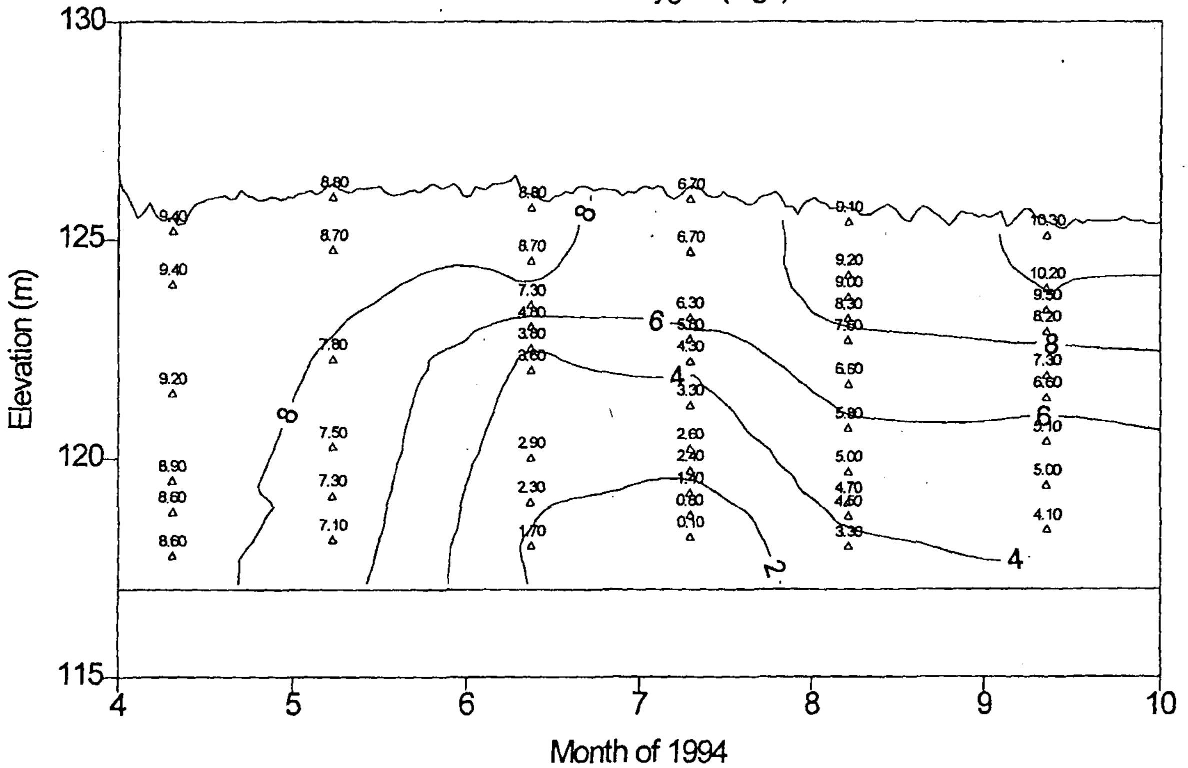


Pickwick Reservoir - Bear Creek Mile 8.4

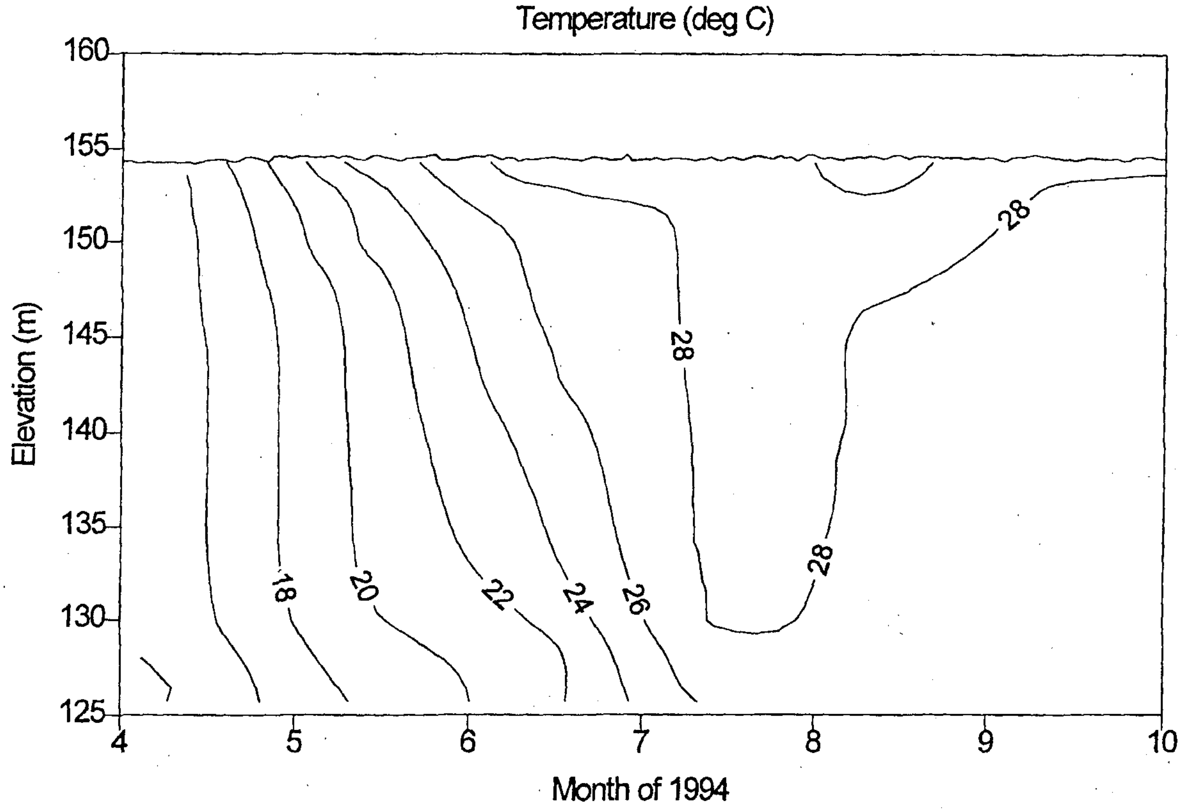
Temperature (deg C)

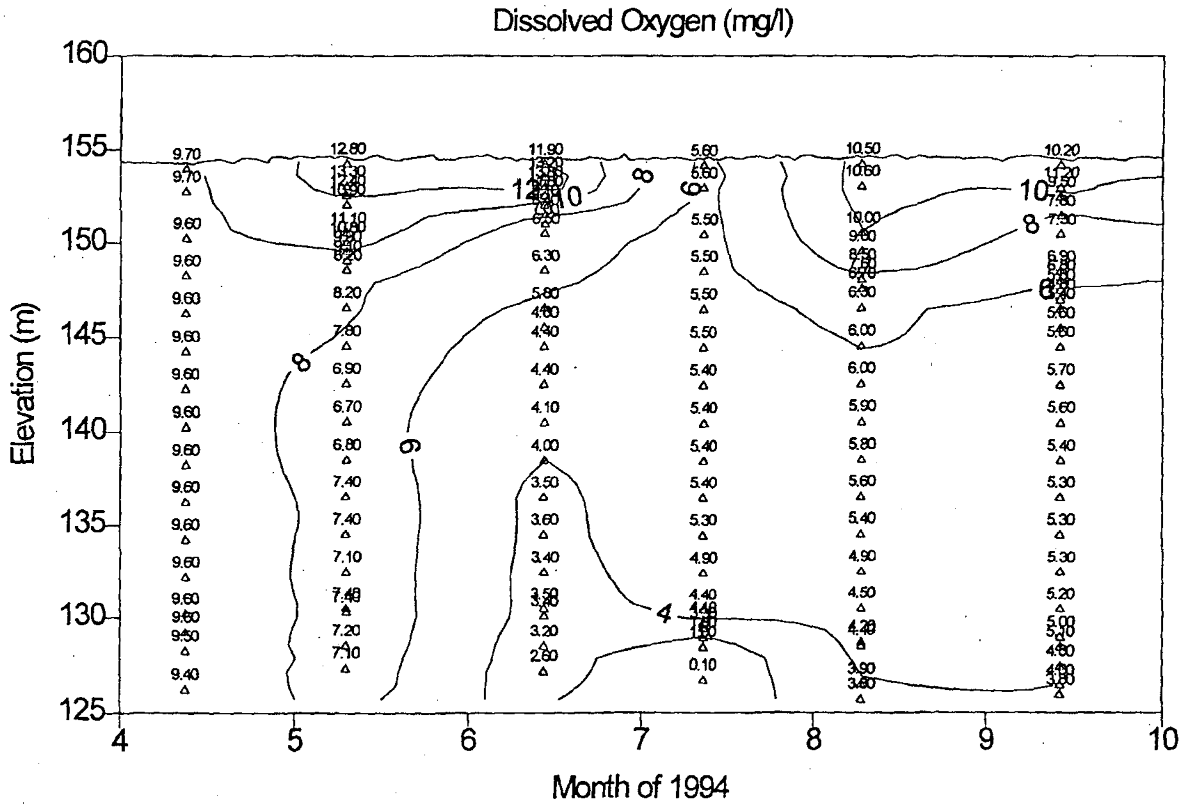


Dissolved Oxygen (mg/l)



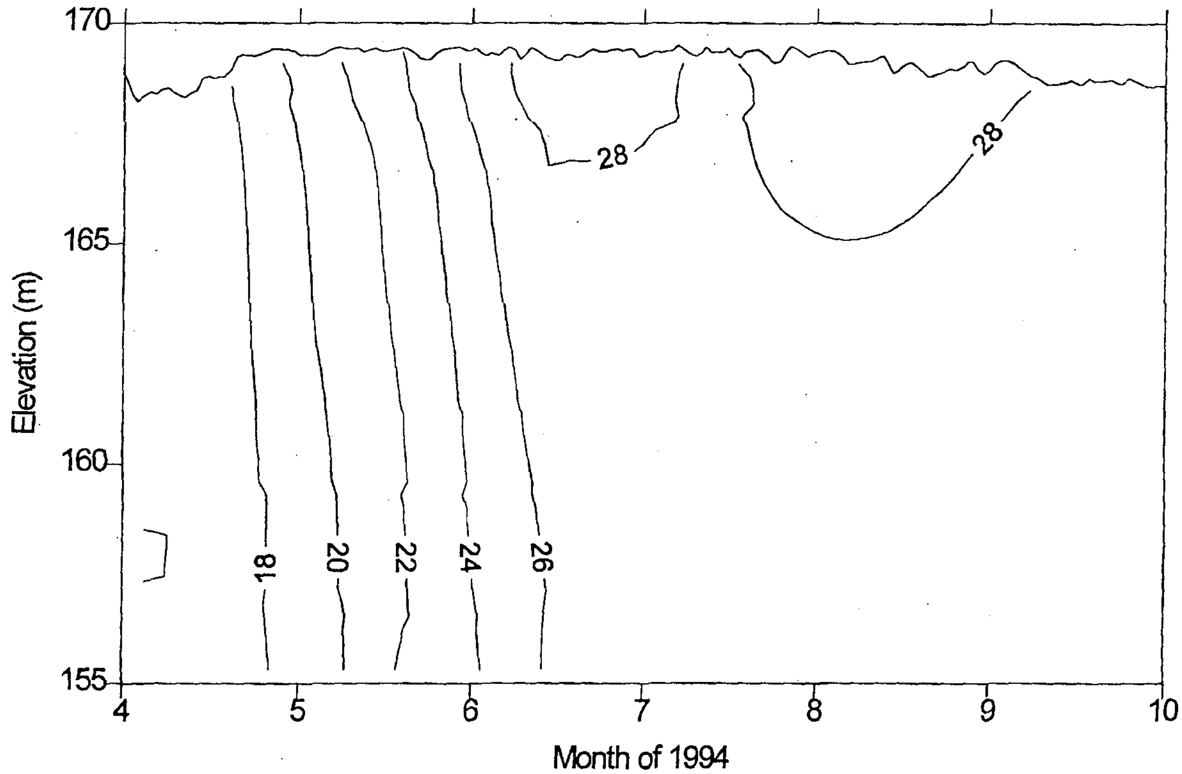
Wilson Reservoir - TRM 260.8



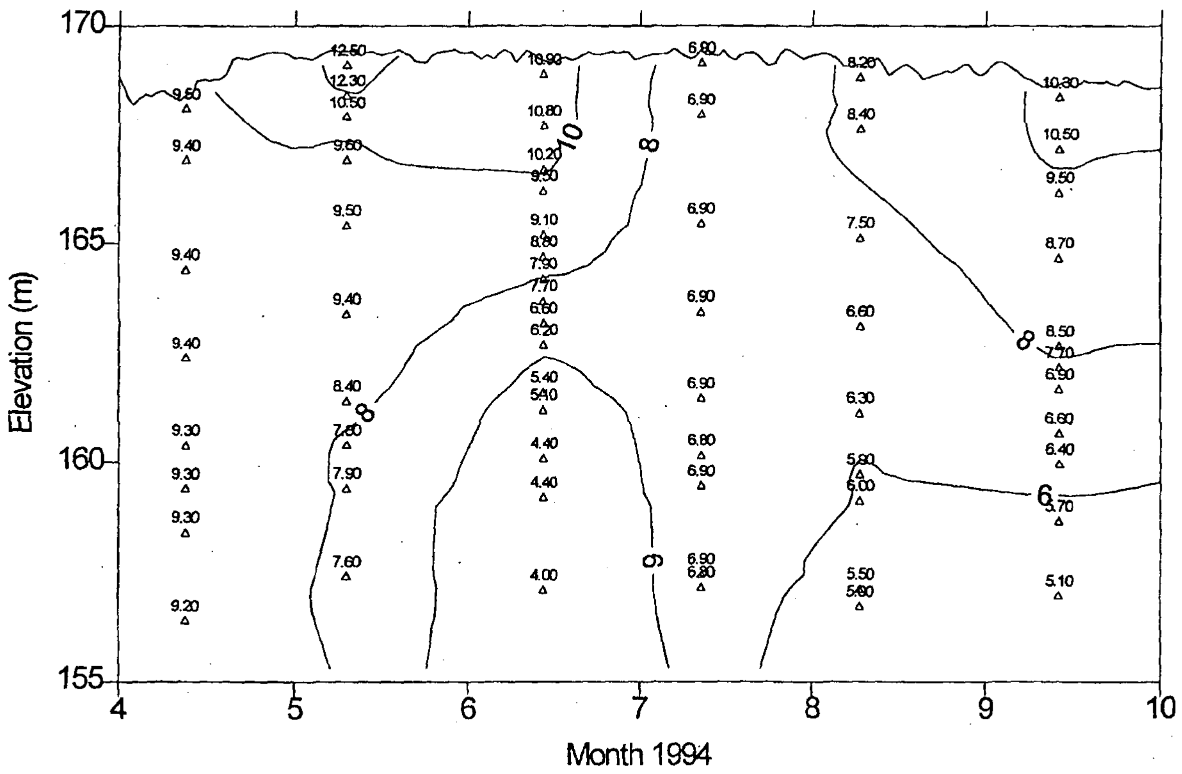


Wheeler Reservoir - TRM 277.0

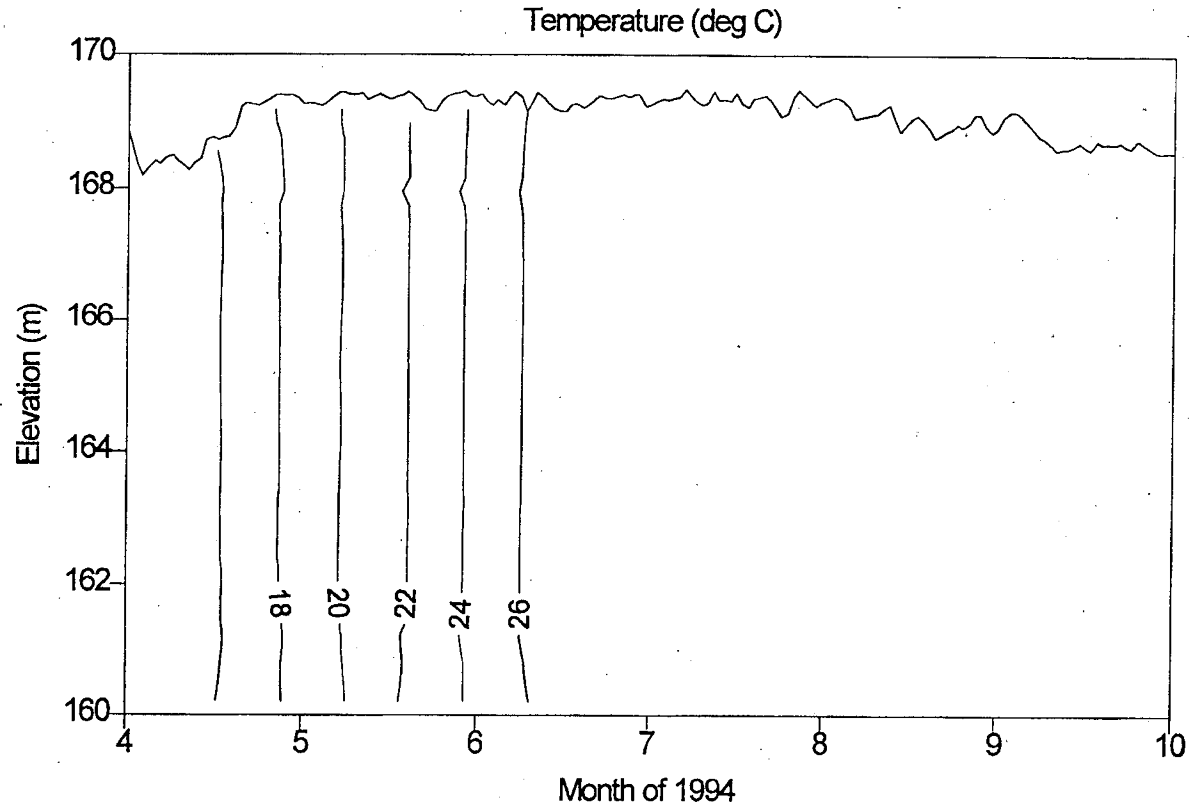
Temperature (deg C)

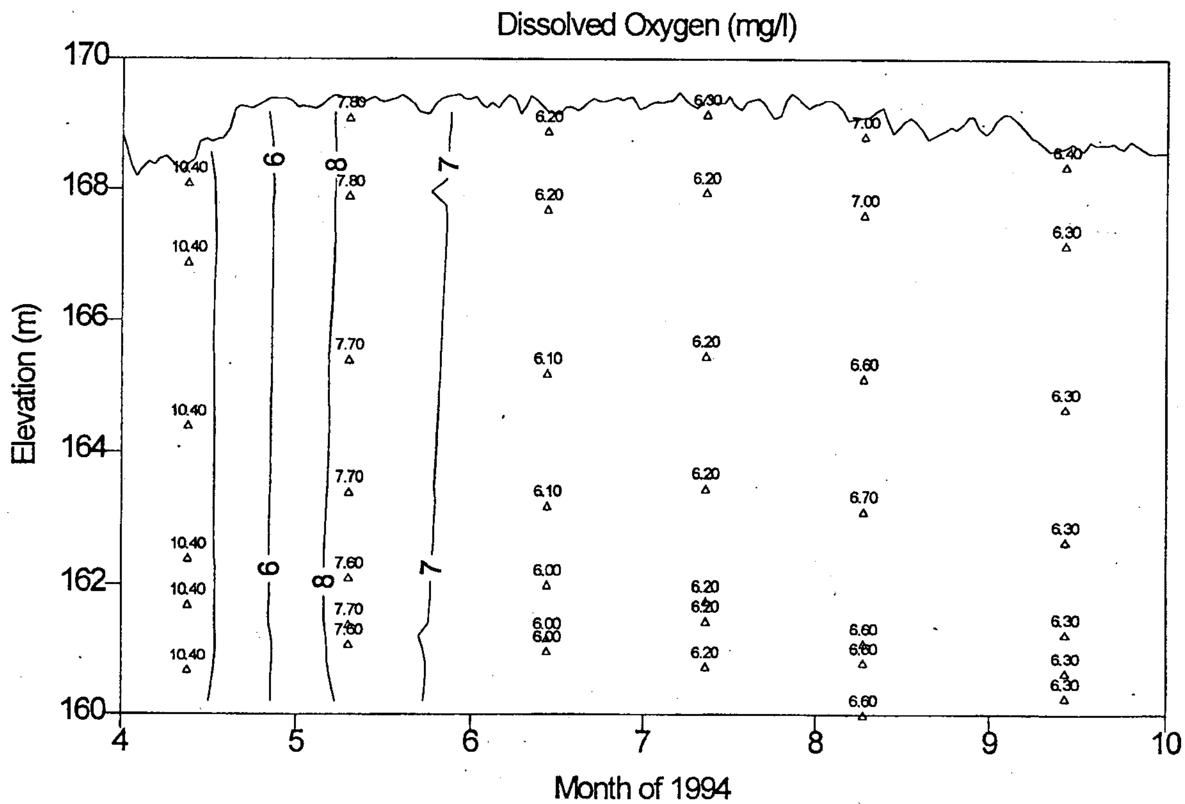


Dissolved Oxygen (mg/l)



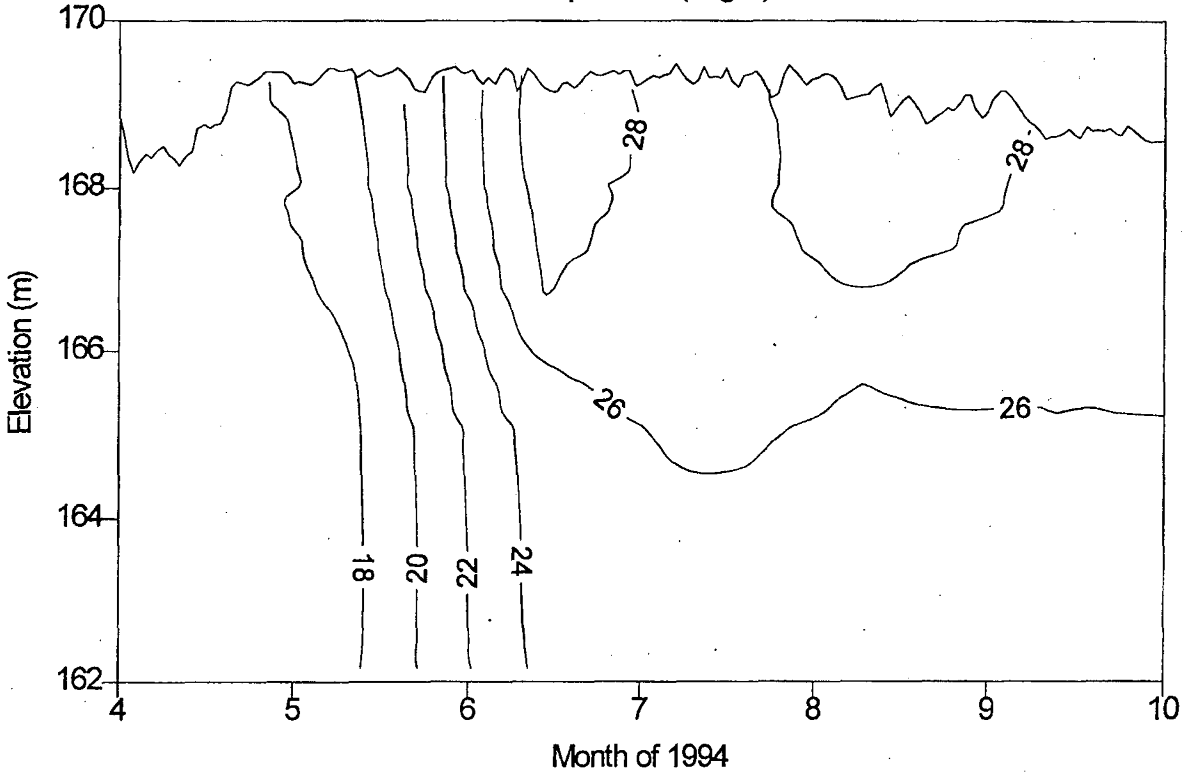
Wheeler Reservoir - TRM 295.87



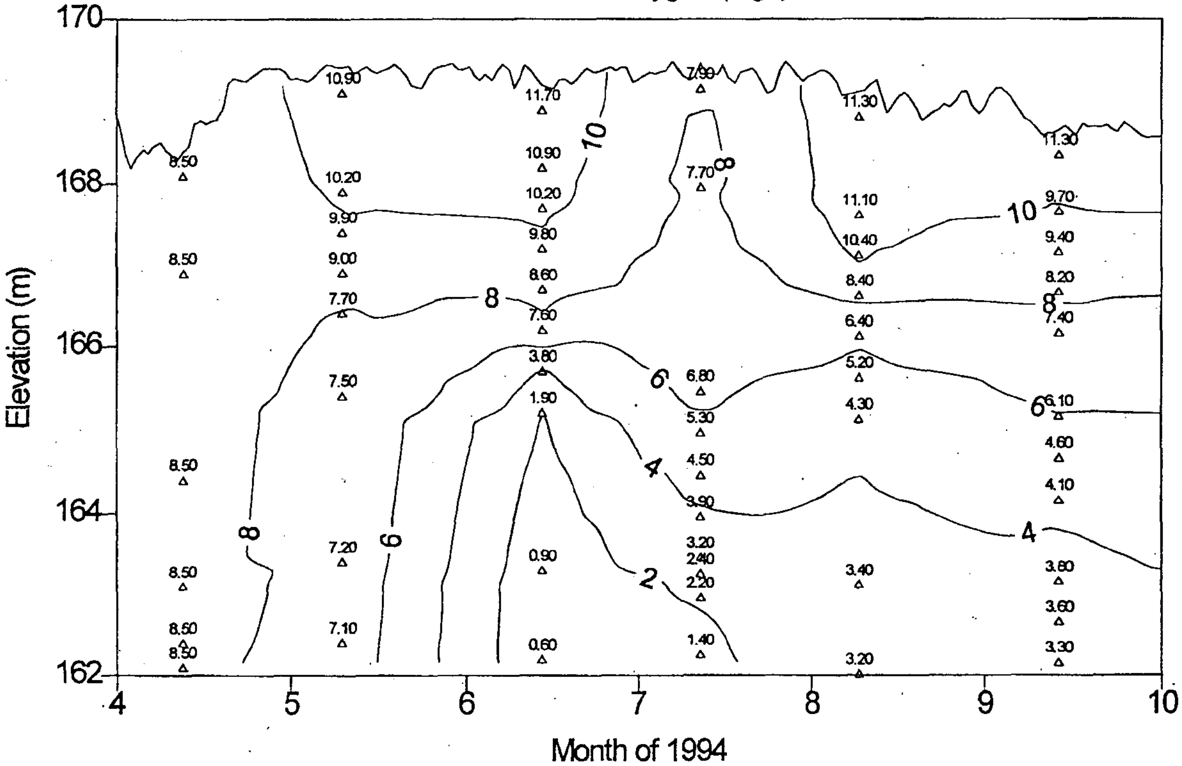


Wheeler Reservoir - Elk River Mile 6.0

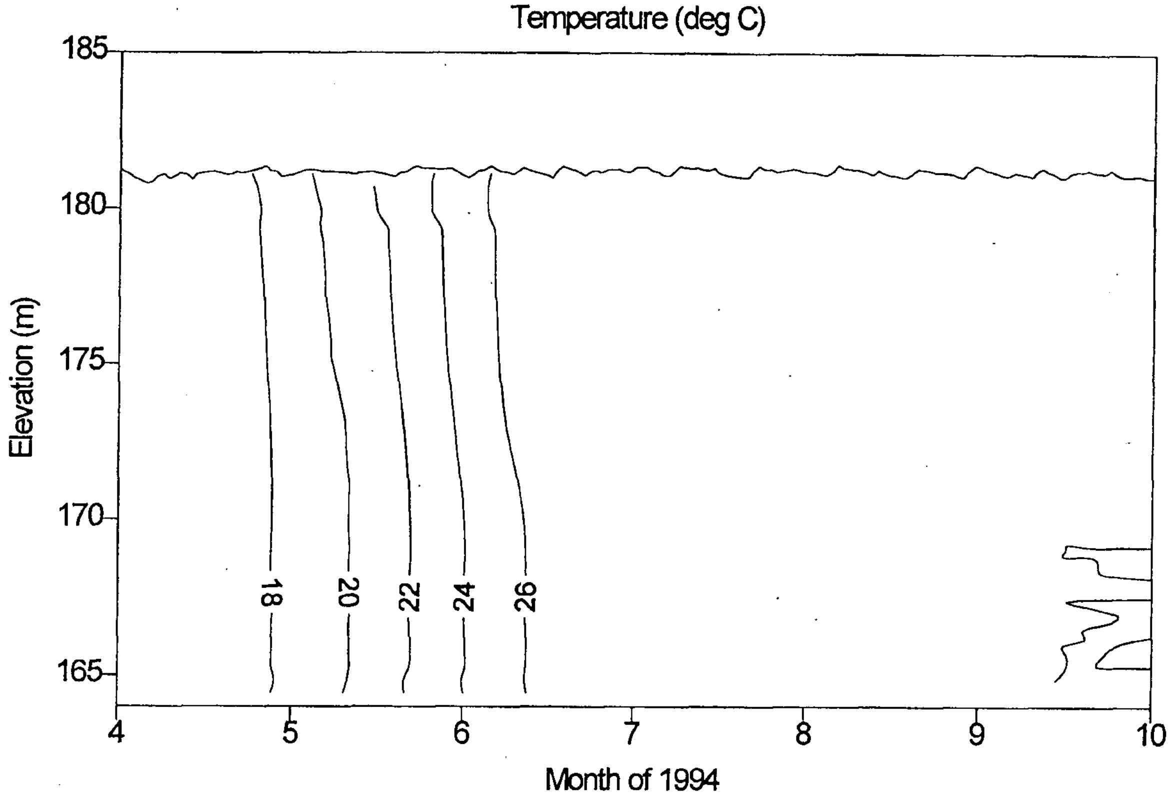
Temperature (deg C)

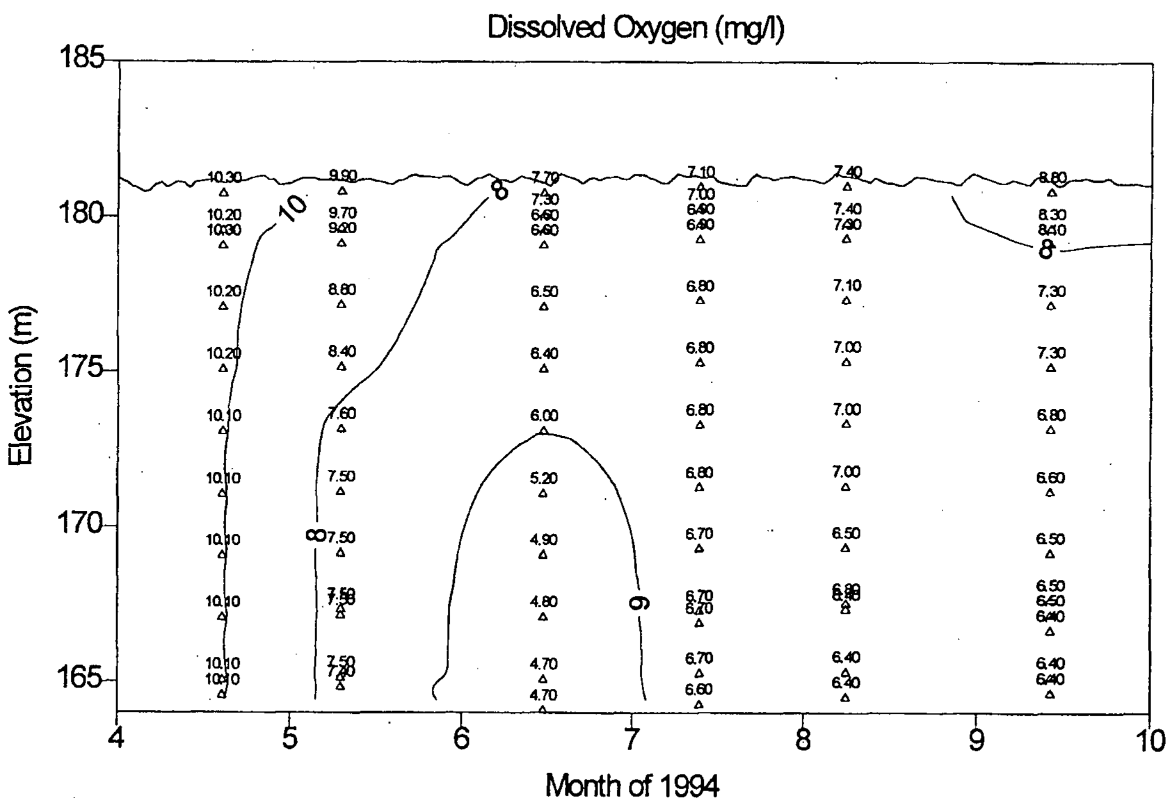


Dissolved Oxygen (mg/l)

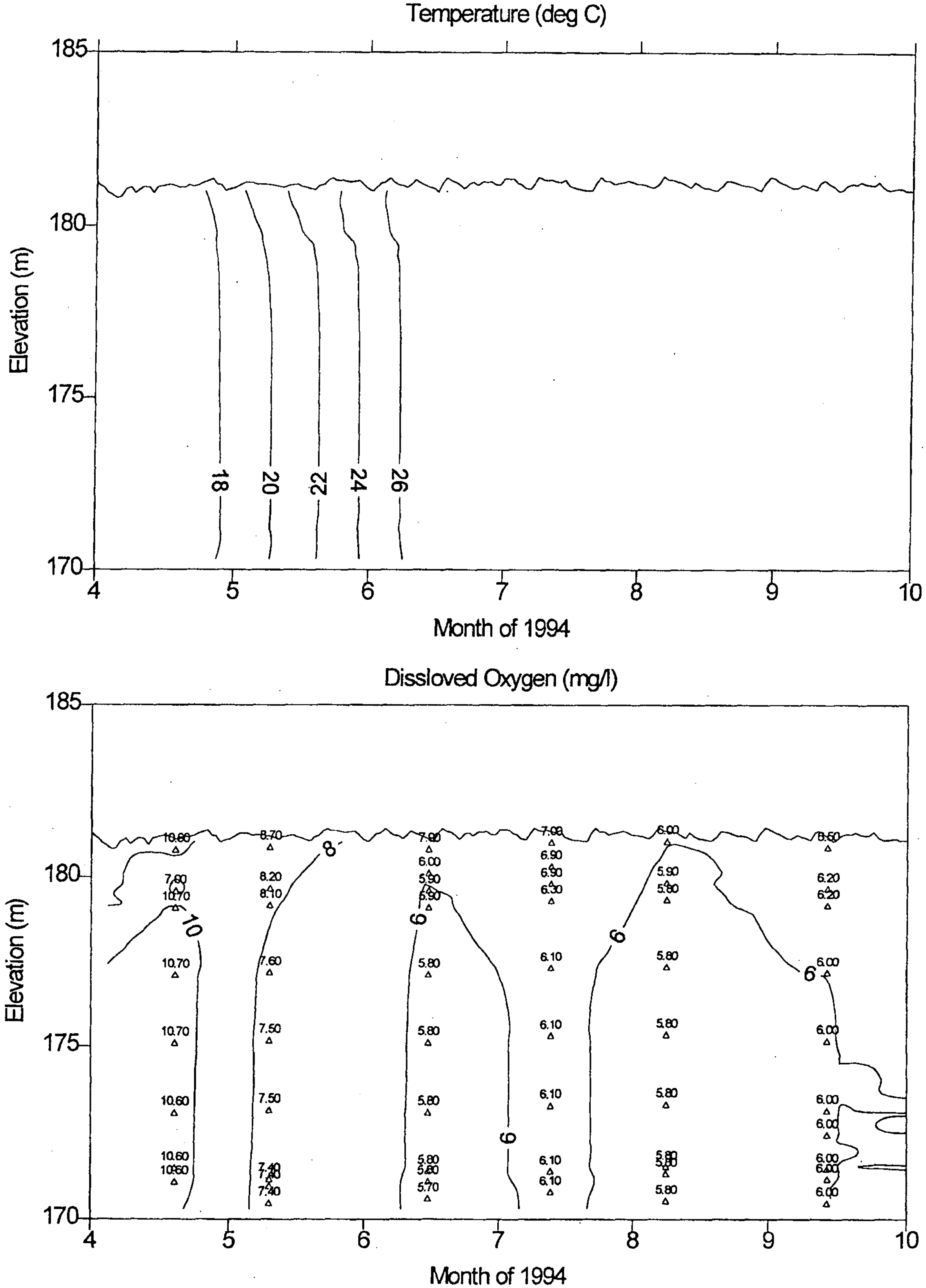


Guntersville Reservoir - TRM 350.0

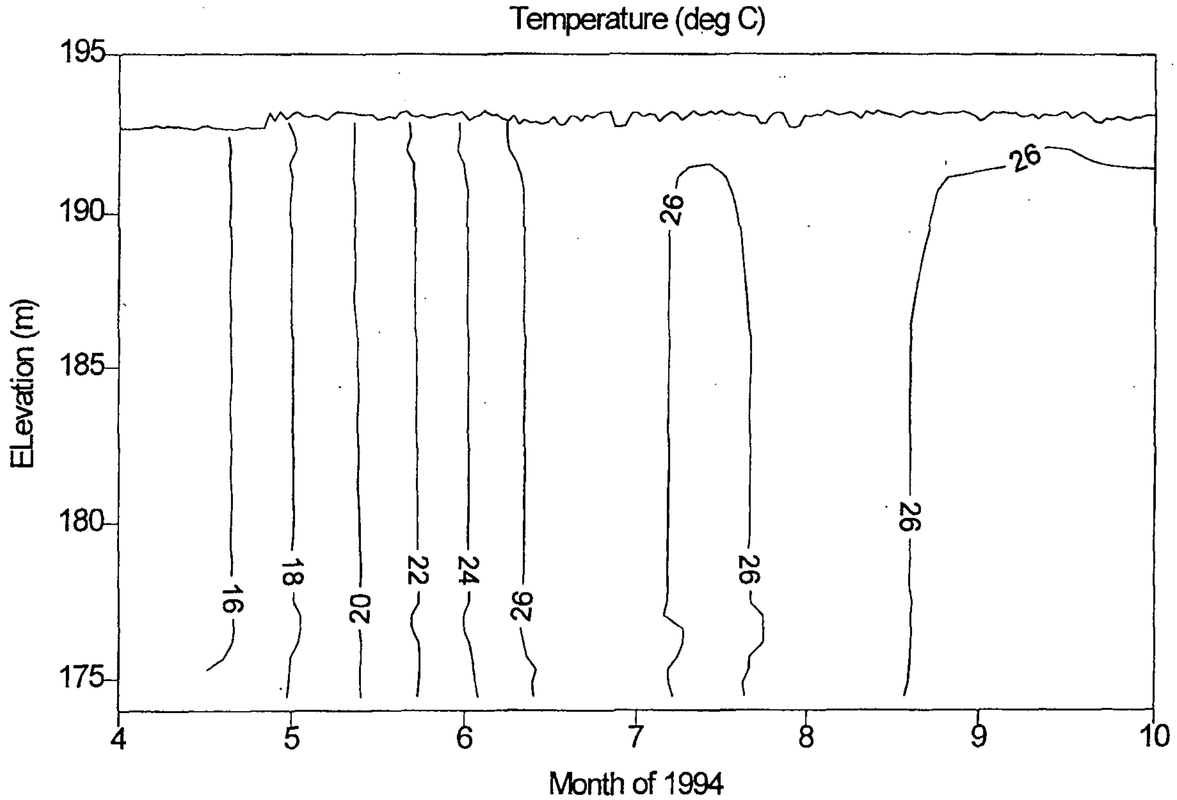


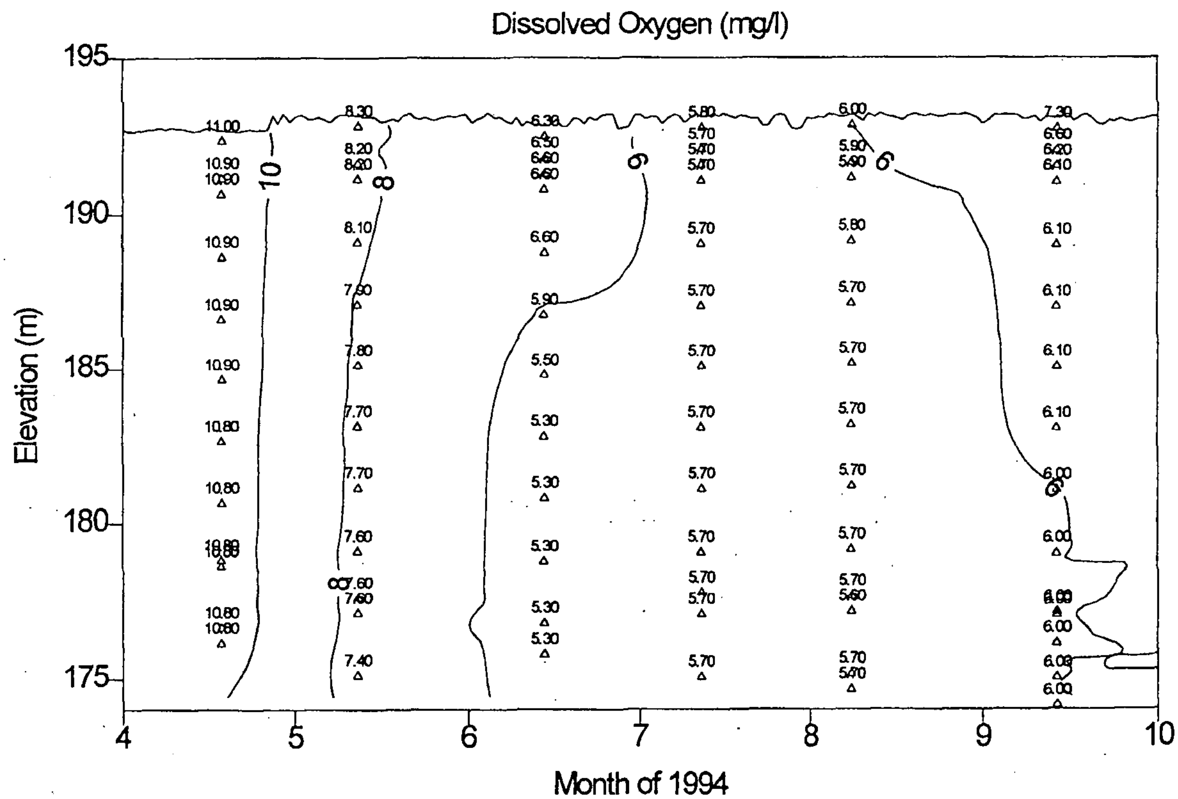


Guntersville Reservoir - TRM 375.2



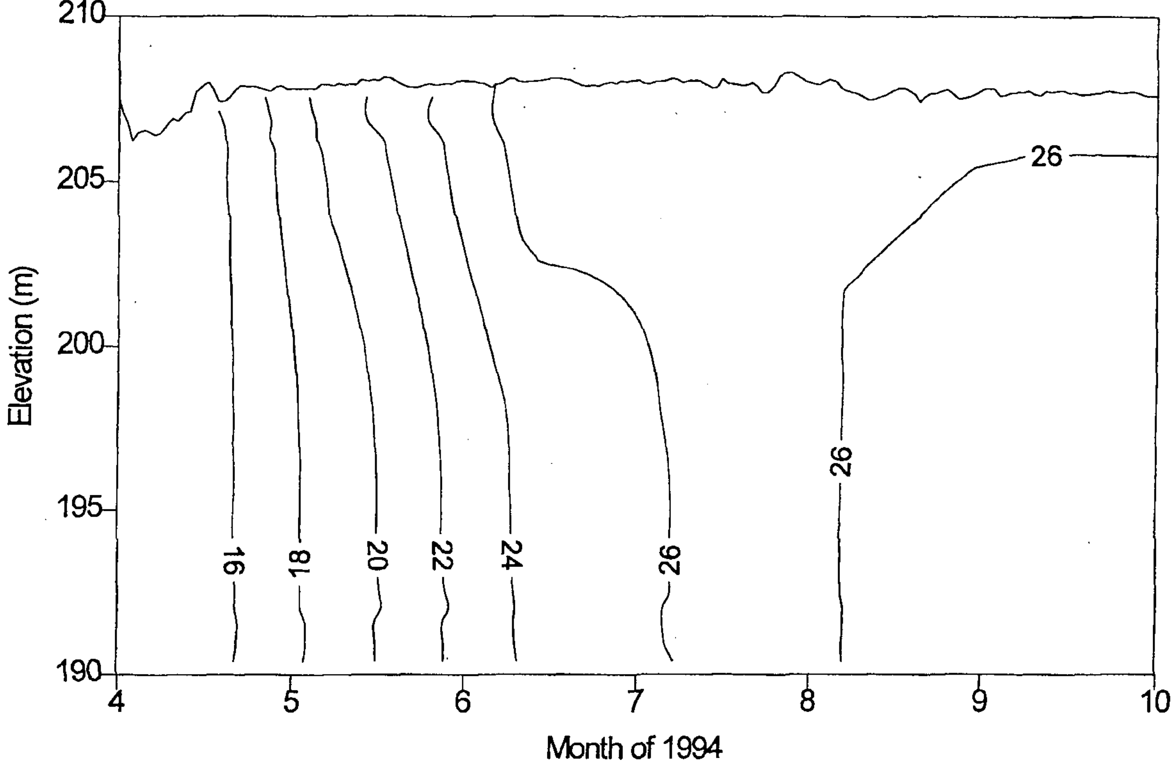
Nickajack Reservoir - TRM 425.5



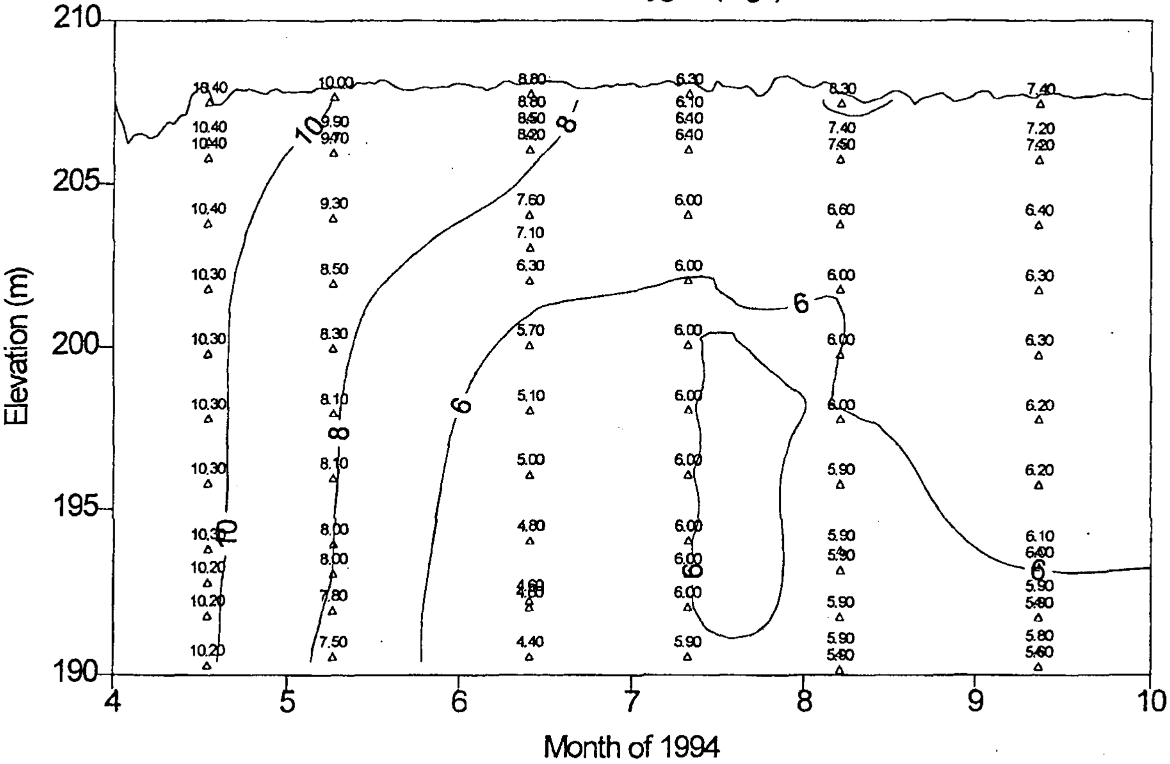


Chickamauga Reservoir - TRM 472.3

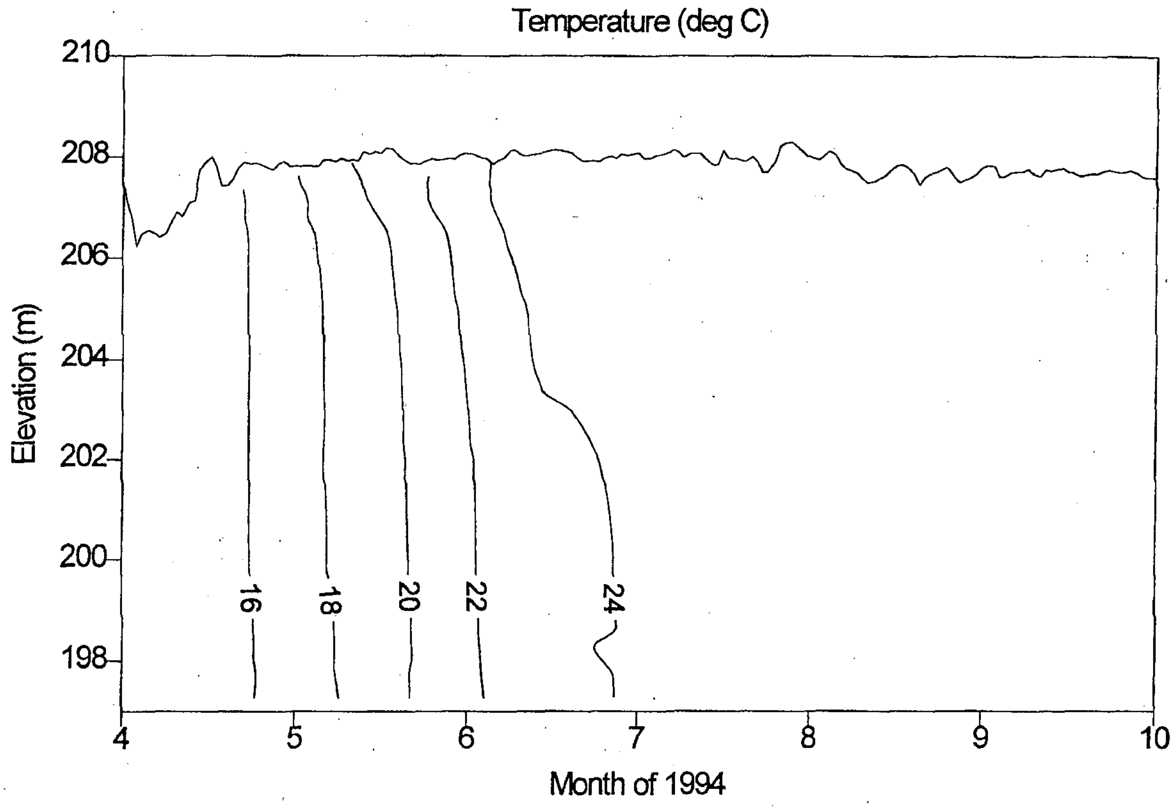
Temperature (deg C)

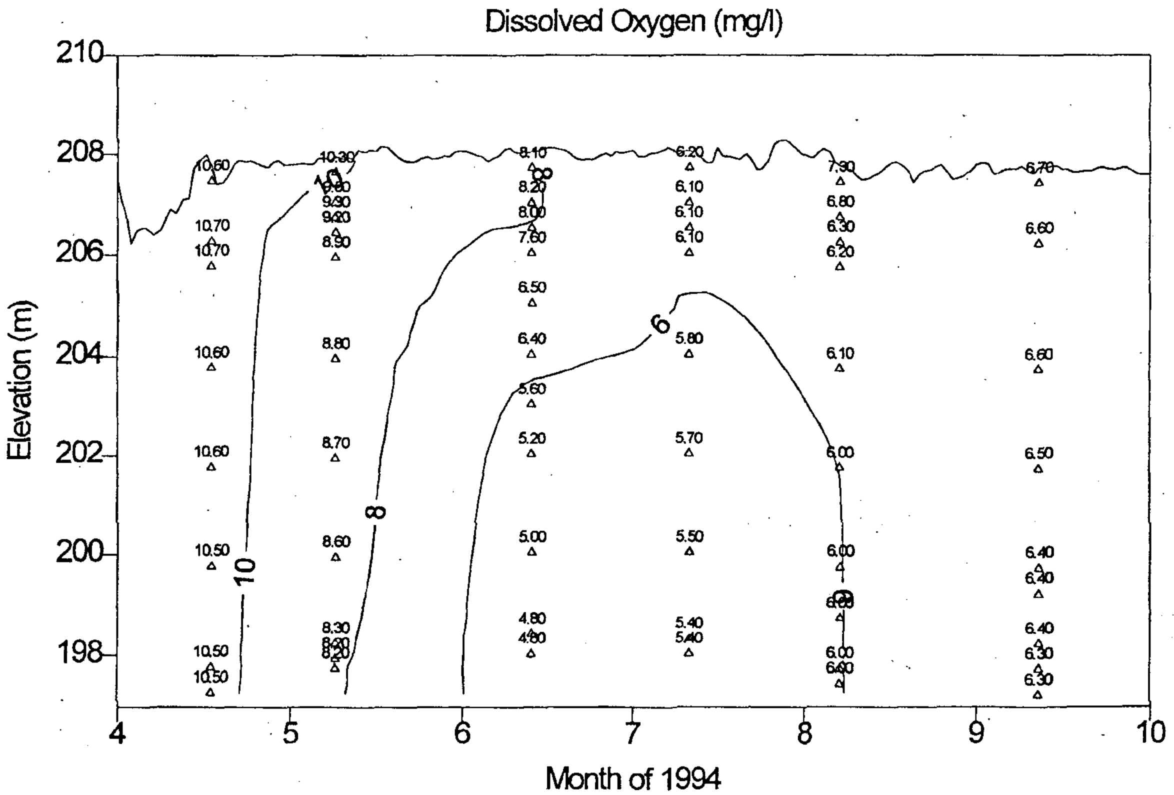


Dissolved Oxygen (mg/l)



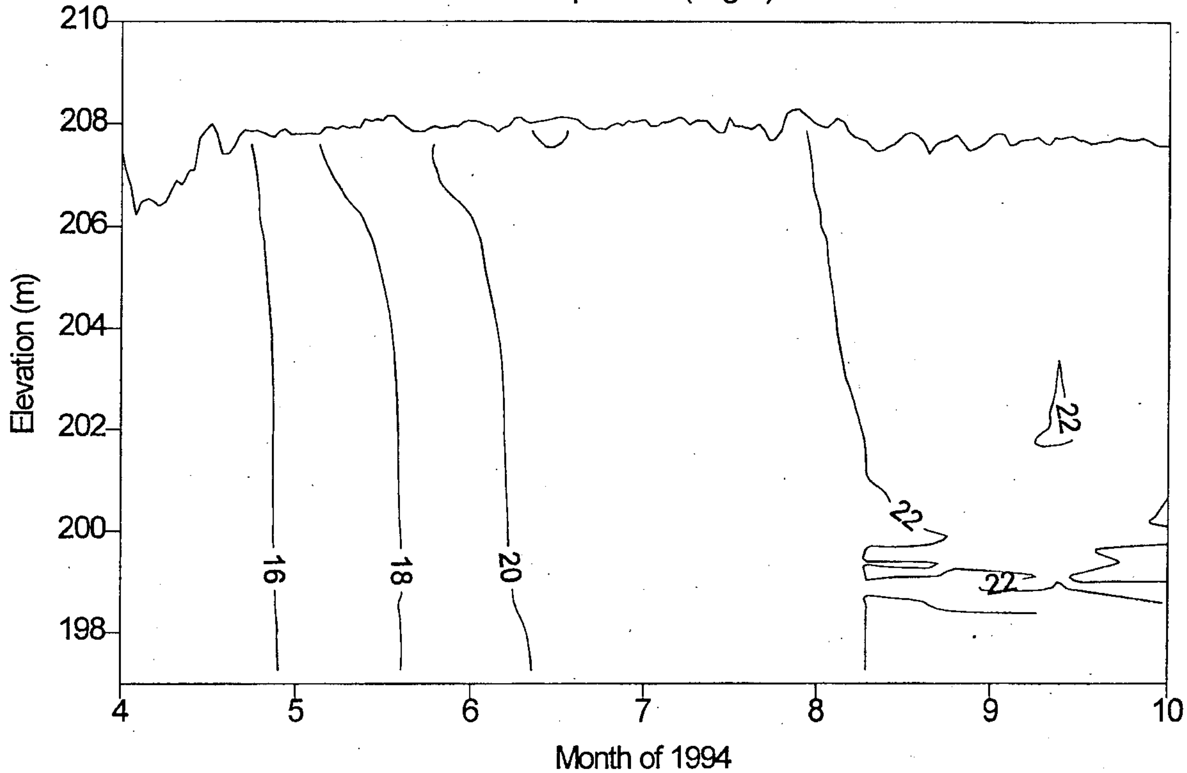
Chickamauga Reservoir - TRM 490.5



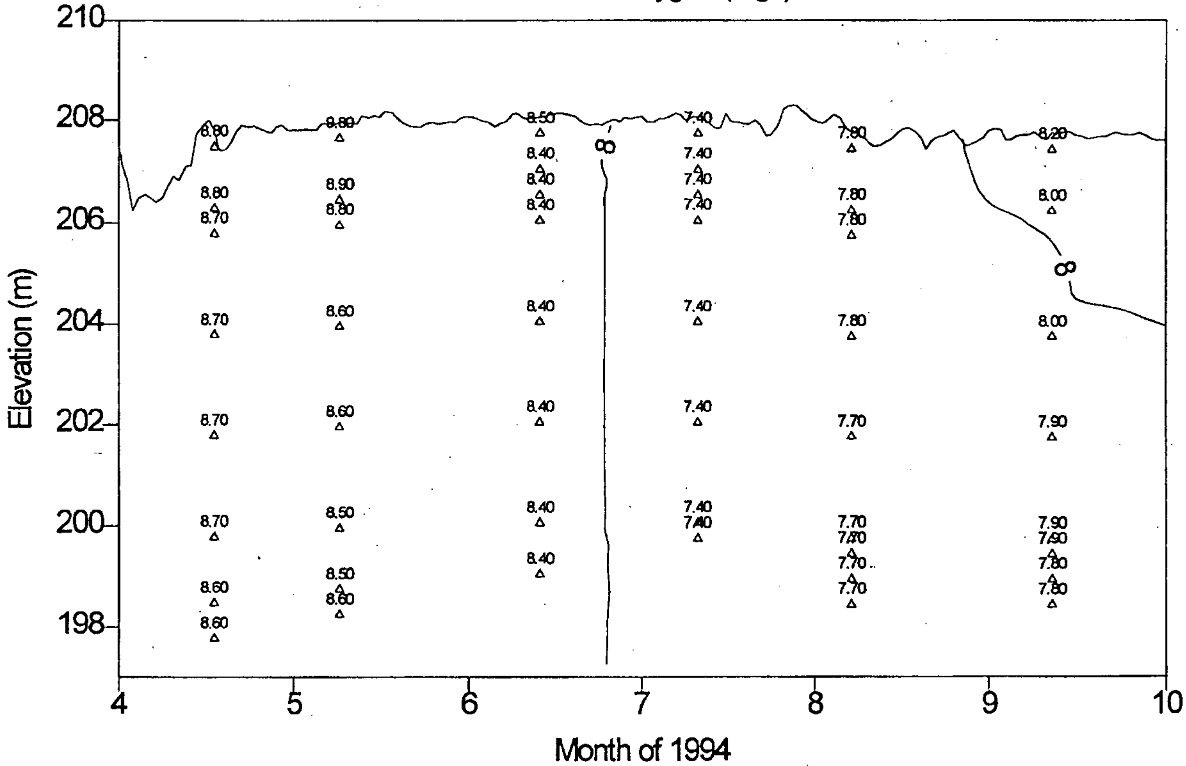


Chickamagua Reservoir - Hiwassee River Mile 8.5

Temperature (deg C)

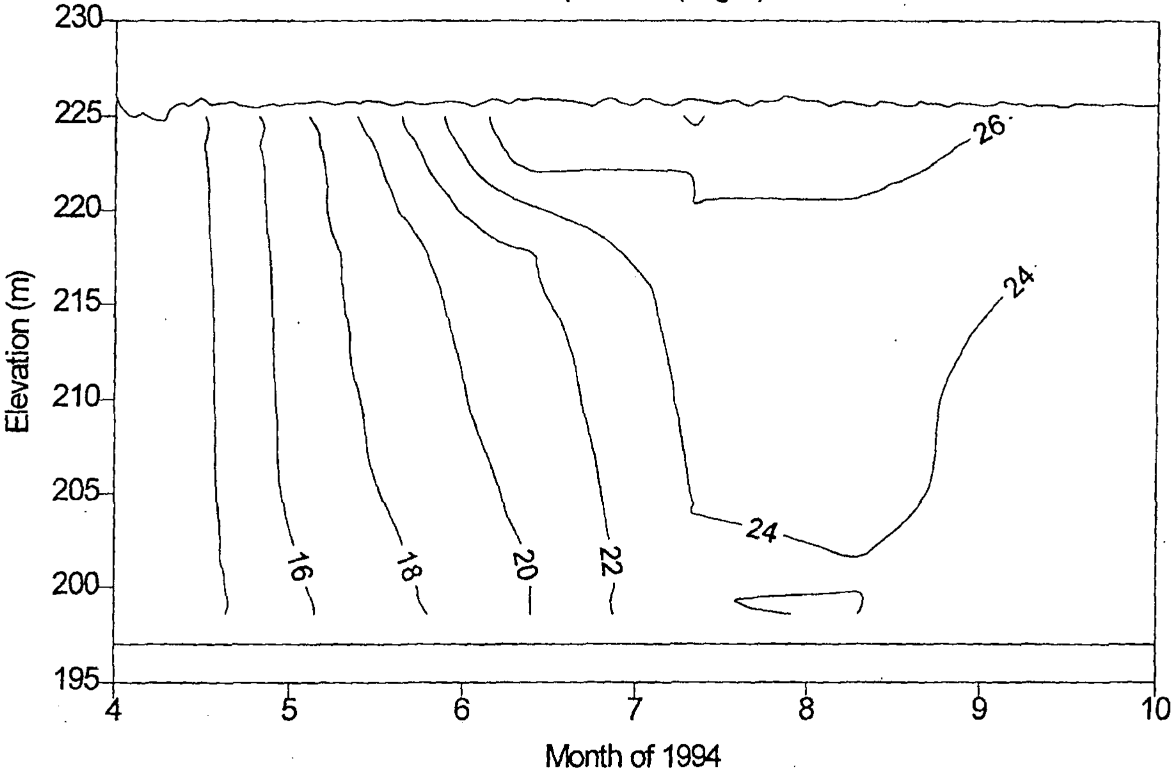


Dissolved Oxygen (mg/l)

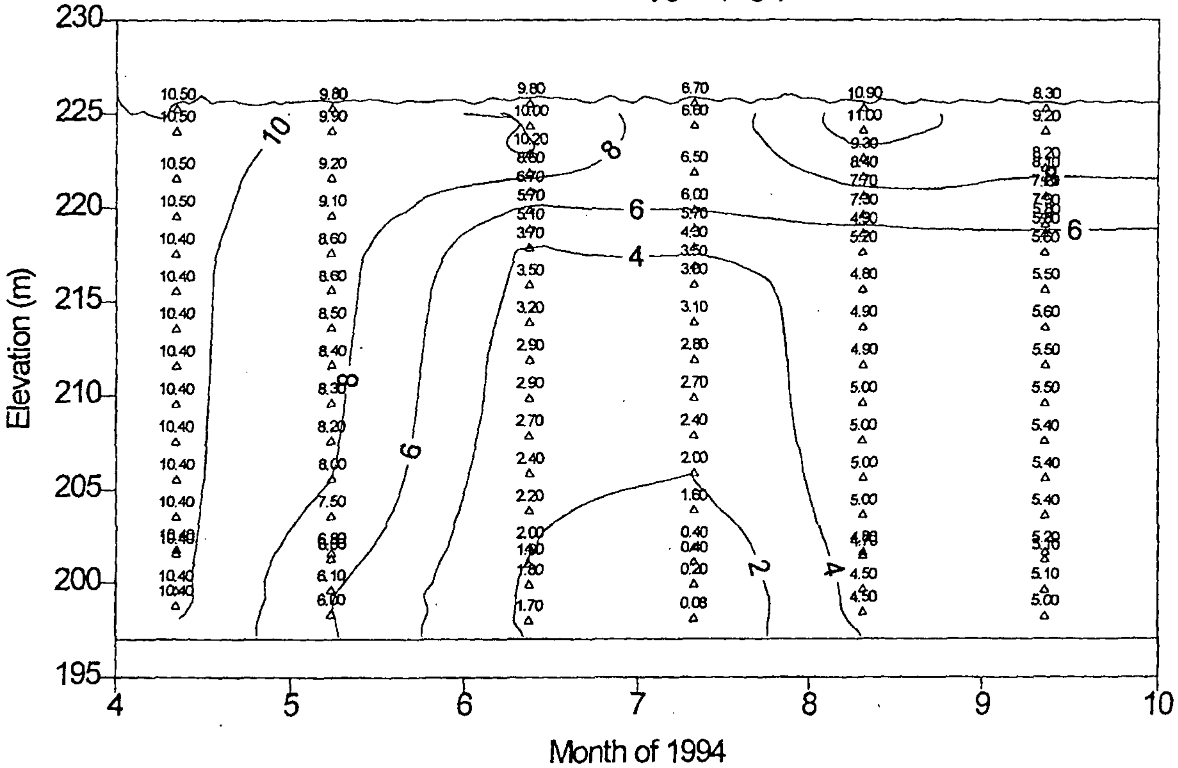


Watts Bar Reservoir - TRM 531.0

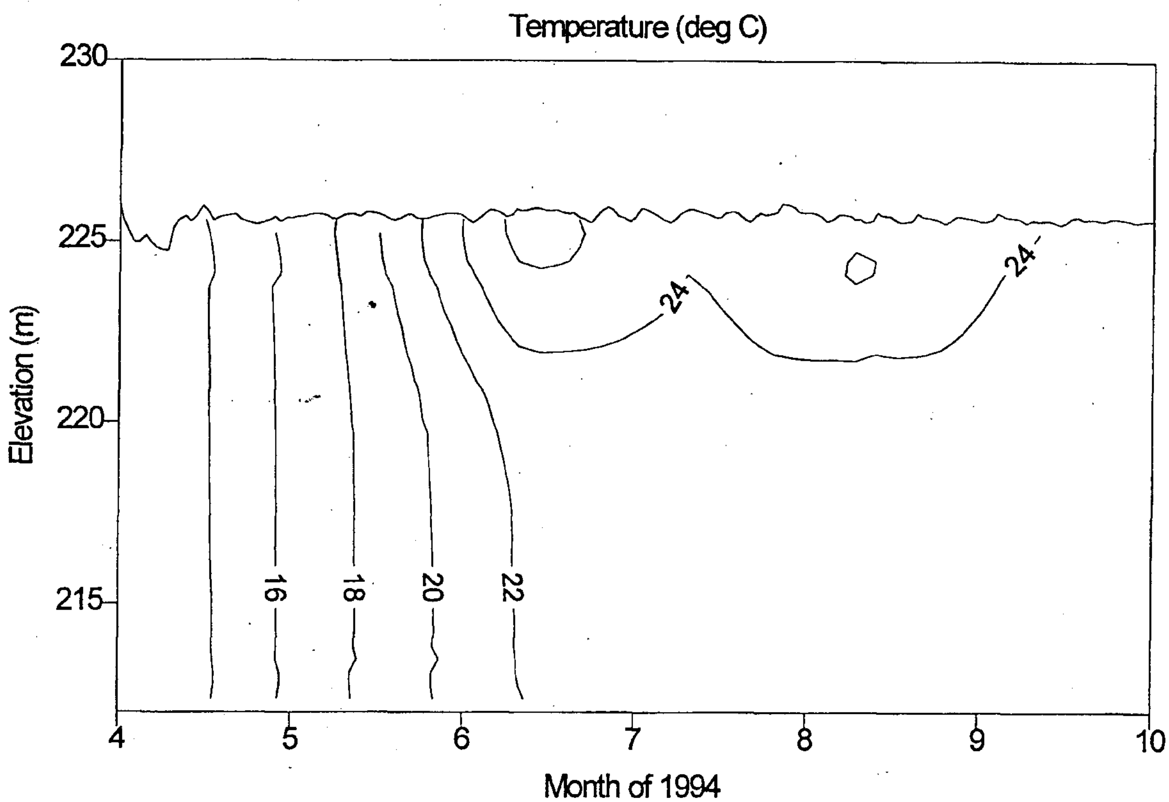
Temperature (deg C)

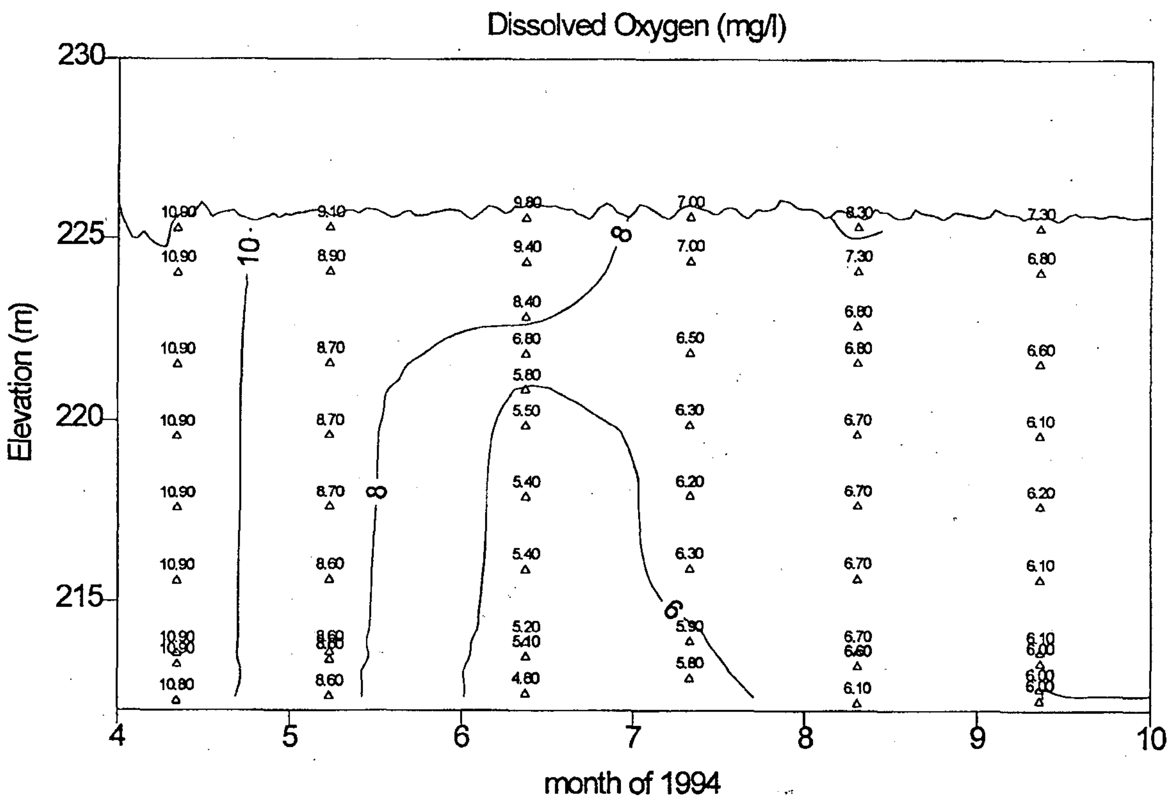


Dissolved Oxygen (mg/l)



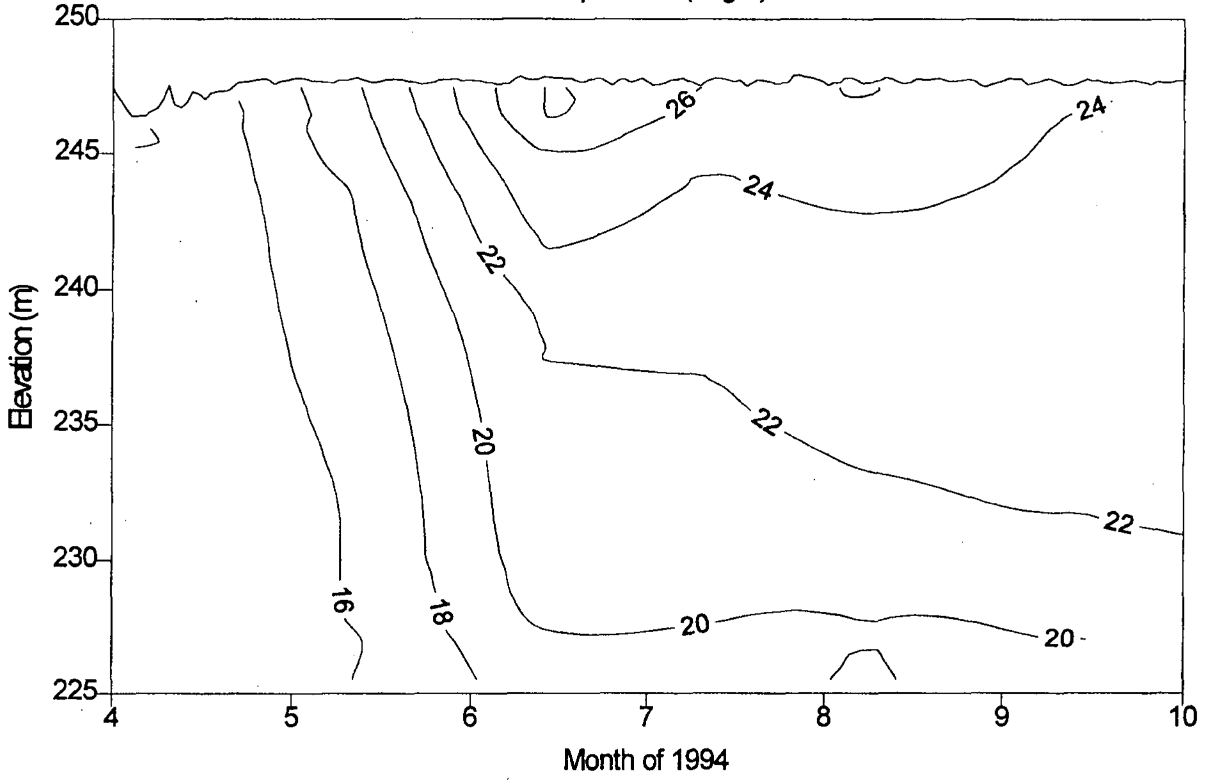
Watts Bar Reservoir - TRM 560.8



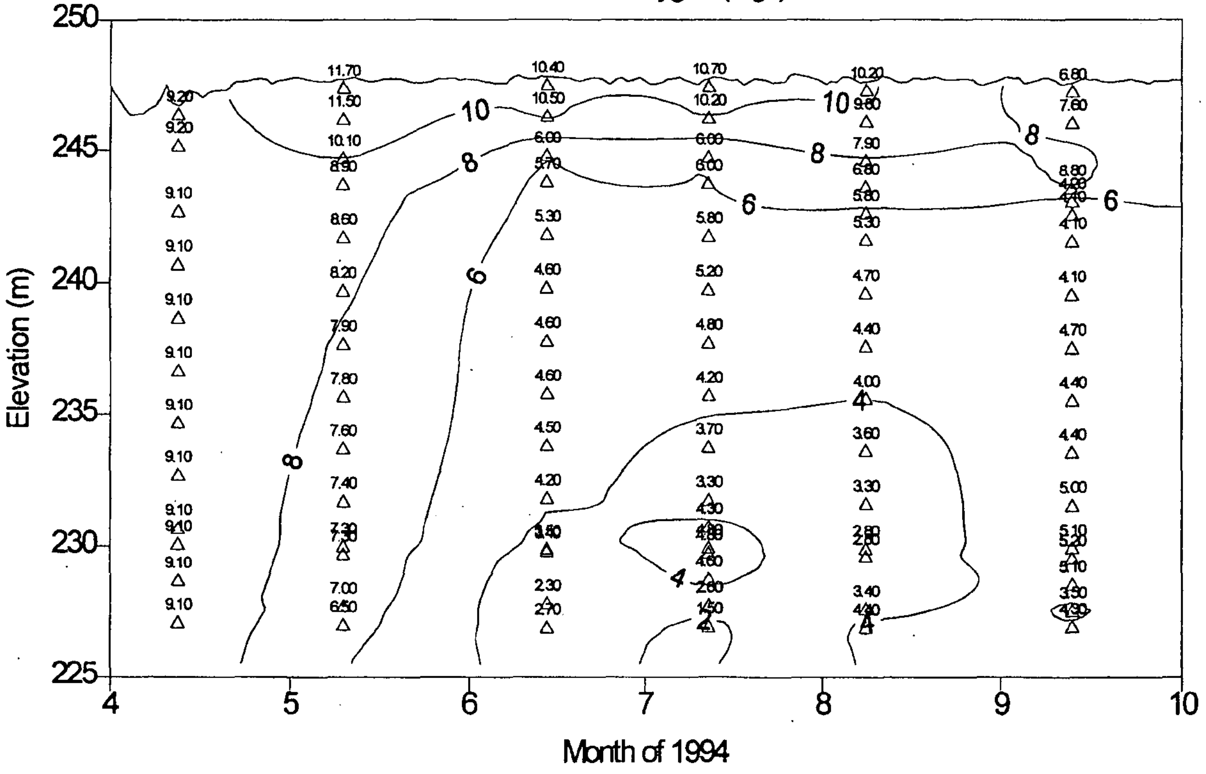


Fort Loudoun Reservoir - TRM 605.5

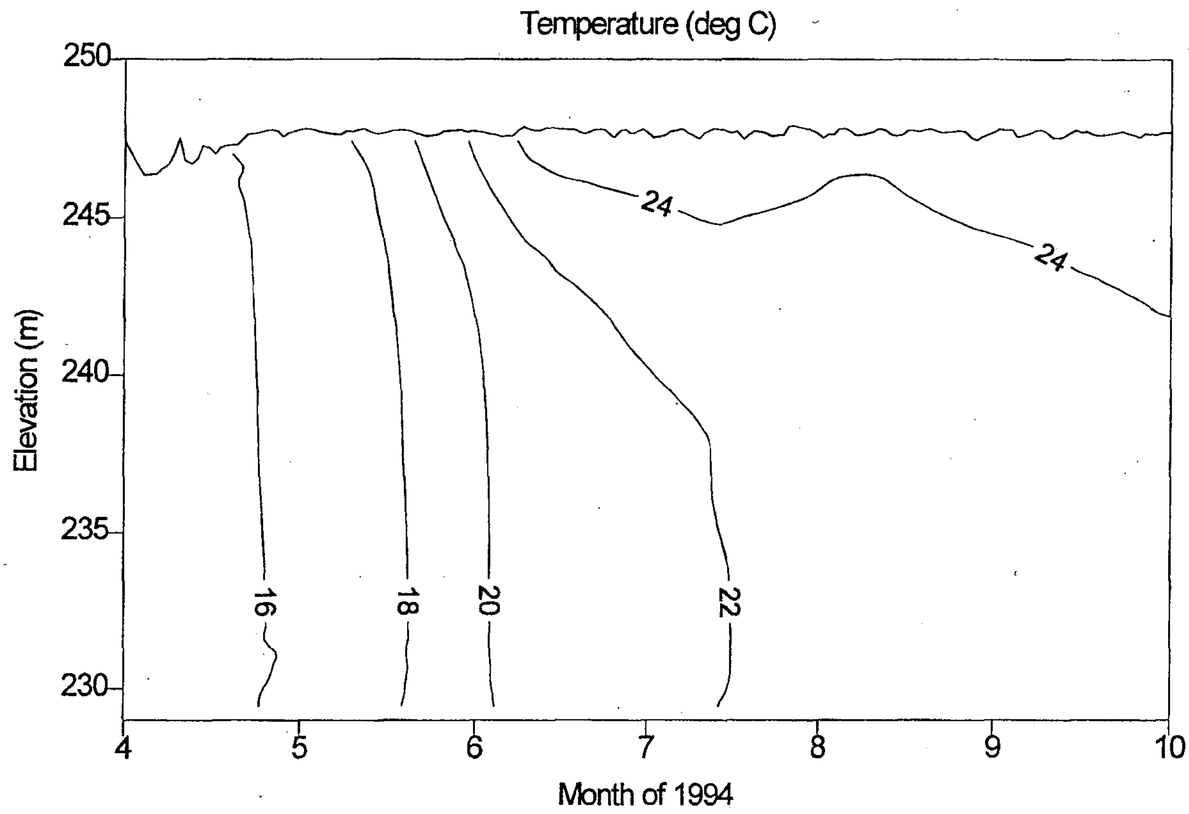
Temperature (deg F)

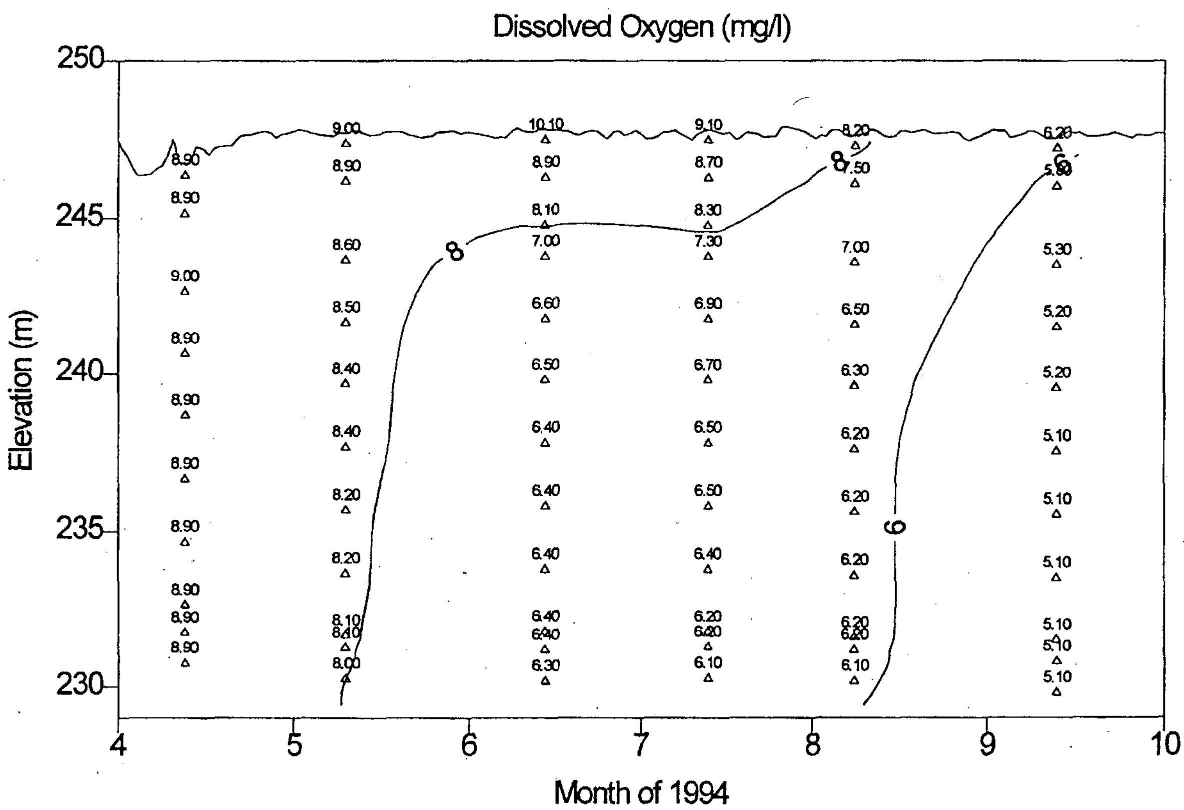


Dissolved Oxygen (mg/l)



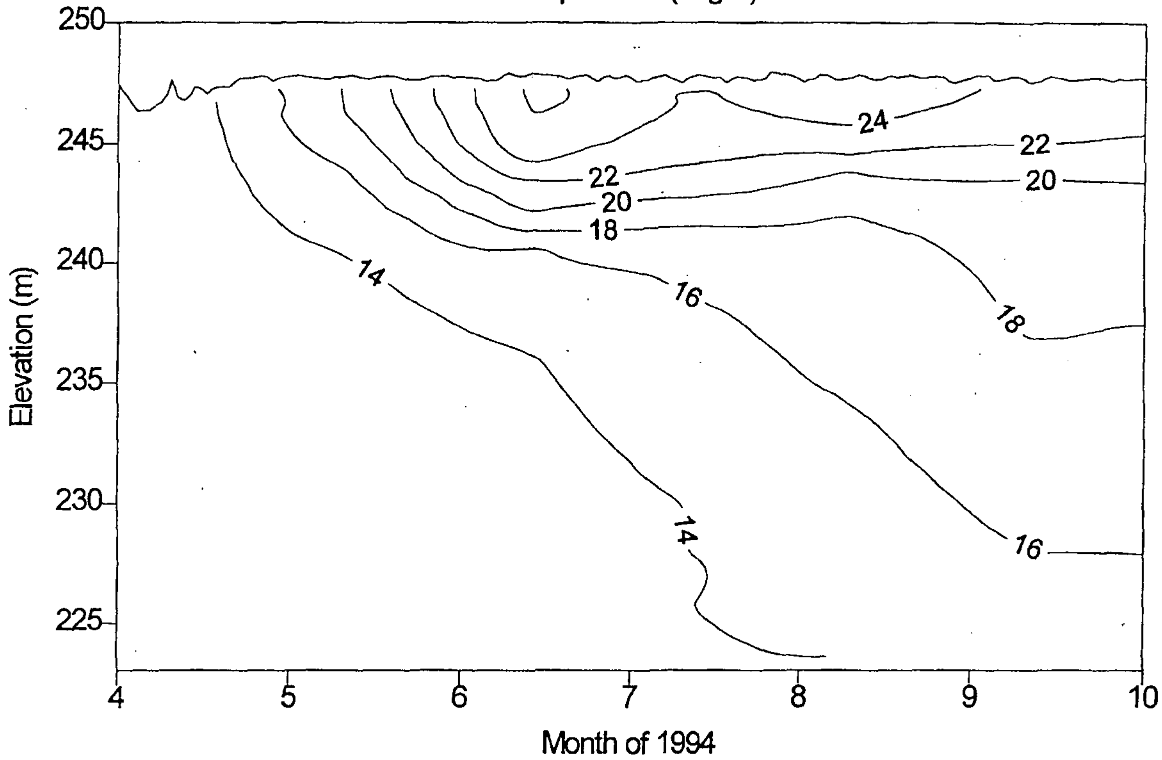
Fort Loudoun Reservoir - TRM 624.6



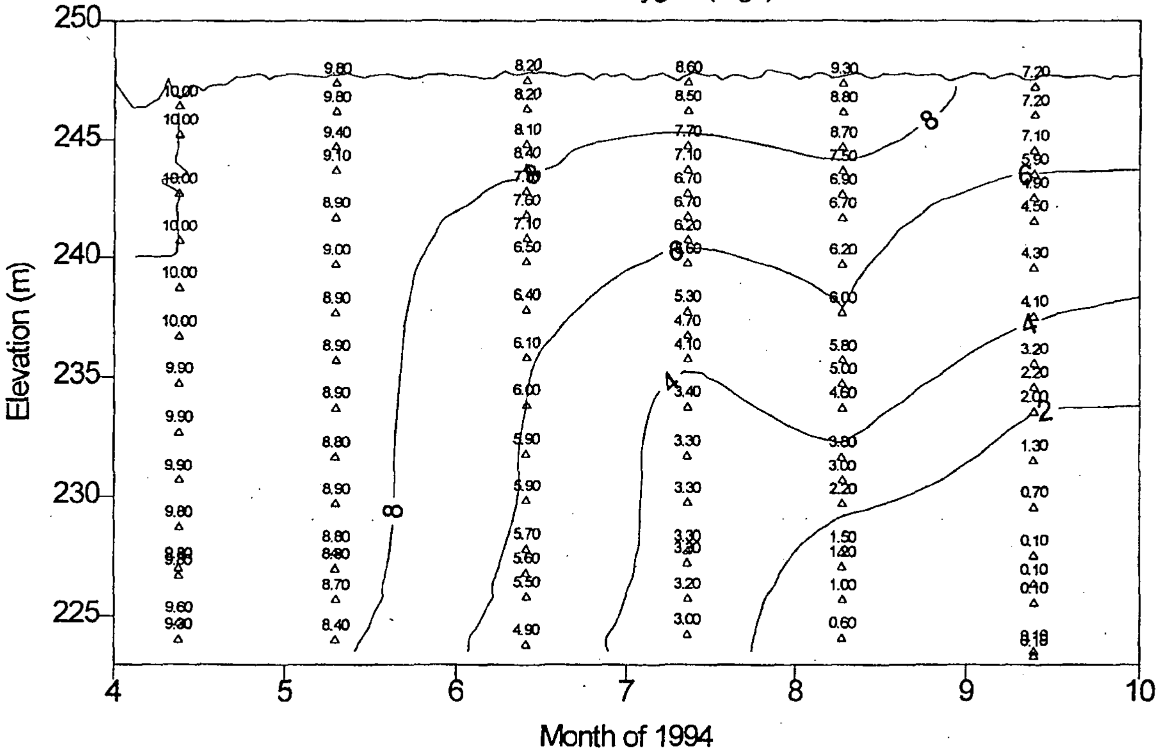


Tellico Reservoir - LTRM 1.0

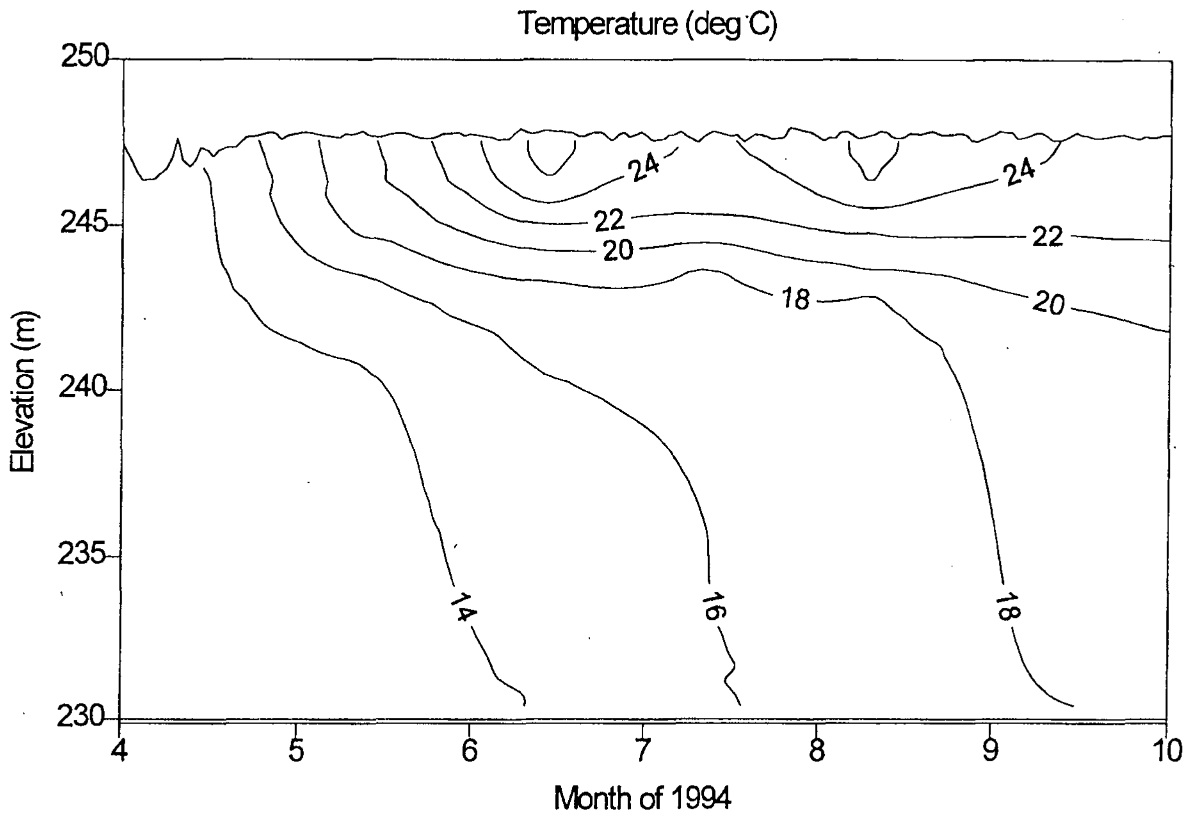
Temperature (deg C)

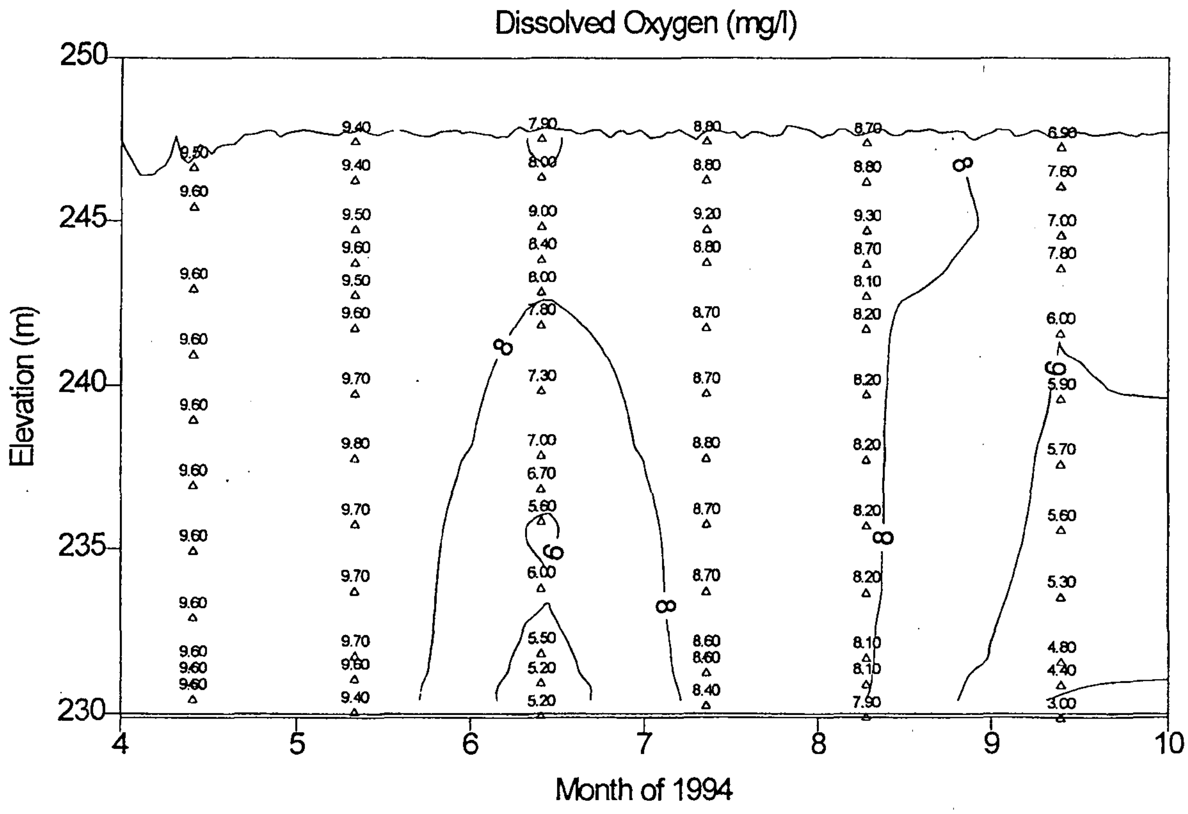


Dissolved Oxygen (mg/l)



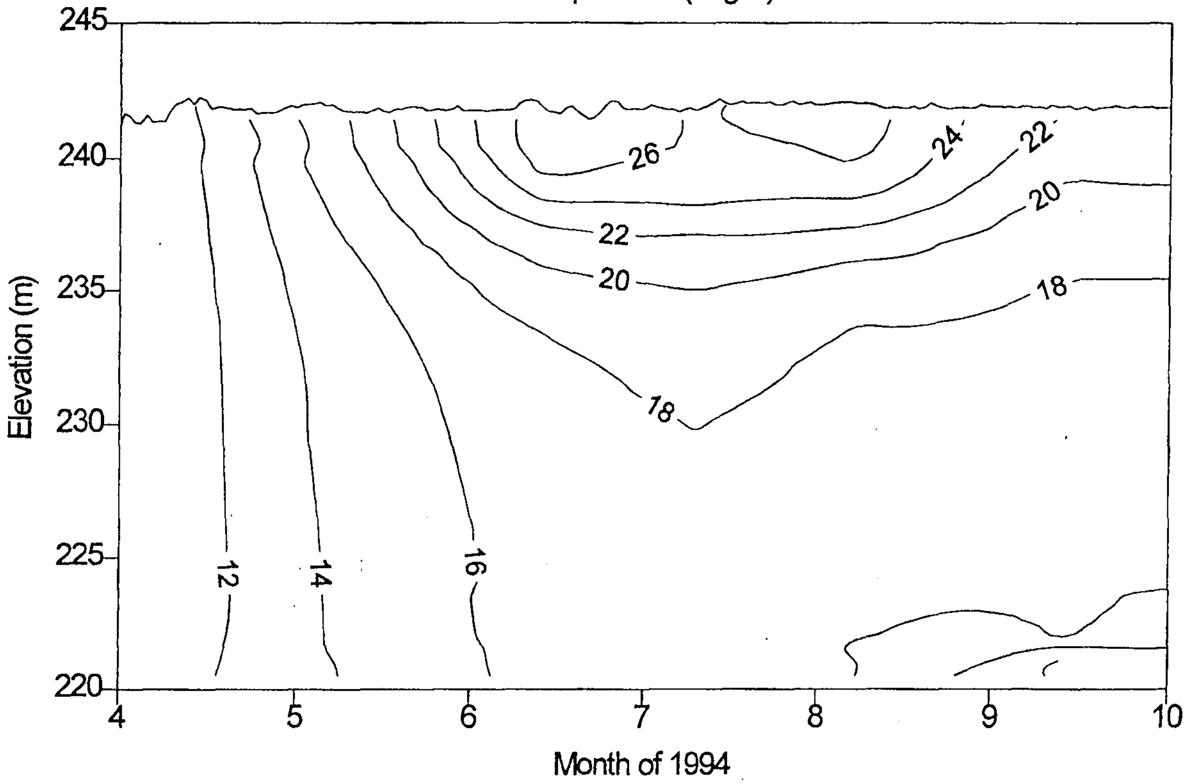
Tellico Reservoir - LTRM 15.0



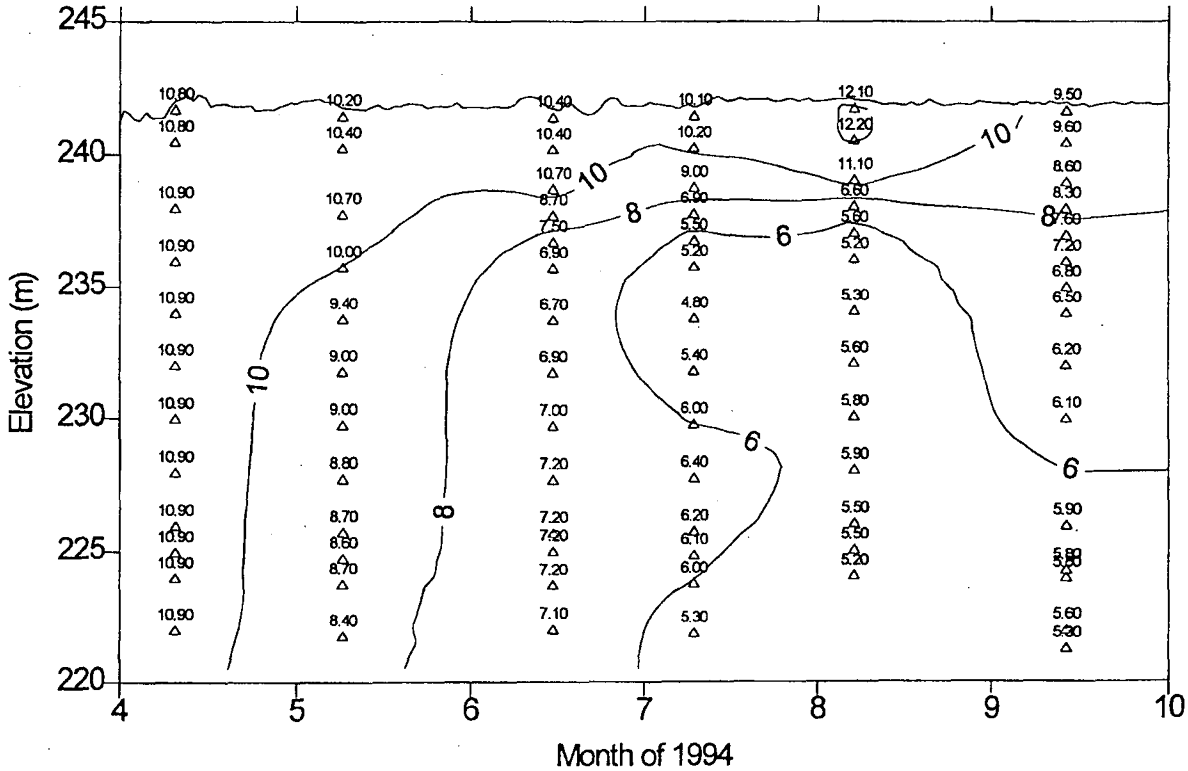


Melton Hill Reservoir - CRM 24.0

Temperature (deg C)

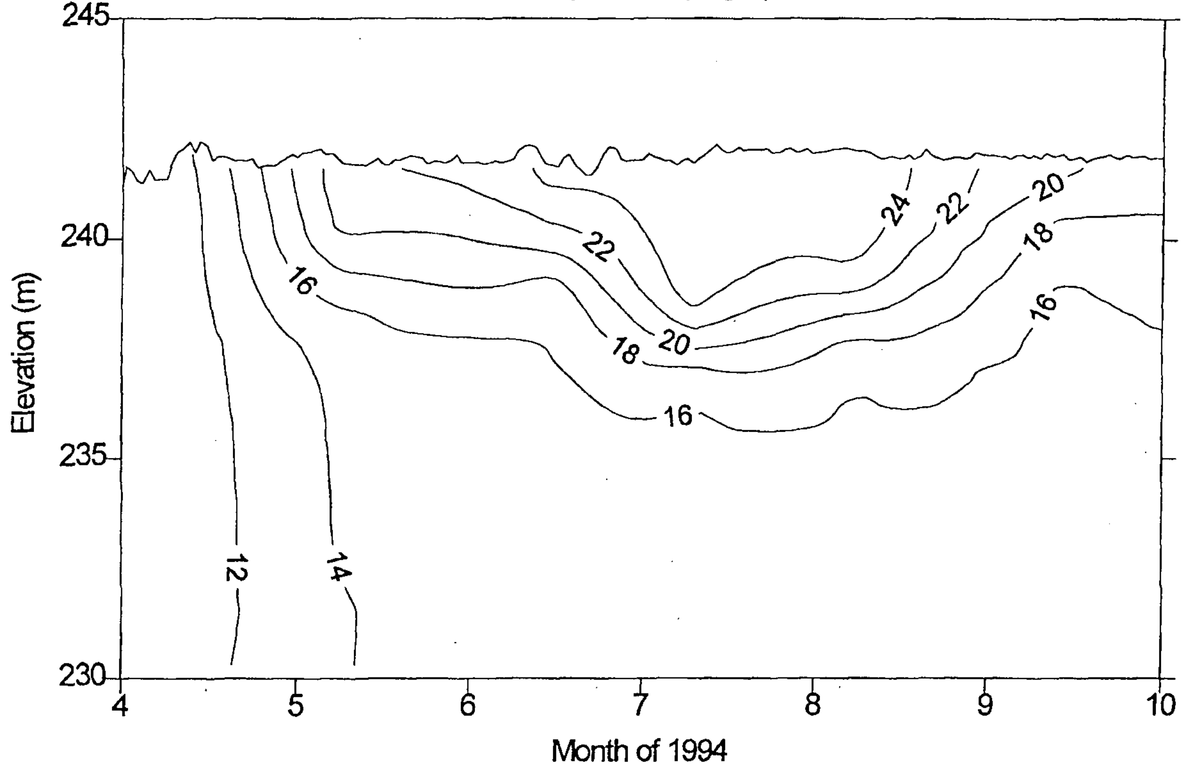


Dissolved Oxygen (mg/l)

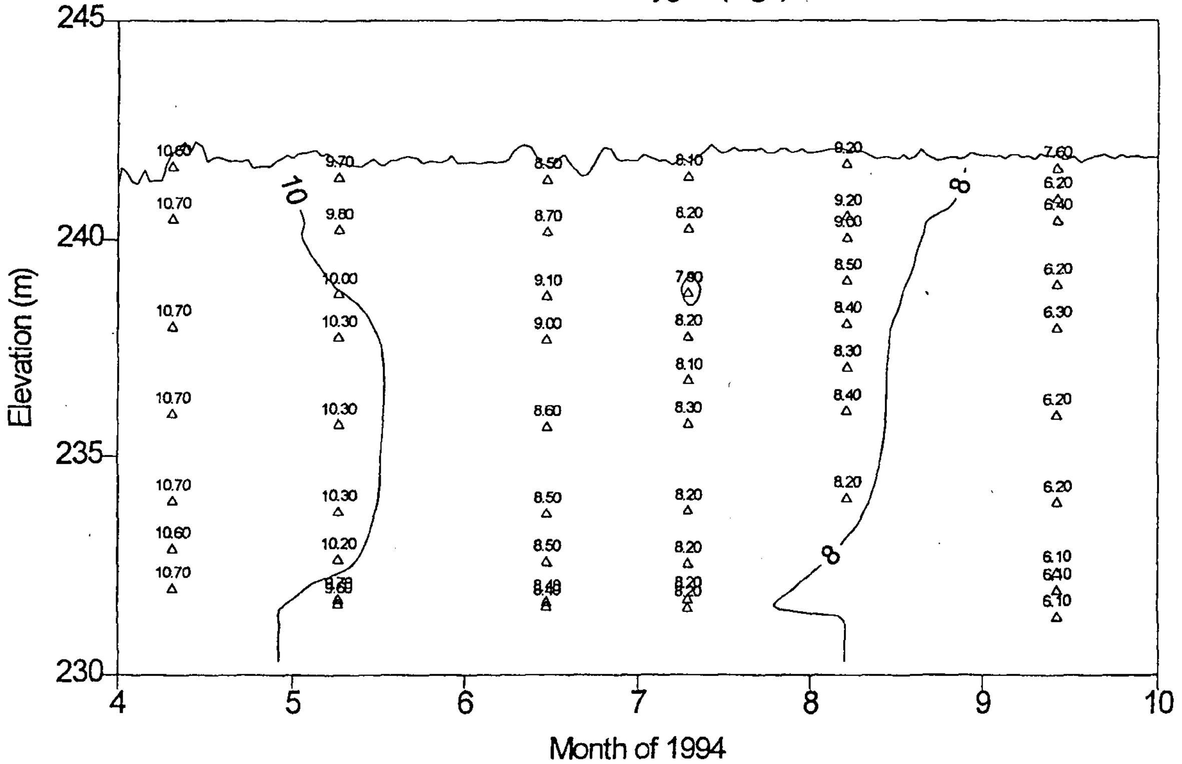


Melton Hill Reservoir - CRM 45.0

Temperature (deg C)

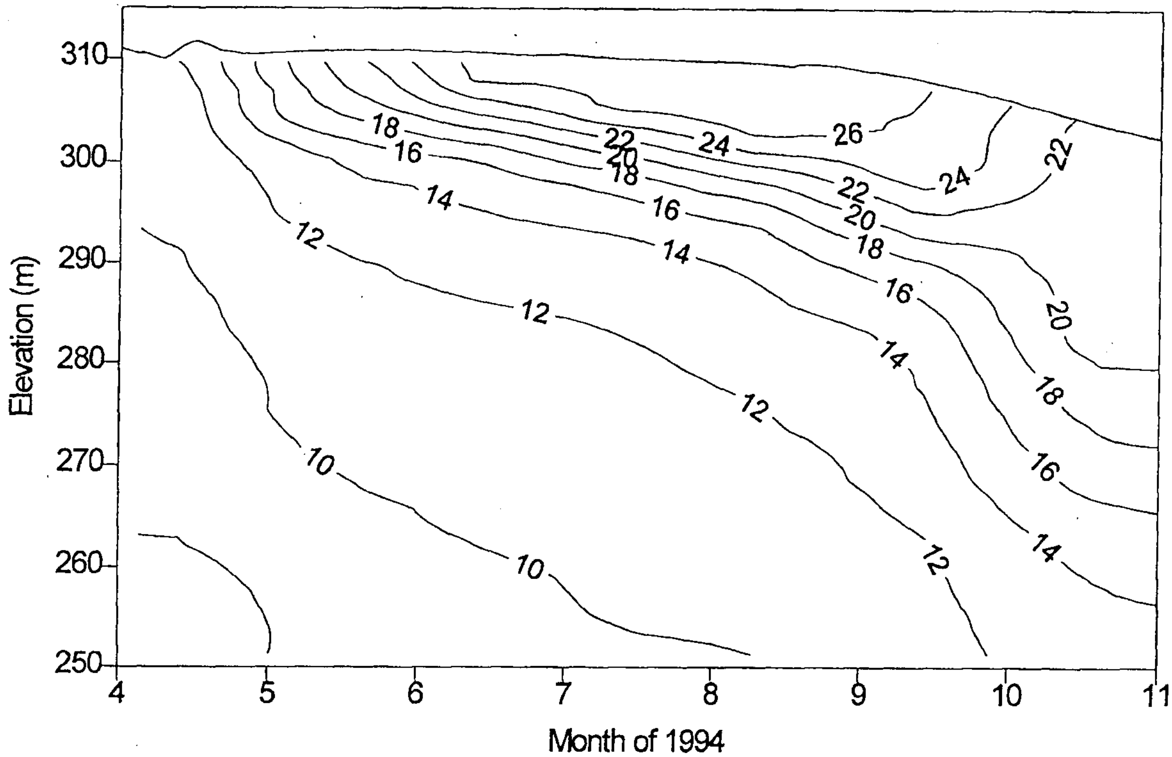


Dissolved Oxygen (mg/l)

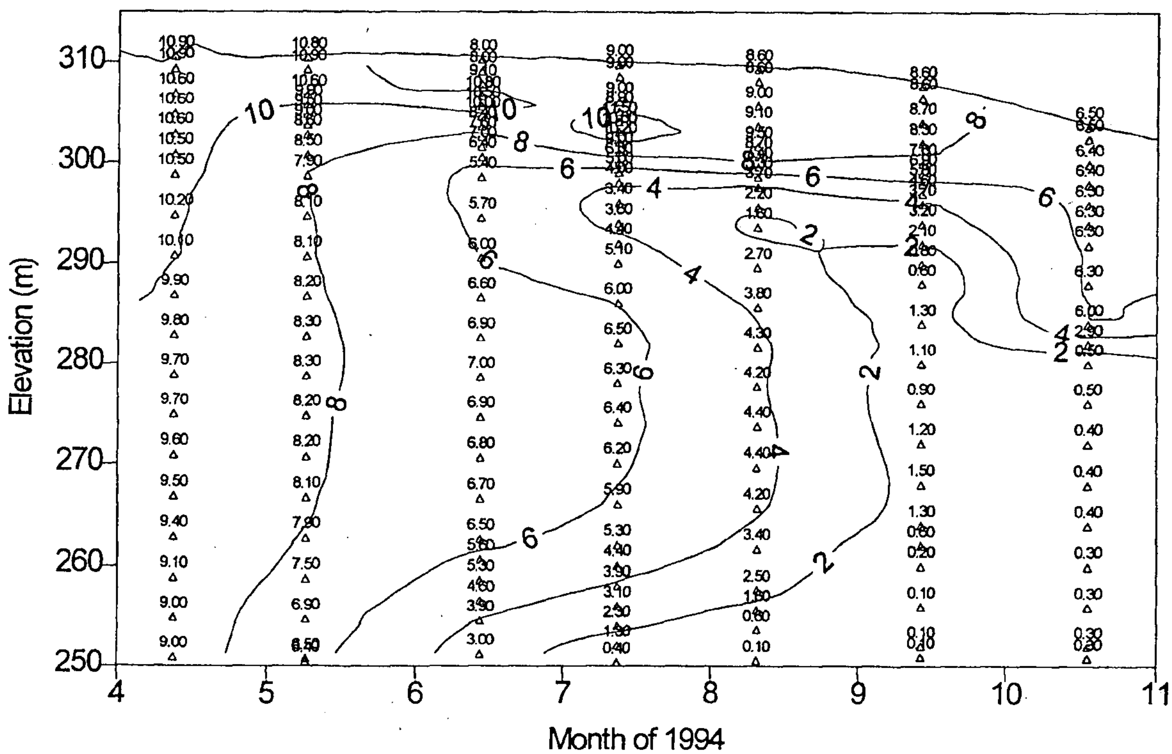


Norris Reservoir - CRM 80

Temperature (deg C)

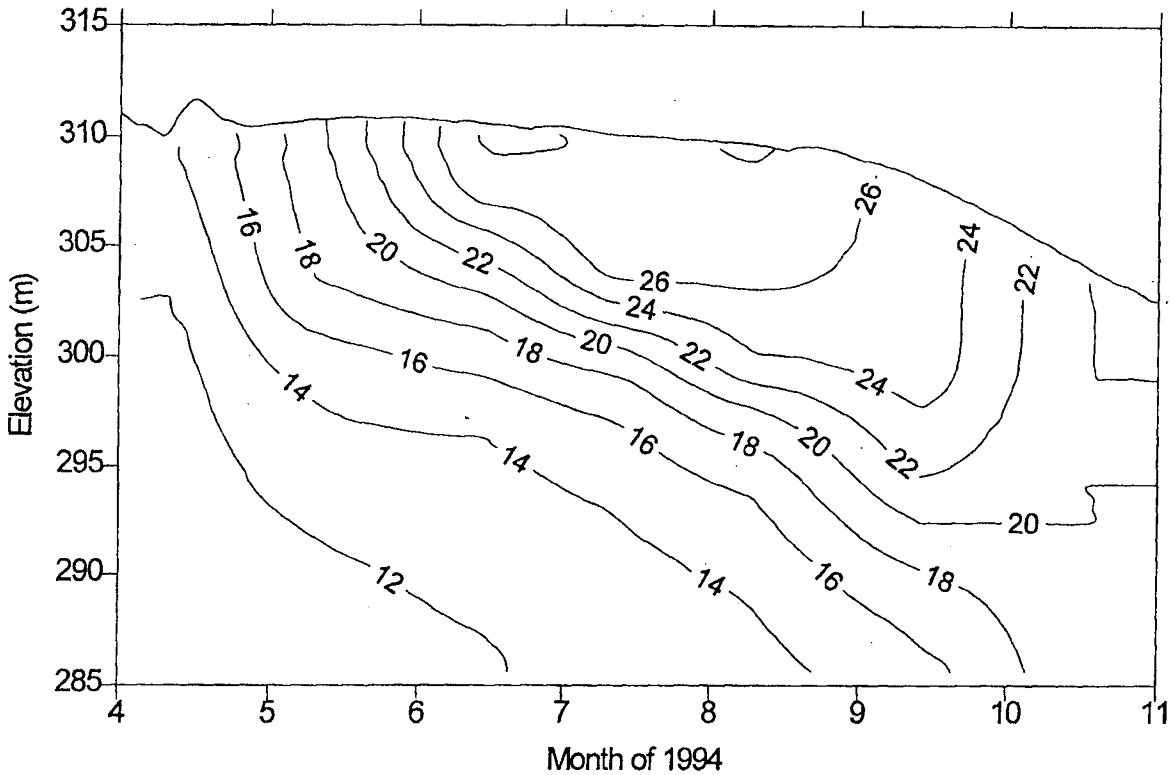


Dissolved Oxygen (mg/l)

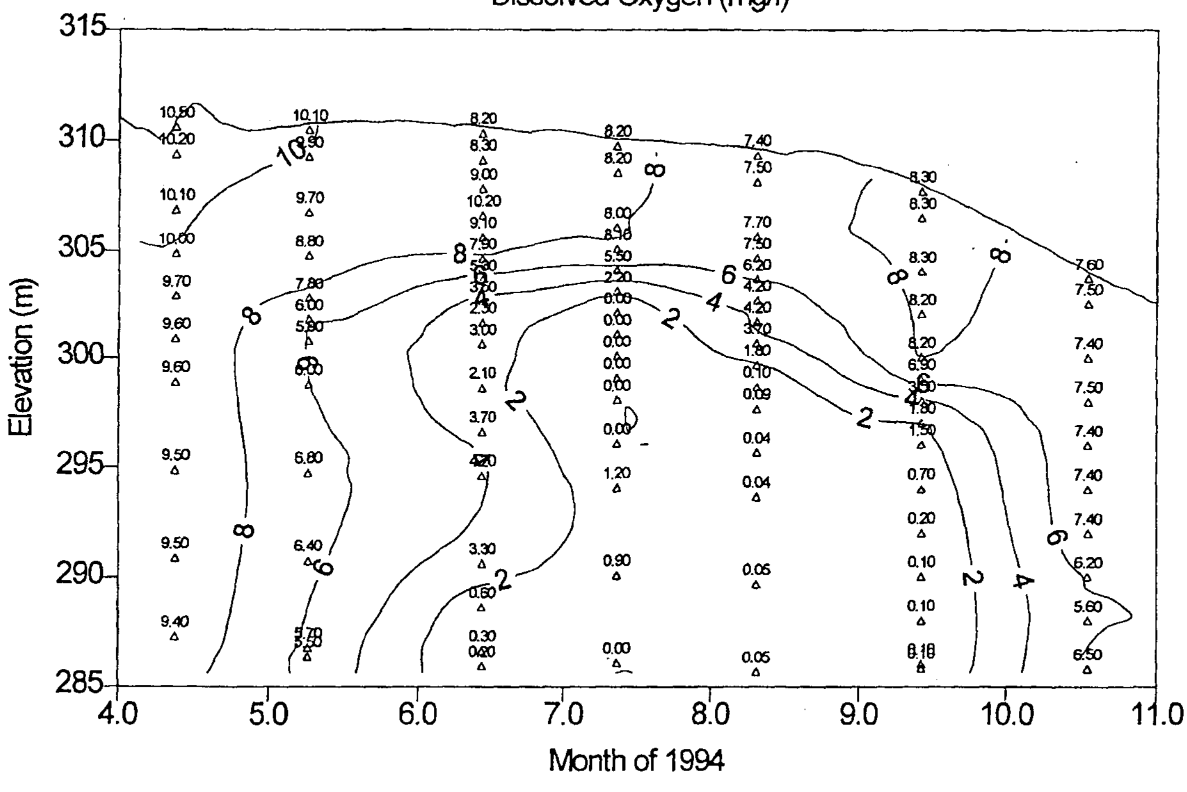


Norris Reservoir - CRM 125

Temperature (deg C)

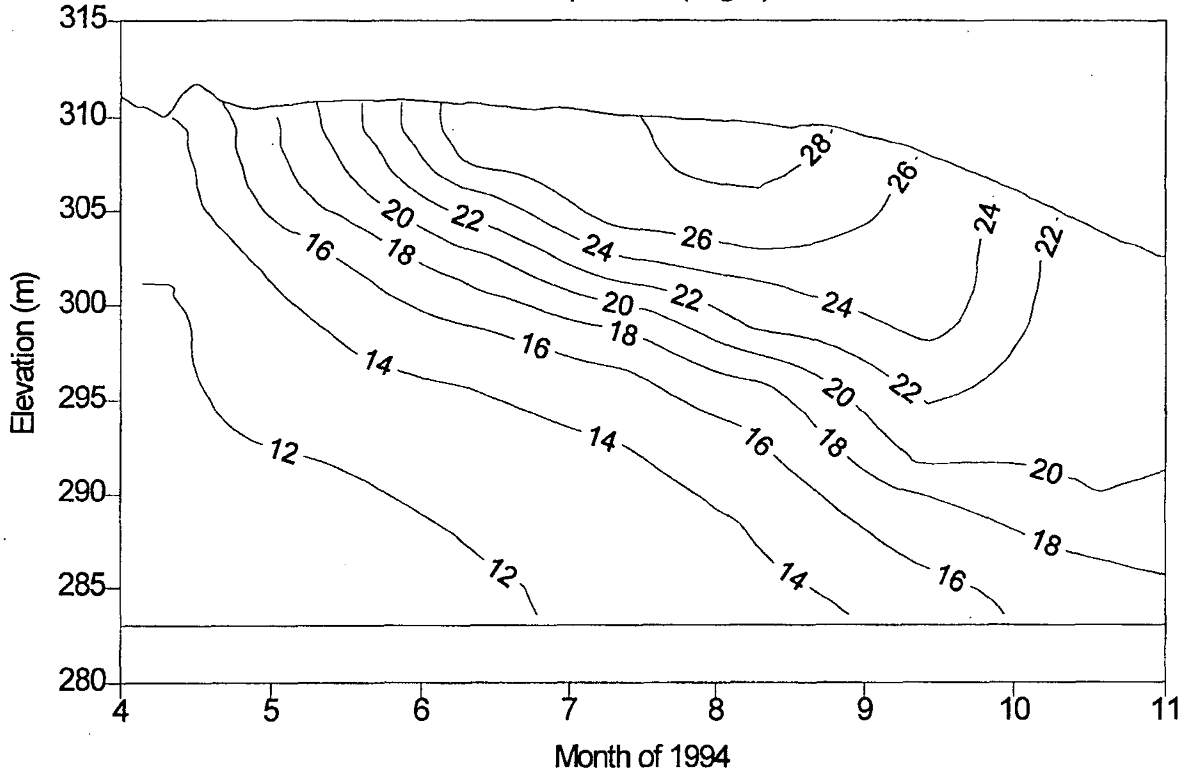


Dissolved Oxygen (mg/l)

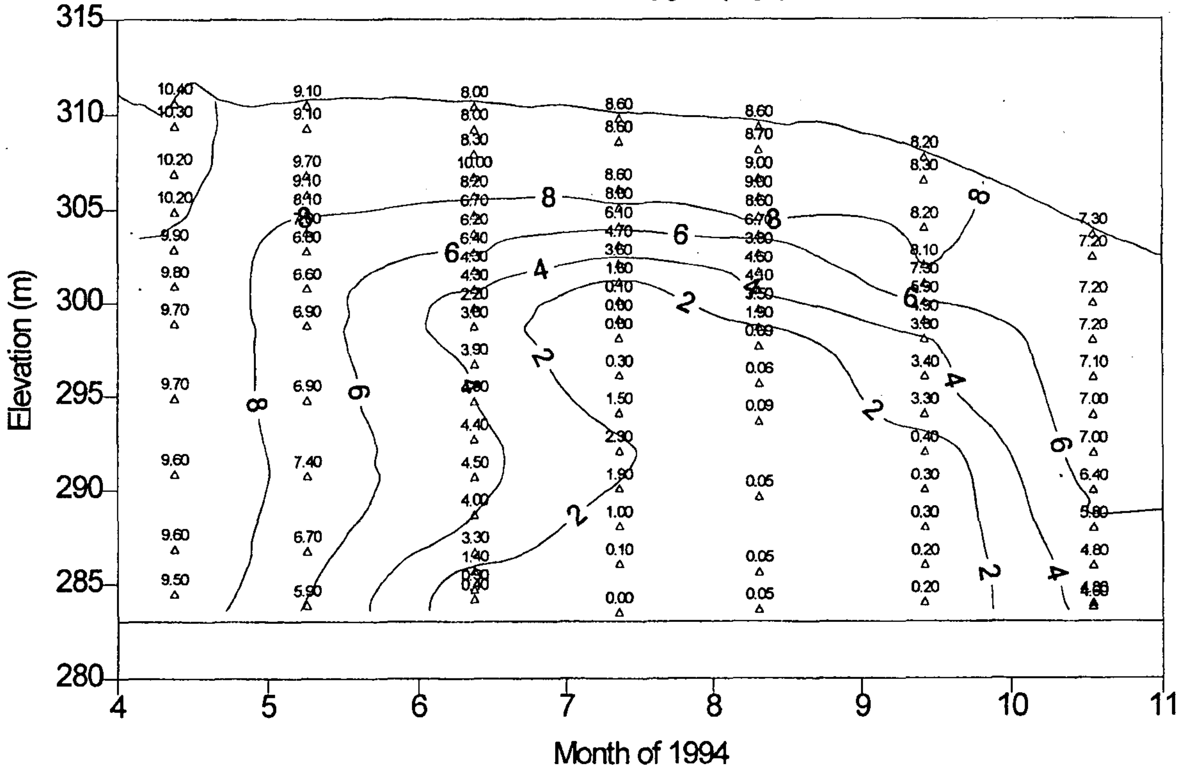


Norris Reservoir - PRM 30

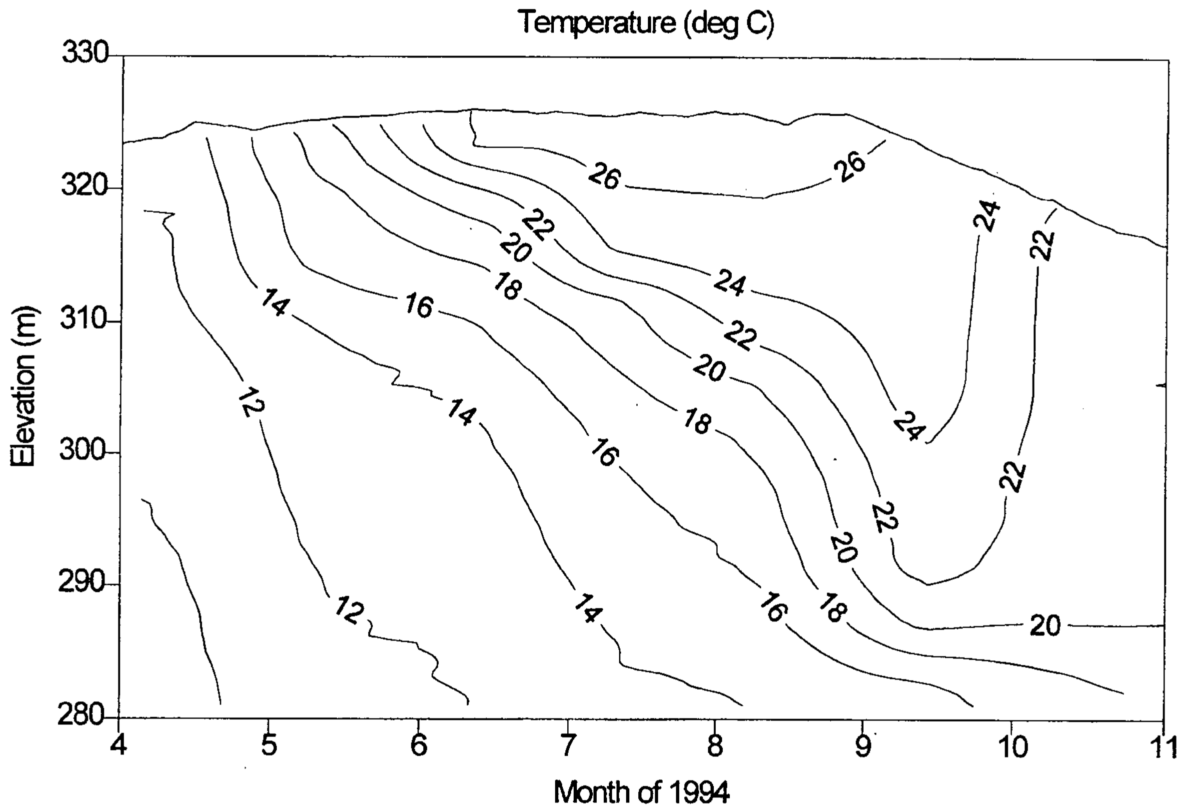
Temperature (deg C)

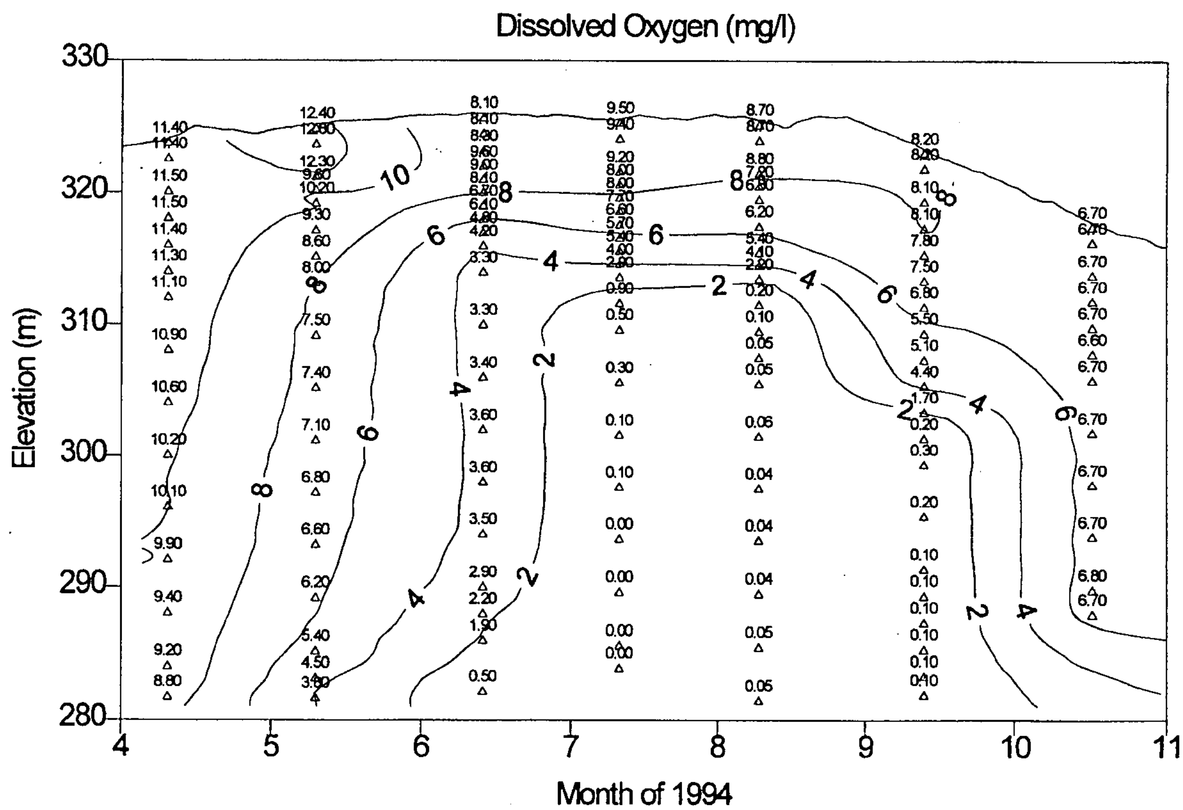


Dissolved Oxygen (mg/l)

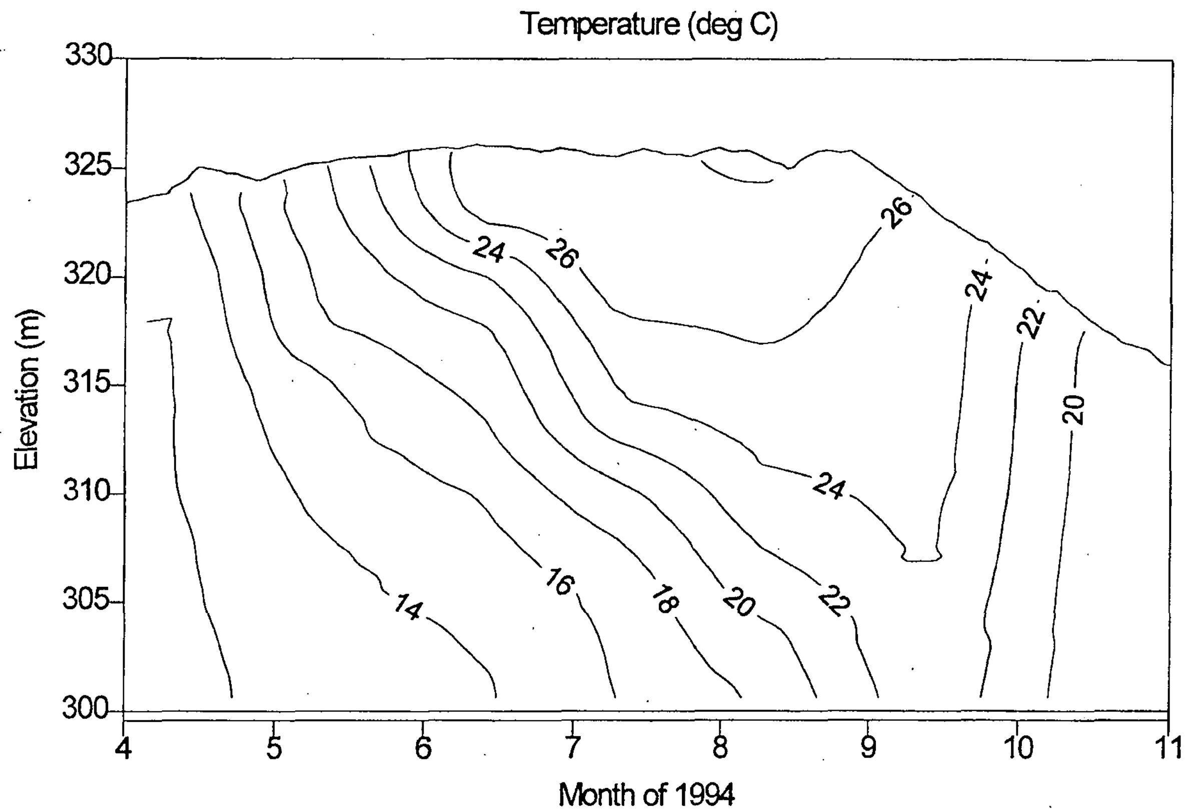


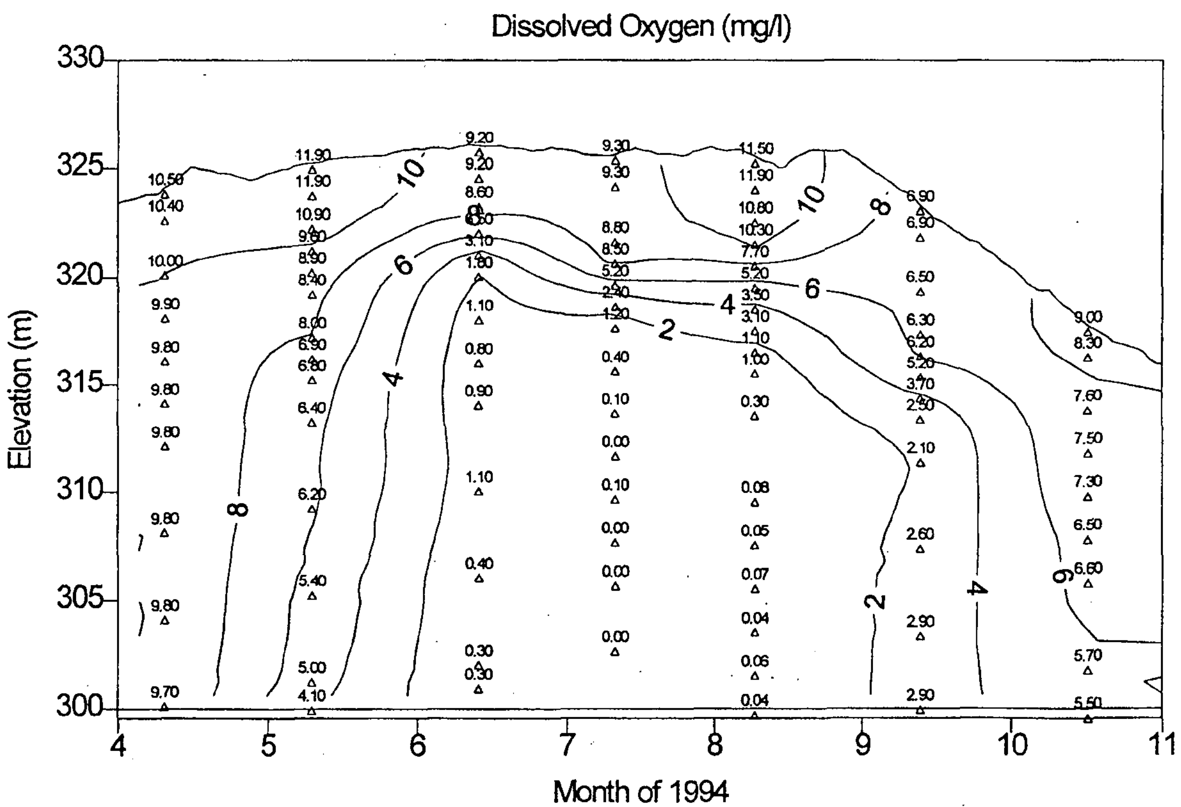
Cherokee Reservoir - HRM 53





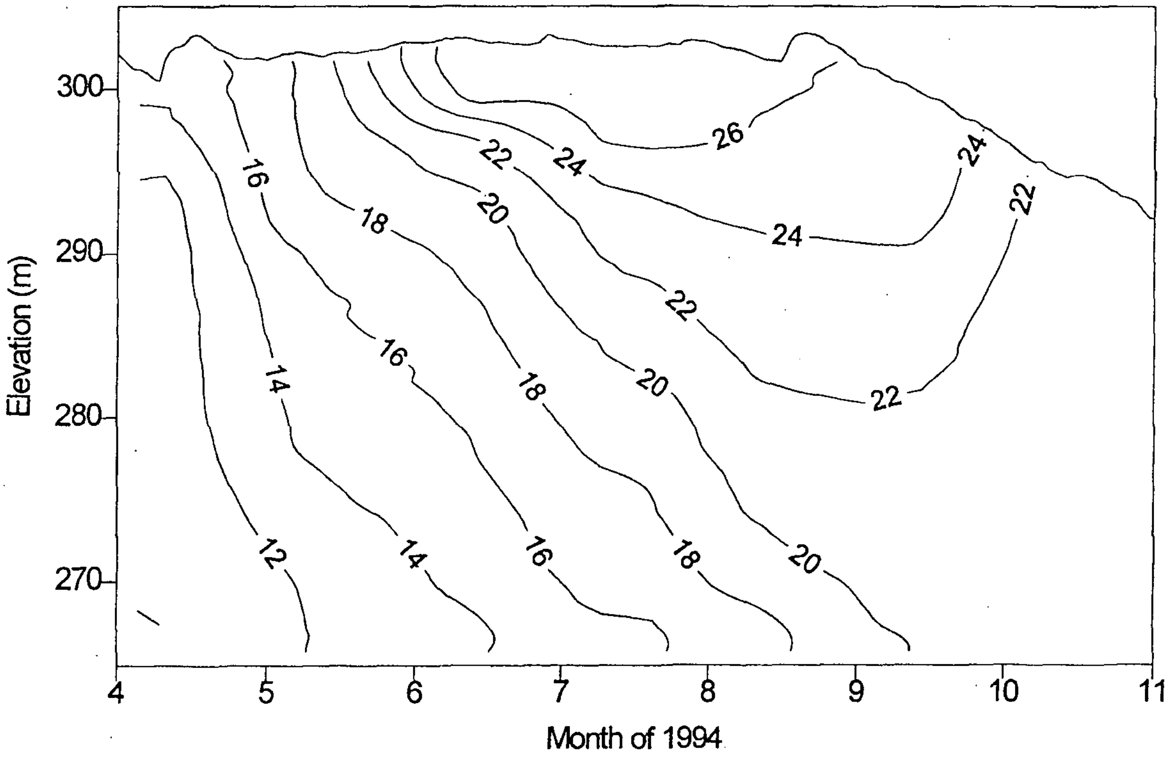
Cherokee Reservoir - HRM 76



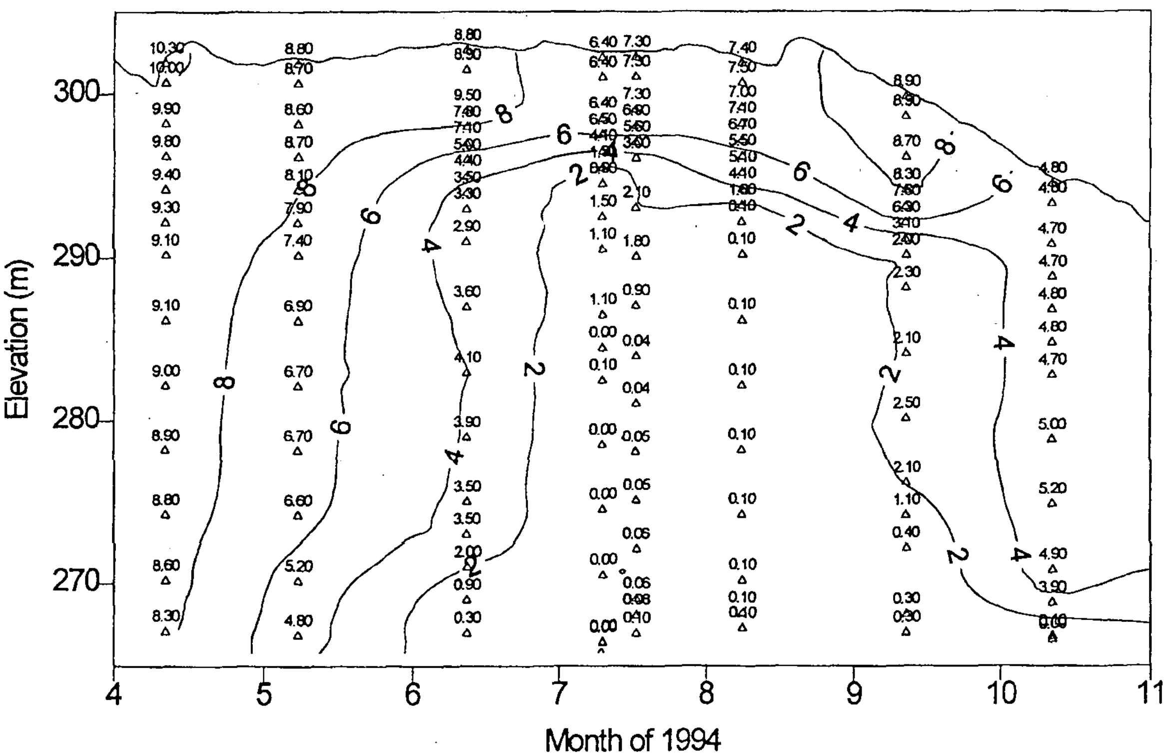


Douglas Reservoir - FBRM 33

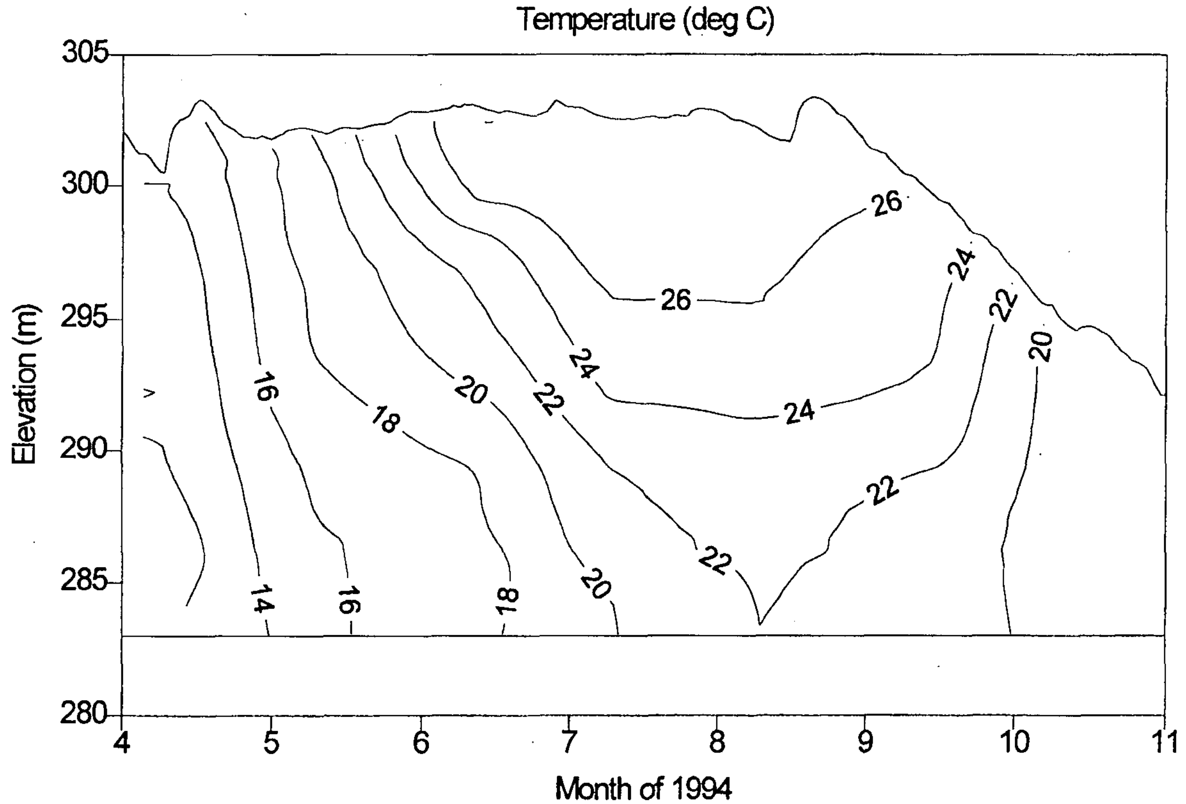
Temperature (deg C)

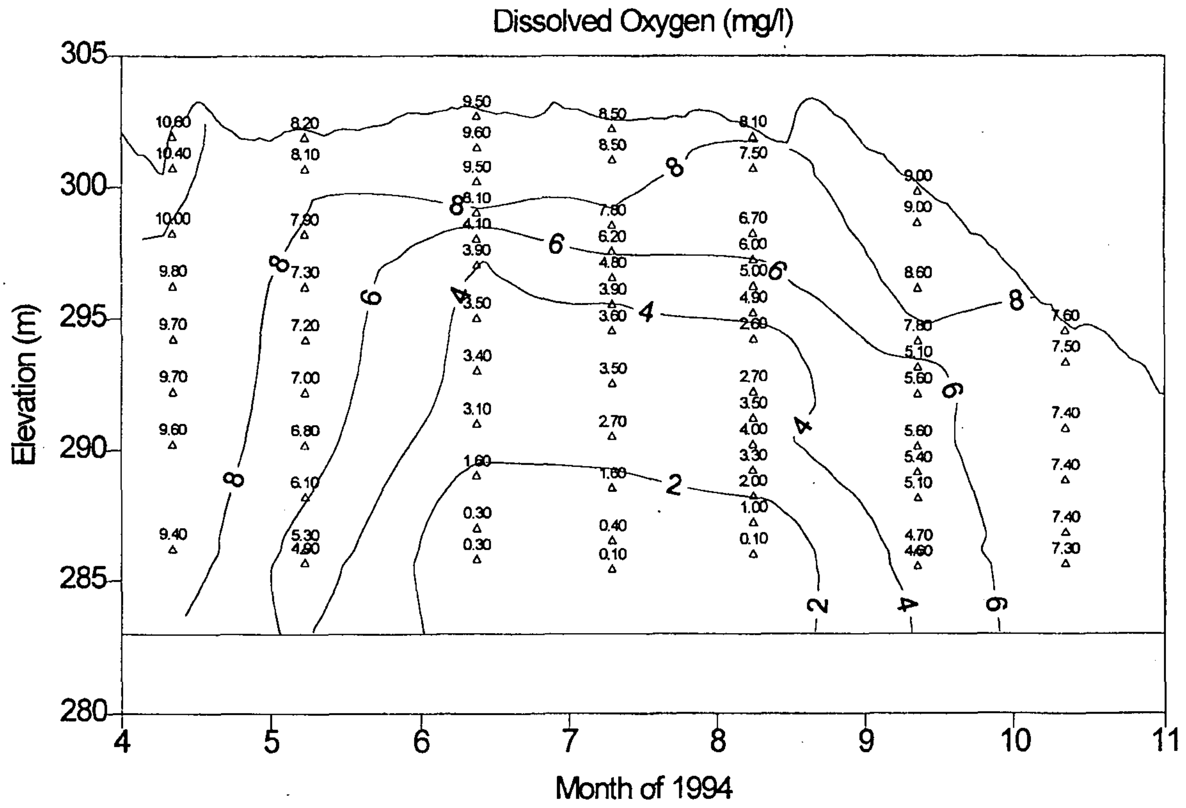


Dissolved Oxygen (mg/l)

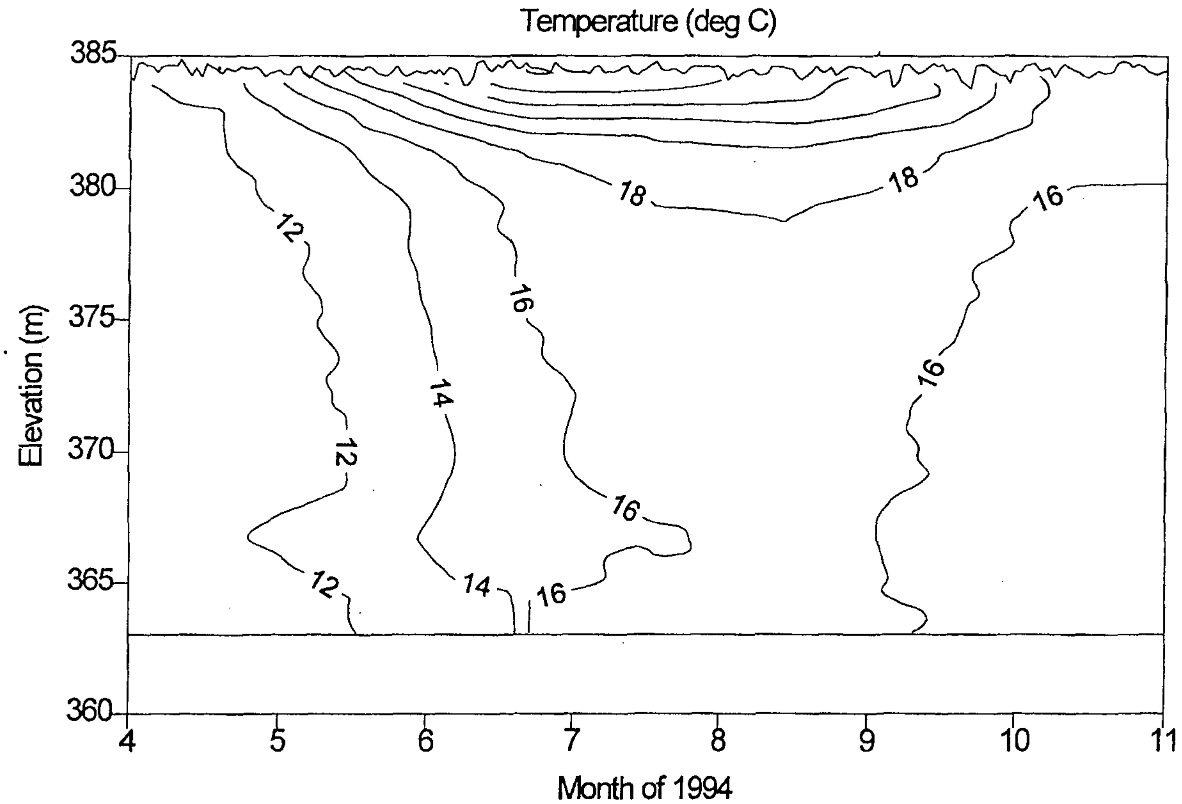


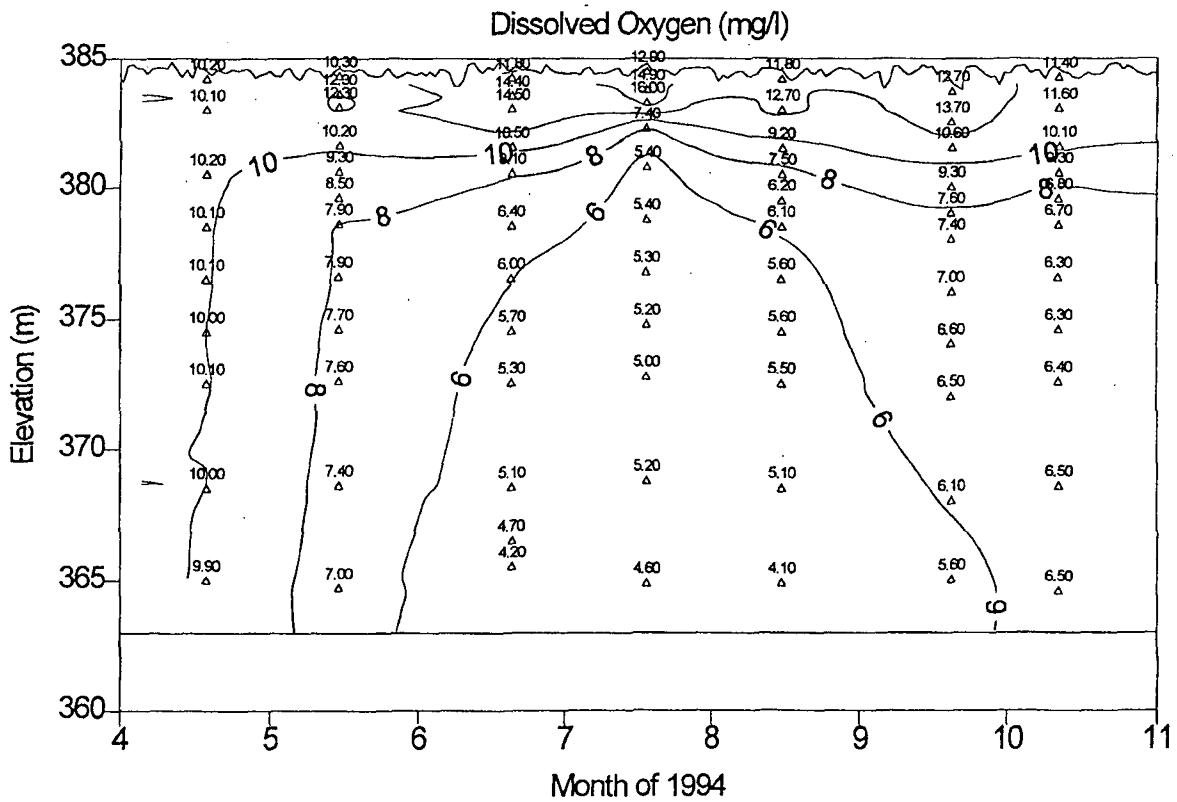
Douglas Reservoir - FBRM 51





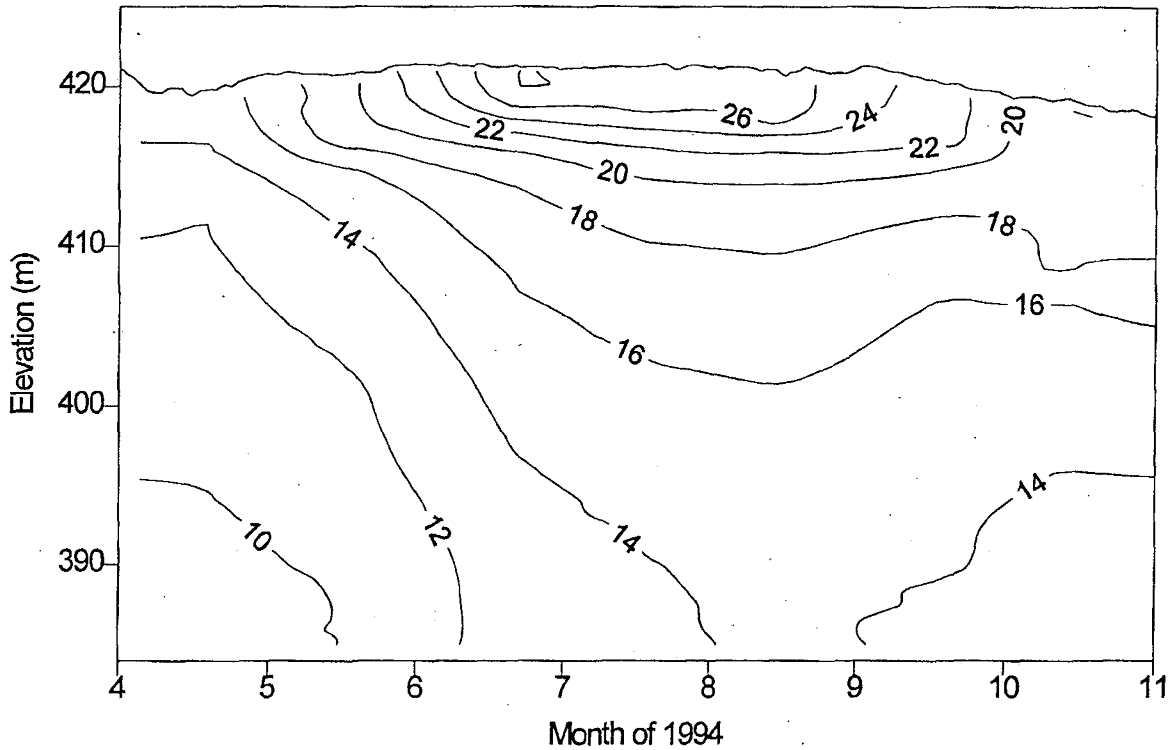
Fort Patrick Henry Reservoir - SFHRM 8.7



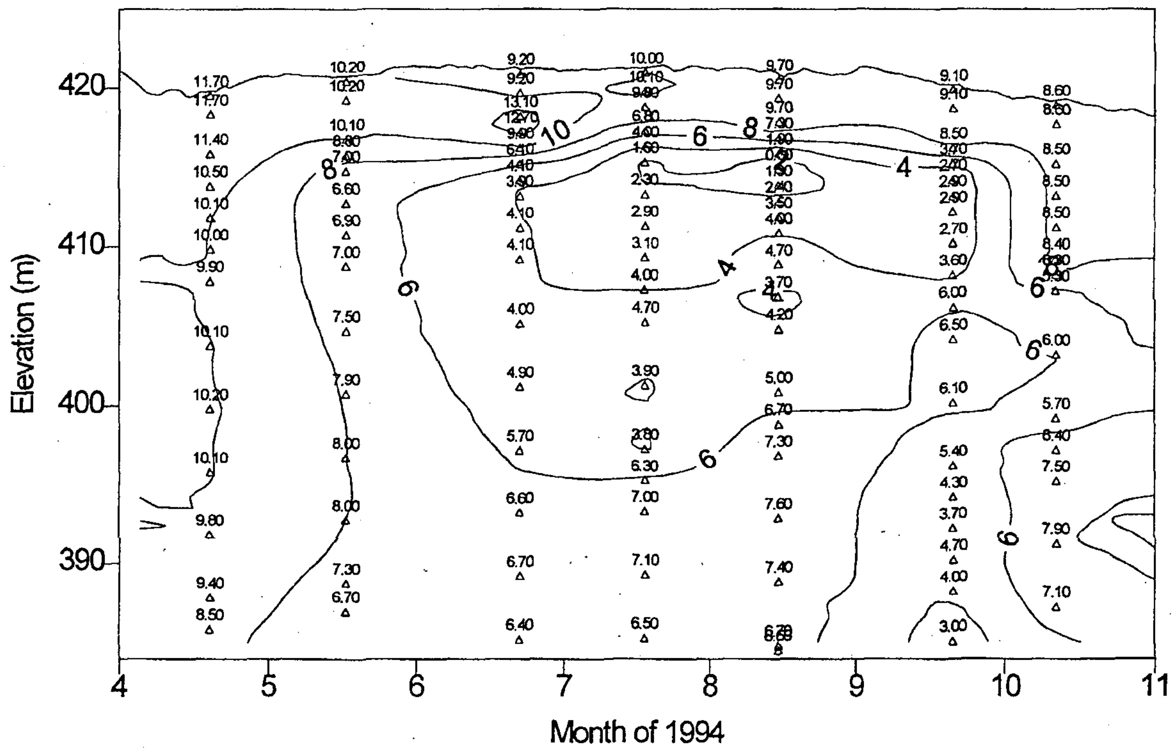


Boone Reservoir - SFHRM 19

Temperature (deg C)

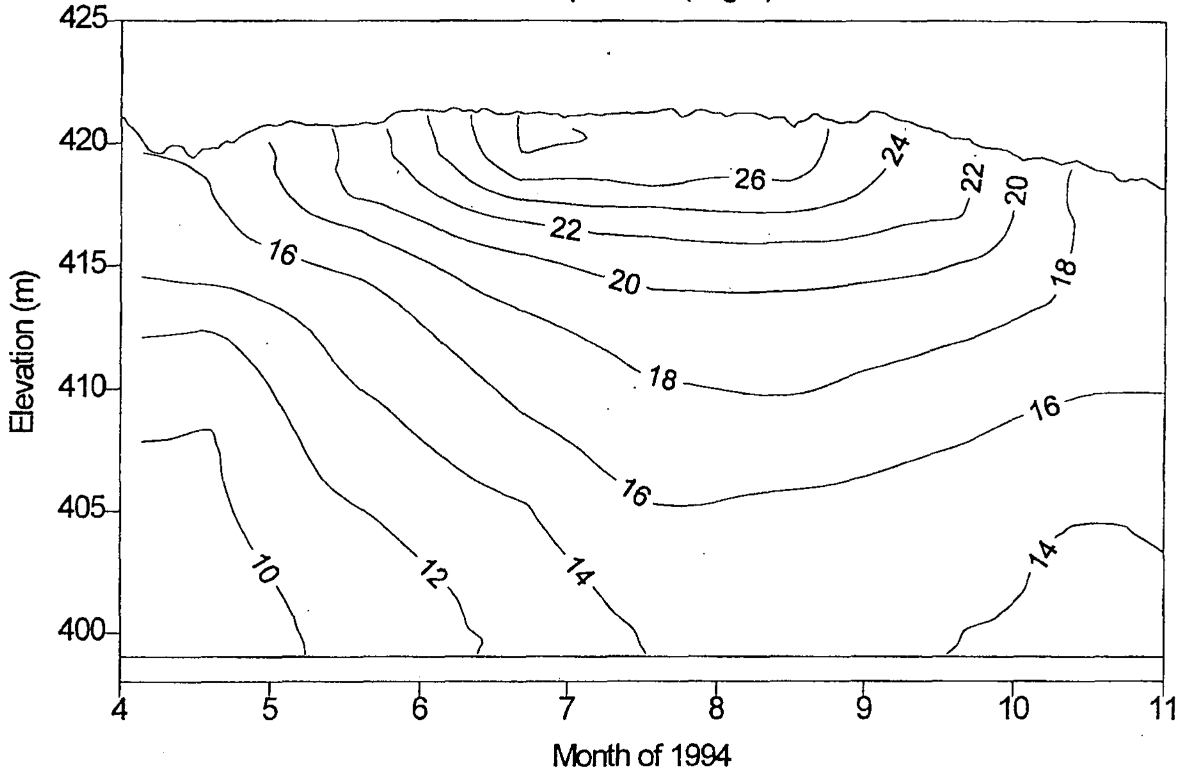


Dissolved Oxygen (mg/l)

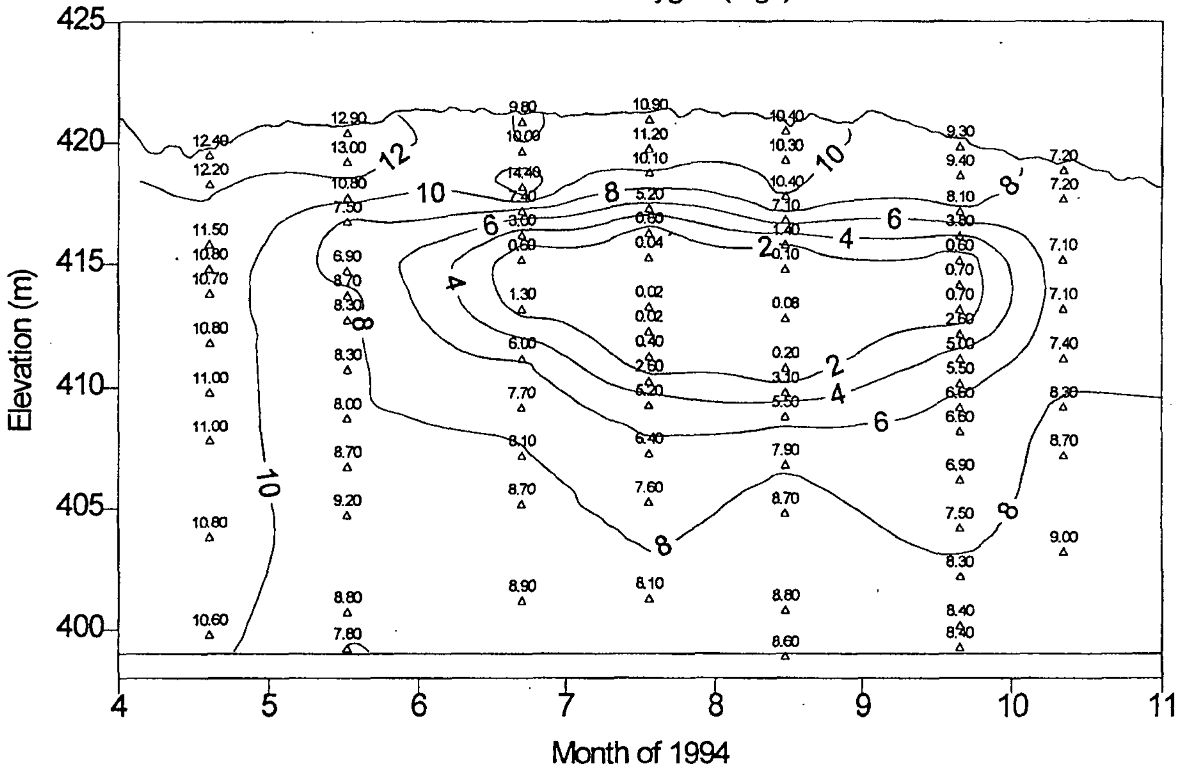


Boone Reservoir - SFHRM 27.0

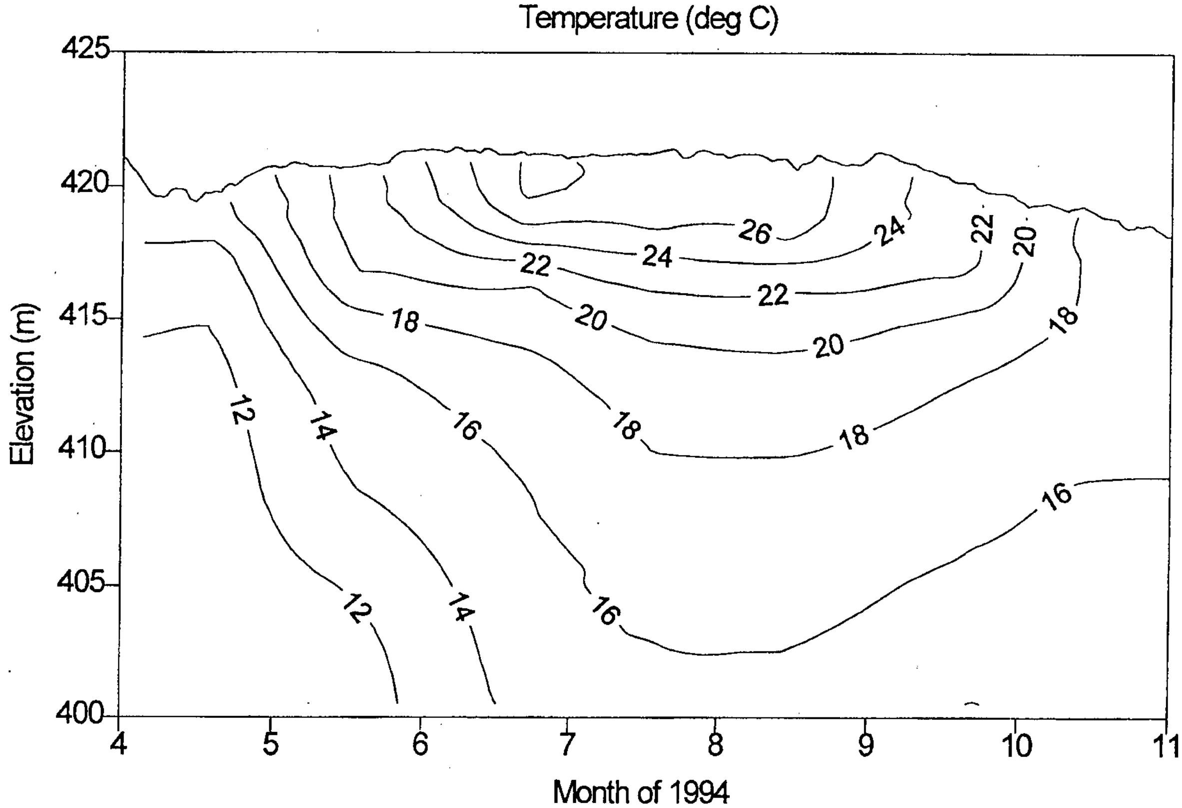
Temperature (deg C)

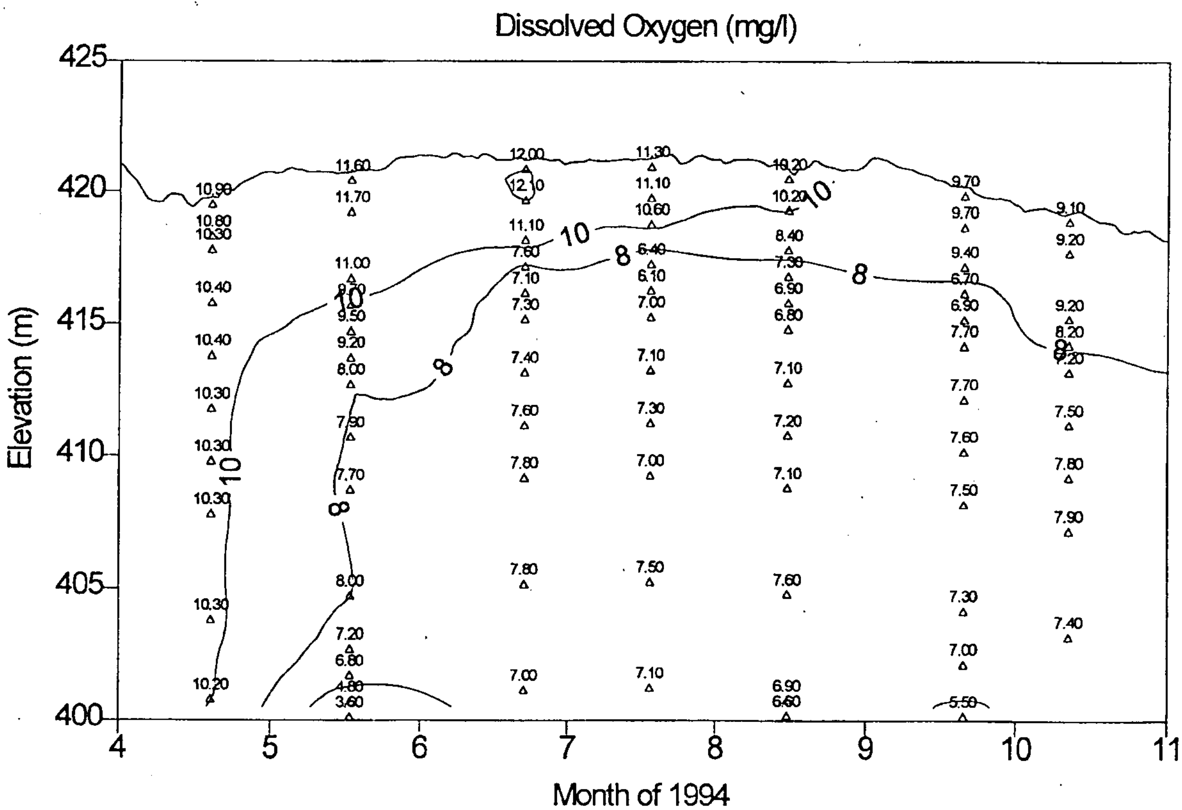


Dissolved Oxygen (mg/l)

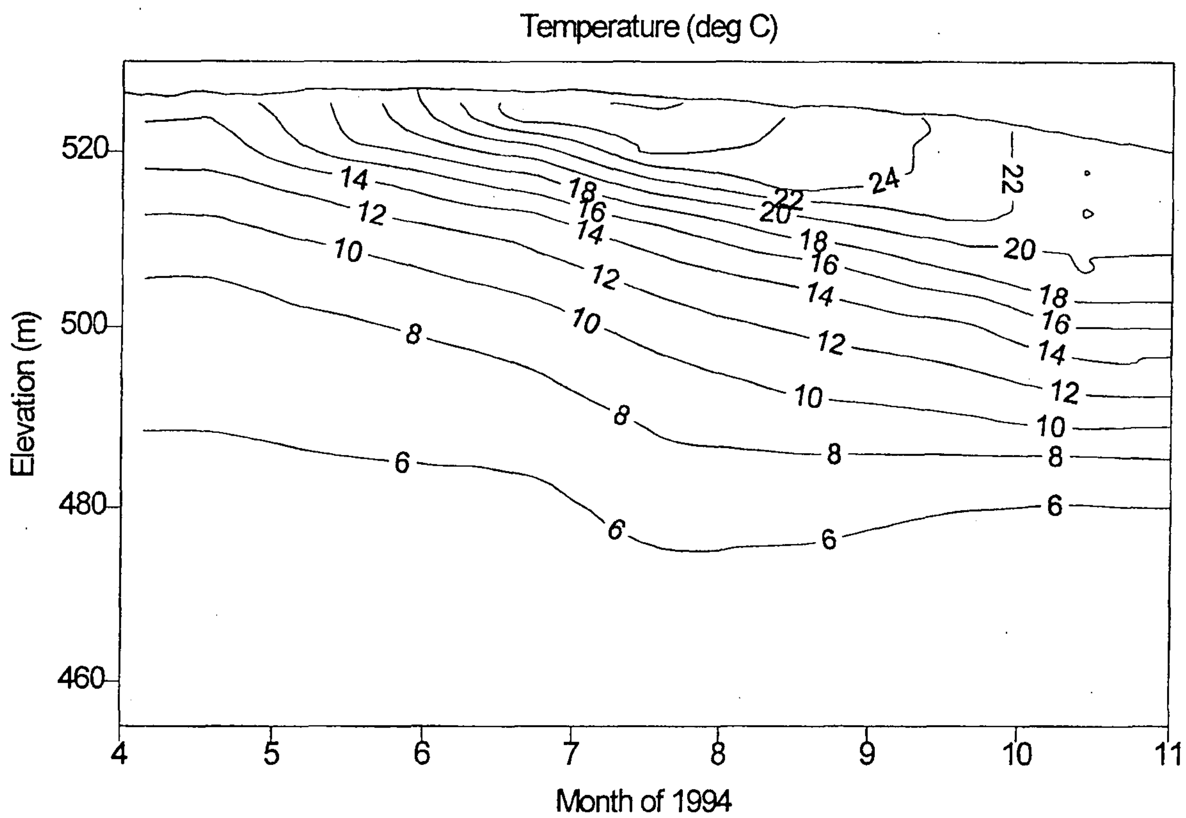


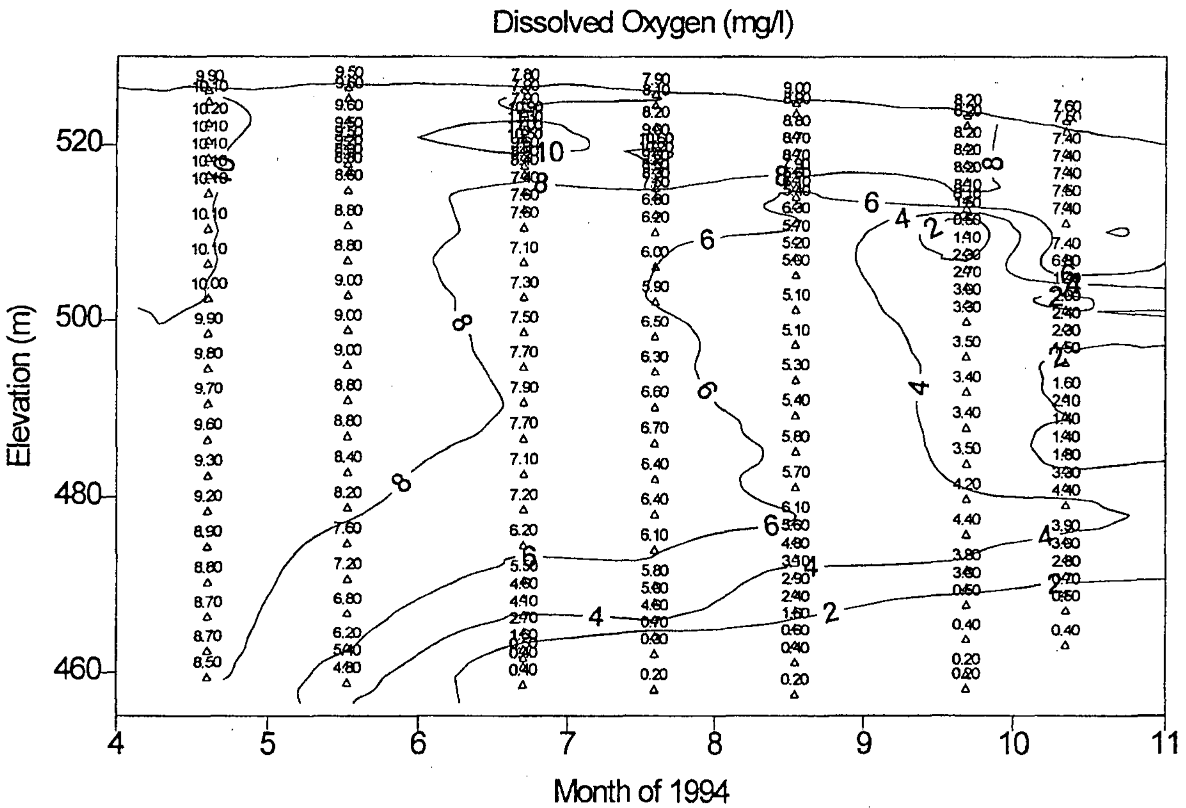
Boone Reservoir - WRM 6.5





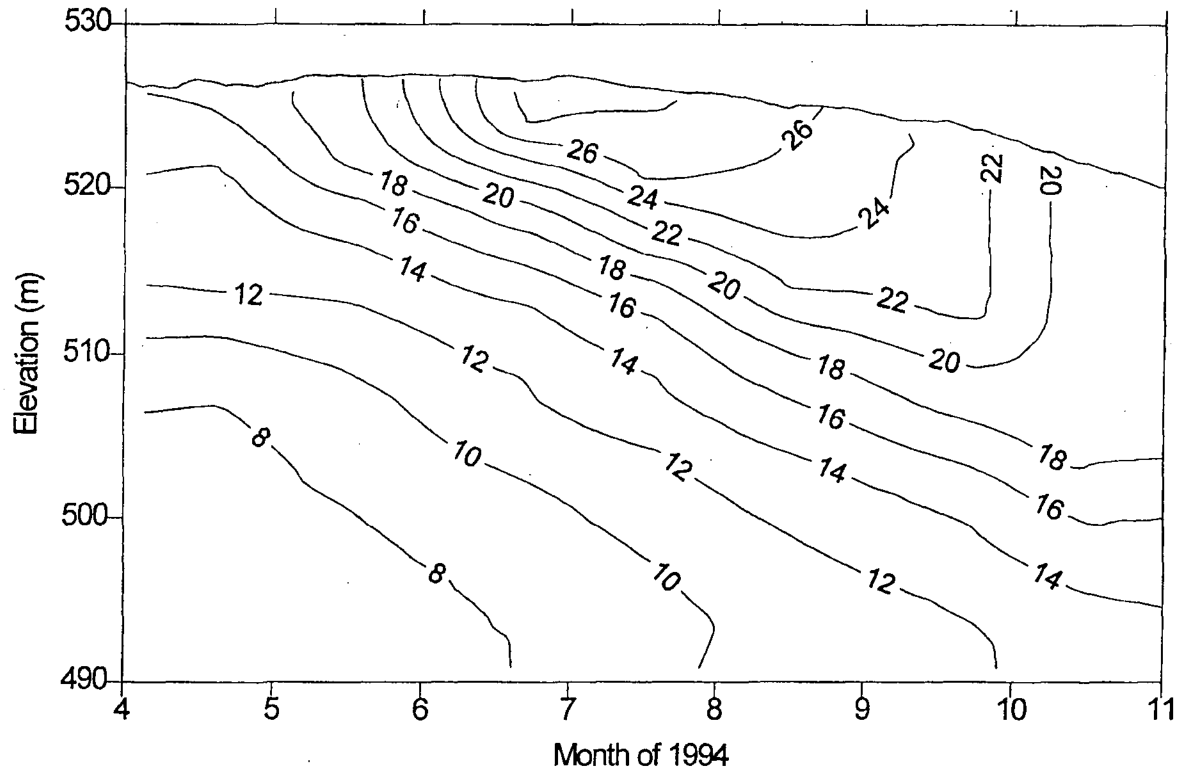
South Holston Reservoir - SFHRM 51



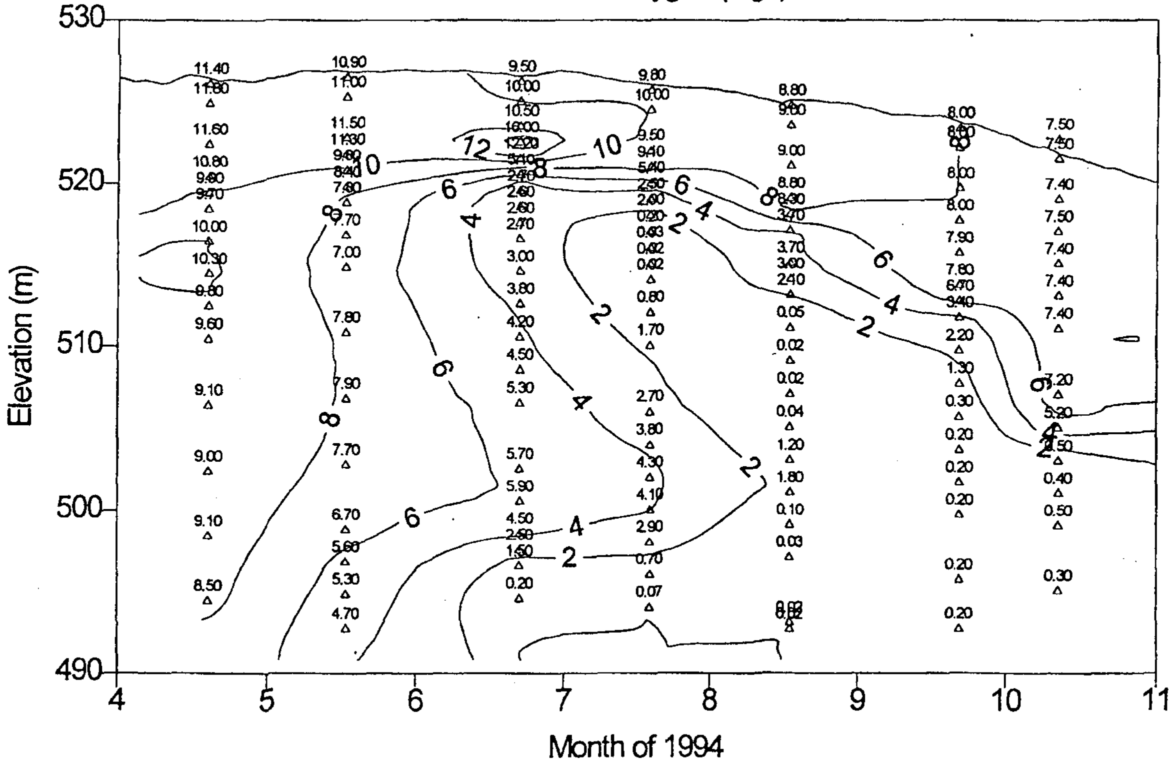


South Holston Reservoir - SFHRM 62.5

Temperature (deg C)

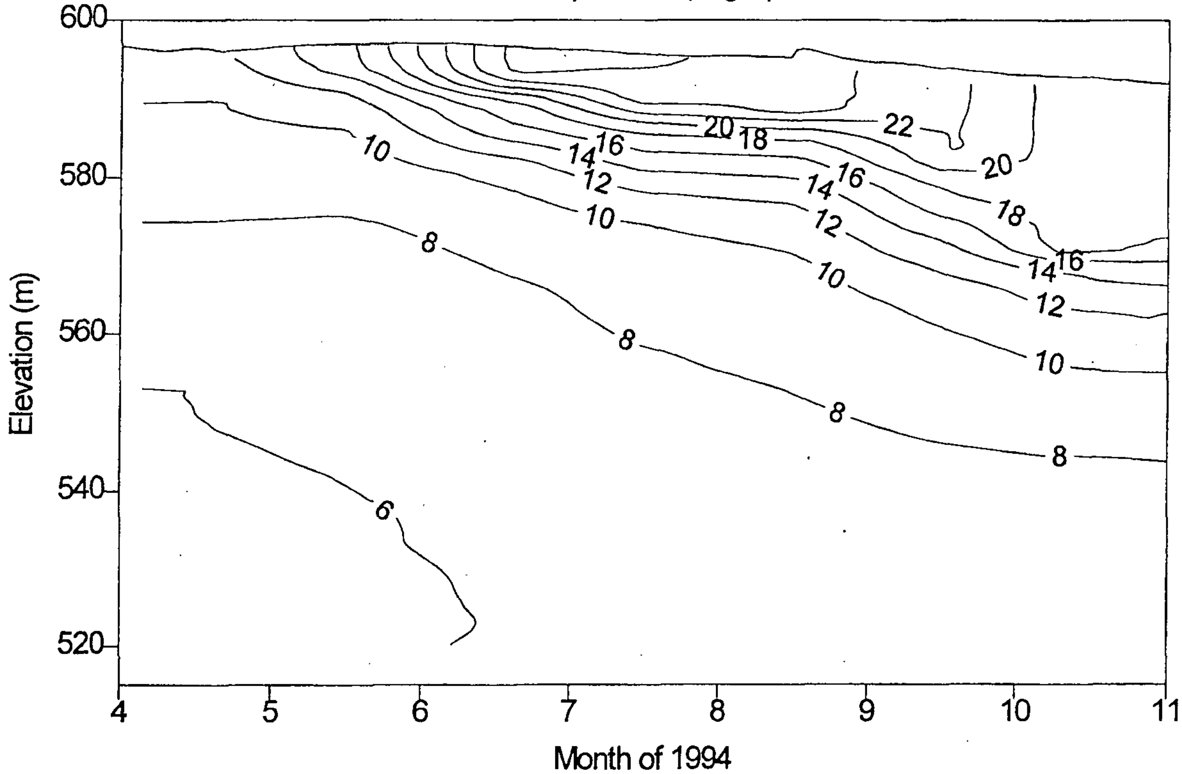


Dissolved Oxygen (mg/l)

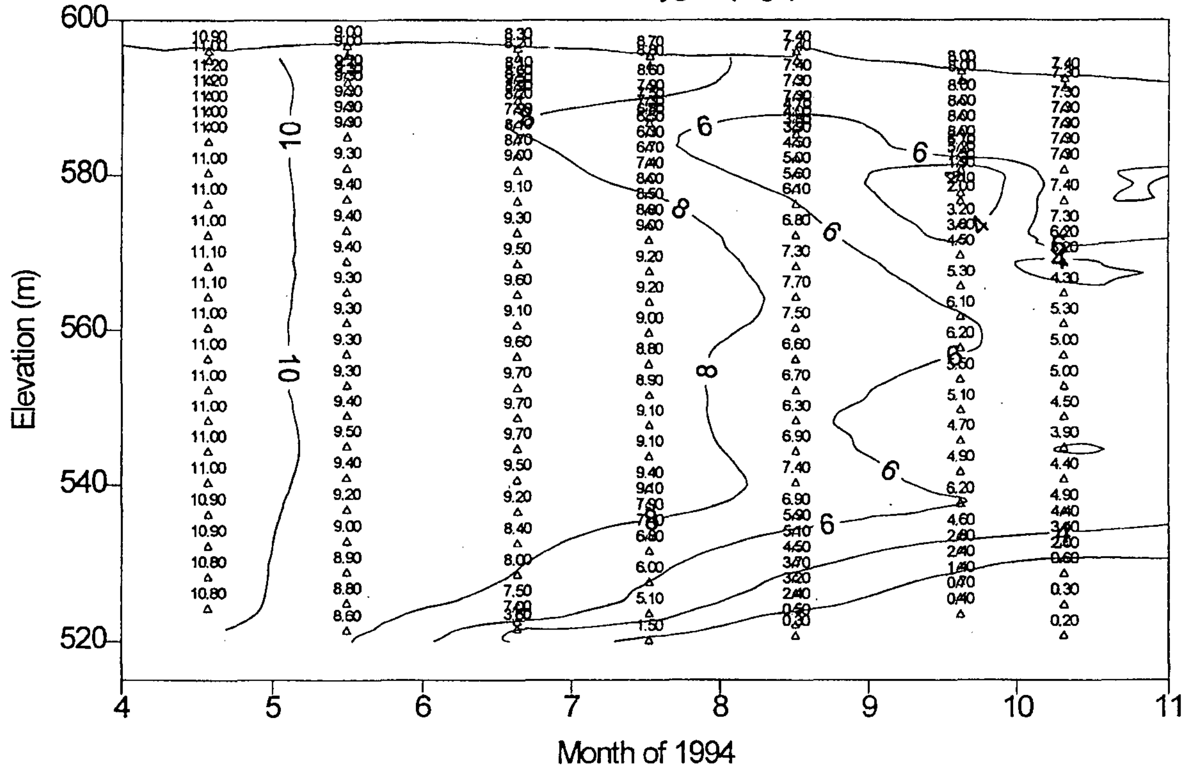


Watauga Reservoir - WRM 37.4

Temperature (deg C)

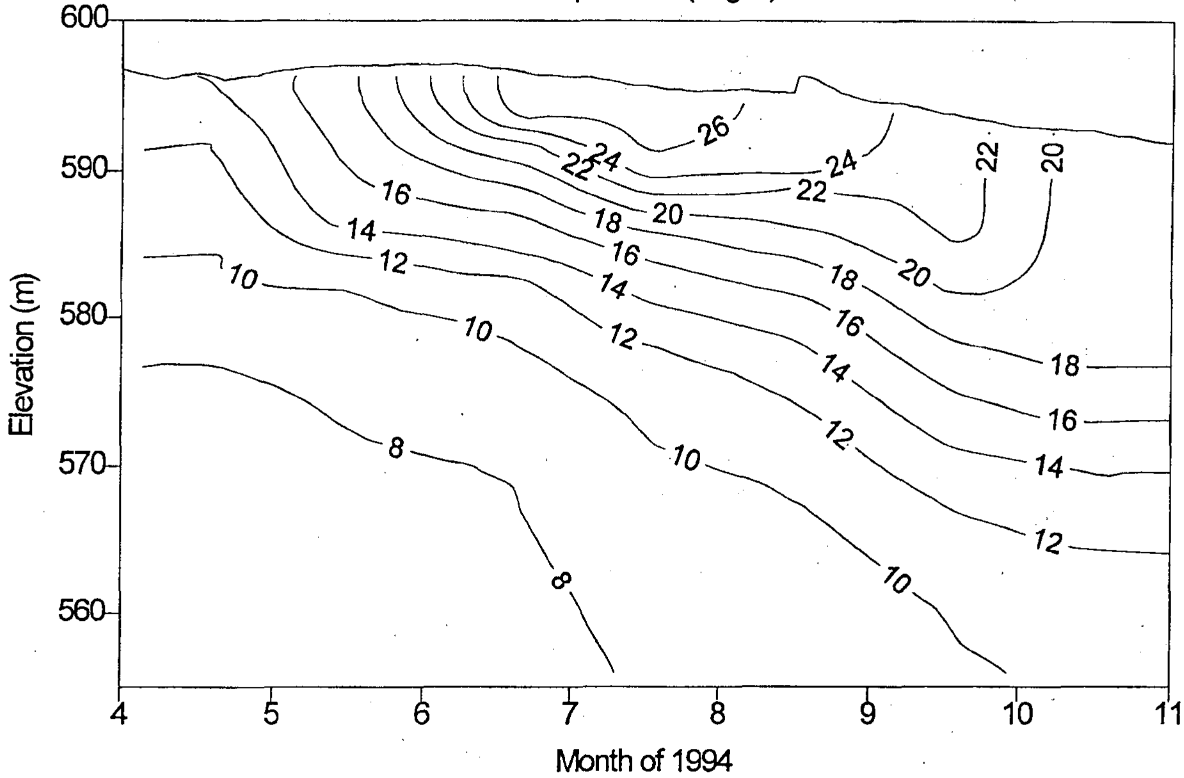


Dissolved Oxygen (mg/l)

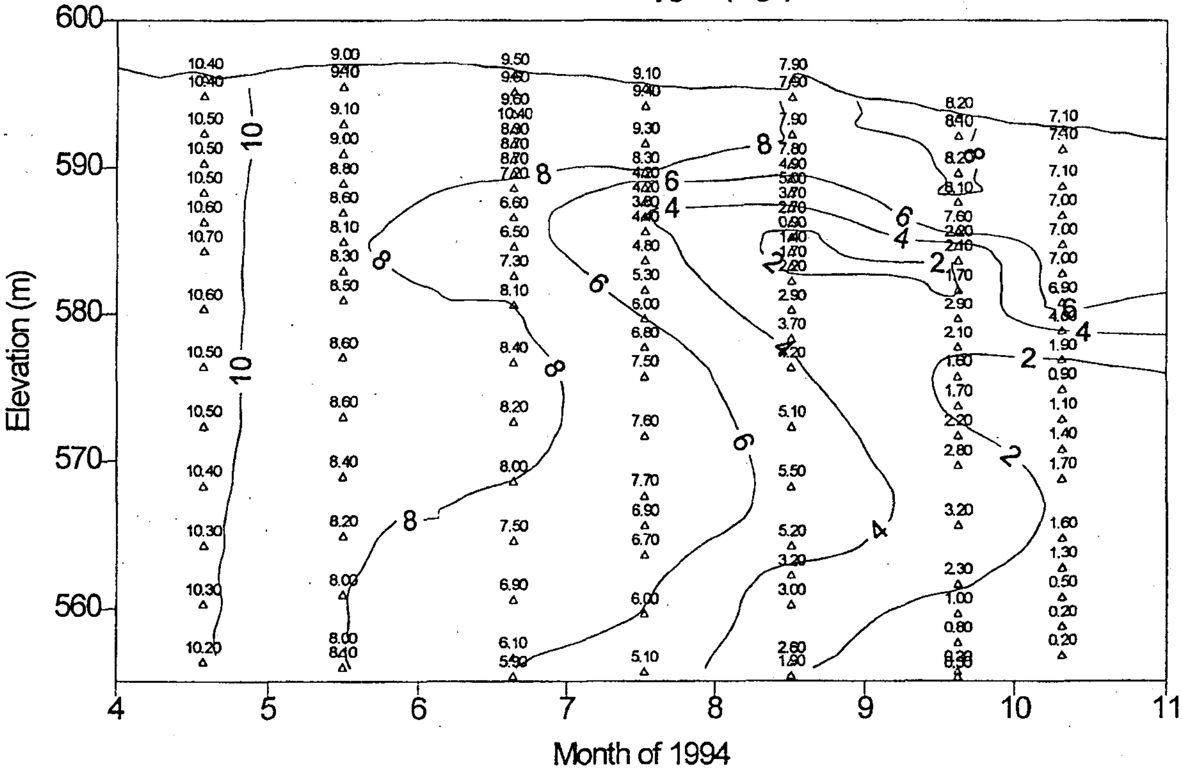


Watauga Reservoir - WRM 45.5

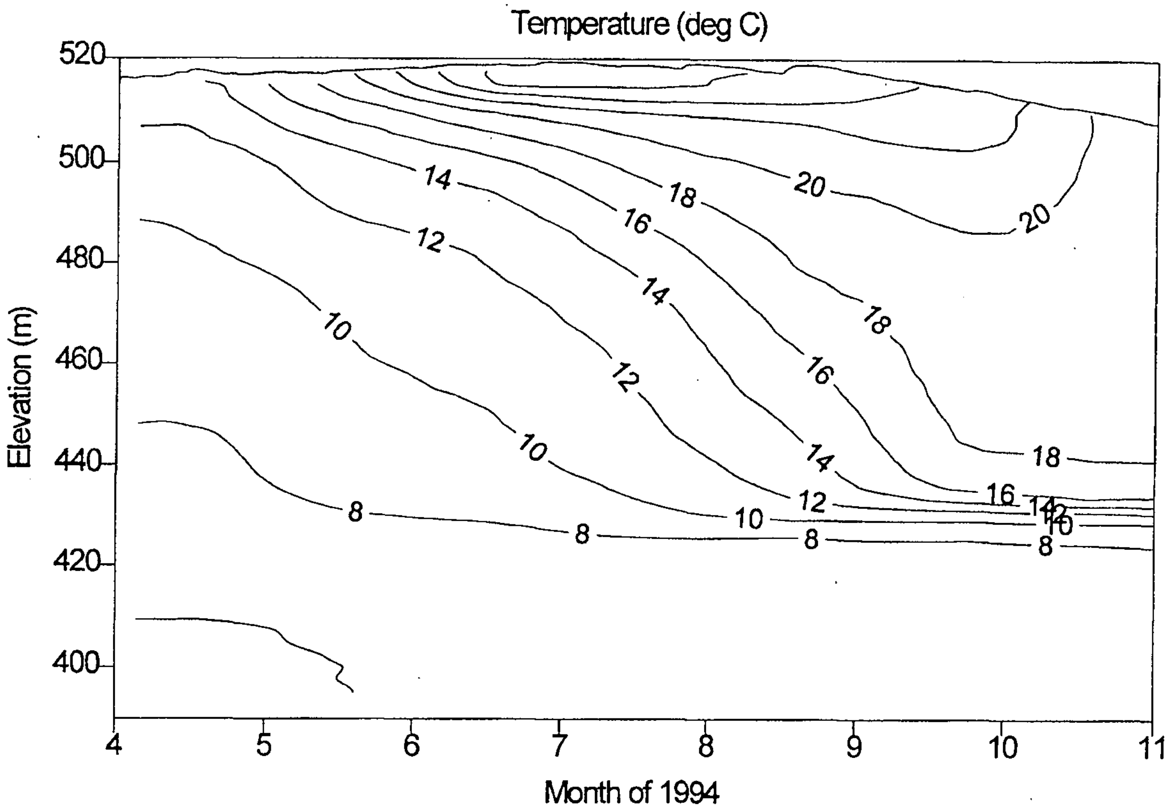
Temperature (deg C)

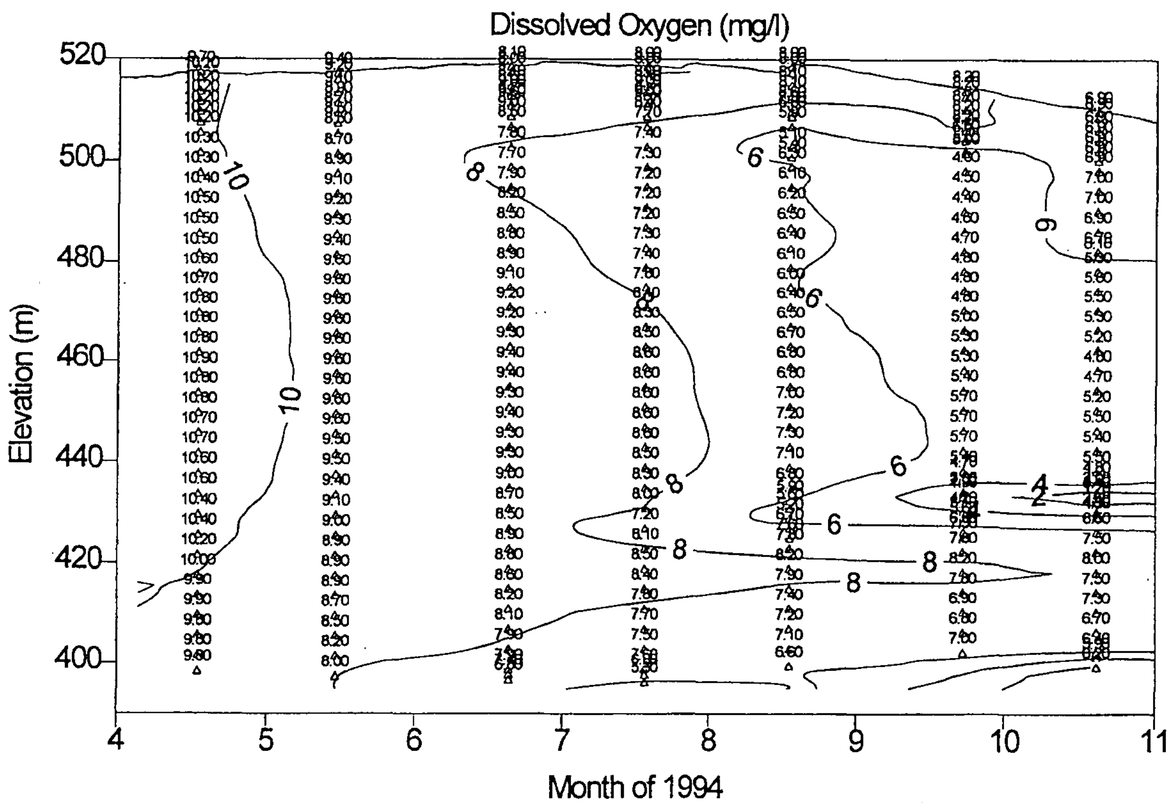


Dissolved Oxygen (mg/l)

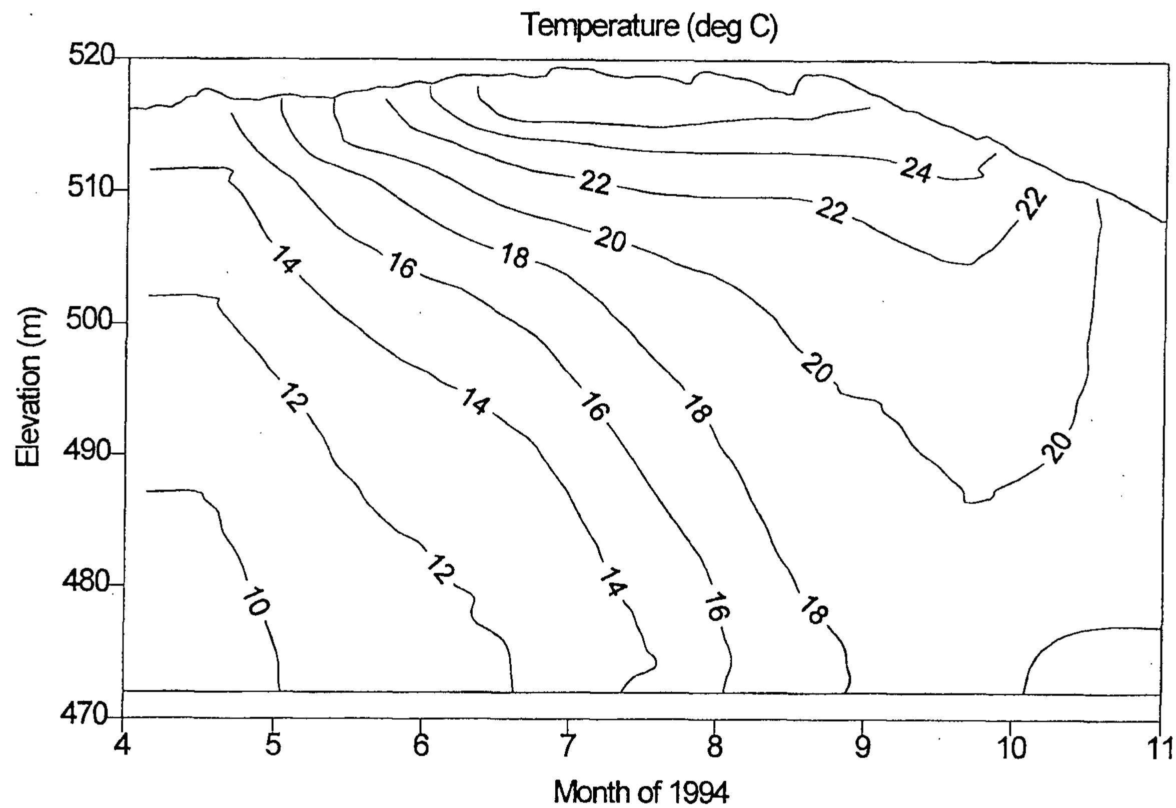


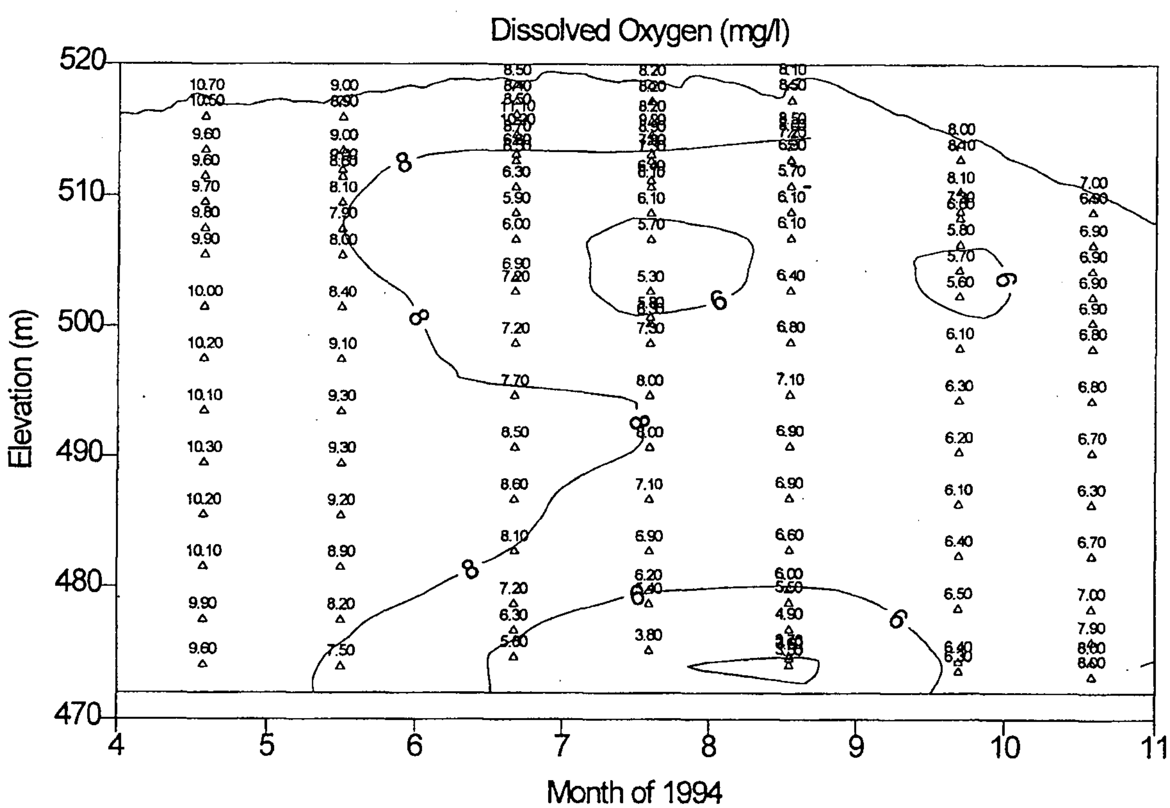
Fontana Reservoir - LTRM 62



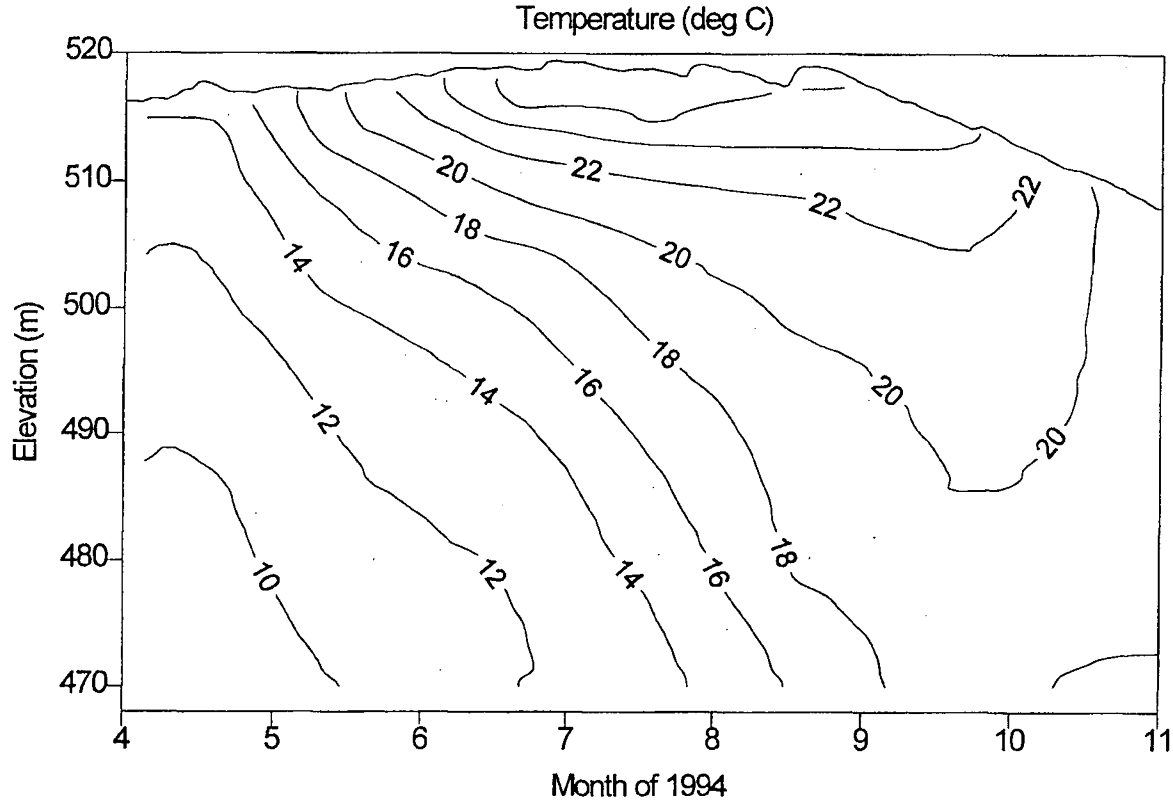


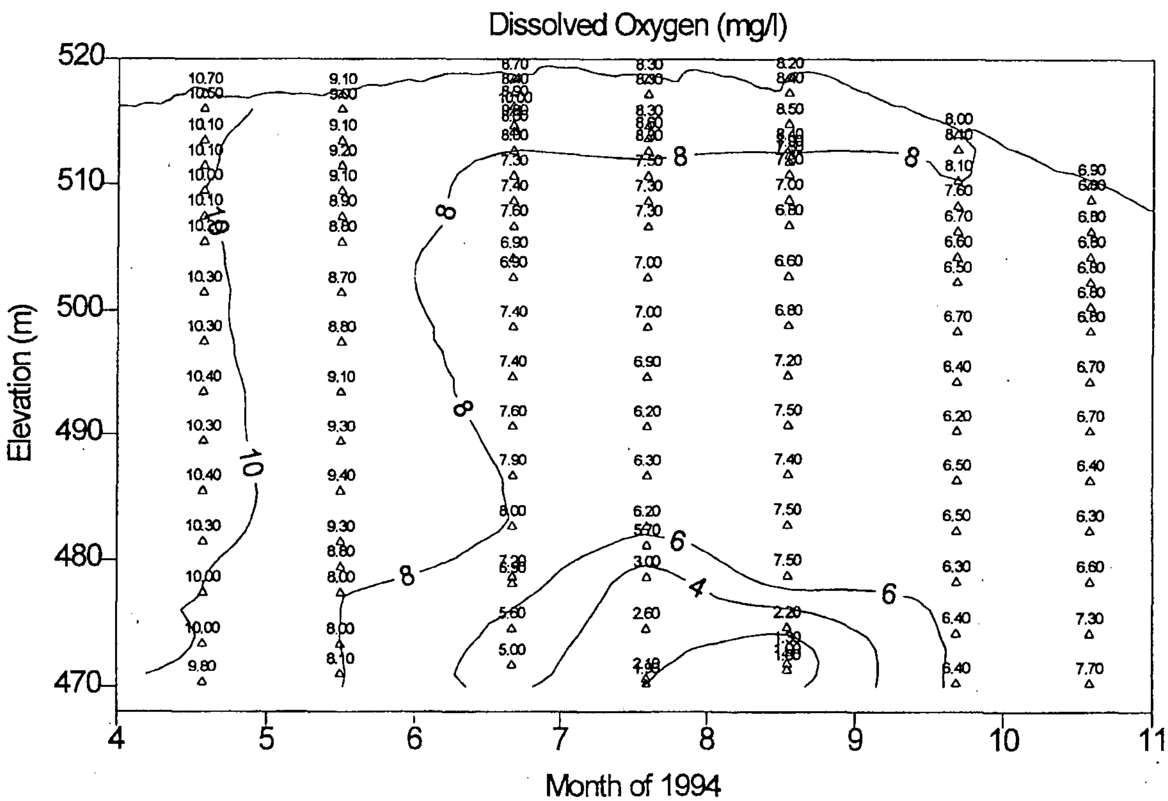
Fontana Reservoir - LTRM 81.5





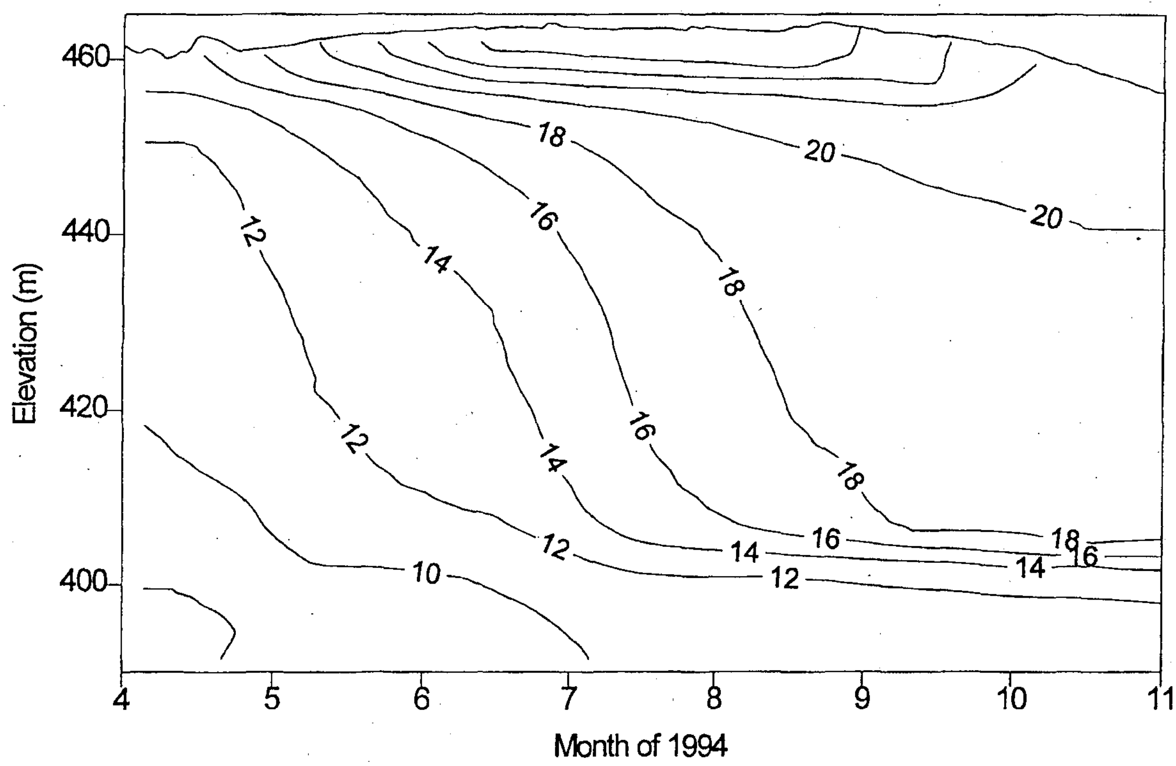
Fontana Reservoir - Tuckaseegee River Mile 3



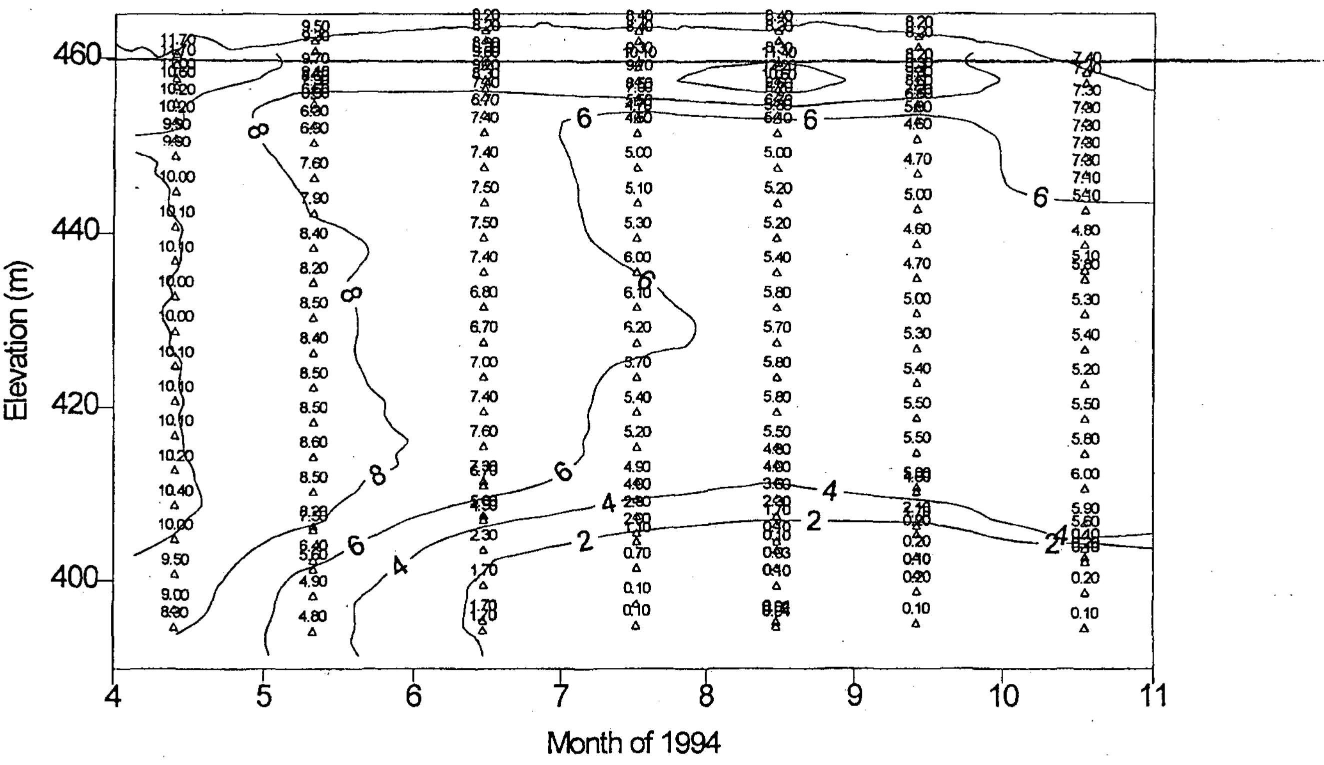


Hiwassee Reservoir - HiRM 77

Temperature (deg C)

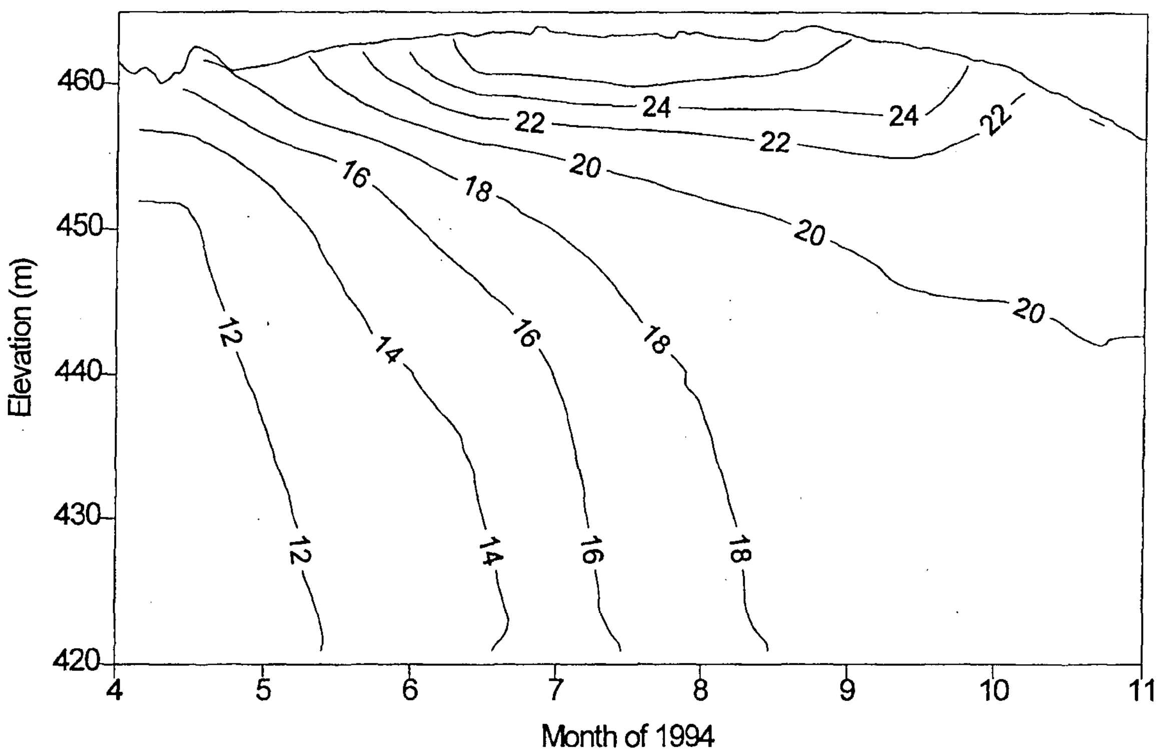


Dissolved Oxygen (mg/l)

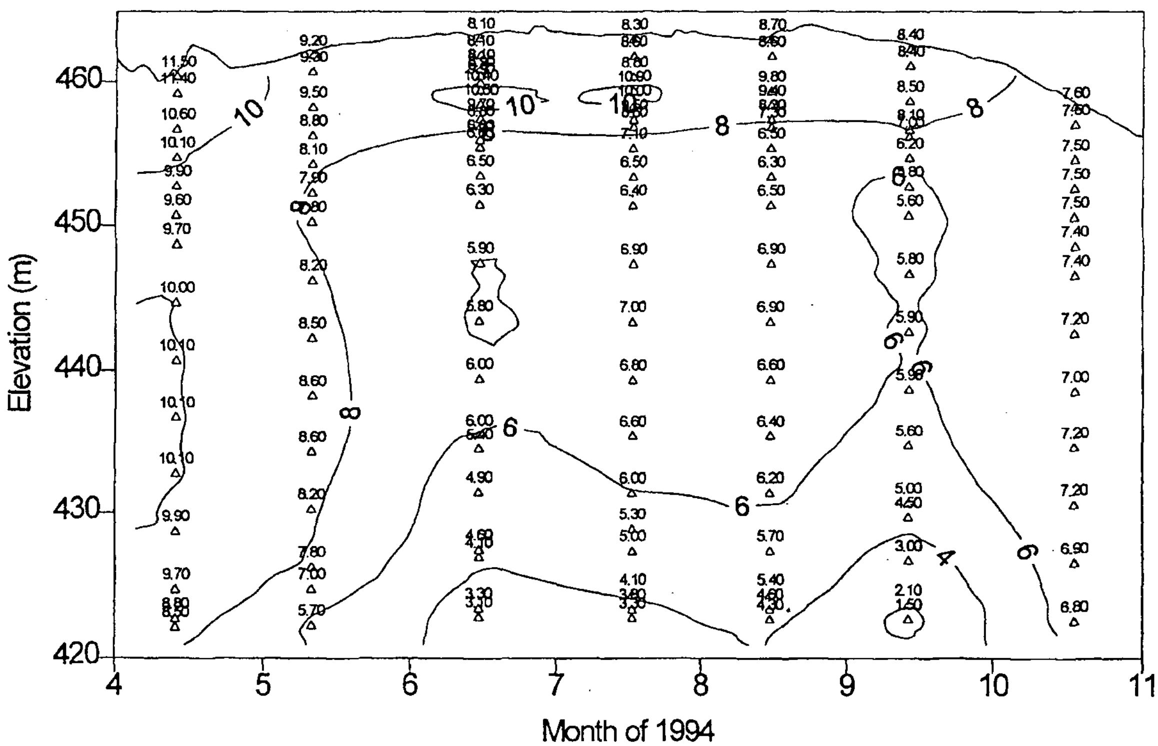


Hiwassee Reservoir - HiRM 85

Temperature (deg C)

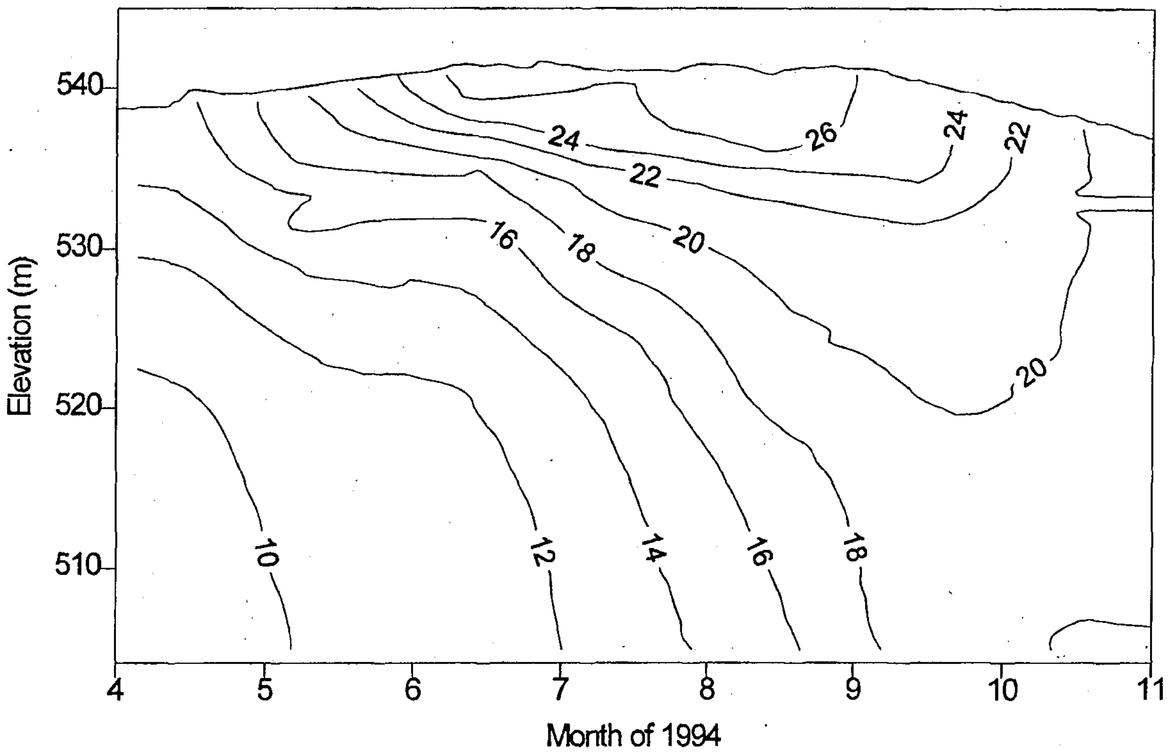


Dissolved Oxygen (mg/l)

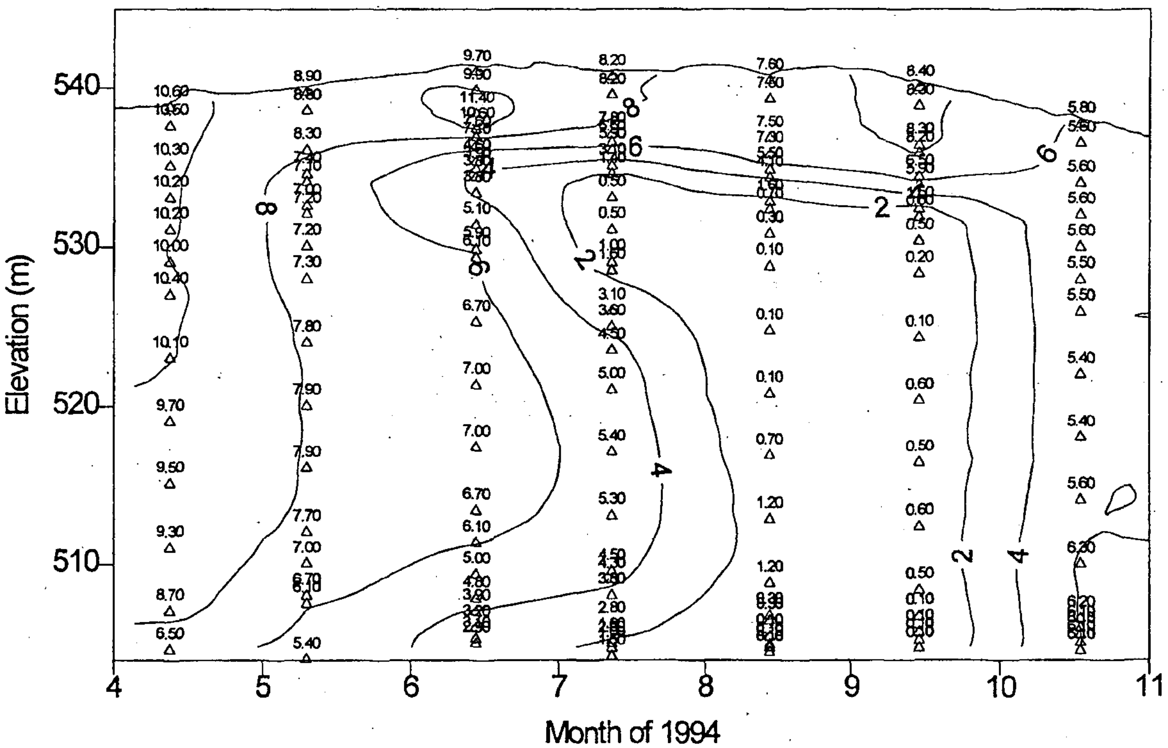


Nottely Reservoir - NRM 23.5

Temperature (deg C)

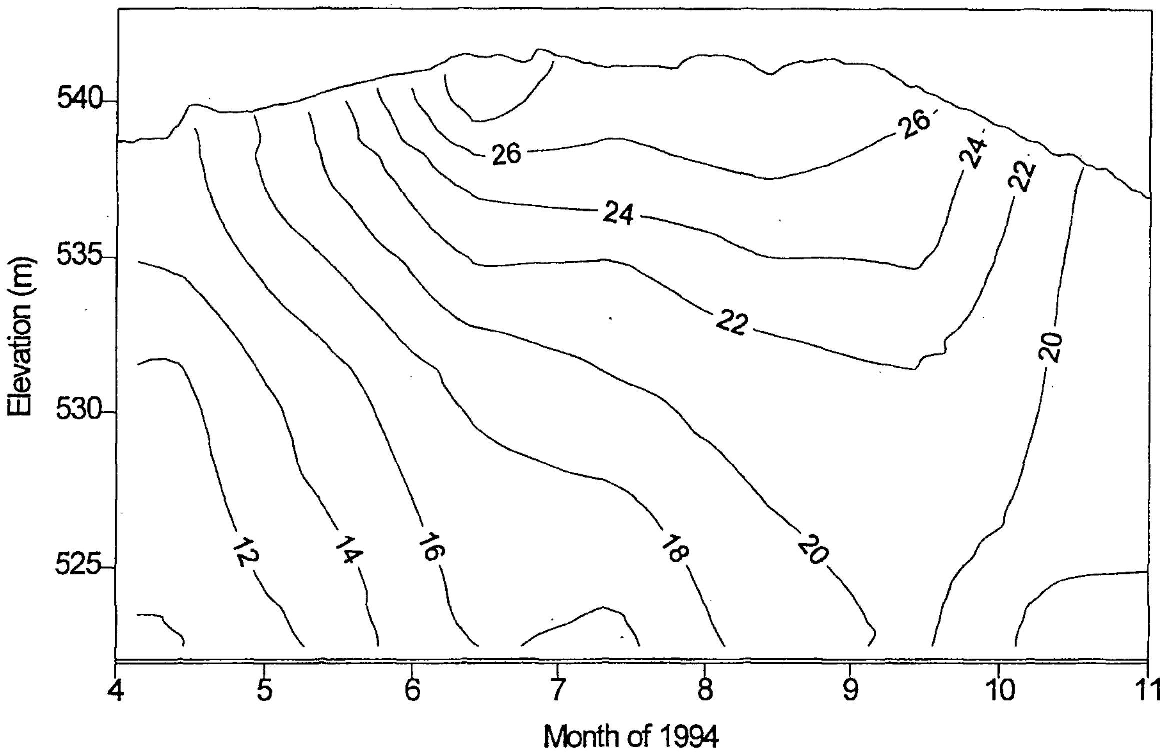


Dissolved Oxygen (mg/l)

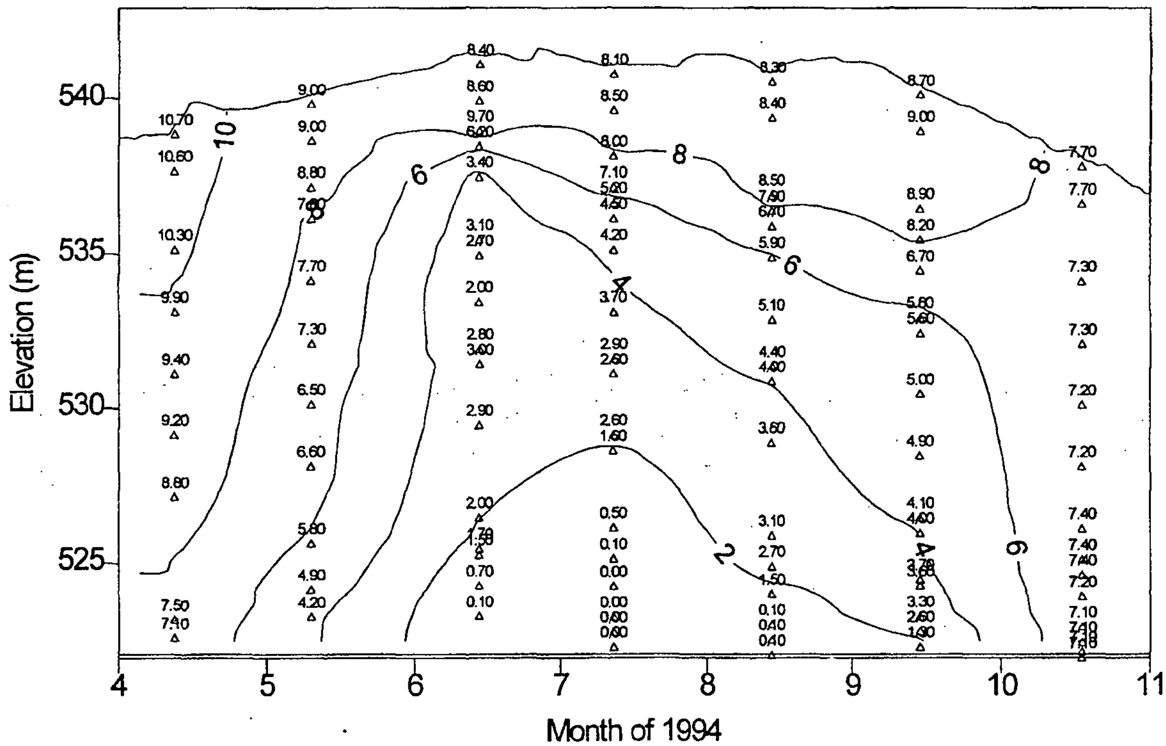


Nottely Reservoir - NRM 31.0

Temperature (deg C)

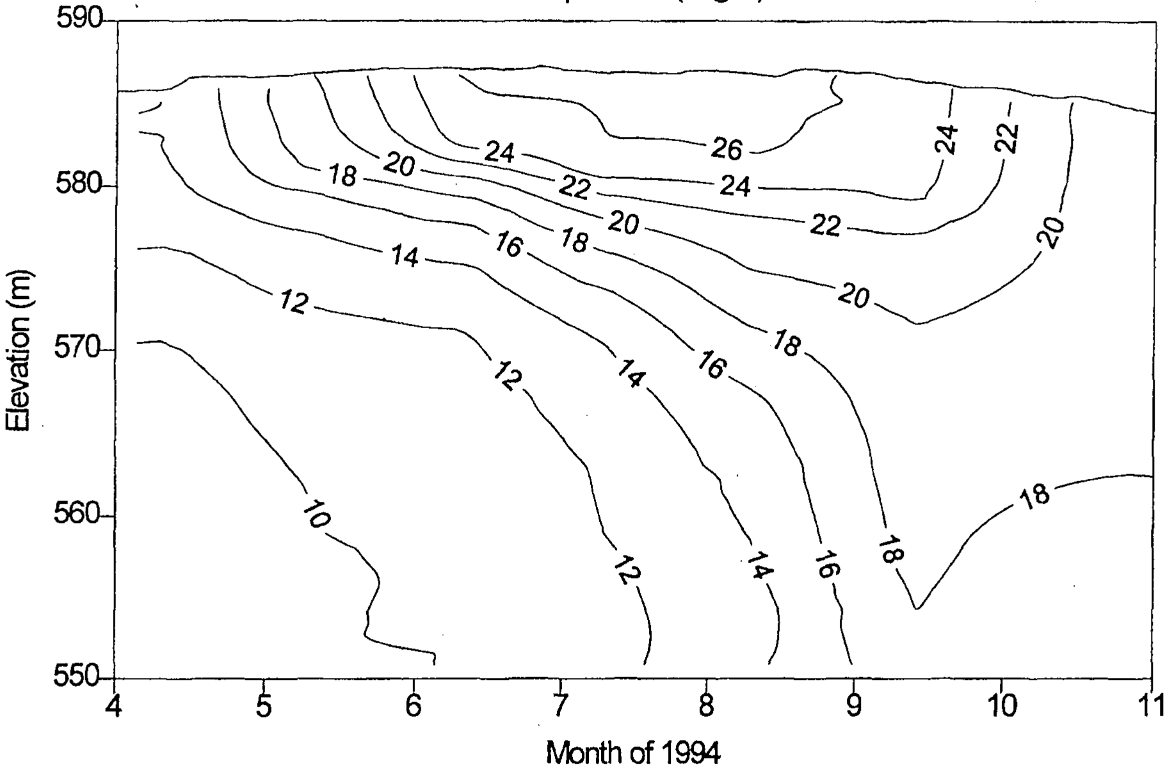


Dissolved Oxygen (mg/l)

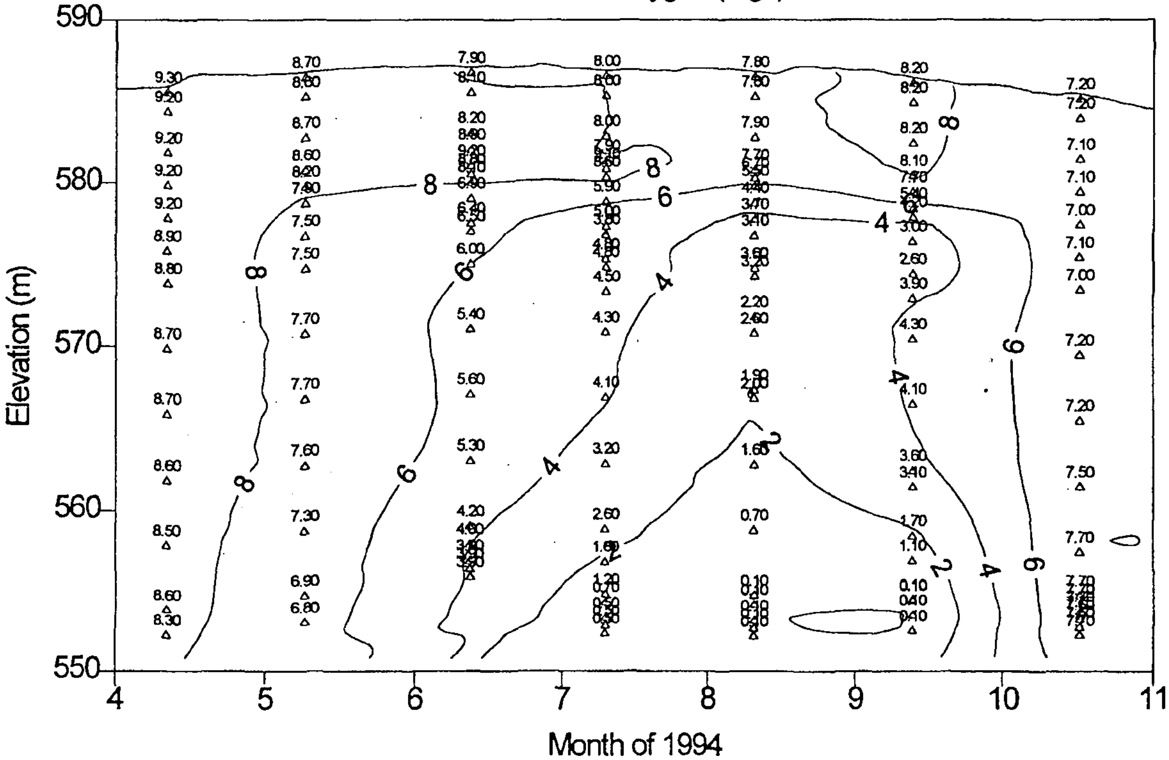


Chatuge Reservoir - HiRM 122

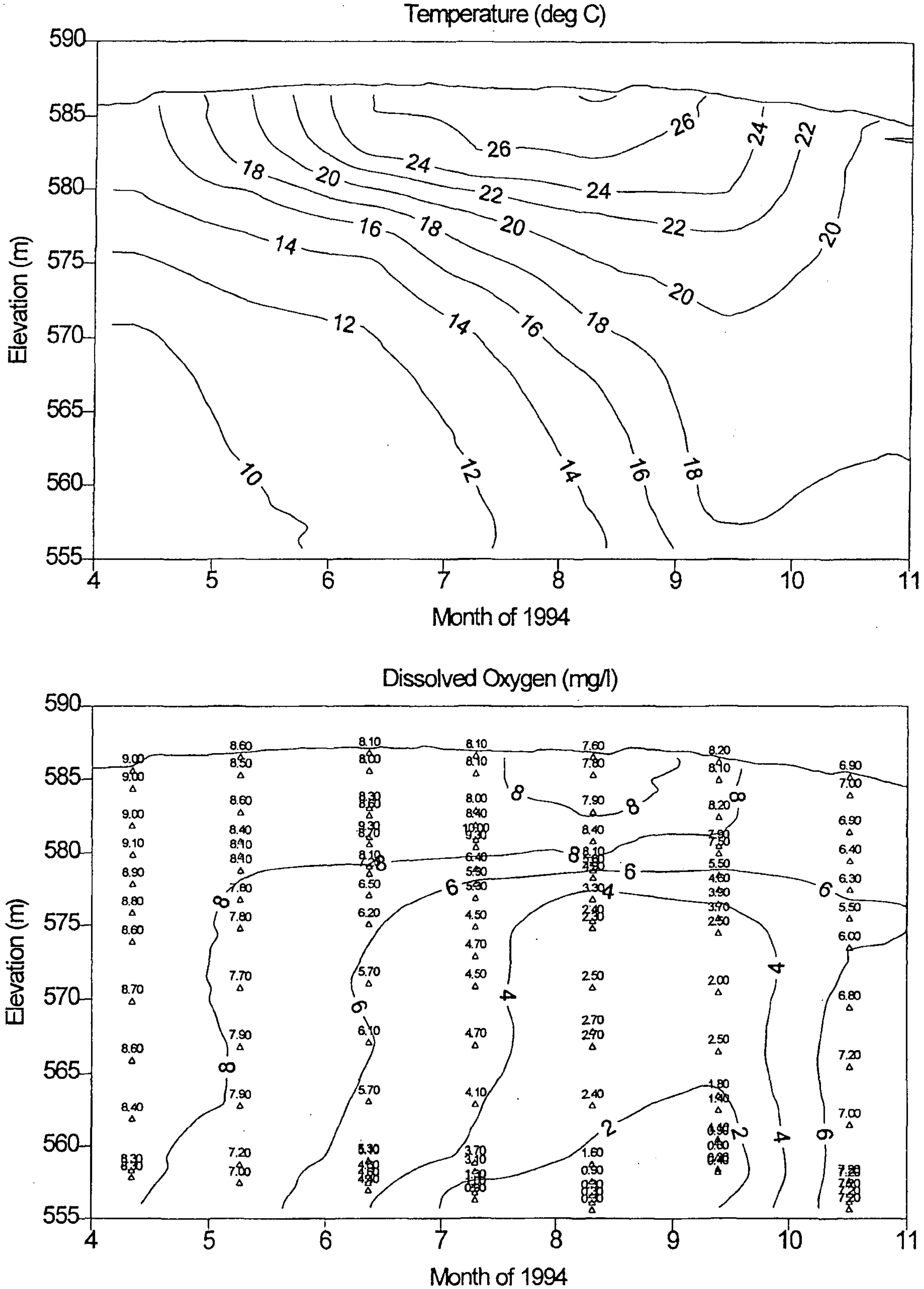
Temperature (deg C)



Dissolved Oxygen (mg/l)

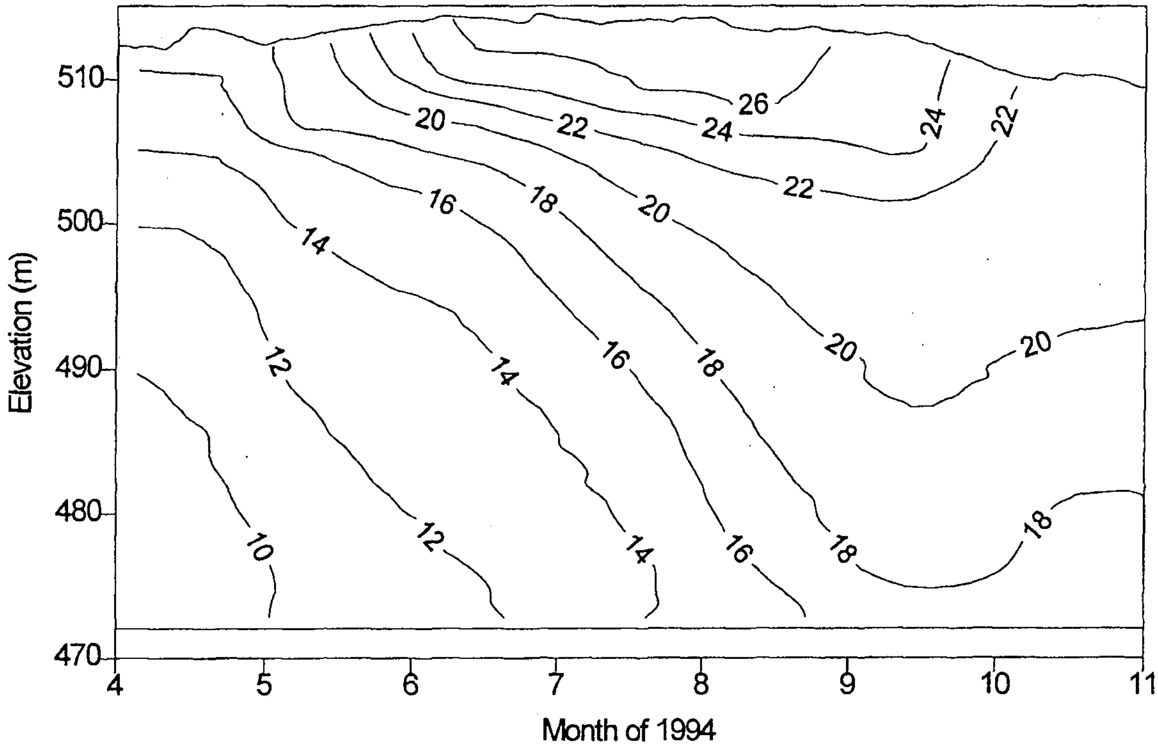


Chatuge Reservoir - Shooting Creek Mile 1.5

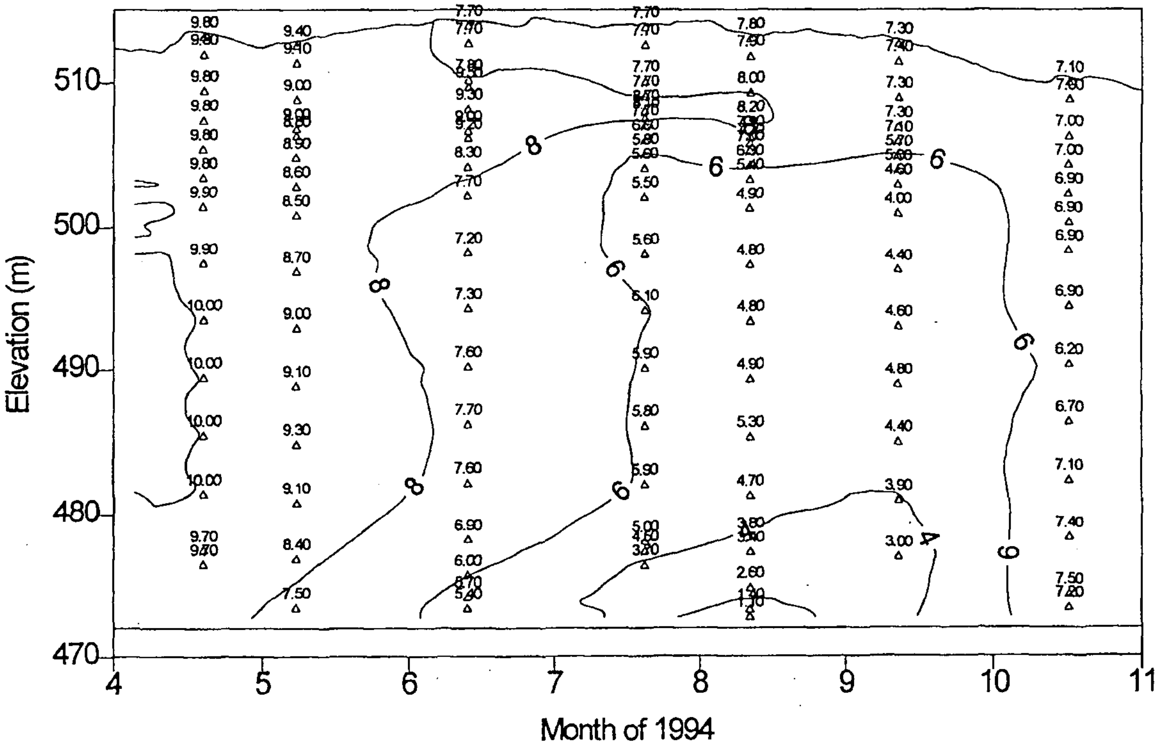


Blue Ridge Reservoir - ToRM 54.1

Temperature (deg C)

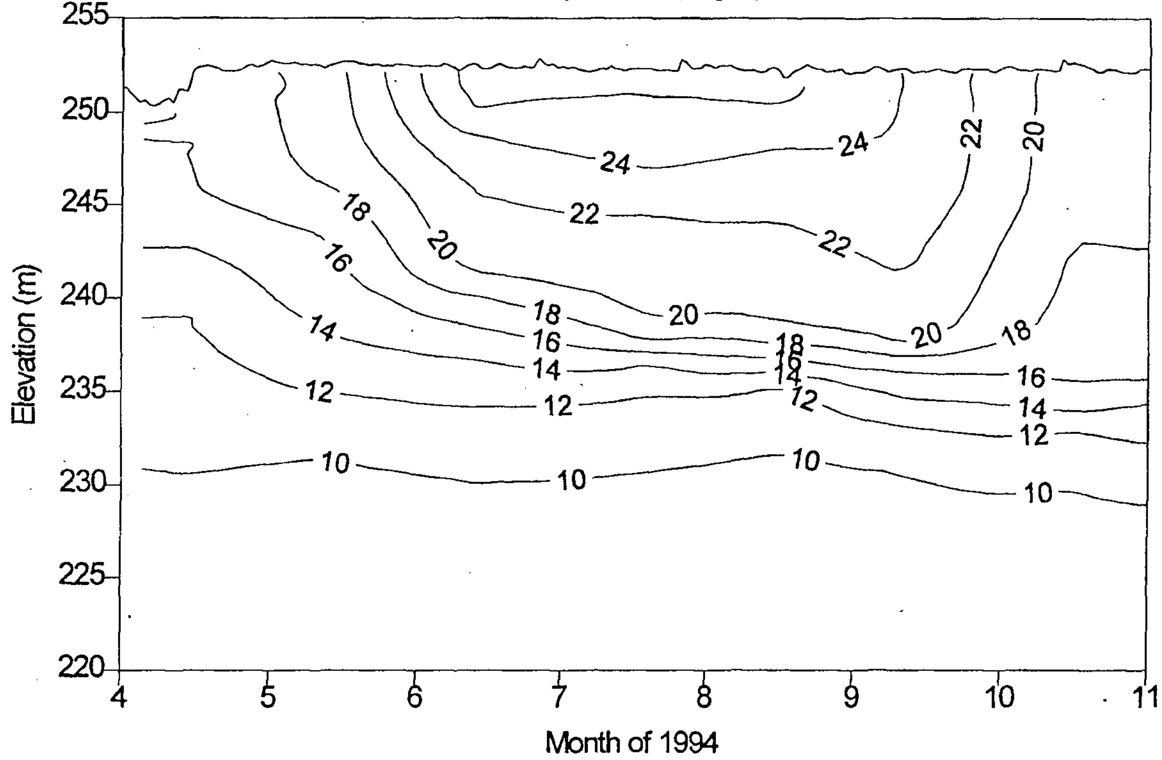


Dissolved Oxygen (mg/l)

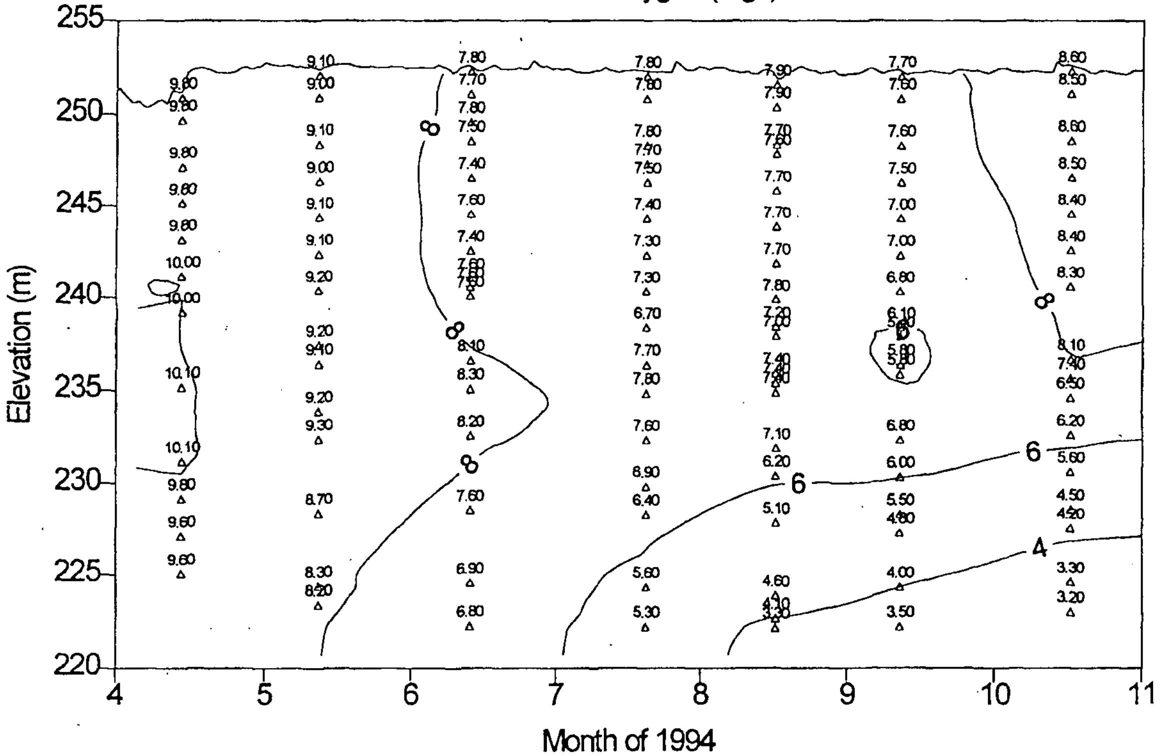


Ocoee #1 Reservoir - ORM 12.5

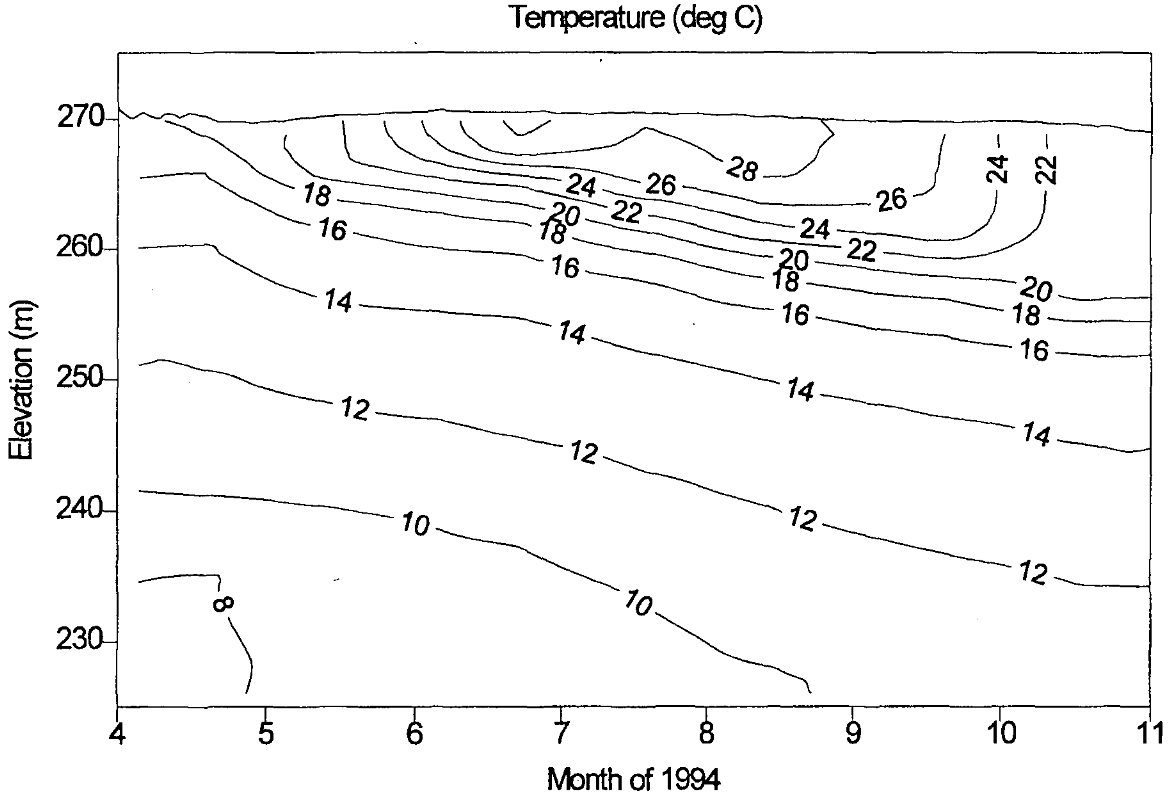
Temperature (deg C)

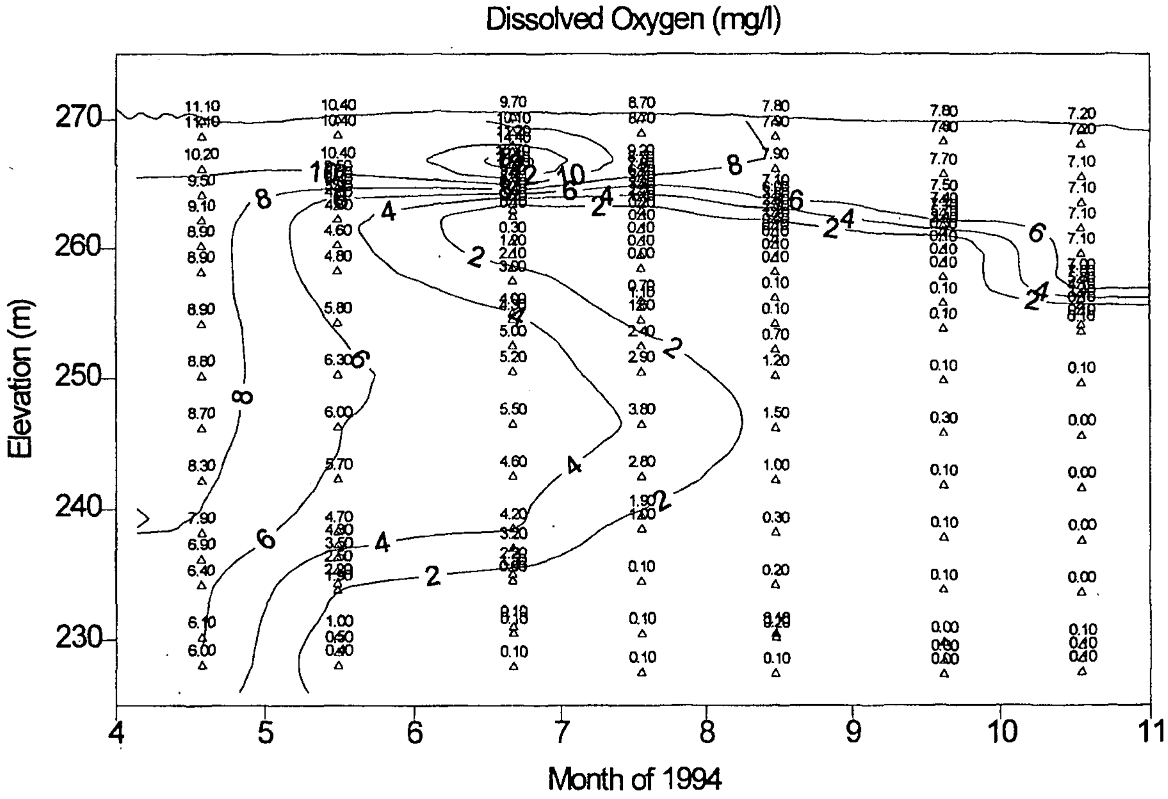


Dissolved Oxygen (mg/l)

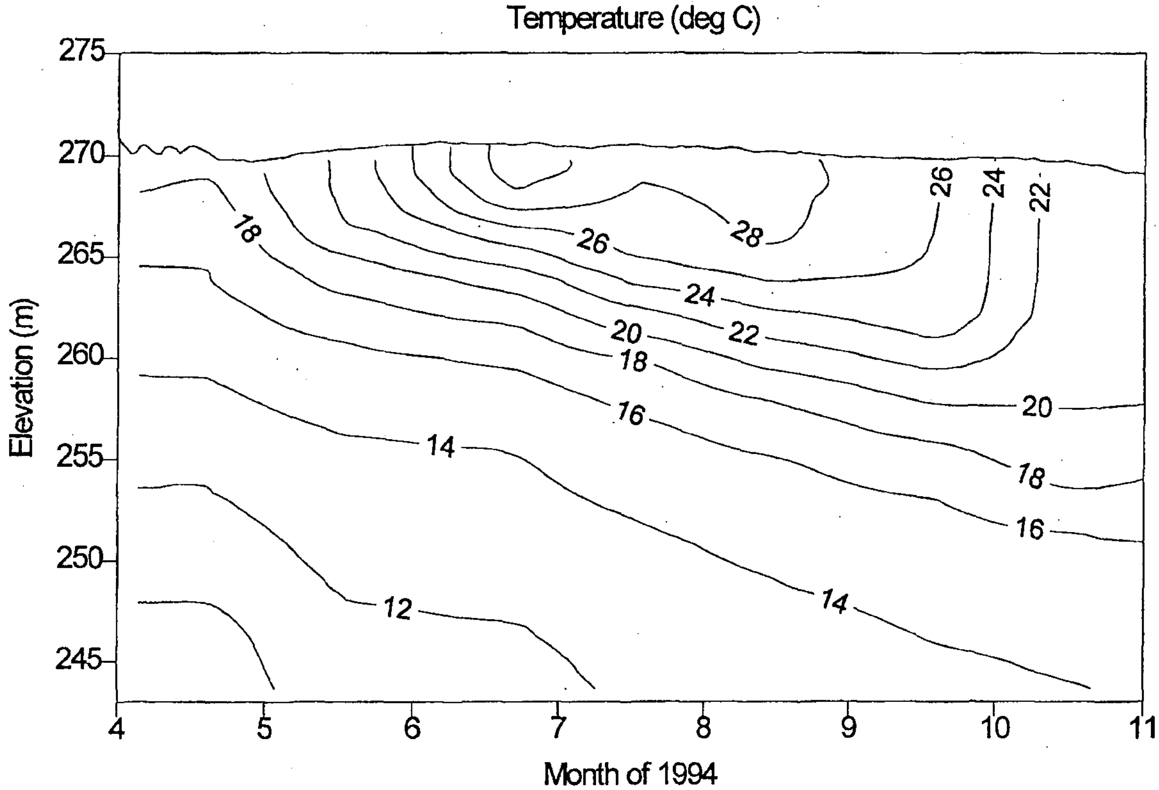


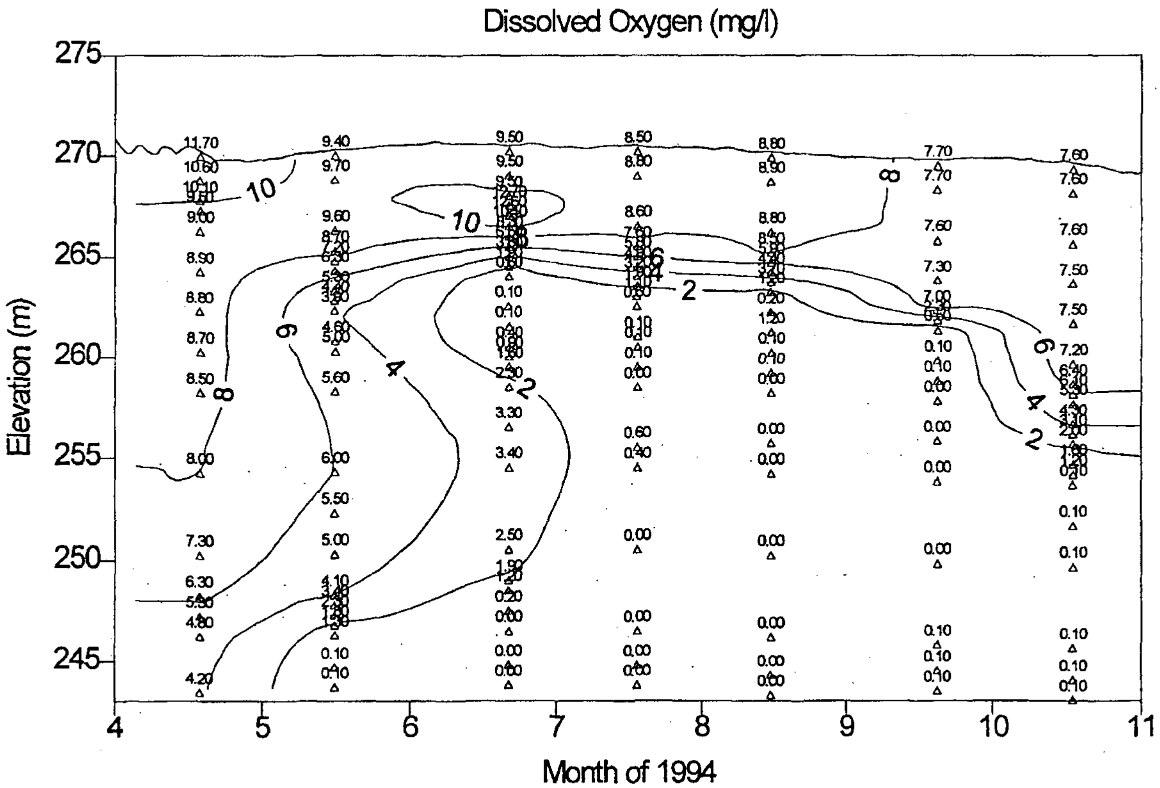
Tims Ford Reservoir - ERM 135





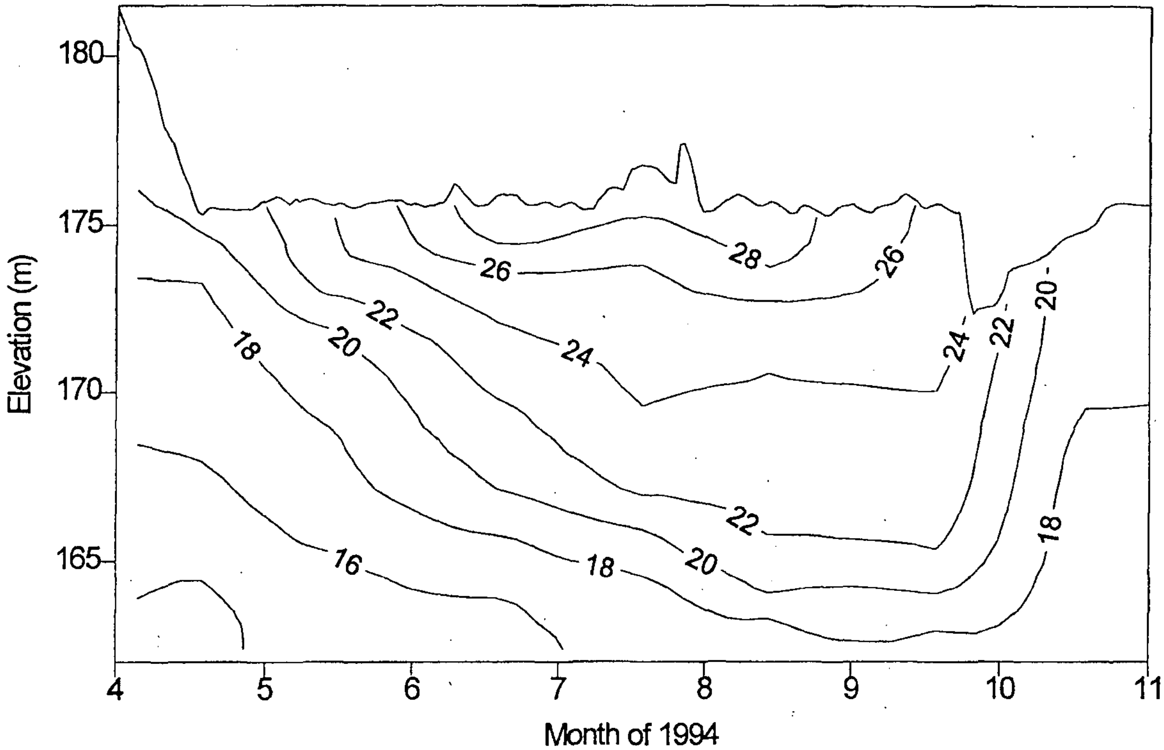
Tims Ford Reservoir - ERM 150



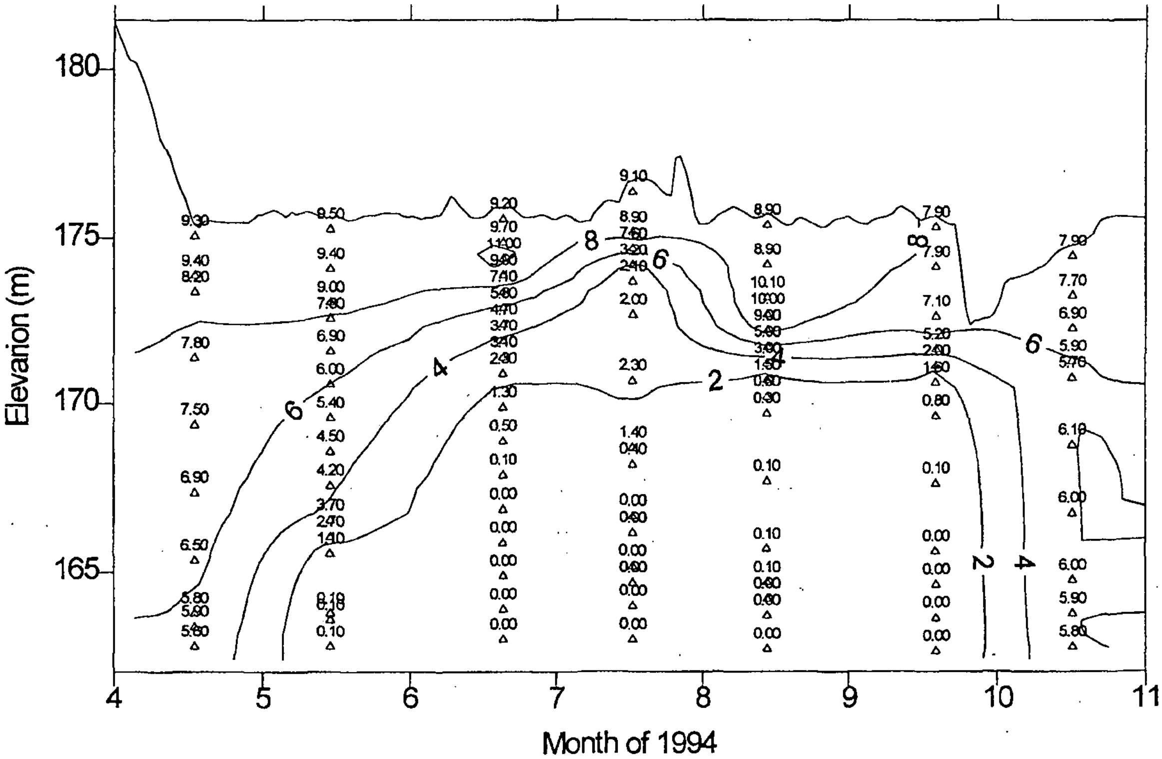


Bear Creek Reservoir - BCM 75.0

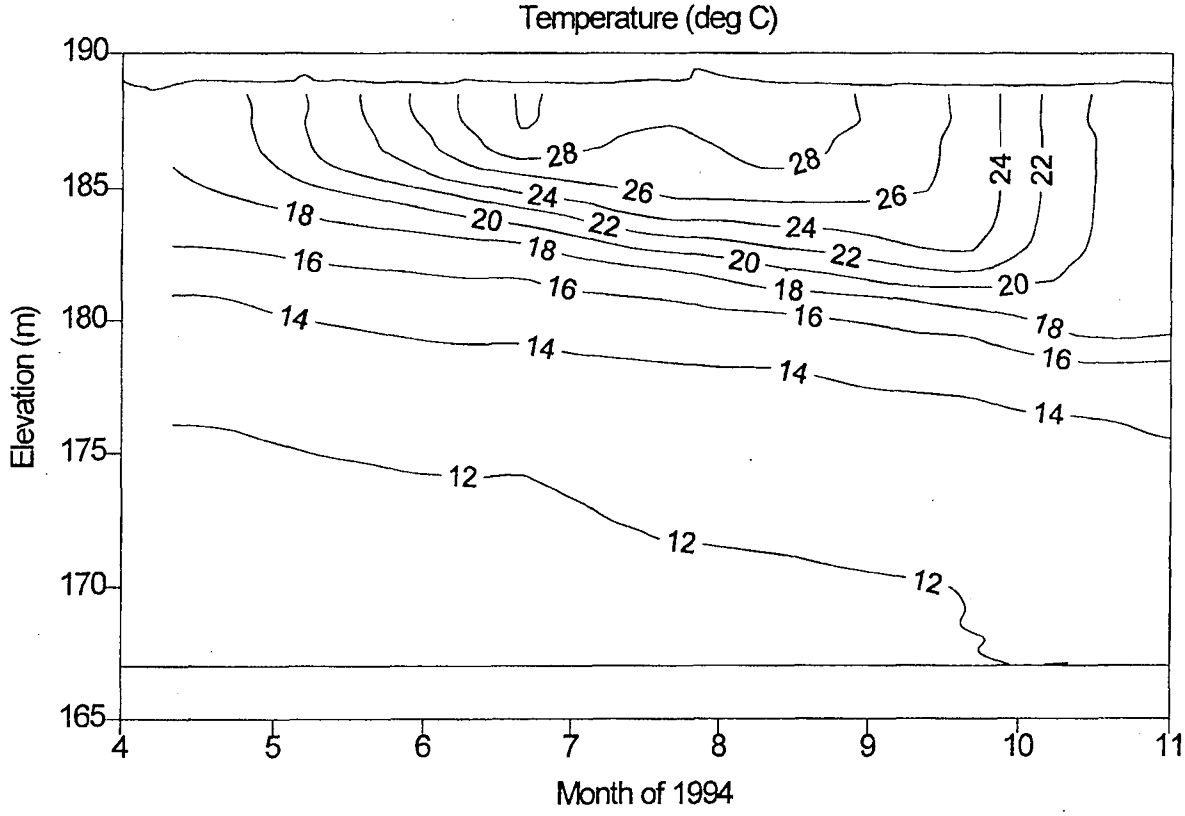
Temperature (deg C)

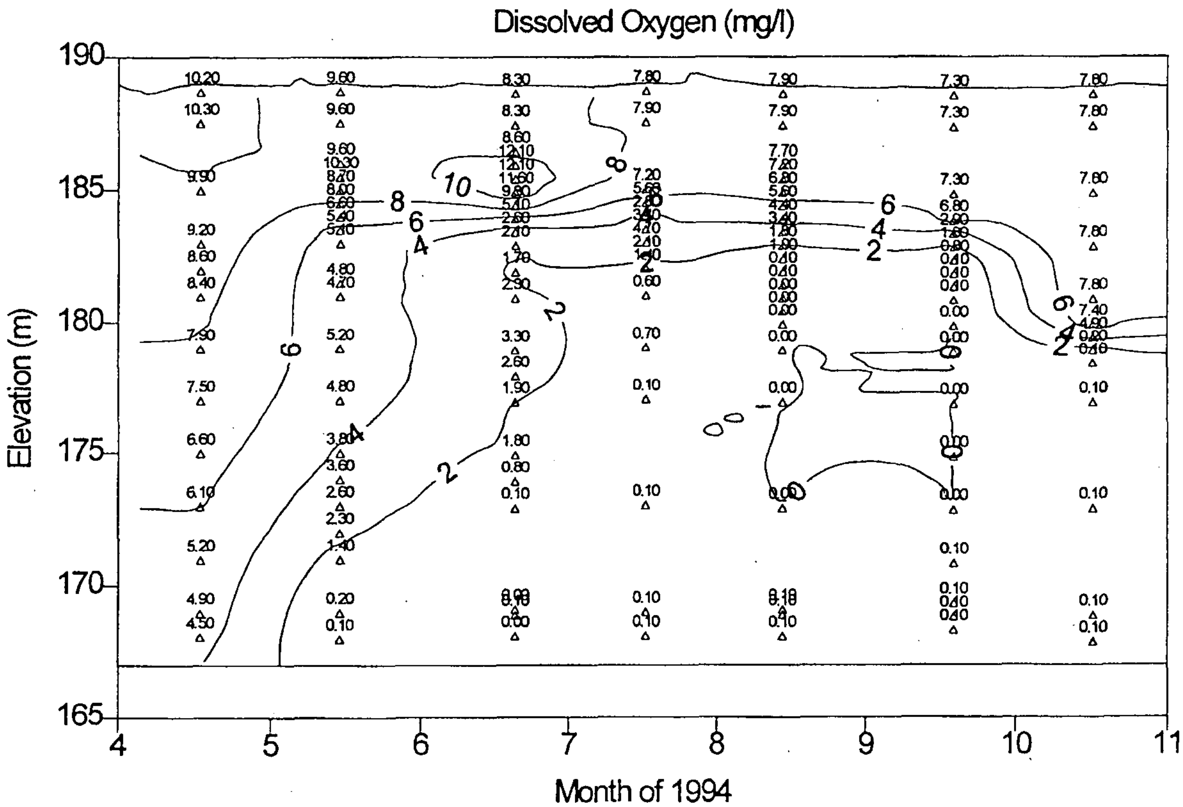


Dissolved Oxygen (mg/l)

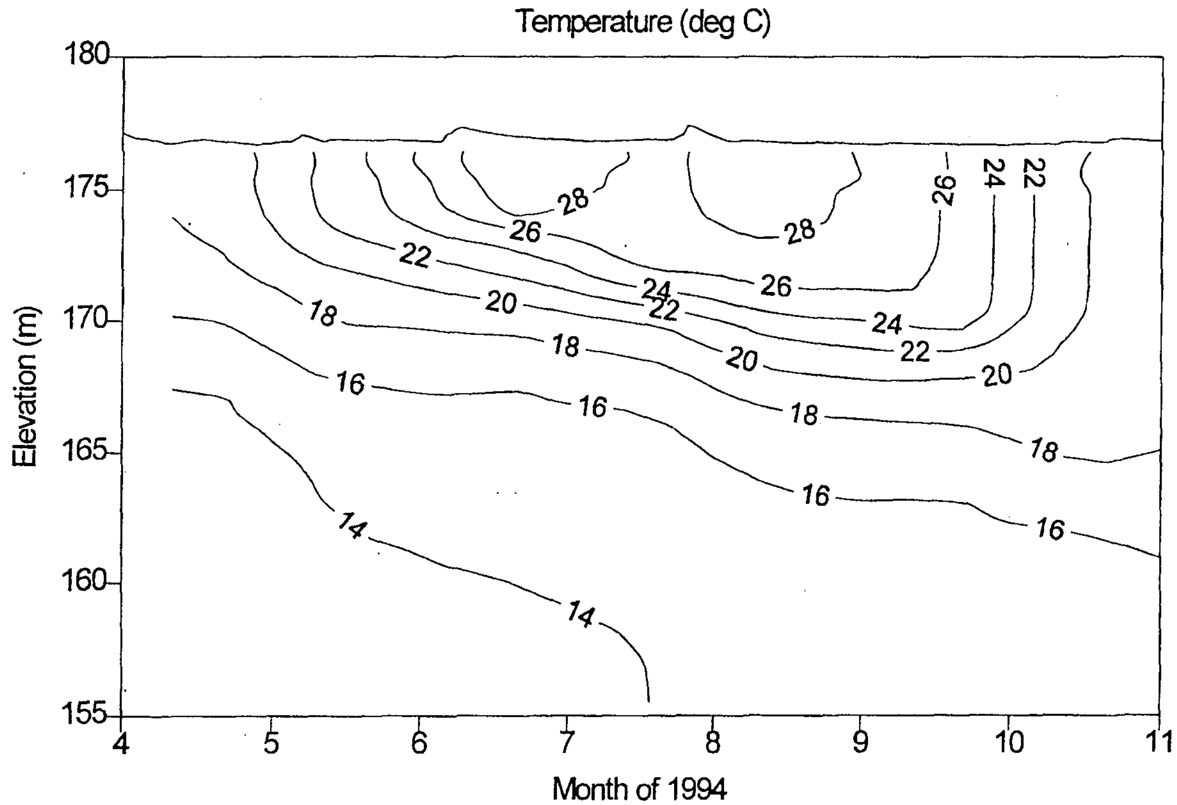


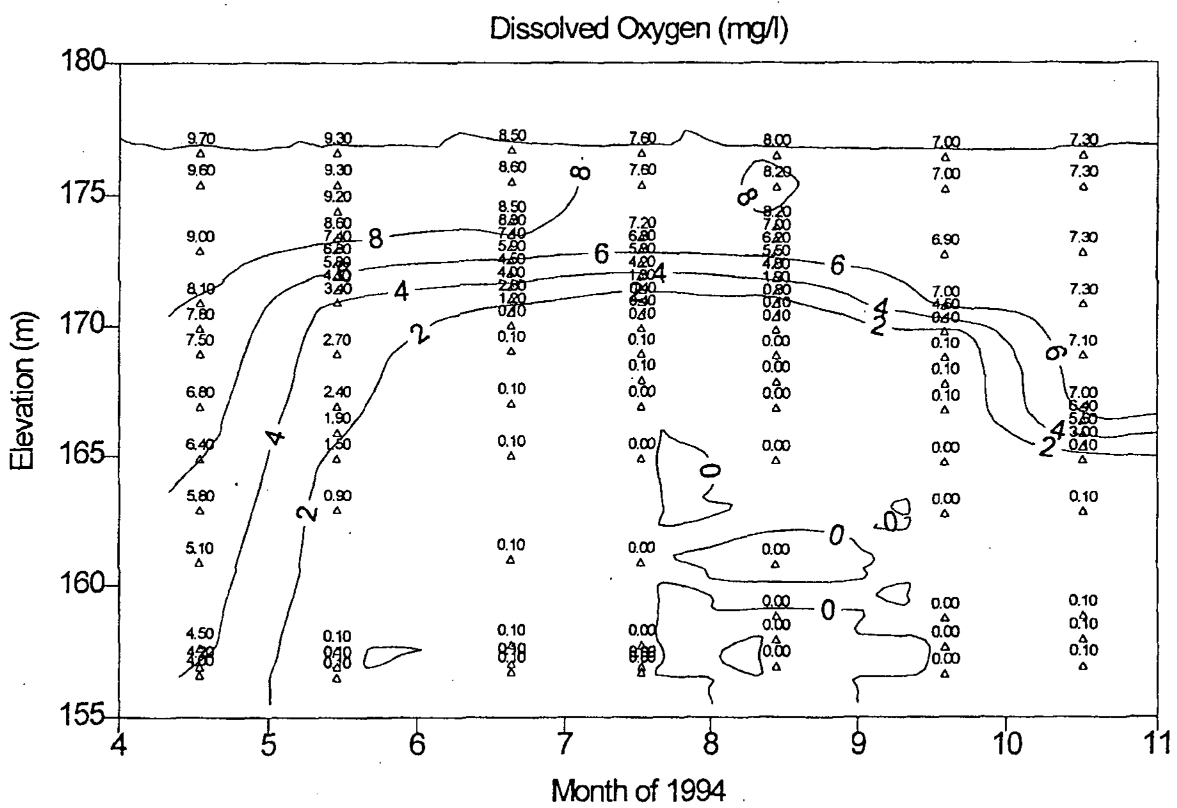
Little Bear Creek Reservoir - LBCM 12.5





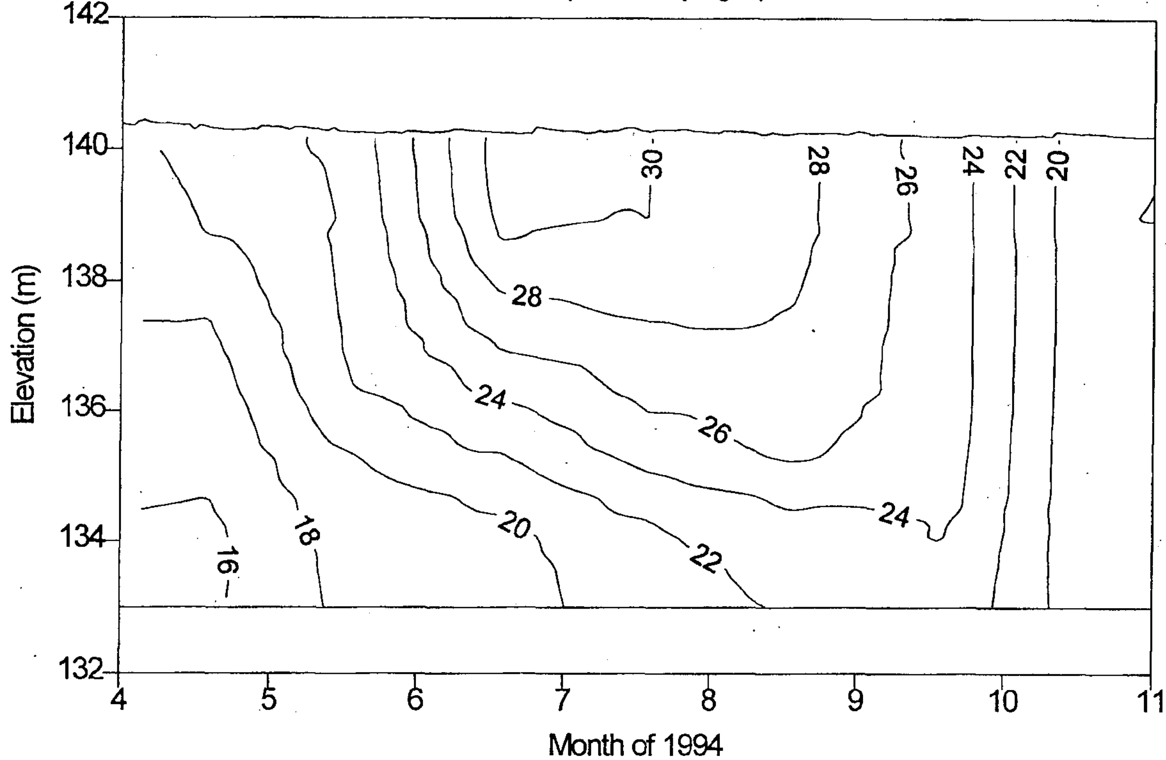
Cedar Creek Reservoir - CCM 25.2



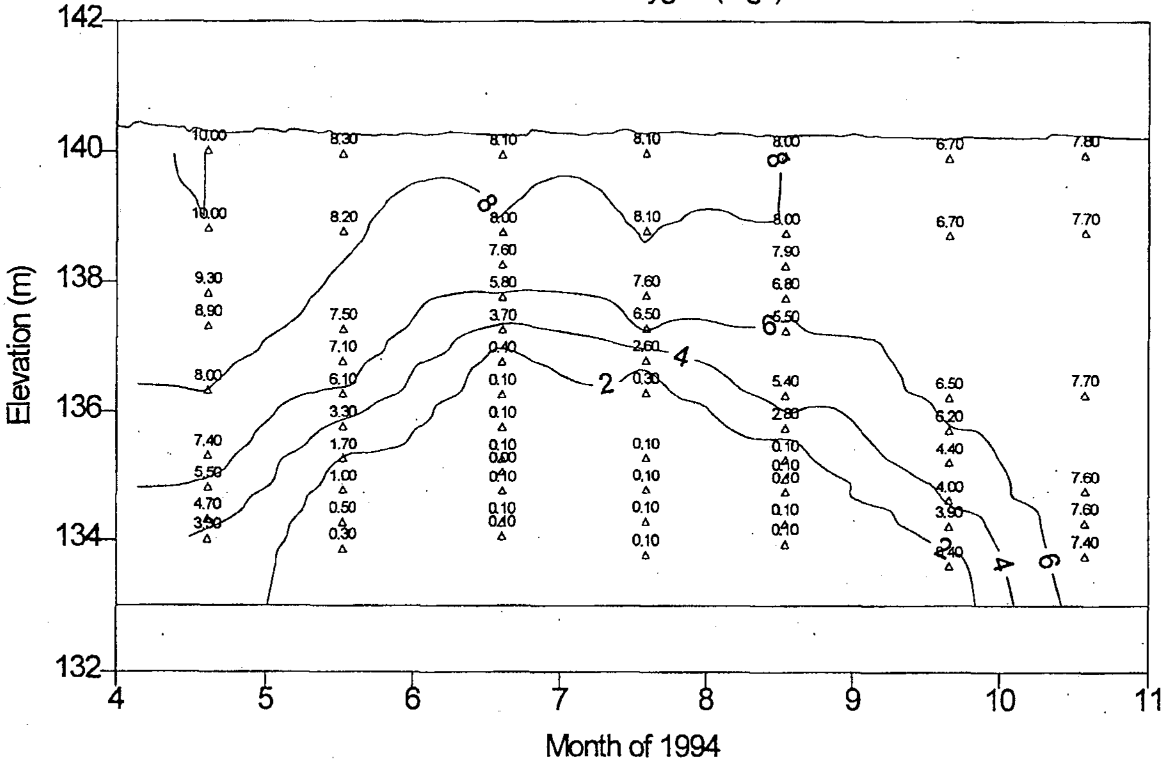


Beech Reservoir - BCM 36.0

Temperature (deg C)

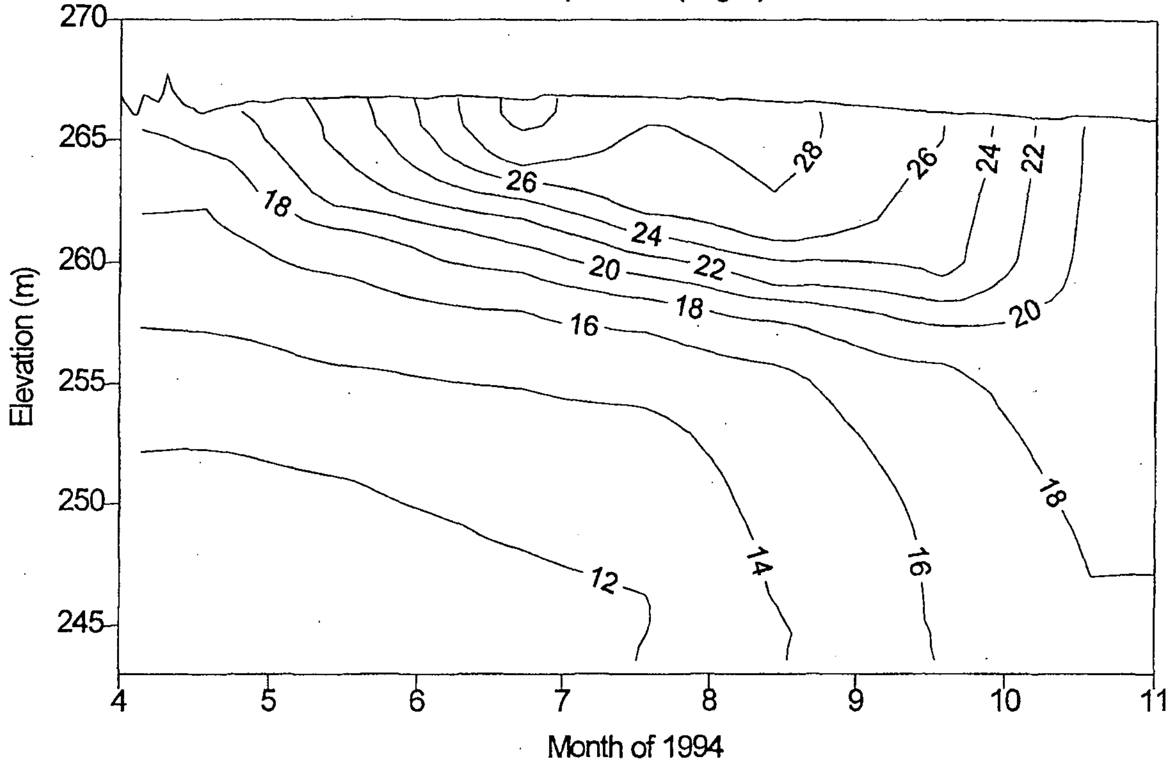


Dissolved Oxygen (mg/l)

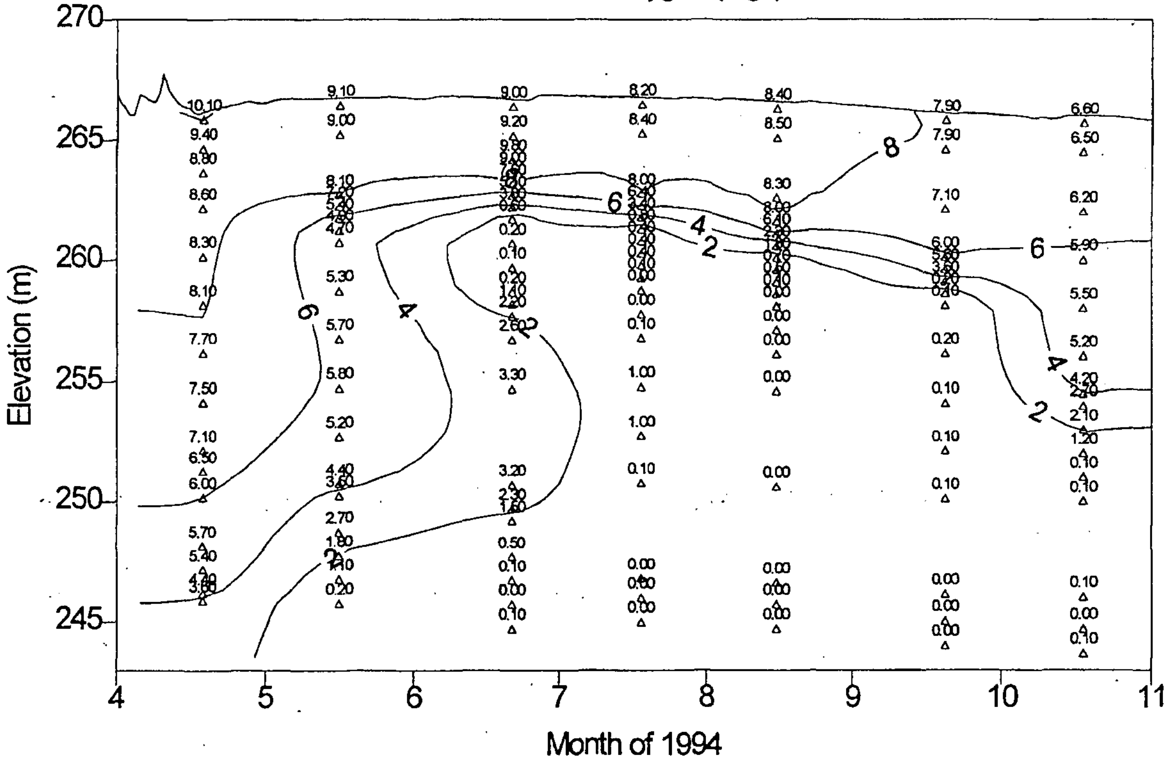


Normandy Reservoir - DRM 249.5

Temperature (deg C)



Dissolved Oxygen (mg/l)



Section 4

Benthic Macroinvertebrate Community

Appendix A.

Reservoir Benthic Macroinvertebrate Sampling -- Late Fall Versus Early Spring Collections

Reservoir Benthic Macroinvertebrate Sampling -- Late Fall vs Early Spring Collections

Summary: The TVA expecience has shown that late winter/early spring sampling period is not acceptable for benthic macroinvertebrates because results are reflective of conditions which occurred the previous year. This causes results from this indicator to be out of synch with the other four indicators. Thorough evaluation showed late fall/early winter collection and use of field identification to the family and order levels would negate problems resulting from early spring sampling and would not impact the contribution of this important community to the overall evaluation.

Detail: Initially, benthic macroinvertebrate sampling was conducted in late winter/early spring (February - April) to avoid aquatic insect emergence. Late fall/early winter was not considered feasible because the required reporting date of mid-January would not allow processing time in the laboratory. Also, there was concern that insect instars would be so small that they could pass through the collection screen and or be difficult to identify.

A potential weakness in this approach was that samples would be collected so early in the year that results would be representative of conditions which had occurred the previous year causing them to be out of synch with results for the other four indicators. This potential was manifested in the TVA monitoring program during consecutive years when dissolved oxygen conditions were good in year one and two, poor the third year, then good again the fourth year. Benthos results were good in years one, two, and three, and poor the fourth year. The overall ecological health score should have been lowest in year three and high again in year four. This difference was not as discernable as it should have been because the good score for the benthos collected late winter the third year (actually representing the good DO in the second year) off-set the poor DO scores which resulted from very low DOs during the summer of the third year. Improved conditions the fourth year were not as evident in the overall score because of the poor rating for benthos.

A thorough evaluation was conducted to examine the feasibility of late fall/early winter sample collection.

- For data to be available by the Mid-January reporting data, rapid bioassessment techniques would have to be used. This would require field identification of specimens; to the family or order level, depending on the group. During years three and four, field identifications had been made in addition to detailed laboratory processing to evaluate the potential for using field identification as a cost cutting effort. Benthic index results based on field identications were compared to corresponding results from the laboratory using correlation analysis. Results were very favorable: for the run-of-the river reservoirs r values were 0.80, 0.93, and 0.87 for forebays, transitions zones, and inflows.
- To test the validity of late fall sampling, special collections were conducted during late fall the fourth year. Benthic index scores based on field identifications during both spring and fall showed very little difference:

	Spring	Fall
Chickmauga Reservoir forebay	34	38
Nickajack Reservoir forebay	36	38
Chickmauga Reservoir inflow	26	26
Nickajack Reservoir inflow	38	38
Chickamauga Reservoir embayment	18	36
Chickamauga Reservoir transition zone	38	38

  There was only one location with a substantial difference between the two sample periods. Interestingly, results for fall sampling the fourth year were similar to results for spring sampling the third year, indicating unstable conditions which need to be watched closely in future sampling events.
- Concerns about size of insect instars and ability to identify them satisfactorily were allayed by the successful efforts during the fall test period described above.
- One further test to compare fall versus spring collections was to use Sorensen's Quotient of Similarity to examine taxa present during the two periods. Results of the above test samples showed that taxa present in the fall were as comparable to those collected in the spring as replicate spring sample sets were to each other.

Package Subject: Reservoir Benthics

Item Title: Reservoir Benthics

During the past year, steps have been taken to determine if the cost and timeliness of the Reservoir Benthic Vital Signs data could be improved. Using statistics on past data, we have decided to go from a full laboratory analysis of the samples (approx. $88,000/year lab cost) to a rapid bioassessment (approx $10,000/year lab cost). This will drastically reduce our turn-around time of the data. The Benthic Vital Signs datalogger program already in place will be further implemented to add to the timeliness of the data. We've also decided to move the sampling season from early spring to early winter, so that when RiverPulse comes out in the spring, the benthic information won't be a year old and will correspond with the rest of the ecological health indicators. If you would like more information or would like to discuss these decisions please contact Amy Wales, Anita Masters, Tom McDonough, or Don Dycus.

Combined 93 + 94 Rapid Bio vs Standard

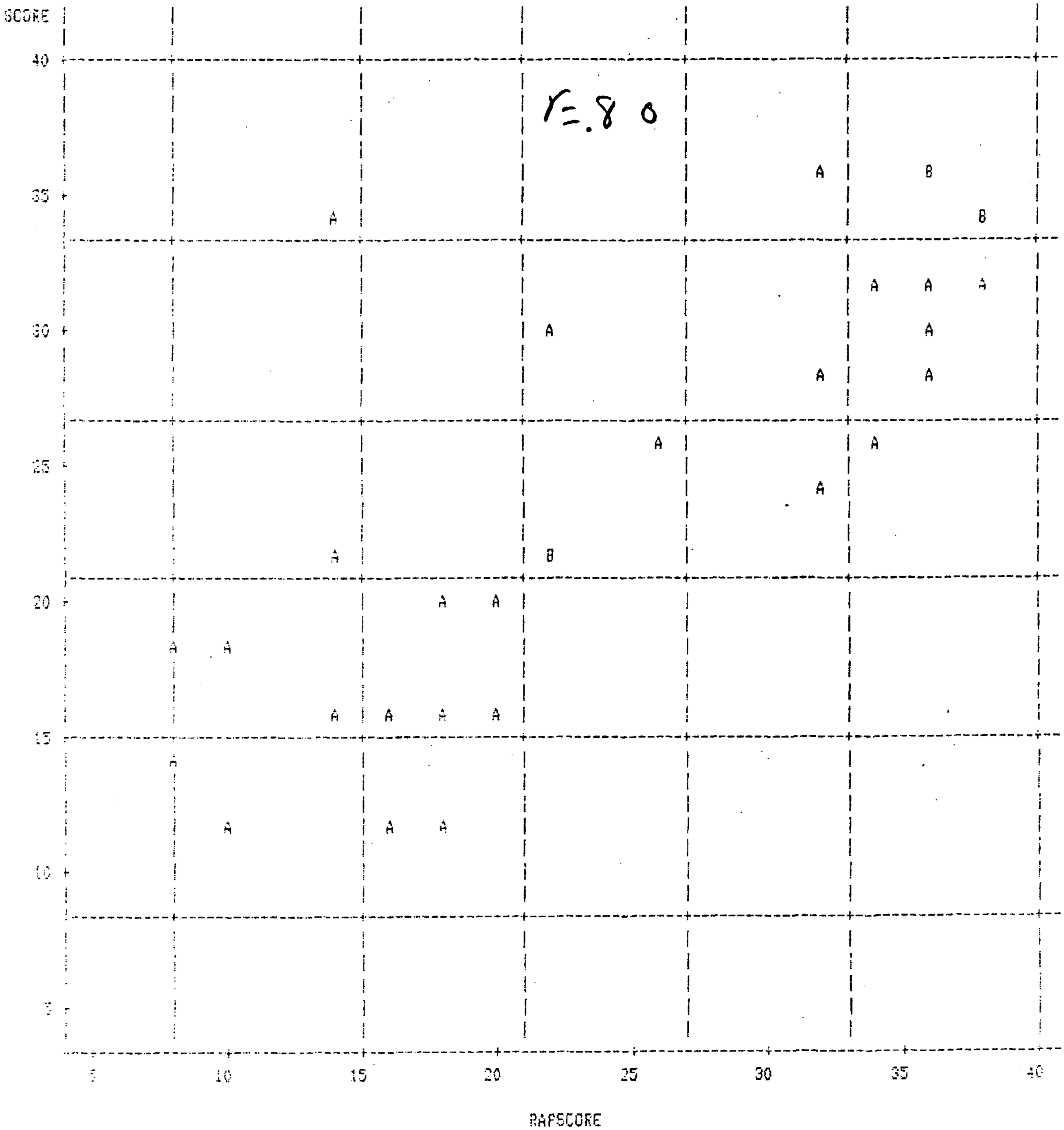
Figure 1. Run-of-River, Forebays (Spring Sampling)

The SAS System 10:23 Tuesday, February 14, 1995

Correlations

RESTYPE=MAIN WBOSECNA=FOREBAY

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.



Combined 93 & 94 Rapid Bio vs Standard

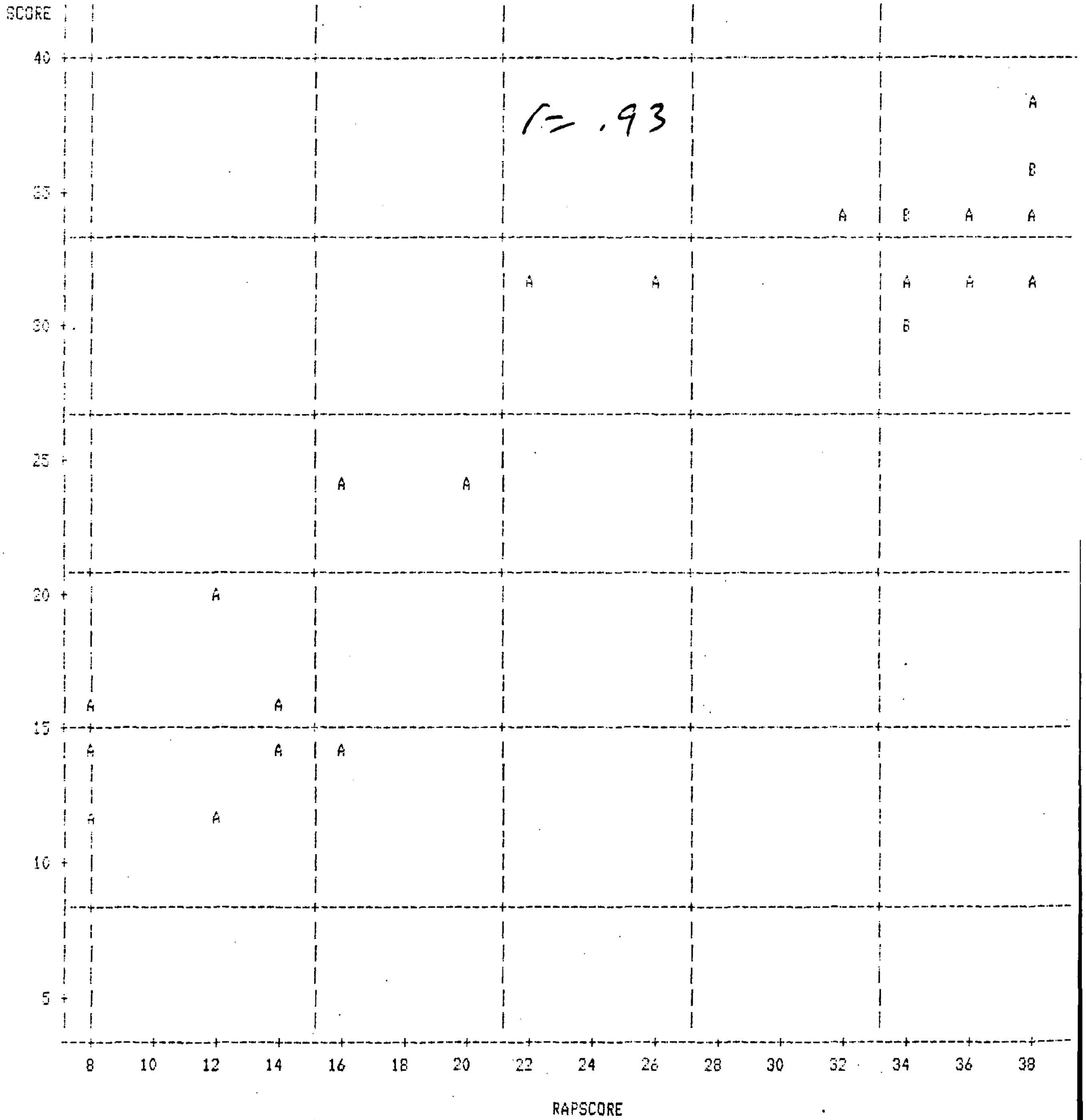
Figure 2. Run-of-River Reservoirs, Transition Zones (Spring collections)

The SAS System 10:23 Tuesday, February 14,

Correlations

RESTYPE=MAIN WBDSECNA=TRANSITION

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.

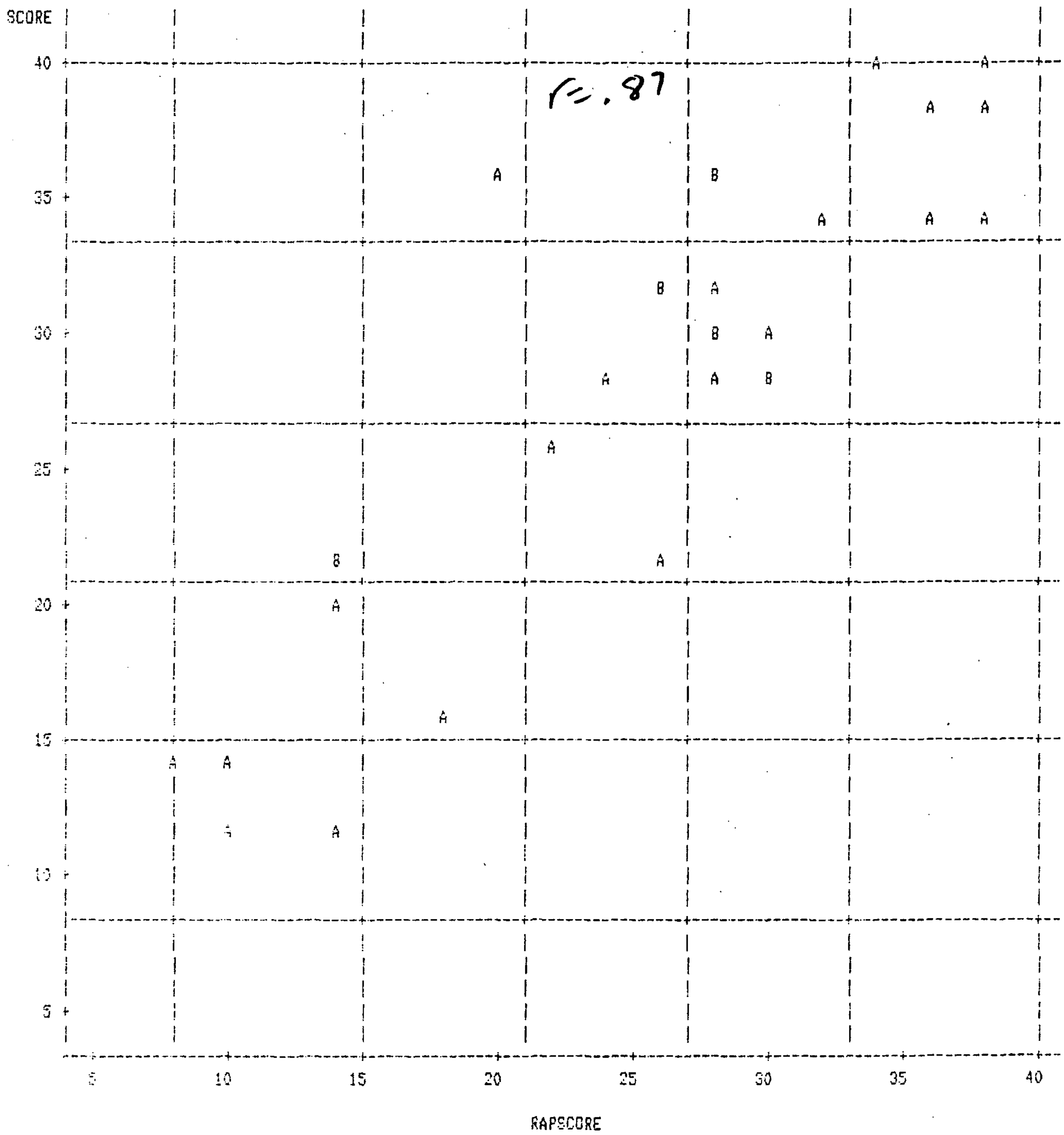


Combined 93 & 94 Rapid Bio vs Standard
Figure 3. Run-of-River Resorvoirs, Inflows (Spring Sampling)

Correlations

RESTYPE=MAIN WBDSECNA=INFLOW

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.



NOTE: 1 obs had missing values.

1994 Rapid Bio US standard

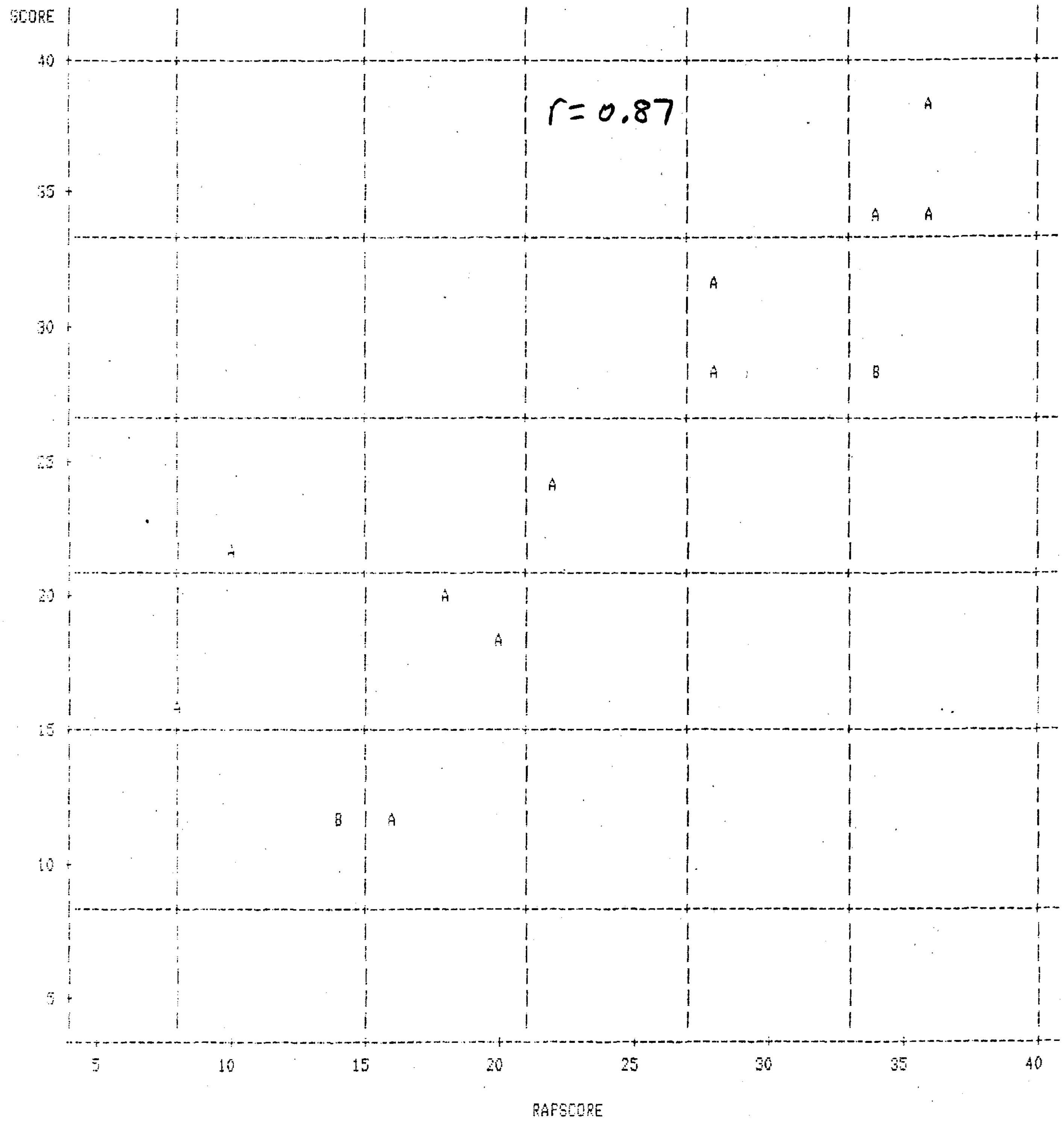
Figure 4. Run-of-River Reservoirs, Forebays (Spring Sampling)

The SAS System 11:34 Wednesday, February 8, 1995

Correlations

RESTYPE=MAIN WBDSECNA=FOREBAY

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.



1994 Rapid Bio vs Standard

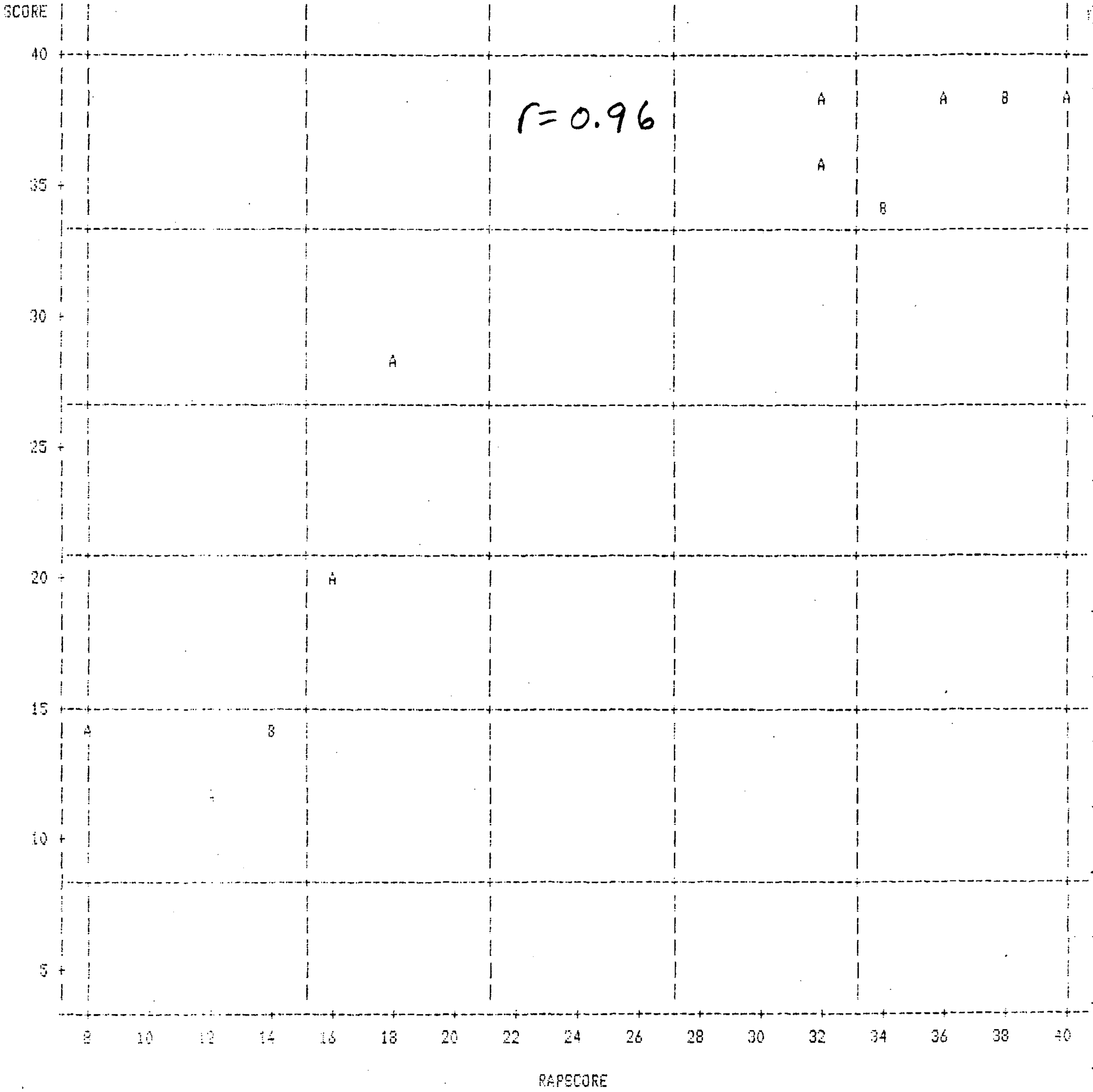
Figure 5. Run-of-River Reservoirs, Transition Zones (Spring Collections)

The SAS System 11:34 Wednesday, February 8, 1995

Correlations

RESTYPE=MAIN WBOSECNA=TRANSITION

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.



1994 Rapid Bio vs Standard

Figure 6. Run-of-River Reservoirs, Inflow

Correlations

RESTYPE=MAIN WBDSECNA=INFLOW

Plot of SCORE*RAPSCORE. Legend: A = 1 obs, B = 2 obs, etc.

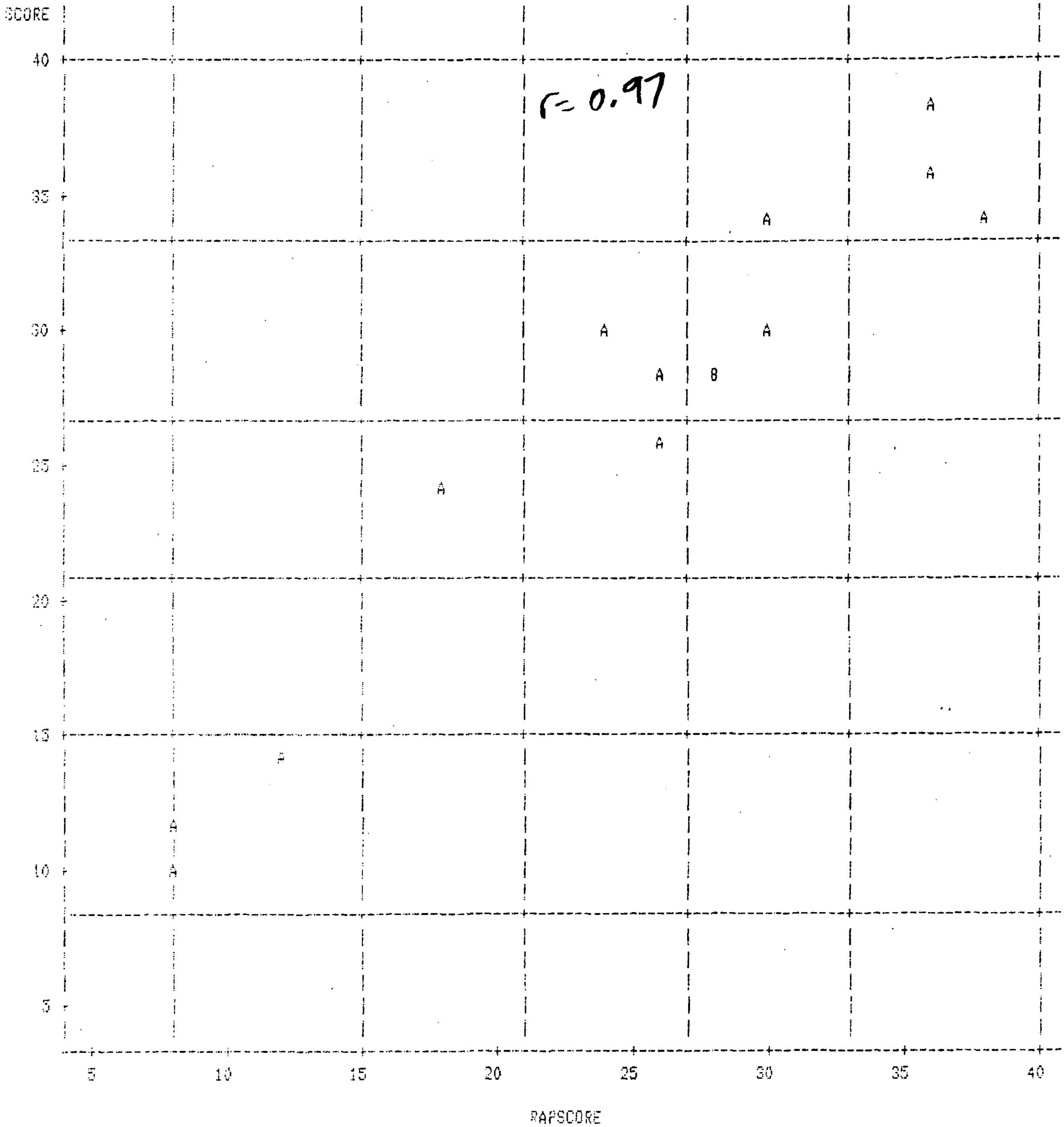


Table 1. Comparison of Benthos Scores -- Fall 1994 Sampling and Spring 1994 Sampling -- For Specific Reservoirs

RESTYPE=MAIN WBOSECNA=FOREBAY

RESVORNA	SITE		YEAR	BENIBI	RAPSCORE	TAXRAP	LONRAP	EPTRAP	NCTRAP	CHIRAP	TUBRAP	DOMRAP	ZERRAP
BEAR CREEK	PICK_EMBA_	8.4	94		16	3	1	1	1	1	3	1	5
CHICKAMAUGA	CHIC_FORE_	472.3	94		34	5	5	3	3	3	5	5	5
CHICKAMAUGA	CHIC_FORE_	472.3	94	FALL	38	5	5	3	5	5	5	5	5
CHICKAMAUGA	CHIC_FOREQ	472.3	94		34	5	5	3	5	5	1	5	5
FORT LOUDOUN	FORT_FORE_	605.5	94		14	1	1	1	1	3	1	1	5
GUNTERSVILLE	GUNT_FORE_	350	94		28	3	5	3	3	3	3	3	5
KENTUCKY	KENT_EMBA_	7.4	94		22	5	3	1	1	1	5	1	5
KENTUCKY	KENT_FORE_	23	94		28	5	5	1	3	3	1	5	5
MELTON HILL	MELT_FORE_	24	94		14	1	3	3	1	1	3	1	1
NICKAJACK	NICK_FORE_	425.5	94		36	3	5	5	3	5	5	5	5
NICKAJACK	NICK_FORE_	425.5	94	FALL	38	5	5	3	5	5	5	5	5
NICKAJACK	NICK_FOREQ	425.5	94		36	3	5	5	3	5	5	5	5
PICKWICK	PICK_FORE_	207.3	94		34	3	3	3	5	5	5	5	5
TELLICO	TELL_FORE_	1	94		8	1	1	1	1	1	1	1	1
WATTS BAR	WATT_FORE_	531	94		10	1	3	1	1	1	1	1	1
WHEELER	WHEE_FORE_	277	94		18	3	3	1	1	1	3	1	5
WILSON	WILS_FORE_	260.8	94		20	3	3	1	1	1	5	1	5

RESTYPE=MAIN WBOSECNA=INFLOW

RESVORNA	SITE		YEAR	BENIBI	RAPSCORE	TAXRAP	LONRAP	EPTRAP	NCTRAP	CHIRAP	TUBRAP	DOMRAP	ZERRAP
CHICKAMAUGA	CHIC_INFL_	518	94		26	1	5	1	3	5	5	1	5
CHICKAMAUGA	CHIC_INFL_	518	94	FALL	26	1	5	1	3	5	5	1	5
FORT LOUDOUN	FORT_INFL_	652	94		8	1	1	1	1	1	1	1	1
GUNTERSVILLE	GUNT_INFL_	420	94		30	3	5	1	3	5	5	3	5
KENTUCKY	KENT_INFL_	15	94		26	3	5	1	1	5	3	3	5
KENTUCKY	KENT_INFL_	200	94		28	3	5	1	1	5	3	5	5
MELTON HILL	MELT_INFL_	58.8	94		8	1	1	1	1	1	1	1	1
NICKAJACK	NICK_INFL_	469	94		38	5	5	5	5	5	5	3	5
NICKAJACK	NICK_INFL_	469	94	FALL	38	5	5	5	5	5	5	3	5
NICKAJACK	NICK_INFLQ	469	94		36	5	5	5	3	5	5	3	5
PICKWICK	PICK_INFL_	253.2	94		28	3	3	3	1	5	5	3	5
PICKWICK	PICK_INFLQ	253.2	94		24	3	3	1	1	5	5	1	5
WATTS BAR	WATT_INFL_	19	94		12	1	3	1	1	1	3	1	1
WATTS BAR	WATT_INFL_	600	94		18	1	1	1	1	3	5	1	5
WHEELER	WHEE_INFL_	347	94		36	5	5	3	3	5	5	5	5
WILSON	WILS_INFL_	273	94		30	3	5	1	3	5	5	3	5

RESTYPE=MAIN WBOSECNA=TRANSITION

RESVORNA	SITE		YEAR	BENIBI	RAPSCORE	TAXRAP	LONRAP	EPTRAP	NCTRAP	CHIRAP	TUBRAP	DOMRAP	ZERRAP
CHICKAMAUGA	CHIC_EMBA_	8.5	94		18	1	3	3	1	5	1	3	1
CHICKAMAUGA	CHIC_EMBA_	8.5	94	FALL	36	5	5	5	3	5	3	5	5
CHICKAMAUGA	CHIC_EMBAQ	8.5	94		16	1	3	1	1	5	1	3	1
CHICKAMAUGA	CHIC_TRAN_	490.5	94		38	5	5	5	3	5	5	5	5
CHICKAMAUGA	CHIC_TRAN_	490.5	94	FALL	38	5	5	5	5	5	3	5	5
CHICKAMAUGA	CHIC_TRANQ	490.5	94		40	5	5	5	5	5	5	5	5
FORT LOUDOUN	FORT_TRAN_	624.[illegible]	94		14	1	3	1	1	1	1	1	5
GUNTERSVILLE	GUNT_TRAN_	375.2	94		38	5	5	5	5	5	5	3	5
KENTUCKY	KENT_TRAN_	35	94		34	3	5	3	3	5	5	5	5

All scores based on field identifications (rapid bioassessment protocols)

Table 2. Sorensen's Quotient of Similarity

standard Full

% Similarity (Sorensen)

QA

		CHIC IN	CHIF IN	
CHIC	IN	1.00		
CHIF	IN	0.42	1.00	
		CHIC EM	CHIF EM	CHIQ EM
CHIC	EM	1.00		
CHIF	EM	0.63	1.00	
CHIQ	EM	0.68	0.76	1.00
		CHIC FO	CHIF FO	CHIQ FO
CHIC	FO	1.00		
CHIF	FO	0.52	1.00	
CHIQ	FO	0.75	0.62	1.00
		CHIC TR	CHIF TR	CHIQ TR
CHIC	TR	1.00		
CHIF	TR	0.68	1.00	
CHIQ	TR	0.75	0.67	1.00
		NICF FO	NICK FO	NICQ FO
NICF	FO	1.00		
NICK	FO	0.61	1.00	
NICQ	FO	0.69	0.65	1.00
		NICF IN	NICK IN	NICQ IN
NICF	IN	1.00		
NICK	IN	0.57	1.00	
NICQ	IN	0.55	0.62	1.00

Fall was about as similar to spring as spring QA reps were to one another

Section 4

Benthic Macroinvertebrate Community

Appendix B.

Mean Density for Each Species at Each Sample Location in 1994

OBS	STREAM	STREAMMI	STREAMMI	SAMCNT	SITECNT	SUMAREA	LATD	LATM	LATS	LONGD	LONGM
1	BEAR CR	8.4	8.4	10	1	0.60	34	49	12	88	5
2	BEAR CR	75.0	75.0	10	2	0.60	34	23	56	87	58
3	BEECH R	36.0	36.0	10	3	0.60	35	40	31	88	25
4	TOCCOA R	54.1	54.1	20	4	1.20	34	52	12	84	16
5	S FK HOLSTON R	19.0	19.0	10	5	0.85	36	26	18	82	26
6	S FK HOLSTON R	27.0	27.0	10	6	1.10	36	28	9	82	20
7	WATAUGA R	6.5	6.5	10	7	0.65	36	24	48	82	22
8	CEDAR CR	25.2	25.2	10	8	0.60	34	32	14	87	57
9	HIWASSEE R	122.0	122.0	10	9	0.70	35	0	21	83	47
10	SHOOTING CR	1.5	1.5	10	10	0.70	35	1	14	83	46
11	HOLSTON R	53.0	53.0	10	11	0.60	36	10	1	83	29
12	HOLSTON R	91.0	91.0	10	12	0.60	36	21	29	83	10
13	TENNESSEE	472.3	472.3	20	13	1.20	35	6	13	85	12
14	TENNESSEE	490.5	490.5	20	14	1.20	35	17	55	85	4
15	TENNESSEE	518.0	518.0	10	15	0.60	35	32	16	84	52
16	HIWASSEE R	8.5	8.5	20	16	1.20	35	21	38	84	53
17	FRENCH BROAD R	33.0	33.0	10	17	0.60	35	57	52	83	31
18	FRENCH BROAD R	51.0	51.0	10	18	0.60	35	59	49	83	15
19	LITTLE TENNESSEE R	81.5	81.5	10	19	0.65	35	24	36	83	33
20	TUCKASEGEE R	3.0	3.0	10	20	0.60	35	26	27	83	33
21	TENNESSEE	605.5	605.5	10	21	0.65	35	45	46	84	12
22	TENNESSEE	624.6	624.6	10	22	0.60	35	49	49	84	3
23	TENNESSEE	652.0	652.0	10	23	1.10	35	57	31	83	51
24	S FK HOLSTON R	8.7	8.7	10	24	0.60	36	30	10	82	30
25	TENNESSEE	350.0	350.0	10	25	0.60	34	25	25	86	22
26	TENNESSEE	375.2	375.2	10	26	0.60	34	33	15	86	7
27	TENNESSEE	420.0	420.0	10	27	1.10	35	1	45	85	40
28	HIWASSEE R	77.0	77.0	10	28	0.70	35	9	58	84	10
29	HIWASSEE R	85.0	85.0	20	29	1.55	35	6	27	84	8
30	HIWASSEE R	90.0	90.0	10	30	0.60	35	5	31	84	5
31	TENNESSEE	15.0	15.0	10	31	1.10	37	3	37	88	22
32	TENNESSEE	23.0	23.0	10	32	0.60	37	0	12	88	15
33	TENNESSEE	85.0	85.0	20	33	1.20	36	12	33	87	56
34	TENNESSEE	200.0	200.0	10	34	1.10	35	7	39	88	18
35	BIG SANDY R	7.4	7.4	10	35	0.60	36	20	31	88	5
36	LITTLE BEAR CR	12.5	12.5	20	36	1.20	34	27	14	87	58
37	CLINCH R	24.0	24.0	10	37	0.60	35	52	43	84	17
38	CLINCH R	45.0	45.0	10	38	0.60	35	59	30	84	10
39	CLINCH R	58.8	58.8	10	39	1.00	36	5	45	84	7
40	TENNESSEE	425.5	425.5	20	40	1.20	35	0	3	85	36
41	TENNESSEE	469.0	469.0	20	41	2.20	35	5	46	85	15
42	DUCK R	249.5	249.5	10	42	0.60	35	28	21	86	14
43	CLINCH R	80.4	80.4	10	43	1.10	36	13	46	84	5
44	CLINCH R	125.0	125.0	10	44	0.65	36	21	37	83	41
45	POWELL R	30.0	30.0	10	45	0.60	36	24	36	83	50
46	NOTTELY R	23.5	23.5	10	46	0.85	34	56	17	84	5
47	NOTTELY R	31.0	31.0	20	47	2.20	34	54	31	84	2
48	OCOEE R	12.5	12.5	20	48	1.20	35	5	54	84	38
49	TENNESSEE	207.3	207.3	10	49	0.60	35	4	14	88	14
50	TENNESSEE	230.0	230.0	10	50	0.70	34	53	49	88	0
51	TENNESSEE	253.2	253.2	20	51	2.20	34	45	43	87	43
52	S FK HOLSTON R	51.0	51.0	10	52	1.10	36	31	31	82	4
53	S FK HOLSTON R	62.5	62.5	10	53	1.05	36	35	26	82	0
54	LITTLE TENNESSEE R	1.0	1.0	10	54	0.60	35	46	21	84	15
55	LITTLE TENNESSEE R	15.0	15.0	10	55	0.60	35	38	0	84	15
56	ELK R	135.0	135.0	10	56	0.60	35	13	4	86	16
57	ELK R	150.0	150.0	10	57	0.60	35	12	58	86	11
58	WATAUGA R	37.4	37.4	10	58	1.10	36	18	53	82	7
59	WATAUGA R	45.5	45.5	20	59	1.20	36	19	52	81	59
60	TENNESSEE	531.0	531.0	10	60	0.60	35	36	10	84	47
61	TENNESSEE	560.8	560.8	10	61	0.60	35	49	50	84	36
62	TENNESSEE	600.0	600.0	10	62	1.10	35	46	30	84	16
63	CLINCH R	19.0	19.0	10	63	1.10	35	53	57	84	21
64	TENNESSEE	277.0	277.0	10	64	0.60	34	48	42	87	20
65	TENNESSEE	295.9	295.9	10	65	0.60	34	40	58	87	6
66	TENNESSEE	347.0	347.0	10	66	1.10	34	26	24	86	25
67	ELK R	6.0	6.0	10	67	0.60	34	48	53	87	12
68	TENNESSEE	260.8	260.8	10	68	0.60	34	48	55	87	36
69	TENNESSEE	273.0	273.0	10	69	0.65	34	48	2	87	24

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	BEAR C BEAR C 8.4	BEAR C BEAR C 75.0
SPECIES		
Nematoda	7	23
Oligochaeta		
Haplotaxida		
Tubificidae	280	40
Branchiura sowerbyi	43	.
Limnodrilus hoffmeisteri	7	.
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	.	3
Trichoptera		
Leptoceridae		
Ceraclea sp.	.	2
Oecetis sp.	.	2
Diptera		
Ceratopogonidae		
Bezzia sp.	3	3
Chironomidae	2	13
Ablabesmyia annulata	2	3
Ablabesmyia sp.	.	2
Chironomus sp.	167	62
Coelotanypus tricolor	168	.
Einfeldia sp.	447	.
Glyptotendipes sp.	.	2
Nilotanypus sp.	.	2
Pagastiella sp.	.	2
Phaenopsectra sp.	.	12
Procladius sp.	65	68
Zalutschia zalutschicola	.	2
Arachnoidea		
Hydrachnellae		
Hygrobatidae		
Atractides sp.	2	.
Unionicolidae		
Unionicola sp.	2	.
Bivalvia		
Veneroida		
Corbiculidae		
Corbicula fluminea	2	.
Sphaeriidae	5	.
Number of samples	10	10
Sum	1202	241
Number of species	15	16
Number of ept taxa	0	3
Sum of area	0.60	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	BEECH
STREAM	BEECH
STREAMMI	36.0
SPECIES	
Nematoda	27
Oligochaeta	
Haplotaxida	
Tubificidae	67
Limnodrilus hoffmeisteri	13
Insecta	
Ephemeroptera	
Ephemeridae	
Hexagenia limbata	3
Trichoptera	
Leptoceridae	
Oecetis sp.	3
Diptera	
Ceratopogonidae	
Bezzia sp.	30
Chironomidae	10
Ablabesmyia annulata	3
Chironomus sp.	848
Coelotanypus sp.	35
Cryptochironomus fulvus	15
Glyptotendipes sp.	507
Procladius sp.	53
Arachnoidea	
Hydrachnellae	8
Bivalvia	
Veneroida	
Sphaeriidae	22
Number of samples	10
Sum	1644
Number of species	15
Number of ept taxa	2
Sum of area	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	BLUE R
STREAM	TOCCOA
STREAMMI	54.1
SPECIES	
Nematoda	3
Oligochaeta	
Haplotaxida	
Tubificidae	106
Limnodrilus hoffmeisteri	18
Quistadrilus multisetosus	10
Crustacea	
Amphipoda	
Crangonyctidae	
Crangonyx sp.	2
Insecta	
Ephemeroptera	
Ephemeridae	
Hexagenia limbata	13
Trichoptera	
Leptoceridae	
Oecetis sp.	1
Diptera	
Ceratopogonidae	
Bezzia sp.	8
Chironomidae	
Chironomus sp.	71
Cryptochironomus sp.	1
Dicrotendipes sp.	1
Polypedilum halterale	1
Procladius sp.	42
Bivalvia	
Veneroida	
Sphaeriidae	136
Number of samples	20
Sum	413
Number of species	14
Number of ept taxa	2
Sum of area	1.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	BOONE S FK H 19.0	BOONE S FK H 27.0	BOONE WATAUG 6.5
SPECIES			
Nematoda	1	.	2
Oligochaeta			
Haplotaxida			
Tubificidae	431	134	102
Limnodrilus sp.	114	.	.
Limnodrilus hoffmeisteri	255	180	35
Crustacea			
Amphipoda			
Gammaridae			
Gammarus sp.	1	.	.
Insecta			
Diptera			
Chironomidae	.	1	.
Chironomus sp.	28	136	25
Cryptochironomus sp.	.	1	3
Dicrotendipes sp.	.	1	.
Harnischia sp.	.	.	2
Phaenopsectra sp.	.	.	2
Polypedilum sp.	.	1	.
Procladius sp.	13	3	38
Tanytarsus sp.	.	1	2
Tribelos sp.	.	2	.
Arachnoidea			
Hydrachnellae			
Hygrobatidae			
Atractides sp.	1	.	2
Gastropoda			
Basommatophora			
Physidae			
Physella sp.	1	.	.
Bivalvia			
Veneroida			
Corbiculidae			
Corbicula fluminea	.	.	17
Sphaeriidae	.	.	6
Number of samples	10	10	10
Sum	845	460	236
Number of species	9	10	12
Number of ept taxa	0	0	0
Sum of area	0.85	1.10	0.65

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	CEDAR
STREAM	CEDAR
STREAMMI	25.2
SPECIES	
Nematoda	17
Oligochaeta	
Haplotaxida	
Naididae	
Nais communis	2
Tubificidae	147
Branchiura sowerbyi	12
Limnodrilus hoffmeisteri	18
Insecta	
Ephemeroptera	
Ephemeridae	
Hexagenia limbata	25
Trichoptera	
Leptoceridae	
Oecetis sp.	2
Diptera	
Ceratopogonidae	
Bezzia sp.	5
Chironomidae	8
Ablabesmyia sp.	3
Axarus sp.	3
Chironomus sp.	70
Coelotanypus tricolor	2
Cryptochironomus sp.	13
Dicrotendipes sp.	2
Pagastiella sp.	7
Polypedilum sp.	18
Procladius sp.	7
Tanytarsus sp.	3
Tribelos sp.	2
Bivalvia	
Veneroida	
Corbiculidae	
Corbicula fluminea	3
Sphaeriidae	75
Number of samples	10
Sum	444
Number of species	22
Number of ept taxa	2
Sum of area	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	CHATUG HIWASS 122.0	CHATUG SHOOTI 1.5
SPECIES		
Nematoda	1	19
Oligochaeta		
Haplotaxida		
Naididae		
Arcteonais lomondi	.	20
Tubificidae	127	141
Aulodrilus pigueti	1	.
Limnodrilus hoffmeisteri	9	6
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	4	6
Trichoptera		
Leptoceridae		
Oecetis sp.	.	1
Megaloptera		
Sialidae		
Sialis sp.	.	3
Diptera		
Ceratopogonidae		
Bezzia sp.	.	1
Chironomidae		
Ablabesmyia annulata	.	1
Chironomus sp.	27	80
Cladotanytarsus sp.	3	4
Coelotanypus tricolor	4	9
Cryptochironomus sp.	6	.
Polypedilum sp.	.	1
Procladius sp.	31	51
Tanytarsus sp.	3	4
Zalutschia zalutschicola	71	141
Bivalvia		
Veneroida		
Sphaeriidae	.	1
Number of samples	10	10
Sum	287	489
Number of species	12	17
Number of ept taxa	1	2
Sum of area	0.70	0.70

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	CHEROK	CHEROK
STREAM	HOLSTO	HOLSTO
STREAMMI	53.0	91.0
SPECIES		
Nematoda	2	.
Oligochaeta		
Haplotaxida		
Enchytraeidae	.	2
Tubificidae	158	205
Branchiura sowerbyi	2	2
Limnodrilus sp.	.	35
Limnodrilus hoffmeisteri	38	2
Insecta		
Odonata		
Gomphidae		
Gomphus sp.	.	2
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	2	95
Diptera		
Ceratopogonidae		
Bezzia sp.	2	.
Chironomidae	3	3
Ablabesmyia annulata	2	8
Chironomus sp.	198	17
Coelotanypus tricolor	.	7
Cryptochironomus sp.	3	17
Epoicocladius sp.	.	7
Polypedilum sp.	.	3
Procladius sp.	40	10
Tipulidae		
Pseudolimnophila sp.	.	2
Coleoptera		
Elmidae		
Dubiraphia sp.	.	2
Arachnoidea		
Hydrachnellae		
Hygrobatidae		
Atractides sp.	.	3
Bivalvia		
Veneroida		
Sphaeriidae	.	5
Number of samples	10	10
Sum	450	427
Number of species	11	19
Number of ept taxa	1	1
Sum of area	0.60	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	CHICKA TENNE 472.3	CHICKA TENNE 490.5	CHICKA TENNE 518.0	CHICKA HIWASS 8.5
SPECIES				
Nematoda	.	.	.	6
Hydrozoa				
Hydroida				
Hydridae				
Hydra americana	.	.	7	.
Turbellaria				
Tricladida				
Planariidae				
Dugesia tigrina	.	.	12	.
Oligochaeta				
Haplotaxida				
Naididae				
Nais sp.	.	1	.	.
Nais bretscheri	.	.	.	1
Tubificidae	219	148	10	168
Aulodrilus pigueti	1	.	.	.
Branchiura sowerbyi	15	10	.	9
Limnodrilus sp.	.	.	.	18
Limnodrilus hoffmeisteri	.	.	5	.
Hirudinea	1	.	.	1
Rhynchobdellida				
Glossiphoniidae				
Helobdella stagnalis	.	2	.	.
Pharyngobdellida				
Erpobdellidae	.	.	.	2
Crustacea				
Isopoda				
Asellidae				
Lirceus sp.	.	.	.	1
Amphipoda				
Gammaridae				
Gammarus sp.	5	3	302	.
Talitridae				
Hyalella azteca	.	1	.	.
Insecta				
Ephemeroptera				
Baetidae				
Baetis sp.	.	.	.	2
Caenidae				
Caenis sp.	.	1	.	.
Ephemeridae				
Hexagenia sp.	.	.	.	1
Hexagenia limbata	77	371	.	103
Trichoptera				
Leptoceridae				
Oecetis sp.	.	.	.	1
Polycentropodidae				
Cyrnellus fraternus	.	2	.	.
Megaloptera				
Sialidae				
Sialis sp.	.	1	.	.
Diptera				
Ceratopogonidae				
Bezzia sp.	.	.	.	4
Chironomidae	1	2	.	3
Ablabesmyia annulata	34	37	.	9
Axarus sp.	3	.	.	.
Chironomus sp.	6	36	.	8
Coelotanypus sp.	54	6	.	.
Coelotanypus tricolor	261	190	.	7
Cricotopus sp.	.	1	.	1
Cryptochironomus sp.	6	11	.	9
Dicrotendipes sp.	1	8	.	.
Einfeldia sp.	38	.	.	.
Epoicocladius sp.	.	2	.	5
Microtendipes sp.	.	1	.	1
Parachironomus sp.	.	.	.	1
Polypedilum sp.	.	.	.	8
Procladius sp.	42	86	.	1
Rheotanytarsus sp.	.	1	.	.
Stictochironomus sp.	.	.	2	.
Tanytarsus sp.	.	.	.	4
Tribelos sp.	.	.	2	.
Simuliidae				
Simulium sp.	.	.	.	4
Coleoptera				
Elmidae				
Dubiraphia sp.	.	1	.	.
Arachnoidea				
Hydrachnellae				
Eylaidae				
Eylais sp.	.	9	.	.
Hygrobatidae				
Hygrobates sp.	1	.	.	.
Unionicolidae				
Unionicola sp.	2	.	.	.
Gastropoda				
Mesogastropoda				
Pleuroceridae				
Leptoxis praerosa	5	.	.	1
Viviparidae				
Viviparus sp.	2	.	.	.
Bivalvia				

Veneroida				
Corbiculidae				
Corbicula fluminea	145	174	115	13
Sphaeriidae	4	83	.	158
Musculium transversum	48	77	2	.
Number of samples	20	20	10	20
Sum	971	1265	457	550
Number of species	23	27	9	29
Number of ept taxa	1	3	0	4
Sum of area	1.20	1.20	0.60	1.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	DOUGLA FRENCH 33.0	DOUGLA FRENCH 51.0
SPECIES		
Nematoda	2	.
Oligochaeta		
Haplotaxida		
Tubificidae	97	100
Branchiura sowerbyi	.	8
Limnodrilus hoffmeisteri	27	10
Insecta		
Diptera		
Chironomidae	5	2
Chironomus sp.	117	147
Cryptochironomus sp.	.	5
Dicrotendipes sp.	.	2
Phaenopsectra sp.	.	7
Procladius sp.	110	25
Rheotanytarsus sp.	.	2
Number of samples	10	10
Sum	358	308
Number of species	6	10
Number of ept taxa	0	0
Sum of area	0.60	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	FONTAN	FONTAN
STREAM	LITTLE	TUCKAS
STREAMMI	81.5	3.0
SPECIES		
Oligochaeta		
Haplotaxida		
Tubificidae	335	1057
Branchiura sowerbyi	5	.
Limnodrilus hoffmeisteri	43	15
Crustacea		
Amphipoda		
Crangonyctidae		
Crangonyx sp.	.	3
Insecta		
Diptera		
Chironomidae		
Chironomus sp.	454	460
Cryptochironomus sp.	2	.
Polypedilum sp.	3	8
Procladius sp.	17	33
Arachnoidea		
Hydrachnellae		
Hygrobatidae		
Atractides sp.	2	.
Number of samples	10	10
Sum	861	1576
Number of species	8	6
Number of ept taxa	0	0
Sum of area	0.65	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA / STREAM / STREAMMI	FORT L TENNE 605.5	FORT L TENNE 624.6	FORT L TENNE 652.0
SPECIES			
Nematoda	.	.	2
Oligochaeta			
Haplotaxida			
Tubificidae	89	72	62
Branchiura sowerbyi	5	17	.
Limnodrilus hoffmeisteri	12	28	24
Lumbriculida			
Lumbriculidae	2	.	5
Crustacea			
Amphipoda			
Gammaridae			
Gammarus sp.	.	.	2
Insecta			
Odonata			
Gomphidae	.	2	.
Gomphus sp.	.	.	2
Ephemeroptera			
Ephemeridae			
Hexagenia limbata	5	15	.
Heteroptera			
Corixidae	.	2	.
Trichoptera			
Brachycentridae			
Brachycentrus sp.	.	.	1
Hydropsychidae			
Cheumatopsyche sp.	.	.	1
Psychomyiidae			
Psychomyia flavida	.	.	1
Diptera			
Ceratopogonidae			
Bezzia sp.	.	2	.
Chironomidae			
Ablabesmyia annulata	2	23	.
Chironomus sp.	228	342	.
Coelotanypus sp.	2	.	.
Coelotanypus tricolor	57	17	.
Cricotopus sp.	.	.	1
Cryptochironomus sp.	11	8	3
Epoicocladius sp.	.	2	.
Glyptotendipes sp.	2	.	.
Phaenopsectra sp.	.	.	2
Polypedilum sp.	.	.	7
Procladius sp.	55	62	.
Xenochironomus xenolabis	.	.	1
Simuliidae			
Simulium sp.	.	.	1
Bivalvia			
Veneroida			
Corbiculidae			
Corbicula fluminea	17	10	151
Sphaeriidae			
Musculium transversum	.	50	.
Number of samples	10	10	10
Sum	487	652	266
Number of species	13	15	16
Number of ept taxa	1	1	3
Sum of area	0.65	0.60	1.10

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	FORT P
STREAM	S FK H
STREAMMI	8.7
SPECIES	
Oligochaeta	
Haplotaxida	
Tubificidae	107
Limnodrilus hoffmeisteri	77
Crustacea	
Isopoda	
Asellidae	
Caecidotea sp.	3
Insecta	
Diptera	
Chironomidae	
Chironomus sp.	137
Cryptochironomus sp.	2
Glyptotendipes sp.	2
Procladius sp.	70
Bivalvia	
Veneroida	
Corbiculidae	
Corbicula fluminea	3
Number of samples	10
Sum	401
Number of species	8
Number of ept taxa	0
Sum of area	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	GUNTER TENNE 350.0	GUNTER TENNE 375.2	GUNTER TENNE 420.0
SPECIES			
Hydrozoa			
Hydroida			
Hydridae			
Hydra americana	.	.	1
Turbellaria			
Tricladida			
Planariidae			
Dugesia tigrina	.	.	64
Oligochaeta			
Haplotaxida			
Naididae	.	.	7
Tubificidae	102	52	49
Branchiura sowerbyi	10	12	.
Limnodrilus hoffmeisteri	3	.	3
Lumbriculida			
Lumbriculidae	.	3	.
Hirudinea	.	.	5
Rhynchobdellida			
Glossiphoniidae			
Helobdella stagnalis	10	15	.
Placobdella montifera	3	2	.
Crustacea			
Isopoda			
Asellidae			
Lirceus sp.	.	.	8
Amphipoda			
Gammaridae			
Gammarus sp.	.	7	160
Talitridae			
Hyalella azteca	.	218	.
Insecta			
Ephemeroptera			
Ephemeridae			
Hexagenia limbata	68	195	4
Heptageniidae			
Stenacron interpunctatum	.	.	5
Trichoptera			
Leptoceridae			
Ceraclea sp.	.	.	2
Megaloptera			
Sialidae			
Sialis sp.	.	.	2
Diptera			
Ceratopogonidae			
Bezzia sp.	.	.	4
Chironomidae	2	2	5
Ablabesmyia annulata	33	18	1
Ablabesmyia mallochi	.	3	.
Chironomus sp.	.	5	3
Coelotanypus tricolor	278	127	4
Cryptochironomus sp.	8	33	3
Dicrotendipes sp.	5	60	3
Einfeldia sp.	43	5	.
Epoicocladius sp.	2	2	.
Harnischia sp.	.	.	1
Polypedilum sp.	.	.	5
Procladius sp.	32	47	3
Pseudochironomus sp.	.	.	4
Rheotanytarsus sp.	.	3	.
Coleoptera			
Elmidae			
Dubiraphia sp.	.	.	1
Arachnoidea			
Hydrachnellae			
Unionicolidae			
Unionicola sp.	.	3	.
Gastropoda			
Mesogastropoda			
Pleuroceridae			
Lithasia verrucosa	.	.	5
Pleurocera sp.	.	.	2
Viviparidae			
Campeloma sp.	.	.	3
Viviparus sp.	.	2	.
Basommatophora			
Physidae			
Physella sp.	.	2	.
Bivalvia			
Unionoida			
Unionidae			
Cyclonaias tuberculata	.	2	.
Potamilus alatus	.	2	.
Veneroida			
Corbiculidae			
Corbicula fluminea	127	328	196
Sphaeriidae			
Eupera cubensis	12	13	.
Musculium transversum	.	123	.
Number of samples	10	10	10
Sum	738	1284	553
Number of species	16	27	28
Number of ept taxa	1	1	3

Sum of area	0.60	0.60	1.10

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	HIWASS	HIWASS	HIWASS
STREAM	HIWASS	HIWASS	HIWASS
STREAMMI	77.0	85.0	90.0
SPECIES			
Oligochaeta			
Haplotaxida			
Naididae	.	1	.
Slavina appendiculata	.	1	.
Stylaria lacustris	1	1	.
Tubificidae	51	385	167
Limnodrilus hoffmeisteri	.	1	30
Crustacea			
Amphipoda			
Corophiidae			
Corophium lacustre	.	1	.
Crangonyctidae			
Crangonyx sp.	10	4	.
Insecta			
Odonata			
Macromiidae			
Macromia sp.	.	1	.
Ephemeroptera			
Ephemeridae			
Hexagenia limbata	.	1	2
Trichoptera			
Leptoceridae			
Oecetis sp.	.	1	.
Diptera			
Ceratopogonidae			
Bezzia sp.	.	.	2
Chironomidae			
Chironomus sp.	3	37	260
Cryptochironomus sp.	1	1	2
Microtendipes sp.	.	.	2
Phaenopsectra sp.	.	.	3
Polypedilum sp.	.	1	.
Polypedilum halterale	.	1	.
Procladius sp.	9	26	87
Tanytarsus sp.	1	.	.
Arachnoidea			
Hydrachnellae			
Hygrobatidae			
Atractides sp.	.	.	2
Gastropoda			
Basommatophora			
Planorbidae	.	1	.
Bivalvia			
Veneroida			
Corbiculidae			
Corbicula fluminea	.	.	2
Sphaeriidae	1	3	.
Number of samples	10	20	10
Sum	77	467	559
Number of species	8	17	11
Number of ept taxa	0	2	1
Sum of area	0.70	1.55	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	KENTUC	KENTUC	KENTUC	KENTUC	KENTUC
STREAM	TENNE	TENNE	TENNE	TENNE	BIG SA
STREAMMI	15.0	23.0	85.0	200.0	7.4
SPECIES					
Nematoda	2	.	5	.	15
Hydrozoa					
Hydroida					
Hydridae					
Hydra americana	.	.	.	1	.
Turbellaria					
Tricladida					
Planariidae					
Dugesia tigrina	.	.	.	7	.
Oligochaeta					
Haplotaxida					
Naididae					
Nais communis	.	.	.	1	.
Nais simplex	.	.	1	.	.
Tubificidae	8	205	193	5	62
Aulodrilus pigueti	.	.	.	.	2
Branchiura sowerbyi	.	.	2	.	45
Limnodrilus hoffmeisteri	.	20	11	.	.
Lumbriculida					
Lumbriculidae	14	.	1	18	.
Hirudinea	.	.	.	1	.
Rhynchobdellida					
Glossiphoniidae					
Helobdella stagnalis	.	10	.	.	.
Crustacea					
Isopoda					
Asellidae					
Caecidotea sp.	.	.	1	15	.
Lirceus sp.	4	.	.	.	.
Amphipoda					
Corophiidae					
Corophium lacustre	.	.	41	.	.
Talitridae					
Hyalella azteca	.	.	2	.	.
Decapoda					
Cambaridae	1	.	.	.	.
Insecta					
Odonata					
Macromiidae					
Macromia sp.	1	.	.	.	.
Ephemeroptera					
Caenidae					
Caenis sp.	.	.	2	.	.
Ephemeridae					
Hexagenia limbata	1	12	176	.	.
Heptageniidae					
Stenacron sp.	4	.	1	.	.
Stenacron interpunctatum	27	.	.	7	.
Trichoptera					
Leptoceridae					
Ceraclea sp.	3	.	.	2	.
Oecetis sp.	.	.	3	.	7
Polycentropodidae					
Cyrnellus fraternus	.	.	4	.	.
Megaloptera					
Sialidae					
Sialis sp.	.	.	.	.	2
Diptera					
Ceratopogonidae					
Bezzia sp.	.	.	.	.	35
Chironomidae	.	.	3	5	.
Ablabesmyia annulata	.	7	32	4	5
Ablabesmyia mallochi	.	.	2	.	.
Axarus sp.	14	.	2	.	.
Chironomus sp.	1	2	5	.	180
Coelotanypus tricolor	1	200	153	.	277
Cricotopus sp.	.	.	.	3	.
Cryptochironomus sp.	.	3	7	3	.
Dicrotendipes sp.	3	.	6	5	3
Einfeldia sp.	2	295	1	.	332
Epoicocladius sp.	.	.	2	.	.
Glyptotendipes sp.	.	.	.	2	2
Harnischia sp.	.	.	.	1	.
Hydrobaenus sp.	.	.	1	.	.
Nanocladius sp.	.	.	.	28	.
Parachironomus sp.	.	.	1	.	.
Polypedilum sp.	.	.	.	1	.
Procladius sp.	.	22	28	.	162
Psectrocladius sp.	.	.	5	.	.
Rheotanytarsus sp.	.	.	.	1	.
Tanytarsus sp.	.	2	.	.	10
Arachnoidea					
Hydrachnellae	.	.	2	.	.
Krendowskiidae					
Krendowskia similis	.	.	.	.	7
Unionicolidae					
Unionicola sp.	.	.	3	1	.
Gastropoda					
Mesogastropoda					
Hydrobiidae	.	.	1	.	.
Somatogyrus sp.	110	7	1	.	.
Pleuroceridae					
Leptoxis praerosa	.	7	.	18	.

Lithasia armigera	3	.	.	1	.
Lithasia sp.	6	.	.	.	.
Lithasia verrucosa	.	.	.	10	.
Pleurocera sp.	.	.	.	4	.
Pleurocera canaliculata	.	.	11	.	.
Viviparidae					
Campeloma sp.	3	.	6	.	.
Basommatophora					
Ancylidae					
Ferrissia rivularis	2	.	.	.	.
Planorbidae	.	.	.	.	10
Bivalvia					
Unionoida					
Unionidae					
Amblema plicata	1	.	.	.	.
Cyclonaias tuberculata	.	.	.	1	.
Ellipsaria lineolata	.	.	.	1	.
Fusconaia ebena	2	.	1	5	.
Megalonaias nervosa	.	2	.	.	.
Obliquaria reflexa	1	.	.	5	.
Pleurobema sp.	.	.	1	.	.
Quadrula metanevra	1	.	.	1	.
Quadrula pustulosa pustulo	1	.	.	4	.
Quadrula quadrula	1	.	.	.	.
Tritogonia verrucosa	.	.	.	1	.
Truncilla donaciformis	2	.	.	.	.
Truncilla truncata	1	.	.	.	.
Veneroida					
Corbiculidae					
Corbicula fluminea	113	55	219	49	.
Dreissenidae					
Dreissena polymorpha	.	2	.	.	.
Sphaeriidae	.	122	5	.	5
Musculium transversum	1	43	33	.	58
Pisidium sp.	.	25	.	.	.
Number of samples	10	10	20	10	10
Sum	334	1041	974	211	1219
Number of species	30	19	39	32	19
Number of ept taxa	4	1	5	2	1
Sum of area	1.10	0.60	1.20	1.10	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	LITTLE LITTLE 12.5
SPECIES	
Nematoda	5
Oligochaeta	
Haplotaxida	
Tubificidae	2132
Limnodrilus sp.	24
Limnodrilus hoffmeisteri	10
Crustacea	
Amphipoda	
Corophiidae	
Corophium lacustre	1
Insecta	
Ephemeroptera	
Caenidae	
Caenis sp.	1
Ephemeridae	
Hexagenia limbata	28
Megaloptera	
Sialidae	
Sialis sp.	2
Diptera	
Ceratopogonidae	
Bezzia sp.	1
Chironomidae	3
Ablabesmyia sp.	1
Chironomus sp.	98
Coelotanypus tricolor	3
Cryptochironomus sp.	2
Cryptochironomus fulvus	4
Dicrotendipes sp.	1
Epoicocladius sp.	1
Pagastiella sp.	6
Paramerina sp.	1
Polypedilum sp.	8
Procladius sp.	4
Tanytarsus sp.	2
Gastropoda	
Mesogastropoda	
Pleuroceridae	6
Pleurocera sp.	3
Bivalvia	
Veneroida	
Corbiculidae	
Corbicula fluminea	3
Sphaeriidae	3
Number of samples	20
Sum	2353
Number of species	26
Number of ept taxa	2
Sum of area	1.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	MELTON CLINCH 24.0	MELTON CLINCH 45.0	MELTON CLINCH 58.8
SPECIES			
Nematoda	18	5	7
Oligochaeta			
Haplotaxida			
Enchytraeidae	.	2	.
Naididae	.	2	.
Nais communis	.	5	.
Nais simplex	.	2	.
Vejdovskyella intermedia	.	2	.
Tubificidae	83	117	99
Branchiura sowerbyi	2	48	.
Limnodrilus hoffmeisteri	8	.	29
Insecta			
Ephemeroptera			
Ephemeridae			
Hexagenia limbata	12	5	.
Trichoptera			
Leptoceridae			
Oecetis sp.	.	2	.
Megaloptera			
Sialidae			
Sialis sp.	.	2	.
Diptera			
Ceratopogonidae			
Bezzia sp.	.	2	.
Chironomidae	2	5	.
Ablabesmyia annulata	13	2	.
Ablabesmyia sp.	.	2	.
Chaetocladius sp.	.	3	.
Chironomus sp.	177	135	73
Conchapelopia sp.	.	2	.
Cryptochironomus sp.	13	15	.
Dicrotendipes sp.	.	10	4
Glyptotendipes sp.	.	2	.
Harnischia sp.	12	.	.
Microtendipes sp.	2	.	1
Paratendipes sp.	.	.	10
Phaenopsectra sp.	.	.	47
Polypedilum sp.	.	62	3
Polypedilum halterale	.	7	.
Procladius sp.	55	77	.
Psectrocladius sp.	.	.	1
Rheotanytarsus sp.	.	2	.
Tanytarsus sp.	5	12	3
Tribelos sp.	.	2	.
Tvetenia discoloripes sp.	.	.	1
Coleoptera			
Ptilodactylidae			
Anchytarsus bicolor	.	2	.
Arachnoidea			
Hydrachnellae	2	.	.
Unionicolidae			
Neumania sp.	.	2	.
Bivalvia			
Veneroida			
Corbiculidae			
Corbicula fluminea	2	2	.
Sphaeriidae	.	5	.
Number of samples	10	10	10
Sum	406	543	278
Number of species	15	31	12
Number of ept taxa	1	2	0
Sum of area	0.60	0.60	1.00

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	NICKAJ	NICKAJ
STREAM	TENNE	TENNE
STREAMMI	425.5	469.0
SPECIES		
Turbellaria		
Tricladida		
Planariidae		
Dugesia tigrina	.	89
Oligochaeta		
Haplotaxida		
Naididae		
Chaetogaster sp.	.	14
Tubificidae	63	11
Branchiura sowerbyi	9	.
Limnodrilus hoffmeisteri	.	.
Hirudinea	.	1
Pharyngobdellida		
Erpobdellidae		
Erpobdella punctata	.	4
Crustacea		
Isopoda		
Asellidae		
Lirceus sp.	.	5
Amphipoda		
Crangonyctidae		
Crangonyx sp.	1	29
Gammaridae	1	.
Gammarus sp.	3	35
Talitridae		
Hyalella azteca	3	.
Insecta		
Odonata		
Gomphidae	1	.
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	96	.
Heptageniidae		
Stenacron sp.	.	3
Stenacron interpunctatum	.	10
Trichoptera		
Hydropsychidae	.	17
Cheumatopsyche sp.	1	136
Leptoceridae		
Ceraclea sp.	.	9
Polycentropodidae		
Cyrnellus fraternus	.	1
Diptera		
Ceratopogonidae		
Bezzia sp.	1	.
Chironomidae	1	.
Ablabesmyia annulata	25	.
Chironomus sp.	48	.
Coelotanypus sp.	3	.
Coelotanypus tricolor	103	.
Cryptochironomus sp.	8	.
Dicrotendipes sp.	3	.
Einfeldia sp.	28	.
Procladius sp.	53	.
Tanytarsus sp.	1	.
Xenochironomus xenolabis	.	1
Arachnoidea		
Hydrachnellae		
Hygrobatidae		
Hygrobates sp.	1	.
Unionicolidae		
Unionicola sp.	3	.
Gastropoda		
Mesogastropoda		
Hydrobiidae	.	23
Somatogyrus sp.	.	35
Pleuroceridae		
Elimia sp.	.	2
Elimia laqueata	.	.
Leptoxis praerosa	.	12
Pleurocera sp.	.	1
Pleurocera canaliculata	.	6
Viviparidae		
Campeloma sp.	.	3
Viviparus georgianus	.	1
Basommatophora		
Ancylidae		
Ferrissia rivularis	.	4
Planorbidae		
Gyraulus sp.	.	.
Bivalvia		
Unionoida		
Unionidae		
Quadrula pustulosa pustulo	.	.
Veneroida		
Corbiculidae		
Corbicula fluminea	73	503
Sphaeriidae	2	.
Eupera cubensis	.	38
Musculium transversum	18	2
Number of samples	20	20
Sum	549	995

Number of species	25	27
Number of ept taxa	2	6
Sum of area	1.20	2.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	NORMAN
STREAM	DUCK R
STREAMMI	249.5
SPECIES	
Nematoda	2
Oligochaeta	
Haplotaxida	
Tubificidae	103
Branchiura sowerbyi	2
Limnodrilus sp.	33
Insecta	
Diptera	
Ceratopogonidae	
Bezzia sp.	2
Chironomidae	
Chironomus sp.	33
Chironomus attenuatus gp.	122
Procladius sp.	5
Number of samples	10
Sum	302
Number of species	8
Number of ept taxa	0
Sum of area	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	NORRIS	NORRIS	NORRIS
STREAM	CLINCH	CLINCH	POWELL
STREAMMI	80.4	125.0	30.0
SPECIES			
Nematoda	2	.	2
Oligochaeta			
Haplotaxida			
Tubificidae	198	363	613
Branchiura sowerbyi	.	3	2
Limnodrilus sp.	3	.	.
Limnodrilus hoffmeisteri	78	48	198
Insecta			
Ephemeroptera			
Caenidae			
Caenis sp.	.	2	2
Ephemeridae			
Hexagenia limbata	.	11	2
Trichoptera			
Leptoceridae			
Oecetis sp.	.	2	.
Diptera			
Ceratopogonidae			
Bezzia sp.	2	14	.
Chironomidae	.	.	3
Ablabesmyia annulata	.	6	.
Chironomus sp.	.	351	335
Coelotanypus sp.	1	2	.
Coelotanypus tricolor	.	5	.
Cryptochironomus sp.	.	34	28
Cryptochironomus fulvus	2	.	.
Dicrotendipes sp.	.	3	.
Phaenopsectra sp.	.	.	5
Procladius sp.	2	154	118
Gastropoda			
Basommatophora			
Planorbidae	.	2	.
Bivalvia			
Veneroida			
Corbiculidae			
Corbicula fluminea	45	.	.
Sphaeriidae	2	12	8
Musculium transversum	.	8	50
Number of samples	10	10	10
Sum	335	1020	1366
Number of species	10	17	13
Number of ept taxa	0	3	2
Sum of area	1.10	0.65	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	NOTTEL NOTTEL 23.5	NOTTEL NOTTEL 31.0
SPECIES		
Nematoda	1	6
Oligochaeta		
Haplotaxida		
Naididae		
Stylaria lacustris	2	.
Tubificidae	155	18
Limnodrilus hoffmeisteri	4	4
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	.	14
Trichoptera		
Leptoceridae		
Oecetis sp.	1	.
Megaloptera		
Sialidae		
Sialis sp.	.	1
Diptera		
Ceratopogonidae		
Bezzia sp.	.	19
Chironomidae		
Chironomus sp.	181	270
Cladotanytarsus sp.	.	1
Cryptochironomus sp.	.	2
Cryptochironomus fulvus	2	4
Harnischia sp.	1	.
Phaenopsectra sp.	1	7
Procladius sp.	14	28
Tribelos sp.	.	1
Zalutschia zalutschicola	7	.
Arachnoidea		
Hydrachnellae		
Hygrobatidae		
Atractides sp.	.	.
Number of samples	10	20
Sum	369	375
Number of species	11	13
Number of ept taxa	1	1
Sum of area	0.85	2.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	PARKSV
STREAM	OCOEE
STREAMMI	12.5

SPECIES	
Nematoda	1
Oligochaeta	
Haplotaxida	
Tubificidae	48
Branchiura sowerbyi	1
Limnodrilus hoffmeisteri	7
Crustacea	
Amphipoda	
Crangonyctidae	
Crangonyx sp.	5
Insecta	
Trichoptera	
Polycentropodidae	
Polycentropus sp.	1
Diptera	
Chironomidae	
Procladius sp.	1
Stenochironomus sp.	1
Number of samples	20
Sum	65
Number of species	8
Number of ept taxa	1
Sum of area	1.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	PICKWI TENNE 207.3	PICKWI TENNE 230.0	PICKWI TENNE 253.2
SPECIES			
Nematoda	2	1	.
Hydrozoa			
Hydroida			
Hydridae			
Hydra americana	2	.	1
Turbellaria			
Tricladida			
Planariidae			
Dugesia tigrina	7	1	81
Oligochaeta			
Haplotaxida			
Tubificidae	145	114	35
Branchiura sowerbyi	8	7	.
Limnodrilus hoffmeisteri	2	6	3
Lumbriculida			
Lumbriculidae	2	.	40
Hirudinea			
Rhynchobdellida			
Glossiphoniidae	.	1	.
Helobdella stagnalis	2	1	.
Placobdella sp.	.	.	2
Pharyngobdellida			
Erpobdellidae	2	.	.
Crustacea			
Isopoda			
Asellidae			
Caecidotea sp.	.	1	.
Lirceus sp.	2	.	45
Amphipoda			
Corophiidae			
Corophium lacustre	2	.	.
Crangonyctidae			
Crangonyx sp.	2	.	5
Gammaridae			
Gammarus sp.	.	3	1
Talitridae			
Hyalella azteca	2	.	.
Insecta			
Odonata			
Coenagrionidae			
Argia sp.	.	1	.
Ephemeroptera			
Caenidae			
Caenis sp.	.	7	1
Ephemeridae			
Hexagenia limbata	35	163	.
Heptageniidae	.	.	1
Stenacron sp.	.	.	.
Stenacron interpunctatum	.	.	21
Stenonema sp.	.	.	.
Trichoptera			
Hydropsychidae	.	.	.
Cheumatopsyche sp.	.	.	.
Hydropsyche sp.	.	.	.
Leptoceridae	2	1	.
Ceraclea sp.	.	.	6
Oecetis sp.	5	3	.
Polycentropodidae			
Cyrnellus fraternus	2	3	.
Diptera			
Ceratopogonidae			
Bezzia sp.	.	1	.
Chironomidae	7	.	1
Ablabesmyia annulata	12	33	.
Chironomus sp.	23	41	7
Cladotanytarsus sp.	.	.	.
Coelotanypus tricolor	128	291	.
Cryptochironomus sp.	3	1	.
Cryptochironomus fulvus	.	.	.
Dicrotendipes sp.	.	10	.
Einfeldia sp.	25	.	.
Glyptotendipes sp.	.	1	2
Harnischia sp.	2	.	.
Larsia sp.	.	.	.
Nanocladius sp.	.	.	1
Phaenopsectra sp.	.	.	1
Polypedilum sp.	.	.	1
Procladius sp.	25	29	.
Pseudochironomus sp.	.	.	.
Rheotanytarsus sp.	.	.	.
Stenochironomus sp.	.	1	.
Tanytarsus sp.	.	1	.
Arachnoidea			
Hydrachnellae			
Unionicolidae			
Unionicola sp.	2	.	.
Gastropoda			
Mesogastropoda			
Hydrobiidae	.	3	1
Somatogyrus sp.	15	.	.
Pleuroceridae	.	.	1
Leptoxis praerosa	.	11	.
Lithasia armigera	.	.	.

Lithasia sp.	.	.	.
Lithasia verrucosa	.	.	6
Pleurocera sp.	.	.	3
Pleurocera canaliculata	5	11	.
Viviparidae			
Campeloma sp.	32	16	.
Basommatophora			
Ancylidae			
Ferrissia rivularis	.	1	.
Planorbidae	.	.	1
Bivalvia			
Unionoida			
Unionidae			
Fusconaia ebena	.	.	.
Fusconaia flava	.	.	.
Obliquaria reflexa	.	.	.
Quadrula pustulosa pustulo	.	.	.
Veneroida			
Corbiculidae			
Corbicula fluminea	80	83	264
Dreissenidae			
Dreissena polymorpha	2	.	.
Sphaeriidae	283	6	.
Eupera cubensis	8	.	1
Musculium transversum	133	79	.
Number of samples	10	10	20
Sum	1009	932	532
Number of species	34	33	26
Number of ept taxa	4	5	4
Sum of area	0.60	0.70	2.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	SOUTH	SOUTH
STREAM	S FK H	S FK H
STREAMMI	51.0	62.5
SPECIES		
Oligochaeta		
Haplotaxida		
Tubificidae	111	160
Branchiura sowerbyi	2	.
Limnodrilus hoffmeisteri	23	42
Crustacea		
Isopoda		
Asellidae		
Caecidotea sp.	1	.
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	6	.
Diptera		
Ceratopogonidae		
Bezzia sp.	1	.
Chironomidae	.	2
Ablabesmyia annulata	2	.
Chironomus sp.	15	74
Cryptochironomus sp.	.	3
Dicrotendipes sp.	.	3
Polypedilum halterale	.	2
Procladius sp.	6	6
Tanytarsus sp.	2	3
Bivalvia		
Veneroida		
Corbiculidae		
Corbicula fluminea	3	.
Number of samples	10	10
Sum	172	295
Number of species	11	9
Number of ept taxa	1	0
Sum of area	1.10	1.05

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	TELLIC	TELLIC
STREAM	LITTLE	LITTLE
STREAMMI	1.0	15.0
SPECIES		
Nematoda	.	2
Oligochaeta		
Haplotaxida		
Naididae	2	.
Tubificidae	155	25
Branchiura sowerbyi	.	2
Limnodrilus hoffmeisteri	18	.
Lumbriculida		
Lumbriculidae	.	2
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	.	8
Trichoptera		
Leptoceridae		
Oecetis sp.	2	.
Diptera		
Chironomidae		
Ablabesmyia annulata	2	3
Chironomus sp.	13	17
Cryptochironomus sp.	.	2
Parachironomus sp.	.	2
Procladius sp.	23	10
Stictochironomus sp.	.	15
Tanytarsus sp.	.	20
Zalutschia zalutschicola	.	60
Bivalvia		
Veneroida		
Corbiculidae		
Corbicula fluminea	23	2
Sphaeriidae	2	.
Number of samples	10	10
Sum	240	170
Number of species	9	14
Number of ept taxa	1	1
Sum of area	0.60	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	TIMS F ELK R 135.0	TIMS F ELK R 150.0
SPECIES		
Oligochaeta		
Haplotaxida		
Tubificidae	33	2
Limnodrilus hoffmeisteri	5	.
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	.	2
Diptera		
Chironomidae		
Chironomus sp.	2	20
Cryptochironomus sp.	.	2
Polypedilum sp.	.	2
Polypedilum halterale	15	.
Procladius sp.	.	3
Tanytarsus sp.	.	2
Number of samples	10	10
Sum	55	33
Number of species	4	7
Number of ept taxa	0	1
Sum of area	0.60	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA STREAM STREAMMI	WATAUG WATAUG 37.4	WATAUG WATAUG 45.5
SPECIES		
Turbellaria		
Tricladida		
Planariidae		
Dugesia tigrina	.	8
Oligochaeta		
Haplotaxida		
Tubificidae	14	463
Limnodrilus hoffmeisteri	.	38
Lumbriculida		
Lumbriculidae	.	3
Crustacea		
Isopoda		
Asellidae		
Caecidotea sp.	.	75
Amphipoda		
Crangonyctidae		
Crangonyx sp.	.	131
Insecta		
Ephemeroptera		
Ephemeridae		
Hexagenia limbata	.	2
Diptera		
Chironomidae		
Ablabesmyia annulata	.	1
Chironomus sp.	.	323
Cryptochironomus sp.	.	6
Microtendipes sp.	2	.
Procladius sp.	.	3
Tanytarsus sp.	2	16
Zalutschia zalutschicola	.	1
Simuliidae	1	.
Bivalvia		
Veneroida		
Corbiculidae		
Corbicula fluminea	2	2
Sphaeriidae	2	.
Number of samples	10	20
Sum	23	1072
Number of species	6	14
Number of ept taxa	0	1
Sum of area	1.10	1.20

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	WATTS	WATTS	WATTS	WATTS
STREAM	TENNE	TENNE	TENNE	CLINCH
STREAMMI	531.0	560.8	600.0	19.0
SPECIES				
Nematoda	2	2	.	.
Hydrozoa				
Hydroida				
Hydridae				
Hydra americana	.	.	4	.
Turbellaria				
Tricladida				
Planariidae				
Dugesia tigrina	.	.	1	2
Oligochaeta				
Haplotaxida				
Enchytraeidae	.	2	.	.
Tubificidae	58	177	26	.
Branchiura sowerbyi	20	3	.	.
Limnodrilus hoffmeisteri	3	12	1	.
Lumbriculida				
Lumbriculidae	.	.	2	.
Hirudinea	.	.	.	1
Crustacea				
Isopoda				
Asellidae				
Caecidotea sp.	.	.	1	1
Lirceus sp.	.	.	2	3
Amphipoda				
Corophiidae				
Corophium lacustre	.	.	3	.
Crangonyctidae				
Crangonyx sp.	.	.	.	1
Gammaridae				
Gammarus sp.	.	.	32	.
Talitridae				
Hyalella azteca	.	.	.	1
Insecta				
Odonata				
Cordulegastridae				
Cordulegaster sp.	.	2	.	.
Ephemeroptera				
Ephemeridae				
Hexagenia limbata	10	410	.	.
Heptageniidae				
Stenacron interpunctatum	.	.	2	3
Trichoptera				
Leptoceridae				
Ceraclea sp.	2	.	6	6
Polycentropodidae				
Cyrnellus fraternus	.	2	8	4
Diptera				
Ceratopogonidae				
Bezzia sp.	.	2	.	.
Chironomidae	.	.	19	5
Ablabesmyia annulata	2	95	.	.
Axarus sp.	.	.	1	1
Chironomus sp.	292	180	8	.
Coelotanypus tricolor	67	122	.	.
Cricotopus sp.	.	.	.	4
Cryptochironomus sp.	5	15	.	.
Dicrotendipes sp.	.	.	20	6
Einfeldia sp.	.	13	.	.
Epoicocladius sp.	.	10	.	.
Glyptotendipes sp.	.	2	.	6
Harnischia sp.	.	2	.	.
Microtendipes sp.	.	2	.	.
Nanocladius sp.	.	.	24	1
Paratendipes sp.	.	.	1	.
Procladius sp.	18	117	1	.
Pseudochironomus sp.	.	2	1	.
Rheotanytarsus sp.	.	.	14	4
Stenochironomus sp.	.	2	.	.
Tanytarsus sp.	.	.	1	3
Tvetenia bavarica sp. gp.	.	.	.	1
Empididae				
Hemerodromia sp.	.	.	.	1
Simuliidae				
Prosimulium sp.	.	2	.	.
Coleoptera				
Elmidae				
Dubiraphia sp.	.	2	.	.
Arachnoidea				
Hydrachnellae				
Unionicolidae				
Unionicola sp.	.	2	.	.
Gastropoda				
Mesogastropoda				
Hydrobiidae	.	.	.	4
Bivalvia				
Unionoida				
Unionidae				
Obliquaria reflexa	.	.	1	.
Truncilla truncata	.	.	1	.
Veneroida				
Corbiculidae				
Corbicula fluminea	20	.	103	35
Sphaeriidae	15	267	.	.

Musculium transversum	5	7	.	.
Number of samples	10	10	10	10
Sum	519	1454	283	93
Number of species	14	26	25	21
Number of ept taxa	2	2	3	3
Sum of area	0.60	0.60	1.10	1.10

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	WHEELE	WHEELE	WHEELE	WHEELE
STREAM	TENNE	TENNE	TENNE	ELK R
STREAMMI	277.0	295.9	347.0	6.0
SPECIES				
Nematoda	.	.	.	15
Hydrozoa				
Hydroida				
Hydridae				
Hydra americana	.	.	7	.
Turbellaria				
Tricladida				
Planariidae				
Dugesia tigrina	.	.	30	.
Oligochaeta				
Haplotaxida				
Naididae	.	2	.	.
Nais communis	.	.	1	.
Nais simplex	.	2	.	.
Tubificidae	125	98	.	2555
Branchiura sowerbyi	2	12	.	92
Limnodrilus hoffmeisteri	5	.	.	163
Lumbriculida				
Lumbriculidae	.	3	5	.
Hirudinea				
Rhynchobdellida				
Glossiphoniidae				
Helobdella stagnalis	42	.	.	.
Helobdella triserialis	.	.	1	.
Crustacea				
Isopoda				
Asellidae				
Lirceus sp.	.	.	8	.
Amphipoda				
Crangonyctidae				
Crangonyx sp.	.	.	17	.
Gammaridae				
Gammarus sp.	.	.	42	.
Talitridae				
Hyalella azteca	.	15	.	.
Insecta				
Odonata				
Coenagrionidae				
Enallagma sp.	.	.	1	.
Ephemeroptera				
Caenidae				
Caenis sp.	.	3	2	.
Ephemerellidae				
Ephemerella sp.	.	.	1	.
Ephemeridae				
Hexagenia limbata	2	175	.	5
Heptageniidae				
Stenacron interpunctatum	.	.	23	.
Trichoptera				
Leptoceridae	.	.	1	.
Ceraclea sp.	.	.	9	.
Oecetis sp.	.	2	.	.
Polycentropodidae				
Cyrnellus fraternus	.	2	4	.
Diptera				
Ceratopogonidae				
Bezzia sp.	.	.	.	23
Chironomidae	.	.	5	.
Ablabesmyia annulata	2	17	3	.
Axarus sp.	.	2	.	2
Chironomus sp.	210	27	.	657
Coelotanypus sp.	.	35	.	58
Coelotanypus tricolor	217	103	1	122
Cryptochironomus sp.	.	27	3	18
Dicrotendipes sp.	.	27	4	2
Einfeldia sp.	17	13	.	190
Glyptotendipes sp.	.	.	.	2
Nanocladius sp.	.	.	7	.
Parachironomus sp.	.	.	3	.
Paralauterborniella sp.	.	.	.	2
Phaenopsectra sp.	.	.	.	2
Procladius sp.	60	42	.	347
Tanytarsus sp.	.	.	1	3
Tribelos sp.	.	.	.	2
Coleoptera				
Hydrophilidae				
Berosus sp.	.	.	1	.
Arachnoidea				
Hydrachnellae	.	.	.	2
Hygrobatidae				
Atractides sp.	2	.	.	.
Unionicolidae				
Unionicola sp.	3	2	.	3
Gastropoda				
Mesogastropoda				
Hydrobiidae	.	3	21	.
Somatogyrus sp.	2	.	.	.
Pleuroceridae	.	.	3	.
Elimia sp.	.	2	.	.
Pleurocera sp.	.	3	9	.
Pleurocera canaliculata	.	8	.	2
Viviparidae				
Campeloma sp.	5	2	.	.

Viviparus sp.	.	7	2	.
Basommatophora				
Ancylidae				
Ferrissia rivularis	.	.	12	.
Planorbidae	.	3	.	.
Bivalvia				
Unionoida				
Unionidae				
Ellipsaria lineolata	.	.	1	.
Elliptio crassidens	.	.	2	.
Quadrula pustulosa pustulo	.	.	2	.
Veneroida				
Corbiculidae				
Corbicula fluminea	20	130	203	.
Sphaeriidae	23	2	.	2
Eupera cubensis	.	.	1	.
Musculium transversum	3	30	.	5
Pisidium compressum	.	.	.	3
Number of samples	10	10	10	10
Sum	740	799	436	4277
Number of species	17	30	34	25
Number of ept taxa	1	4	6	1
Sum of area	0.60	0.60	1.10	0.60

VS 94 DENSITY/SQ.METER BY SITE

RESVORNA	WILSON	WILSON
STREAM	TENNE	TENNE
STREAMMI	260.8	273.0
SPECIES		
Turbellaria		
Tricladida		
Planariidae		
Dugesia tigrina	.	6
Oligochaeta		
Haplotaxida		
Tubificidae	78	158
Limnodrilus sp.	8	.
Limnodrilus hoffmeisteri	.	6
Hirudinea	.	22
Rhynchobdellida		
Glossiphoniidae		
Helobdella stagnalis	52	8
Pharyngobdellida		
Erpobdellidae	.	2
Erpobdella sp.	.	8
Crustacea		
Isopoda		
Asellidae		
Caecidotea sp.	.	3
Lirceus sp.	.	14
Amphipoda		
Crangonyctidae		
Crangonyx sp.	.	29
Gammaridae		
Gammarus sp.	.	45
Talitridae		
Hyalella azteca	2	3
Insecta		
Odonata		
Coenagrionidae		
Enallagma sp.	.	3
Ephemeroptera		
Caenidae		
Caenis sp.	.	3
Ephemeridae		
Hexagenia limbata	.	2
Heptageniidae		
Stenacron sp.	.	3
Stenacron interpunctatum	.	2
Trichoptera		
Hydroptilidae		
Hydroptila sp.	.	2
Leptoceridae		
Ceraclea sp.	.	3
Oecetis sp.	.	9
Polycentropodidae		
Cyrnellus fraternus	.	48
Diptera		
Chironomidae	3	.
Ablabesmyia sp.	.	25
Chironomus sp.	485	.
Coelotanypus sp.	7	.
Coelotanypus tricolor	20	.
Cryptochironomus fulvus	.	3
Glyptotendipes sp.	.	9
Nanocladius sp.	.	2
Procladius sp.	27	3
Stenochironomus sp.	.	2
Xenochironomus xenolabis	.	2
Coleoptera		
Elmidae		
Ancyronyx variegatus	.	2
Gastropoda		
Mesogastropoda		
Hydrobiidae	.	2
Pleuroceridae	.	25
Pleurocera sp.	.	3
Pleurocera canaliculata	.	3
Viviparidae		
Campeloma sp.	.	15
Viviparus sp.	.	3
Basommatophora		
Ancylidae		
Ferrissia rivularis	.	2
Physidae		
Physella sp.	.	3
Bivalvia		
Unionoida		
Unionidae	.	8
Anodonta imbecillis	.	8
Veneroida		
Corbiculidae		
Corbicula fluminea	.	315
Sphaeriidae	30	69
Eupera cubensis	.	20
Musculium transversum	8	100
Number of samples	10	10
Sum	720	1003
Number of species	11	43
Number of ept taxa	0	8
Sum of area	0.60	0.65

Section 5

Fish Community

Appendix A.

Results and Ratings for Individual Metrics and Final RFAI Score for Each Sample Location in 1994

Table 1. 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Beach Lake Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		18	3
2. Piscivore species		6	3
3. Sunfish species		6	5
4. Sucker species		1	1
5. Intolerant species		1	1
6. Percent tolerant species	electrofishing	27.8%	1.5
	gill netting	54.3%	0.5
7. Dominance *	electrofishing	32.9%	2.5
	gill netting	50.7%	0.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	28.7%	0.5
	gill netting	60.1%	0.5
9. Percent insectivores	electrofishing	39.5%	0.5
	gill netting	0.4%	0.5
C. Reproductive composition			
10. Lithophilic spawning species		1	1
D. Fish abundance and health			
11. Average number of individuals	electrofishing	35.3	0.5
	gill netting	27.6	2.5
12. Percent anomalies		1.5%	5
RFAI			29 poor

* Percent composition of most abundant species.

Table 2 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Bear Creek Reservoir.

Metric		Forebay Obs.	Score
A. Species richness and composition			
1. Number of species		23	5
2. Piscivore species		6	3
3. Sunfish species		5	5
4. Sucker species		7	5
5. Intolerant species		3	5
6. Percent tolerant species	electrofishing	38.8%	0.5
	gill netting	27.2%	1.5
7. Dominance *	electrofishing	33.5%	2.5
	gill netting	26.5%	2.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	36.1%	0.5
	gill netting	55.8%	1.5
9. Percent insectivores	electrofishing	39.5%	0.5
	gill netting	16.3%	2.5
C. Reproductive composition			
10. Lithophilic spawning species		6	3
D. Fish abundance and health			
11. Average number of individuals	electrofishing	43.0	1.5
	gill netting	14.7	1.5
12. Percent anomalies		2.7%	3
RFAI			44 good

* Percent composition of most abundant species.

Table 3 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Blue Ridge Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		16	5
2. Piscivore species		6	5
3. Sunfish species		4	5
4. Sucker species		3	3
5. Intolerant species		2	3
6. Percent tolerant species	electrofishing	6.0%	2.5
	gill netting	35.8%	0.5
7. Dominance *	electrofishing	45.8%	1.5
	gill netting	35.8%	1.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	0.0%	2.5
	gill netting	40.3%	0.5
9. Percent insectivores	electrofishing	81.7%	1.5
	gill netting	4.5%	1.5
C. Reproductive composition			
10. Lithophilic spawning species		5	5
D. Fish abundance and health			
11. Average number of individuals	electrofishing	18.9	0.5
	gill netting	6.7	0.5
12. Percent anomalies		2.5%	3
RFAI			42 good

* Percent composition of most abundant species.

Table 4. 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Boone Reservoir.

Metric		Transition 1 Obs.	Transition 1 Score	Transition 2 Obs.	Transition 2 Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		20	3	21	5	19	3
2. Piscivore species		9	5	9	5	7	5
3. Sunfish species		4	5	3	3	4	5
4. Sucker species		3	3	2	1	2	1
5. Intolerant species		1	1	0	1	0	1
6. Percent tolerant species	electrofishing	29.1%	1.5	14.9%	2.5	30.3%	0.5
	gill netting	54.8%	0.5	59.2%	0.5	39.3%	1.5
7. Dominance *	electrofishing	31.9%	2.5	50.7%	1.5	39.6%	2.5
	gill netting	32.2%	1.5	37.4%	1.5	29.5%	2.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	27.6%	0.5	13.5%	1.5	22.4%	1.5
	gill netting	61.0%	0.5	88.3%	0.5	51.6%	1.5
9. Percent insectivores	electrofishing	64.4%	1.5	67.0%	1.5	67.1%	1.5
	gill netting	3.4%	1.5	1.7%	0.5	4.1%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		5	3	3	3	3	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	88.0	2.5	81.0	2.5	57.9	1.5
	gill netting	14.6	0.5	17.9	1.5	12.2	0.5
12. Percent anomalies		2.4%	3	1.2%	5	5.7%	1
RFAI			36 fair		37 fair		34 fair

* Percent composition of most abundant species.

Table 5 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Cedar Creek Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		28	5
2. Piscivore species		9	5
3. Sunfish species		4	5
4. Sucker species		7	5
5. Intolerant species		3	5
6. Percent tolerant species	electrofishing	13.4%	2.5
	gill netting	26.9%	1.5
7. Dominance *	electrofishing	55.4%	1.5
	gill netting	22.6%	2.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	12.5%	1.5
	gill netting	39.2%	2.5
9. Percent insectivores	electrofishing	76.3%	1.5
	gill netting	6.6%	2.5
C. Reproductive composition			
10. Lithophilic spawning species		8	5
D. Fish abundance and health			
11. Average number of individuals	electrofishing	39.3	0.5
	gill netting	21.2	2.5
12. Percent anomalies		6.3%	1
RFAI			50 good

* Percent composition of most abundant species.

Table 6 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Chatuge Reservoir.

Metric		Forebay Obs.	Forebay Score	Shooting Creek Obs.	Shooting Creek Score
A. Species richness and composition					
1. Number of species		18	5	16	5
2. Piscivore species		8	5	7	5
3. Sunfish species		4	5	4	5
4. Sucker species		1	1	0	1
5. Intolerant species		0	1	0	1
6. Percent tolerant species	electrofishing	10.7%	2.5	7.6%	2.5
	gill netting	12.8%	1.5	13.4%	1.5
7. Dominance *	electrofishing	47.8%	1.5	57.0%	1.5
	gill netting	29.7%	2.5	31.7%	1.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	0.5%	2.5	0.8%	2.5
	gill netting	15.4%	1.5	14.8%	2.5
9. Percent insectivores	electrofishing	76.8%	1.5	84.2%	1.5
	gill netting	10.3%	2.5	4.2%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		3	3	2	1
D. Fish abundance and health					
11. Average number of individuals	electrofishing	37.4	1.5	42.1	1.5
	gill netting	19.5	2.5	14.2	1.5
12. Percent anomalies		2.5%	3	3.5%	3
RFAI			43 good		39 fair

* Percent composition of most abundant species.

Table 7 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Cherokee Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		23	5	23	5
2. Piscivore species		10	5	7	5
3. Sunfish species		3	3	2	3
4. Sucker species		2	1	4	3
5. Intolerant species		0	1	0	1
6. Percent tolerant species	electrofishing	11.8%	2.5	4.0%	2.5
	gill netting	40.1%	1.5	17.1%	2.5
7. Dominance *	electrofishing	49.1%	1.5	51.2%	1.5
	gill netting	31.1%	1.5	41.7%	1.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	11.9%	1.5	13.6%	1.5
	gill netting	68.2%	0.5	65.9%	0.5
9. Percent insectivores	electrofishing	82.9%	2.5	78.8%	1.5
	gill netting	3.4%	1.5	3.3%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		3	3	4	3
D. Fish abundance and health					
11. Average number of individuals	electrofishing	85.6	2.5	36.7	0.5
	gill netting	26.7	1.5	21.1	1.5
12. Percent anomalies		3.9%	3	4.0%	3
RFAI			38 fair		38 fair

* Percent composition of most abundant species.

Table 8 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Chickamauga Reservoir.

Metric		Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		36	5	29	3	27	3
2. Piscivore species		10	5	10	5	9	5
3. Sunfish species		6	5	6	5	5	5
4. Sucker species		5	3	2	1	2	1
5. Intolerant species		4	3	3	3	3	3
6. Percent tolerant species	electrofishing	15.3%	5	27.2%	1.5	10.5%	2.5
	gill netting	.	.	18.7%	2.5	45.9%	0.5
7. Dominance *	electrofishing	28.8%	5	32.1%	2.5	33.6%	2.5
	gill netting	.	.	40.0%	1.5	41.5%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	14.7%	5	26.1%	1.5	7.1%	2.5
	gill netting	.	.	23.9%	2.5	56.3%	0.5
9. Percent insectivores	electrofishing	67.8%	5	61.0%	2.5	77.9%	2.5
	gill netting	.	.	13.5%	1.5	10.4%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		9	5	6	3	6	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	111.7	5	45.1	0.5	71.8	1.5
	gill netting	.	.	15.5	1.5	13.5	0.5
12. Percent anomalies		8.6%	1	3.1%	3	1.7%	5
RFAI			52 excellent		41 good		41 good

* Percent composition of most abundant species.

Table 9. 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Douglas Reservoir.

Metric		Transition		Forebay	
		Obs.	Score	Obs.	Score
A. Species richness and composition					
1. Number of species		24	5	24	5
2. Piscivore species		8	5	8	5
3. Sunfish species		4	5	3	3
4. Sucker species		6	3	6	5
5. Intolerant species		1	1	1	1
6. Percent tolerant species	electrofishing	12.0%	2.5	28.2%	1.5
	gill netting	33.8%	1.5	62.2%	0.5
7. Dominance *	electrofishing	52.8%	1.5	33.6%	2.5
	gill netting	30.8%	1.5	60.9%	0.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	11.8%	1.5	27.6%	0.5
	gill netting	62.7%	0.5	65.5%	0.5
9. Percent insectivores	electrofishing	73.8%	2.5	61.0%	1.5
	gill netting	7.5%	2.5	3.4%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		6	3	7	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	76.0	1.5	40.1	1.5
	gill netting	20.1	1.5	32.5	2.5
12. Percent anomalies		1.4%	5	0.6%	5
RFAI			44 good		42 good

* Percent composition of most abundant species.

Table 10 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Fontana Reservoir.

Metric		Transition 1 Obs.	Transition 1 Score	Transition 2 Obs.	Transition 2 Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		19	5	14	3	18	5
2. Piscivore species		6	5	6	5	6	5
3. Sunfish species		2	3	2	3	2	3
4. Sucker species		4	5	2	3	2	3
5. Intolerant species		2	3	1	1	2	3
6. Percent tolerant species	electrofishing	49.0%	0.5	65.3%	0.5	25.3%	1.5
	gill netting	19.0%	1.5	7.9%	2.5	5.2%	2.5
7. Dominance *	electrofishing	46.5%	1.5	65.0%	0.5	51.5%	1.5
	gill netting	39.5%	1.5	34.1%	1.5	40.9%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	2.4%	2.5	0.3%	2.5	0.8%	2.5
	gill netting	23.8%	1.5	9.8%	2.5	8.7%	2.5
9. Percent insectivores	electrofishing	78.7%	1.5	91.0%	2.5	89.5%	2.5
	gill netting	7.5%	2.5	6.1%	2.5	6.1%	2.5
C. Reproductive composition							
10. Lithophilic spawning species		6	5	4	3	4	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	19.1	0.5	23.6	0.5	43.2	1.5
	gill netting	14.7	1.5	16.4	1.5	11.5	1.5
12. Percent anomalies		5.7%	1	1.4%	5	11.7%	1
RFAI			42 good		40 fair		43 good

* Percent composition of most abundant species.

Table 11 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Fort Loudoun Reservoir.

Metric		Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		29	5	30	5	27	3
2. Piscivore species		7	5	9	5	8	5
3. Sunfish species		4	3	5	5	5	5
4. Sucker species		8	5	3	1	4	3
5. Intolerant species		2	3	2	3	1	1
6. Percent tolerant species	electrofishing	68.6%	1	63.1%	0.5	66.8%	0.5
	gill netting	.	.	30.8%	1.5	17.4%	2.5
7. Dominance *	electrofishing	56.4%	3	54.8%	1.5	63.4%	0.5
	gill netting	.	.	19.7%	2.5	47.6%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	71.5%	1	65.5%	0.5	67.2%	0.5
	gill netting	.	.	47.9%	0.5	25.1%	2.5
9. Percent insectivores	electrofishing	21.9%	1	28.0%	0.5	24.5%	0.5
	gill netting	.	.	13.7%	1.5	6.4%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		10	5	6	3	5	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	32.5	1	71.6	1.5	118.8	2.5
	gill netting	.	.	11.7	0.5	31.1	1.5
12. Percent anomalies		2.2%	3	1.7%	5	2.2%	3
RFAI			36 fair		38 fair		37 fair

* Percent composition of most abundant species.

Table 12 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Fort Patrick Henry Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		19	3
2. Piscivore species		7	5
3. Sunfish species		4	5
4. Sucker species		2	1
5. Intolerant species		2	3
6. Percent tolerant species	electrofishing	34.1%	0.5
	gill netting	86.4%	0.5
7. Dominance *	electrofishing	32.4%	2.5
	gill netting	59.9%	0.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	33.2%	0.5
	gill netting	93.2%	0.5
9. Percent insectivores	electrofishing	55.7%	0.5
	gill netting	0.7%	0.5
C. Reproductive composition			
10. Lithophilic spawning species		2	3
D. Fish abundance and health			
11. Average number of individuals	electrofishing	72.2	1.5
	gill netting	14.7	0.5
12. Percent anomalies		1.0%	5
RFAI			33 fair

* Percent composition of most abundant species.

Table 13 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Guntersville Reservoir.

Metric		Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		30	5	24	3	24	3
2. Piscivore species		10	5	8	5	10	5
3. Sunfish species		5	5	4	3	4	3
4. Sucker species		5	3	1	1	1	1
5. Intolerant species		3	3	3	3	3	3
6. Percent tolerant species	electrofishing	32.8%	3	64.3%	0.5	20.8%	1.5
	gill netting	.	.	27.7%	1.5	57.7%	0.5
7. Dominance *	electrofishing	22.6%	5	62.5%	0.5	46.5%	1.5
	gill netting	.	.	41.5%	1.5	57.7%	0.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	39.5%	3	64.2%	0.5	19.7%	2.5
	gill netting	.	.	37.4%	1.5	63.5%	0.5
9. Percent insectivores	electrofishing	41.2%	3	30.3%	1.5	65.2%	1.5
	gill netting	.	.	8.7%	1.5	5.1%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		7	3	6	3	5	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	41.9	1	64.2	1.5	44.6	0.5
	gill netting	.	.	19.5	1.5	13.7	0.5
12. Percent anomalies		5.0%	3	1.4%	5	6.8%	1
RFAI			42 good		35 fair		30 poor

* Percent composition of most abundant species.

Table 14 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Hiwassee Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		17	5	23	5
2. Piscivore species		7	5	7	5
3. Sunfish species		2	3	3	3
4. Sucker species		4	5	6	5
5. Intolerant species		1	1	3	5
6. Percent tolerant species	electrofishing	6.9%	2.5	42.9%	0.5
	gill netting	20.1%	0.5	11.5%	1.5
7. Dominance *	electrofishing	76.9%	0.5	42.9%	1.5
	gill netting	24.8%	2.5	23.1%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	0.8%	2.5	3.2%	2.5
	gill netting	20.1%	1.5	13.7%	2.5
9. Percent insectivores	electrofishing	84.1%	1.5	84.3%	1.5
	gill netting	8.7%	2.5	18.1%	2.5
C. Reproductive composition					
10. Lithophilic spawning species		6	5	8	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	26.0	0.5	31.4	1.5
	gill netting	14.9	1.5	18.2	2.5
12. Percent anomalies		2.4%	3	1.7%	5
RFAI			43 good		52 excellent

* Percent composition of most abundant species.

Table 15 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Kentucky Reservoir.

Metric		Inflow		Transition		Forebay	
		Obs.	Score	Obs.	Score	Obs.	Score
A. Species richness and composition							
1. Number of species		34	5	39	5	39	5
2. Piscivore species		14	5	12	5	14	5
3. Sunfish species		3	3	5	5	5	5
4. Sucker species		7	3	4	3	6	3
5. Intolerant species		4	3	4	3	3	3
6. Percent tolerant species	electrofishing	84.2%	1	72.2%	0.5	94.1%	0.5
	gill netting	.	.	34.7%	1.5	63.9%	0.5
7. Dominance *	electrofishing	84.0%	1	71.3%	0.5	93.6%	0.5
	gill netting	.	.	30.0%	2.5	62.6%	0.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	84.7%	1	72.5%	0.5	94.2%	0.5
	gill netting	.	.	38.0%	1.5	72.4%	0.5
9. Percent insectivores	electrofishing	4.1%	1	21.1%	0.5	4.0%	0.5
	gill netting	.	.	19.3%	2.5	4.2%	0.5
C. Reproductive composition							
10. Lithophilic spawning species		9	5	9	5	8	5
D. Fish abundance and health							
11. Average number of individuals	electrofishing	548.1	5	134.9	2.5	756.9	2.5
	gill netting	.	.	33.7	1.5	62.0	2.5
12. Percent anomalies		9.0%	1	2.6%	3	2.4%	3
RFAI			34 fair		43 good		38 fair

* Percent composition of most abundant species.

Table 16 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Little Bear Creek Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		23	5
2. Piscivore species		6	3
3. Sunfish species		4	5
4. Sucker species		4	3
5. Intolerant species		3	5
6. Percent tolerant species	electrofishing	2.9%	2.5
	gill netting	35.6%	0.5
7. Dominance *	electrofishing	63.7%	0.5
	gill netting	31.9%	1.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	16.5%	1.5
	gill netting	47.2%	1.5
9. Percent insectivores	electrofishing	80.2%	2.5
	gill netting	29.4%	2.5
C. Reproductive composition			
10. Lithophilic spawning species		6	3
D. Fish abundance and health			
11. Average number of individuals	electrofishing	105.2	2.5
	gill netting	16.3	1.5
12. Percent anomalies		1.6%	5
RFAI			46 good

* Percent composition of most abundant species.

Table 17 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Melton Hill Reservoir.

Metric		Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		15	3	31	5	25	5
2. Piscivore species		2	1	9	5	9	5
3. Sunfish species		3	3	5	5	4	3
4. Sucker species		4	3	7	5	4	3
5. Intolerant species		0	1	2	3	2	3
6. Percent tolerant species	electrofishing	57.7%	1	43.9%	1.5	17.1%	2.5
	gill netting	.	.	24.1%	1.5	10.2%	2.5
7. Dominance *	electrofishing	49.7%	3	40.0%	2.5	55.3%	1.5
	gill netting	.	.	21.8%	2.5	22.6%	2.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	69.1%	1	46.5%	1.5	17.1%	2.5
	gill netting	.	.	59.8%	0.5	20.4%	2.5
9. Percent insectivores	electrofishing	28.0%	3	44.9%	1.5	78.4%	2.5
	gill netting	.	.	9.2%	1.5	5.3%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		3	3	7	3	4	3
D. Fish abundance and health							
11. Average number of individuals	electrofishing	11.7	1	47.2	0.5	111.3	2.5
	gill netting	.	.	8.7	0.5	22.6	1.5
12. Percent anomalies		0.0%	5	3.9%	3	2.0%	5
RFAI			28 poor		43 good		49 good

* Percent composition of most abundant species.

Table 18 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Nickajack Reservoir.

Metric		Inflow Obs.	Inflow Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		33	5	30	5
2. Piscivore species		11	5	9	5
3. Sunfish species		5	5	6	5
4. Sucker species		5	3	3	1
5. Intolerant species		5	5	4	3
6. Percent tolerant species	electrofishing	18.1%	5	21.7%	1.5
	gill netting	.	.	27.1%	1.5
7. Dominance *	electrofishing	17.0%	5	37.9%	2.5
	gill netting	.	.	28.0%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	27.3%	5	14.4%	2.5
	gill netting	.	.	39.8%	1.5
9. Percent insectivores	electrofishing	39.5%	3	71.6%	2.5
	gill netting	.	.	11.9%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		9	5	7	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	70.5	3	50.0	1.5
	gill netting	.	.	11.8	0.5
12. Percent anomalies		6.8%	1	4.8%	3
RFAI			50 good		45 good

* Percent composition of most abundant species.

Table 19 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Normandy Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		23	5
2. Piscivore species		10	5
3. Sunfish species		3	3
4. Sucker species		3	3
5. Intolerant species		4	5
6. Percent tolerant species	electrofishing	21.4%	1.5
	gill netting	37.8%	0.5
7. Dominance *	electrofishing	34.4%	2.5
	gill netting	27.0%	2.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	7.2%	2.5
	gill netting	41.3%	1.5
9. Percent insectivores	electrofishing	80.2%	2.5
	gill netting	12.8%	2.5
C. Reproductive composition			
10. Lithophilic spawning species		6	3
D. Fish abundance and health			
11. Average number of individuals	electrofishing	39.0	0.5
	gill netting	19.6	2.5
12. Percent anomalies		3.5%	3
RFAI			46 good

* Percent composition of most abundant species.

Table 20 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Norris Reservoir.

Metric		Transition Clinch Obs.	Transition Clinch Score	Transition Powell Obs.	Transition Powell Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		28	5	31	5	17	3
2. Piscivore species		12	5	11	5	7	5
3. Sunfish species		2	3	1	1	1	1
4. Sucker species		6	3	8	5	3	3
5. Intolerant species		4	5	3	5	2	3
6. Percent tolerant species	electrofishing	10.2%	2.5	3.4%	2.5	2.0%	2.5
	gill netting	27.2%	2.5	30.6%	1.5	26.5%	2.5
7. Dominance *	electrofishing	39.1%	2.5	37.6%	2.5	79.6%	0.5
	gill netting	24.7%	2.5	24.4%	2.5	46.9%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	10.0%	1.5	3.9%	2.5	2.0%	2.5
	gill netting	55.1%	1.5	35.0%	2.5	26.5%	2.5
9. Percent insectivores	electrofishing	65.7%	1.5	81.3%	2.5	87.9%	2.5
	gill netting	6.3%	2.5	26.9%	2.5	8.0%	2.5
C. Reproductive composition							
10. Lithophilic spawning species		9	5	10	5	6	5
D. Fish abundance and health							
11. Average number of individuals	electrofishing	32.9	0.5	27.4	0.5	33.7	0.5
	gill netting	15.8	1.5	16.0	1.5	11.3	0.5
12. Percent anomalies		1.6%	5	0.7%	5	1.3%	5
RFAI			50 good		52 excellent		43 good

* Percent composition of most abundant species.

Table 21 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Nottely Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		19	5	21	5
2. Piscivore species		8	5	9	5
3. Sunfish species		4	5	3	3
4. Sucker species		1	1	1	1
5. Intolerant species		0	1	0	1
6. Percent tolerant species	electrofishing	13.7%	2.5	8.9%	2.5
	gill netting	29.5%	0.5	21.0%	0.5
7. Dominance *	electrofishing	71.0%	0.5	78.9%	0.5
	gill netting	24.2%	2.5	17.8%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	4.0%	2.5	6.6%	1.5
	gill netting	34.4%	0.5	26.2%	1.5
9. Percent insectivores	electrofishing	86.0%	2.5	83.1%	1.5
	gill netting	0.8%	0.5	0.9%	0.5
C. Reproductive composition					
10. Lithophilic spawning species		3	3	3	3
D. Fish abundance and health					
11. Average number of individuals	electrofishing	56.7	1.5	32.3	1.5
	gill netting	24.4	2.5	21.4	2.5
12. Percent anomalies		10.3%	1	1.3%	5
RFAI			37 fair		38 fair

* Percent composition of most abundant species.

Table 22 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Parksville - ocoee no 1 Reservoir.

Metric		Forebay Obs.	Forebay Score
A. Species richness and composition			
1. Number of species		18	5
2. Piscivore species		5	3
3. Sunfish species		5	5
4. Sucker species		1	1
5. Intolerant species		2	3
6. Percent tolerant species	electrofishing	0.6%	2.5
	gill netting	0.0%	2.5
7. Dominance *	electrofishing	79.5%	0.5
	gill netting	41.5%	1.5
B. Trophic compostion			
8. Percent omnivores	electrofishing	0.5%	2.5
	gill netting	18.9%	1.5
9. Percent insectivores	electrofishing	96.0%	2.5
	gill netting	32.1%	2.5
C. Reproductive composition			
10. Lithophilic spawning species		2	1
D. Fish abundance and health			
11. Average number of individuals	electrofishing	98.7	2.5
	gill netting	5.3	0.5
12. Percent anomalies		1.3%	5
RFAI			42 good

* Percent composition of most abundant species.

Table 23 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Pickwick Reservoir.

Metric		Inflow Obs.	Inflow Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition							
1. Number of species		35	5	38	5	34	5
2. Piscivore species		13	5	10	5	11	5
3. Sunfish species		3	3	4	5	5	5
4. Sucker species		8	5	6	3	4	3
5. Intolerant species		8	5	6	5	3	3
6. Percent tolerant species	electrofishing	40.2%	3	23.8%	2.5	38.6%	1.5
	gill netting	.	.	44.2%	0.5	34.5%	1.5
7. Dominance *	electrofishing	33.7%	5	22.9%	2.5	35.2%	2.5
	gill netting	.	.	43.4%	1.5	33.4%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	50.4%	3	25.8%	1.5	38.5%	1.5
	gill netting	.	.	56.6%	0.5	40.3%	1.5
9. Percent insectivores	electrofishing	35.3%	3	67.8%	2.5	53.6%	1.5
	gill netting	.	.	20.2%	2.5	6.5%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		13	5	9	5	7	5
D. Fish abundance and health							
11. Average number of individuals	electrofishing	88.3	3	58.7	1.5	92.7	1.5
	gill netting	.	.	12.9	0.5	29.3	1.5
12. Percent anomalies		7.9%	1	3.3%	3	22.3%	1
RFAI			46 good		47 good		43 good

* Percent composition of most abundant species.

Table 24 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for South Holston Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		22	5	21	5
2. Piscivore species		6	3	8	5
3. Sunfish species		2	3	2	3
4. Sucker species		7	5	4	3
5. Intolerant species		2	3	1	1
6. Percent tolerant species	electrofishing	25.3%	1.5	4.9%	2.5
	gill netting	33.6%	1.5	41.9%	1.5
7. Dominance *	electrofishing	53.2%	1.5	75.9%	0.5
	gill netting	22.1%	2.5	31.6%	1.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	25.5%	0.5	9.2%	2.5
	gill netting	52.2%	1.5	45.6%	1.5
9. Percent insectivores	electrofishing	70.2%	2.5	87.4%	2.5
	gill netting	3.2%	1.5	0.7%	0.5
C. Reproductive composition					
10. Lithophilic spawning species		8	5	5	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	38.5	0.5	94.6	2.5
	gill netting	25.3	1.5	13.6	0.5
12. Percent anomalies		1.6%	5	1.3%	5
RFAI			44 good		43 good

* Percent composition of most abundant species.

Table 25 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Tellico Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		30	5	33	5
2. Piscivore species		11	5	12	5
3. Sunfish species		5	5	4	3
4. Sucker species		5	3	5	3
5. Intolerant species		2	3	3	3
6. Percent tolerant species	electrofishing	16.1%	2.5	8.7%	2.5
	gill netting	30.3%	1.5	16.7%	2.5
7. Dominance *	electrofishing	31.8%	2.5	33.8%	2.5
	gill netting	22.5%	2.5	24.8%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	16.2%	2.5	7.8%	2.5
	gill netting	47.2%	0.5	26.6%	2.5
9. Percent insectivores	electrofishing	78.0%	2.5	84.7%	2.5
	gill netting	3.9%	0.5	6.3%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		7	3	8	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	36.9	0.5	67.7	1.5
	gill netting	17.8	1.5	22.2	1.5
12. Percent anomalies		3.0%	3	6.9%	1
RFAI			44 good		47 good

* Percent composition of most abundant species.

Table 26 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Tims Ford Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		24	5	23	5
2. Piscivore species		8	5	10	5
3. Sunfish species		2	3	4	5
4. Sucker species		6	3	4	3
5. Intolerant species		2	3	3	5
6. Percent tolerant species	electrofishing	22.4%	1.5	7.1%	2.5
	gill netting	13.5%	2.5	19.0%	2.5
7. Dominance *	electrofishing	46.2%	1.5	74.9%	0.5
	gill netting	24.0%	2.5	19.0%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	12.6%	1.5	1.8%	2.5
	gill netting	42.1%	1.5	30.6%	2.5
9. Percent insectivores	electrofishing	81.1%	2.5	92.6%	2.5
	gill netting	3.5%	1.5	4.1%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		8	5	5	3
D. Fish abundance and health					
11. Average number of individuals	electrofishing	61.7	1.5	100.7	2.5
	gill netting	17.1	1.5	12.1	1.5
12. Percent anomalies		1.8%	5	4.3%	3
RFAI			47 good		50 good

* Percent composition of most abundant species.

Table 27 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Watauga Reservoir.

Metric		Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and còmposition					
1. Number of species		14	3	15	3
2. Piscivore species		6	5	5	3
3. Sunfish species		1	1	1	1
4. Sucker species		2	3	3	3
5. Intolerant species		2	3	2	3
6. Percent tolerant species	electrofishing	9.5%	2.5	3.1%	2.5
	gill netting	12.2%	1.5	46.3%	0.5
7. Dominance *	electrofishing	60.3%	0.5	54.4%	1.5
	gill netting	61.5%	0.5	37.0%	1.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	11.6%	0.5	5.7%	1.5
	gill netting	12.2%	2.5	50.0%	0.5
9. Percent insectivores	electrofishing	75.1%	1.5	66.3%	0.5
	gill netting	0.0%	0.5	0.0%	0.5
C. Reproductive composition					
10. Lithophilic spawning species		3	3	4	3
D. Fish abundance and health					
11. Average number of individuals	electrofishing	24.7	0.5	23.5	0.5
	gill netting	14.8	1.5	5.4	0.5
12. Percent anomalies		1.2%	5	0.7%	5
RFAI			35 fair		31 poor

* Percent composition of most abundant species.

Table 28 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Watts Bar Reservoir.

Metric		Inflow Clinch Obs.	Inflow Clinch Score	Inflow Tennessee Obs.	Inflow Tennessee Score	Transition Obs.	Transition Score	Forebay Obs.	Forebay Score
A. Species richness and composition									
1. Number of species		29	5	33	5	32	5	31	5
2. Piscivore species		8	5	12	5	10	5	11	5
3. Sunfish species		4	3	4	3	6	5	4	3
4. Sucker species		5	3	6	3	3	1	3	1
5. Intolerant species		4	3	4	3	3	3	2	3
6. Percent tolerant species	electrofishing	46.7%	3	28.6%	5	8.8%	2.5	5.7%	2.5
	gill netting	.	.	.	.	5.1%	2.5	10.7%	2.5
7. Dominance *	electrofishing	44.1%	3	23.1%	5	33.0%	2.5	69.1%	0.5
	gill netting	.	.	.	.	31.4%	1.5	46.4%	1.5
B. Trophic compostion									
8. Percent omnivores	electrofishing	48.5%	3	30.1%	3	9.5%	2.5	5.3%	2.5
	gill netting	.	.	.	.	17.7%	2.5	15.7%	2.5
9. Percent insectivores	electrofishing	20.5%	1	48.2%	3	74.5%	2.5	91.3%	2.5
	gill netting	.	.	.	.	4.0%	0.5	4.3%	0.5
C. Reproductive composition									
10. Lithophilic spawning species		8	5	11	5	6	3	7	5
D. Fish abundance and health									
11. Average number of individuals	electrofishing	61.5	3	54.1	3	124.0	2.5	157.9	2.5
	gill netting	.	.	.	.	17.5	1.5	14.0	0.5
12. Percent anomalies		2.3%	3	3.2%	3	3.1%	3	2.9%	3
RFAI			40 fair		46 good		46 good		43 good

* Percent composition of most abundant species.

Table 29 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Wheeler Reservoir.

		Inflow		Transition		Forebay	
Metric		Obs.	Score	Obs.	Score	Obs.	Score
A. Species richness and composition							
1. Number of species		34	5	33	5	26	3
2. Piscivore species		12	5	11	5	10	5
3. Sunfish species		4	3	5	5	4	5
4. Sucker species		9	5	6	3	4	3
5. Intolerant species		4	3	4	3	4	3
6. Percent tolerant species	electrofishing	22.3%	5	26.4%	1.5	50.7%	0.5
	gill netting	.	.	30.1%	1.5	21.6%	1.5
7. Dominance *	electrofishing	26.2%	5	30.1%	2.5	50.6%	1.5
	gill netting	.	.	28.9%	2.5	39.9%	1.5
B. Trophic compostion							
8. Percent omnivores	electrofishing	26.6%	5	26.8%	1.5	51.4%	0.5
	gill netting	.	.	45.8%	0.5	26.8%	2.5
9. Percent insectivores	electrofishing	29.3%	3	58.4%	1.5	42.4%	1.5
	gill netting	.	.	18.1%	2.5	14.4%	1.5
C. Reproductive composition							
10. Lithophilic spawning species		11	5	9	5	7	5
D. Fish abundance and health							
11. Average number of individuals	electrofishing	82.3	3	55.7	1.5	81.1	1.5
	gill netting	.	.	8.3	0.5	15.3	1.5
12. Percent anomalies		7.3%	1	8.0%	1	3.5%	3
RFAI			48 good		43 good		41 good

* Percent composition of most abundant species.

Table 30 . 1994 scoring results for the tweleve metrics and overall Reservoir Fish Assemblage Index (RFAI) for Wilson Reservoir.

Metric		Inflow Obs.	Inflow Score	Forebay Obs.	Forebay Score
A. Species richness and composition					
1. Number of species		31	5	29	5
2. Piscivore species		12	5	10	5
3. Sunfish species		5	5	4	5
4. Sucker species		4	3	4	3
5. Intolerant species		4	3	4	3
6. Percent tolerant species	electrofishing	42.4%	3	40.8%	1.5
	gill netting	.	.	17.6%	2.5
7. Dominance *	electrofishing	41.8%	3	40.4%	1.5
	gill netting	.	.	17.6%	2.5
B. Trophic compostion					
8. Percent omnivores	electrofishing	47.0%	3	41.5%	1.5
	gill netting	.	.	35.2%	1.5
9. Percent insectivores	electrofishing	41.8%	3	48.8%	1.5
	gill netting	.	.	14.8%	1.5
C. Reproductive composition					
10. Lithophilic spawning species		6	3	8	5
D. Fish abundance and health					
11. Average number of individuals	electrofishing	87.2	3	77.5	1.5
	gill netting	.	.	10.8	0.5
12. Percent anomalies		7.8%	1	4.0%	3
RFAI			40 fair		45 good

* Percent composition of most abundant species.

Section 5

Fish Community

Appendix B.

Mean Catch Per Effort by Species for Electrofishing and Gill Netting Efforts at Each Location in 1994

Table 1. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Bear Creek, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Gizzard shad	14.4	3.9
Threadfin shad	2.8	.
Common carp	.	0.1
River carpsucker	.	0.1
Quillback carpsucker	0.1	2.7
Northern hogsucker	0.6	.
Black buffalo	0.6	0.4
Spotted sucker	0.8	1.2
Black redhorse	2.9	0.6
Golden redhorse	0.6	0.3
Channel catfish	0.5	1.0
Flathead catfish	0.1	0.4
Blackspotted topminnow	2.1	.
White bass	.	0.6
Striped x white bass	.	0.1
Warmouth	0.1	0.1
Green sunfish	2.3	.
Bluegill	6.6	0.2
Longear sunfish	0.7	.
Redear sunfish	0.1	.
Spotted bass	8.5	0.2
Largemouth bass	4.1	0.1
White crappie	2.2	2.7
Logperch	0.5	.
Total	50.6	14.7
Number of samples	15	10
Number collected	759	147
Species collected	20	17

Table 2. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Beech lake, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Gizzard shad	8.7	14.0
Hybrid shad	3.8	.
Common carp	1.0	0.3
Golden shiner	.	0.2
Pugnose minnow	0.7	.
Lake chubsucker	0.1	.
Yellow bullhead	.	0.5
Channel catfish	0.4	1.6
Yellow bass	0.5	8.4
Striped x white bass	.	0.1
Warmouth	0.3	.
Green sunfish	0.1	.
Orangespotted sunfish	0.1	.
Bluegill	30.8	0.1
Longear sunfish	0.5	.
Redear sunfish	0.8	.
Smallmouth bass	0.1	.
Largemouth bass	9.7	1.0
White crappie	.	0.5
Black crappie	0.1	0.9
Total	57.5	27.6
Number of samples	15	10
Number collected	863	276
Species collected	16	11

Table 3. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Blue Ridge, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Gizzard shad	.	2.4
Whitetail shiner	5.5	.
Northern hogsucker	0.1	.
River redhorse	.	0.1
Black redhorse	.	0.1
Channel catfish	1.2	0.3
Flathead catfish	0.1	0.5
White bass	.	0.7
Warmouth	0.1	.
Redbreast sunfish	4.0	.
Green sunfish	0.3	.
Bluegill	10.4	0.1
Smallmouth bass	3.3	1.8
Largemouth bass	3.9	.
Black crappie	1.3	.
Walleye	.	0.7
Total	30.1	6.7
Number of samples	15	10
Number collected	452	67
Species collected	11	9

Table 4. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Boone, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition Watauga	Electrofishing Transition South Fork of the Holston	Electrofishing Forebay	Gill Netting Transition Watauga	Gill Netting Transition South Fork of the Holston	Gill Netting Forebay
Longnose gar	.	.	.	.	0.8	.
Alewife	.	.	.	.	.	0.1
Gizzard shad	4.9	21.8	11.7	3.9	4.7	3.0
Threadfin shad	5.3	.	0.1	.	.	.
Common carp	5.5	2.3	0.9	6.7	2.5	1.8
Spotfin shiner	10.0	28.1	9.5	.	.	.
Bluntnose minnow	0.1	.	0.4	.	.	.
Quillback carpsucker	0.3	.	.	0.5	.	.
Northern hogsucker	.	0.2	0.1	.	.	.
Black redhorse	.	0.5	.	.	.	.
Golden redhorse	0.1	1.3	0.1	.	0.1	.
Blue catfish	.	.	.	1.2	0.1	.
Channel catfish	0.1	0.1	.	3.5	1.6	1.5
Flathead catfish	0.1	0.1	0.2	0.3	0.5	0.4
White bass	.	.	.	0.3	0.1	0.1
Striped bass	0.1	.	.	0.2	.	0.7
Striped x white bass	.	.	0.1	0.7	2.2	3.6
Warmouth	0.1	0.2	1.3	.	.	.
Redbreast sunfish	.	0.3	0.1	.	.	.
Green sunfish	1.6	1.6	4.8	.	.	.
Bluegill	42.2	25.0	30.7	0.3	0.4	0.5
Hybrid sunfish	.	0.1	0.1	.	.	.
Smallmouth bass	6.3	3.4	4.1	0.3	1.2	0.3
Spotted bass	0.2	.	.	.	.	.
Largemouth bass	11.3	3.9	3.7	.	0.1	.
White crappie	0.1	0.3	.	.	0.1	.
Black crappie	0.7	0.2	.	.	0.1	0.2
Logperch	1.3	.	.	.	.	.
Walleye	.	.	.	.	0.1	.
Total	90.5	89.5	67.9	17.9	14.6	12.2
Number of samples	15	15	15	10	10	10
Number collected	1357	1343	1018	179	146	122
Species collected	19	17	16	11	15	11

Table 5. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Cedar Creek, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Longnose gar	.	0.2
Gizzard shad	2.6	4.2
Hybrid shad	0.1	.
Common carp	2.1	1.3
Spotfin shiner	0.1	.
Bluntnose minnow	0.1	.
Quillback carpsucker	.	2.0
Black buffalo	0.1	.
Spotted sucker	0.7	0.6
Silver redhorse	.	0.1
Shorthead redhorse	0.1	.
Black redhorse	0.1	.
Golden redhorse	0.5	0.4
Channel catfish	0.1	0.8
Flathead catfish	0.1	0.1
Blackspotted topminnow	3.6	.
White bass	0.1	4.8
Yellow bass	.	0.4
Striped x white bass	.	0.5
Green sunfish	0.6	.
Bluegill	28.0	0.1
Longear sunfish	1.2	.
Redear sunfish	0.1	.
Smallmouth bass	0.1	0.1
Spotted bass	3.9	4.5
Largemouth bass	1.9	0.7
White crappie	0.1	0.2
Logperch	1.3	.
Freshwater drum	.	0.2
Brook silverside	0.1	.
Total	47.3	21.2
Number of samples	15	10
Number collected	710	212
Species collected	24	18

Table 6. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Chatuge, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Electrofishing Shooting Creek	Gill Netting Forebay	Gill Netting Shooting Creek
Gizzard shad	.	0.3	2.1	1.6
Hybrid shad	.	.	0.2	0.2
Common carp	0.1	0.1	0.4	0.3
Whitetail shiner	6.5	7.1	.	.
Northern hogsucker	0.1	.	0.1	.
Channel catfish	0.1	0.1	0.5	0.2
Snail bullhead	.	0.1	1.5	0.5
White bass	.	.	5.8	3.0
Striped x white bass	.	.	4.6	4.5
Warmouth	0.3	1.3	.	.
Redbreast sunfish	3.9	5.1	.	.
Bluegill	21.9	44.4	0.4	0.1
Redear sunfish	0.1	0.1	.	.
Smallmouth bass	0.2	0.3	0.4	0.1
Spotted bass	15.9	7.1	3.2	3.1
Largemouth bass	2.0	3.5	.	.
Black crappie	.	0.3	0.2	0.2
Yellow perch	0.1	0.1	.	.
Walleye	.	.	0.1	0.4
Total	51.1	69.7	19.5	14.2
Number of samples	15	15	10	10
Number collected	766	1046	195	142
Species collected	12	14	13	12

Table 7. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Cherokee, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Longnose gar	.	.	0.1	.
Alewife	.	0.1	.	.
Gizzard shad	8.6	0.9	8.3	2.7
Threadfin shad	.	.	.	0.4
Hybrid shad	.	.	.	0.1
Common carp	1.3	0.5	2.3	0.9
Spotfin shiner	45.1	9.1	.	.
Bluntnose minnow	0.1	3.4	.	.
River carpsucker	.	.	2.6	0.8
Quillback carpsucker	.	.	3.8	8.8
Smallmouth buffalo	.	.	.	0.1
Golden redhorse	.	0.1	.	.
Blue catfish	.	.	.	0.2
Channel catfish	0.2	0.1	1.3	0.4
Flathead catfish	0.3	0.2	0.8	0.5
White bass	.	0.1	1.0	.
Striped bass	.	0.1	2.1	3.4
Warmouth	1.3	0.1	.	.
Green sunfish	0.2	.	.	.
Bluegill	19.3	22.6	0.8	0.2
Smallmouth bass	0.8	0.3	.	.
Spotted bass	0.1	.	.	.
Largemouth bass	4.5	2.3	0.5	0.4
White crappie	0.1	.	0.2	.
Black crappie	0.1	0.1	1.6	0.4
Logperch	8.1	0.9	.	.
Walleye	.	.	1.3	1.7
Freshwater drum	0.6	0.1	0.1	0.5
Brook silverside	2.1	.	.	.
Total	92.9	40.8	26.8	21.5
Number of samples	15	15	10	10
Number collected	1393	612	268	215
Species collected	17	17	15	16

Table 8. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Chickamauga, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Electrofishing Embayment	Gill Netting Transition	Gill Netting Forebay	Gill Netting Embayment
Chestnut lamprey	.	0.2	.	0.1	.	.	.
Spotted gar	.	.	.	0.2	.	.	.
Skipjack herring	0.7	.	0.1	.	0.8	1.7	.
Gizzard shad	12.4	10.1	4.1	4.3	2.8	5.6	0.8
Threadfin shad	7.1	.	.	.	.	.	.
Central stoneroller	0.4	.	.	.	.	.	.
Common carp	0.9	1.4	1.0	2.1	.	0.1	0.5
Golden shiner	0.4	0.1	.	2.9	0.1	0.5	.
Emerald shiner	4.0	5.8	6.3	2.5	.	.	.
Spotfin shiner	0.8	1.9	.	0.1	.	.	.
Steelcolor shiner	6.2	.	0.1	.	.	.	.
Bluntnose minnow	1.6	.	.	.	.	.	.
Bullhead minnow	.	0.1	.	.	.	.	.
River carpsucker	.	0.1	.	.	.	.	.
Northern hogsucker	0.1	.	0.2	.	.	.	.
Smallmouth buffalo	0.3	.	.	.	.	.	0.1
Spotted sucker	1.9	0.3	0.4	2.3	0.5	.	1.3
Black redhorse	0.4	.	.	.	.	.	.
Golden redhorse	0.5	.	.	.	.	.	0.4
Blue catfish	0.1	.	.	.	0.4	0.7	.
Channel catfish	0.7	.	0.1	.	0.4	0.7	0.6
Flathead catfish	0.5	0.1	0.3	.	0.5	0.3	0.4
White bass	0.4	0.1	.	.	.	.	0.3
Yellow bass	4.9	0.3	.	0.7	6.2	1.4	1.2
Striped bass	.	.	.	.	.	0.1	.
Warmouth	0.6	0.1	.	0.2	.	.	.
Redbreast sunfish	3.4	0.5	2.0	0.2	.	.	.
Green sunfish	0.5	0.1	0.7	.	.	.	.
Bluegill	33.2	14.5	26.3	24.1	0.1	0.3	0.1
Longear sunfish	0.1	0.1	0.2	.	.	.	.
Redear sunfish	18.3	3.7	5.3	7.3	1.0	0.2	0.8
Hybrid sunfish	0.1	.	0.1	.	.	.	.
Smallmouth bass	3.6	0.5	2.1	.	0.1	.	.
Spotted bass	4.3	3.5	8.8	0.9	1.3	0.2	0.5
Largemouth bass	7.7	1.0	2.1	3.5	0.1	0.4	.
White crappie	0.1	0.1	.	.	0.2	.	.
Black crappie	0.5	0.2	0.1	0.5	.	0.2	.
Yellow perch	0.2	0.3	0.1	1.9	.	.	.
Logperch	4.5	.	1.7	0.1	.	.	.
Sauger	0.1	.	.	0.1	0.5	0.2	0.2
Walleye	.	.	.	.	.	.	1.5
Freshwater drum	0.5	0.3	0.7	0.5	0.5	0.9	0.2
Brook silverside	1.9	.	17.3	.	.	.	.
Total	123.9	45.3	80.0	54.5	15.5	13.5	8.9
Number of samples	15	15	15	15	10	10	10
Number collected	1858	680	1200	818	155	135	89
Species collected	37	25	23	20	16	16	15

Table 9. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Douglas, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Gizzard shad	8.9	16.5	6.2	19.8
Threadfin shad	.	.	6.4	.
Common carp	0.2	0.4	0.6	0.4
Spotfin shiner	11.1	3.3	.	.
River carpsucker	.	.	2.0	0.1
Quillback carpsucker	.	.	3.1	0.2
Northern hogsucker	0.1	0.3	.	.
Smallmouth buffalo	.	.	0.3	0.3
Shorthead redhorse	0.3	.	.	0.3
River redhorse	.	0.1	.	.
Black redhorse	0.1	.	.	.
Blue catfish	.	.	.	0.1
Channel catfish	0.1	0.1	0.4	0.4
Flathead catfish	0.7	0.1	0.2	.
White bass	0.3	0.1	3.2	6.2
Striped bass	.	.	0.1	.
Warmouth	0.1	0.3	.	.
Redbreast sunfish	0.1	.	.	.
Green sunfish	0.1	0.3	.	.
Bluegill	10.4	14.5	.	0.7
Smallmouth bass	.	.	.	0.1
Largemouth bass	31.0	11.7	1.5	0.7
White crappie	0.7	0.7	0.3	0.6
Black crappie	0.9	0.7	.	2.3
Hybrid crappie	0.1	.	.	.
Logperch	40.1	6.8	.	.
Sauger	.	.	0.7	0.1
Walleye	.	.	.	0.1
Freshwater drum	0.1	.	1.5	0.1
Total	105.5	55.7	26.5	32.5
Number of samples	15	15	10	10
Number collected	1582	835	265	325
Species collected	19	15	14	17

Table 10. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Fontana, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition Little Tennessee	Electrofishing Transition Tuckasegee	Electrofishing Forebay	Gill Netting Transition Little Tennessee	Gill Netting Transition Tuckasegee	Gill Netting Forebay
Gizzard shad	0.5	0.1	0.3	1.8	0.7	0.3
Threadfin shad	0.8	.	.	.	.	.
Rainbow trout	.	.	.	0.1	.	0.4
Common carp	.	.	.	1.0	0.6	0.3
Golden shiner	.	.	0.1	.	.	.
Whitetail shiner	.	.	22.3	.	.	.
Silver shiner	0.1	.	.	.	.	.
Northern hogsucker	0.1	.	.	.	.	.
Silver redhorse	.	.	.	0.2	0.2	.
River redhorse	0.6	.	.	0.5	0.8	0.2
Golden redhorse	0.1	.	.	0.3	.	.
Sicklefin redhorse	.	.	.	.	.	0.1
Channel catfish	0.1	0.1	0.3	0.7	0.3	0.4
Flathead catfish	0.9	1.0	1.3	0.5	0.5	0.7
White bass	.	.	.	0.8	5.6	0.4
Green sunfish	10.7	16.0	11.0	.	.	.
Bluegill	14.3	6.7	5.7	.	.	.
Smallmouth bass	4.3	4.9	5.5	0.9	2.3	3.4
Largemouth bass	1.8	1.1	0.9	1.3	0.3	0.4
Black crappie	0.1	.	.	0.8	0.4	0.2
Tangerine darter	0.8	0.1	0.2	.	.	.
Walleye	.	.	.	5.8	4.7	4.7
Total	35.2	30.0	47.5	14.7	16.4	11.5
Number of samples	15	15	15	10	10	10
Number collected	528	450	713	147	164	115
Species collected	14	8	10	13	11	12

Table 11. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Fort Loudoun, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Chestnut lamprey	0.1	.	.	.	.
Spotted gar	0.3	0.1	.	.	.
Skipjack herring	.	.	0.1	1.4	14.8
Gizzard shad	18.5	41.2	115.3	2.3	4.1
Threadfin shad	8.9	0.3	2447.1	.	0.1
Hybrid shad	.	.	0.3	.	.
Common carp	3.4	5.5	3.6	1.3	1.3
Golden shiner	.	0.1	.	.	.
Emerald shiner	0.3	1.0	.	.	.
Spotfin shiner	1.9	1.7	1.4	.	.
Bullhead minnow	.	0.1	.	.	.
River carpsucker	0.3	.	.	.	.
Quillback carpsucker	.	.	.	.	0.1
Northern hogsucker	0.1	.	0.3	.	.
Smallmouth buffalo	0.4	1.6	0.7	0.2	0.8
Black buffalo	0.1	0.1	0.1	0.2	0.1
Spotted sucker	.	0.1	.	.	.
Silver redhorse	0.3	.	.	.	.
River redhorse	0.1	.	.	.	.
Black redhorse	0.1	.	.	.	.
Golden redhorse	1.1	.	.	.	.
Blue catfish	0.1	.	.	0.8	0.6
Channel catfish	0.6	0.3	0.1	0.9	0.8
Flathead catfish	0.1	.	.	0.8	0.8
White bass	0.1	0.1	0.5	1.3	4.0
Yellow bass	0.1	0.1	0.1	0.6	0.8
Striped bass	.	.	0.1	.	0.1
Warmouth	.	0.3	.	.	0.1
Redbreast sunfish	0.4	0.3	0.4	.	.
Green sunfish	0.2	0.2	0.1	.	.
Bluegill	0.6	15.3	23.7	0.4	0.9
Redear sunfish	0.1	0.1	0.1	.	0.1
Hybrid sunfish	.	0.1	.	.	.
Smallmouth bass	0.1	0.9	1.2	.	0.4
Spotted bass	1.1	.	.	.	.
Largemouth bass	0.8	3.3	8.1	.	.
White crappie	.	0.2	.	0.1	.
Yellow perch	0.1	0.1	0.3	.	.
Logperch	1.9	0.7	2.7	.	.
Sauger	.	.	.	0.3	0.4
Freshwater drum	.	0.4	0.3	1.2	0.9
Brook silverside	.	0.2	0.1	.	.
Total	42.0	74.4	2606.7	11.8	31.2
Number of samples	15	15	15	10	10
Number collected	630	1116	39101	118	312
Species collected	29	27	23	14	19

Table 12. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Fort Patrick Henry, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Alewife	.	0.4
Gizzard shad	19.9	8.8
Common carp	3.9	3.0
Spotfin shiner	23.4	.
White sucker	.	0.8
Northern hogsucker	0.3	.
Blue catfish	.	0.3
Yellow bullhead	0.1	0.1
Channel catfish	0.1	0.7
Striped bass	0.1	.
Striped x white bass	0.1	.
Rock bass	0.1	0.4
Warmouth	0.9	.
Green sunfish	0.8	.
Bluegill	13.7	0.1
Longear sunfish	1.2	.
Hybrid sunfish	0.2	.
Smallmouth bass	3.2	0.1
Largemouth bass	4.6	.
White crappie	0.1	.
Black crappie	0.1	.
Total	72.5	14.7
Number of samples	15	10
Number collected	1088	147
Species collected	18	10

Table 13. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Guntersville, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Spotted gar	0.6	1.3	1.0	0.4	.
Longnose gar	3.5	.	.	0.1	.
Bowfin	0.1	.	.	.	.
Skipjack herring	0.1	0.3	.	1.4	2.3
Gizzard shad	9.5	40.1	8.3	5.2	7.9
Threadfin shad	.	.	1.7	0.1	2.0
Mooneye	.	.	.	0.1	.
Common carp	0.3	0.6	0.3	.	.
Golden shiner	.	0.3	.	0.1	.
Emerald shiner	2.1	12.7	.	.	.
Spotfin shiner	0.5	.	0.9	.	.
Steelcolor shiner	0.2	.	.	.	.
Smallmouth buffalo	0.6	0.1	.	.	.
Bigmouth buffalo	0.1	.	.	.	.
Black buffalo	0.1	.	.	.	.
Spotted sucker	0.1	.	0.6	.	.
Golden redhorse	0.7	.	.	.	.
Blue catfish	2.6	.	.	0.2	0.3
Channel catfish	3.4	0.1	0.2	1.8	0.5
Flathead catfish	.	.	1.1	.	.
White bass	0.2	.	0.1	0.1	.
Yellow bass	1.3	0.1	0.1	8.1	1.6
Striped bass	.	.	.	.	0.1
Warmouth	0.1	.	.	.	.
Redbreast sunfish	0.5	0.3	0.7	.	.
Bluegill	7.8	7.7	20.9	0.4	0.1
Longear sunfish	0.3	0.2	1.4	.	.
Redear sunfish	3.3	0.9	1.4	1.1	.
Hybrid sunfish	.	0.1	.	.	.
Smallmouth bass	0.3	.	0.1	.	.
Spotted bass	1.2	0.1	3.5	0.2	0.1
Largemouth bass	1.1	2.1	1.4	0.1	.
Yellow perch	.	0.2	.	.	.
Logperch	0.8	0.7	2.9	.	.
Dusky darter	.	.	0.1	.	.
Sauger	0.3	0.1	0.1	0.1	0.2
Freshwater drum	0.6	0.5	0.3	0.1	0.6
Brook silverside	2.3	.	.	.	.
Total	44.4	68.5	47.1	19.6	15.7
Number of samples	15	15	15	10	10
Number collected	666	1027	707	196	157
Species collected	30	20	21	17	11

Table 14. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Hiwassee, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Gizzard shad	0.1	.	2.3	1.9
Threadfin shad	.	0.1	.	.
Hybrid shad	.	.	0.1	.
Rainbow trout	.	.	.	0.1
Common carp	0.1	0.9	0.6	0.2
Whitetail shiner	.	0.2	.	.
Northern hogsucker	0.2	.	.	.
Silver redhorse	.	.	1.0	1.2
Shorthead redhorse	.	.	.	0.1
River redhorse	.	0.1	.	0.2
Black redhorse	0.1	0.1	.	0.2
Golden redhorse	.	0.1	0.2	.
Sicklefin redhorse	.	.	.	0.8
Channel catfish	0.1	0.1	0.1	0.4
Flathead catfish	0.5	0.3	0.7	0.5
White bass	.	.	3.7	2.3
Redbreast sunfish	.	0.4	.	.
Green sunfish	2.1	16.2	0.1	.
Bluegill	27.6	14.9	.	0.2
Smallmouth bass	3.5	1.7	3.5	4.2
Spotted bass	2.2	1.1	0.1	1.5
Largemouth bass	1.2	1.4	1.1	0.5
Black crappie	0.3	0.7	0.3	0.9
Yellow perch	0.1	.	.	0.5
Walleye	0.1	.	1.1	2.5
Total	38.3	38.1	14.9	18.2
Number of samples	15	15	10	10
Number collected	574	572	149	182
Species collected	14	15	14	18

Table 15. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Kentucky, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Electrofishing Embayment	Gill Netting Transition	Gill Netting Forebay	Gill Netting Embayment
Chestnut lamprey	0.1	0.1	0.1	.	0.1	.	.
Longnose gar	.	.	0.1	.	.	.	.
Bowfin	0.5	.	.	.	.	.	.
Skipjack herring	4.6	28.1	0.2	3.9	5.0	7.3	1.3
Gizzard shad	463.9	166.1	741.8	114.3	10.1	38.8	6.5
Threadfin shad	181.4	1997.5	43.1	56.4	1.1	.	0.2
Goldeye	.	.	.	.	.	0.2	.
Chain pickerel	.	0.1	.	.	0.1	.	.
Common carp	0.9	0.5	3.7	0.5	0.6	0.8	0.1
Golden shiner	.	0.2	.	.	0.7	.	.
Emerald shiner	.	1.5	3.9	0.3	.	.	.
Spotfin shiner	0.1	0.3	.	.	.	.	.
Steelcolor shiner	.	0.1	.	.	.	.	.
Bullhead minnow	0.7	0.1	.	.	.	.	.
Grass carp	.	.	0.3	.	.	0.2	.
Bighead carp	.	.	.	.	.	0.1	.
River carpsucker	0.1	.	0.1	.	.	1.3	.
Quillback carpsucker	.	.	.	.	.	0.4	.
Smallmouth buffalo	0.7	.	0.2	0.1	0.4	1.8	.
Bigmouth buffalo	0.1	.	.	.	.	0.5	.
Black buffalo	.	.	.	.	.	0.3	.
Spotted sucker	0.3	3.2	3.1	0.3	2.4	1.0	0.2
Shorthead redhorse	0.1	.	.	.	.	.	.
Black redhorse	0.5	0.1	.	.	.	.	.
Golden redhorse	0.2	0.1	.	.	.	.	.
Blue catfish	.	.	.	.	0.1	0.1	2.2
Yellow bullhead	.	.	.	.	0.3	.	.
Channel catfish	2.2	1.0	0.7	0.4	0.6	1.4	2.2
Flathead catfish	0.3	.	0.7	.	.	0.4	.
American eel	0.1	.	0.1	.	.	.	.
Blackstripe topminnow	.	0.1	.	.	.	.	.
Mosquitofish	.	0.6	.	.	.	.	.
White bass	36.1	0.1	0.5	0.4	0.5	0.6	.
Yellow bass	9.0	0.6	4.1	3.2	3.4	3.4	4.0
Striped bass	0.1	.	0.1	.	0.1	.	.
Striped x white bass	0.3	.	.	.	.	0.1	.
Warmouth	.	0.3	0.1	.	.	.	.
Green sunfish	.	0.1	0.1	.	.	.	.
Bluegill	11.6	11.7	13.7	7.1	0.4	0.2	.
Longear sunfish	4.3	16.1	7.9	0.5	0.1	0.1	.
Redear sunfish	2.6	2.0	1.3	0.5	2.8	0.6	.
Hybrid sunfish	.	0.1	.	.	.	.	.
Smallmouth bass	1.8	0.6	1.6	.	.	.	.
Spotted bass	0.4	0.1	0.1	0.3	0.8	0.2	.
Largemouth bass	7.9	3.2	5.1	0.9	0.4	0.3	0.1
White crappie	0.3	0.6	0.1	0.1	0.1	0.3	1.0
Black crappie	0.3	0.4	1.0	.	.	0.3	.
Yellow perch	.	0.3	0.2	2.3	0.2	.	.
Logperch	1.4	1.3	0.1	0.1	.	.	.
Sauger	0.4	0.3	.	0.1	3.7	0.8	0.1
Hybrid walleye x sauger	.	.	.	.	0.1	.	.
Freshwater drum	0.7	1.1	1.5	2.8	0.6	0.5	3.4
Striped mullet	0.1	.	.	.	0.1	.	.
Brook silverside	0.1	.	0.3	.	.	.	.
Inland silverside	.	0.8	0.1	.	.	.	.
Total	733.9	2239.1	836.0	194.7	34.8	62.0	21.3
Number of samples	15	15	15	15	10	10	10
Number collected	11009	33587	12540	2920	348	620	213
Species collected	35	35	32	20	26	27	12

Table 16. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Little Bear Creek, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Gizzard shad	0.1	5.2
Central stoneroller	0.1	.
Common carp	0.1	0.6
Rosefin shiner	0.2	.
Whitetail shiner	4.0	.
Striped shiner	8.7	.
Bluntnose minnow	8.1	.
Northern hogsucker	0.1	.
Spotted sucker	0.3	3.7
Black redhorse	0.1	0.1
Golden redhorse	0.1	0.6
Channel catfish	0.3	1.9
Flathead catfish	0.4	0.2
White bass	.	0.3
Green sunfish	2.8	.
Bluegill	85.7	0.2
Longear sunfish	8.9	.
Redear sunfish	2.3	0.2
Smallmouth bass	1.6	0.7
Spotted bass	0.7	0.4
Largemouth bass	1.7	2.1
White crappie	.	0.1
Logperch	3.5	.
Total	129.9	16.3
Number of samples	15	10
Number collected	1948	163
Species collected	21	14

Table 17. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Melton Hill, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Longnose gar	.	.	.	0.1	.
Skipjack herring	.	.	.	0.2	5.0
Gizzard shad	5.8	18.9	9356.0	1.9	1.4
Threadfin shad	.	.	9650.9	.	.
Common carp	0.9	1.5	0.9	0.1	0.9
Spotfin shiner	.	1.5	15.4	.	.
Bluntnose minnow	0.2	0.2	.	.	.
Grass carp	.	0.1	.	.	.
River carpsucker	0.8	0.1	.	.	.
Quillback carpsucker	0.1	0.2	.	1.6	0.9
Northern hogsucker	.	0.2	.	.	.
Smallmouth buffalo	0.3	1.1	0.5	0.1	0.4
Black buffalo	.	.	.	.	0.1
Spotted sucker	.	0.1	.	.	.
Silver redhorse	.	.	.	0.6	0.4
Golden redhorse	0.3	0.3	.	.	.
Channel catfish	.	0.1	.	1.5	0.9
Flathead catfish	.	.	.	0.2	0.1
White bass	0.1	.	0.1	0.4	5.1
Yellow bass	.	.	0.1	1.6	3.6
Striped bass	.	.	.	.	0.5
Striped x white bass	.	.	.	.	1.9
Rock bass	.	.	.	.	0.2
Warmouth	.	0.1	0.1	.	.
Redbreast sunfish	0.1	0.3	.	.	.
Green sunfish	.	0.1	0.5	.	.
Bluegill	1.1	6.1	9.0	0.1	0.6
Redear sunfish	0.4	0.3	0.5	0.1	.
Smallmouth bass	.	0.4	1.2	.	0.4
Spotted bass	.	0.1	.	0.1	.
Largemouth bass	0.3	4.6	3.9	0.1	.
White crappie	.	0.1	.	.	.
Yellow perch	0.9	0.6	0.1	.	.
Logperch	0.5	0.7	0.2	.	.
Freshwater drum	.	0.1	0.1	.	0.2
Brook silverside	0.1	11.2	61.6	.	.
Total	11.7	48.7	19101	8.7	22.6
Number of samples	15	15	15	10	10
Number collected	175	730	286514	87	226
Species collected	15	25	17	15	17

Table 18. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Nickajack, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Forebay	Gill Netting Forebay
Chestnut lamprey	0.2	0.2	.
Spotted gar	.	0.4	0.1
Longnose gar	0.6	.	.
Skipjack herring	0.2	0.3	1.5
Gizzard shad	10.2	5.7	3.1
Threadfin shad	0.1	5.1	0.1
Mooneye	.	.	0.2
Common carp	1.3	1.1	.
Golden shiner	.	0.2	0.1
Emerald shiner	2.1	18.9	.
Steelcolor shiner	0.1	.	.
Smallmouth buffalo	0.1	0.1	0.3
Bigmouth buffalo	0.1	0.1	.
Spotted sucker	0.4	0.4	0.5
Black redhorse	0.1	.	.
Golden redhorse	0.2	.	.
Blue catfish	0.3	.	0.5
Channel catfish	7.4	0.1	0.7
Flathead catfish	0.1	0.7	0.3
White bass	0.5	0.1	0.1
Yellow bass	12.0	0.1	3.3
Striped bass	.	0.1	.
Rock bass	0.6	.	.
Warmouth	0.1	0.2	.
Redbreast sunfish	0.6	5.6	.
Green sunfish	.	0.1	.
Bluegill	11.9	18.9	0.2
Longear sunfish	0.2	0.6	.
Redear sunfish	4.2	1.3	0.2
Smallmouth bass	3.7	.	.
Spotted bass	6.5	2.8	0.3
Largemouth bass	1.8	3.3	.
White crappie	.	.	0.1
Black crappie	0.3	.	.
Yellow perch	0.1	.	.
Logperch	6.7	0.8	.
Dusky darter	0.1	.	.
Sauger	0.1	.	.
Freshwater drum	1.2	0.1	0.3
Brook silverside	.	0.1	.
Total	74.1	67.3	11.9
Number of samples	15	15	10
Number collected	1111	1010	119
Species collected	33	27	18

Table 19. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Normandy, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Longnose gar	.	0.1
Gizzard shad	1.5	5.3
Common carp	1.1	2.0
Spotfin shiner	3.7	.
Striped shiner	0.2	.
Spotted sucker	0.4	1.0
Silver redhorse	0.1	0.7
River redhorse	.	0.1
Black redhorse	.	0.2
Channel catfish	0.1	0.8
Flathead catfish	0.1	0.3
White bass	.	4.0
Rock bass	0.1	0.1
Green sunfish	6.0	.
Bluegill	14.1	0.5
Longear sunfish	8.3	.
Smallmouth bass	3.5	0.1
Spotted bass	0.7	1.1
Largemouth bass	1.7	0.5
Black crappie	.	0.8
Logperch	0.3	.
Walleye	.	1.6
Hybrid walleye x sauger	0.1	0.4
Total	41.8	19.6
Number of samples	15	10
Number collected	627	196
Species collected	17	18

Table 20. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Norris, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition Clinch	Electrofishing Transition Powell	Electrofishing Forebay	Gill Netting Transition Clinch	Gill Netting Transition Powell	Gill Netting Forebay
Longnose gar	0.1	0.1	.	0.2	0.3	.
Gizzard shad	3.0	0.7	0.6	2.7	3.9	2.6
Common carp	0.1	0.3	0.1	1.2	0.7	0.4
Popeye shiner	.	0.1	.	.	.	.
Spotfin shiner	3.2	4.1	1.5	.	.	.
Steelcolor shiner	0.6	.	.	.	.	.
Bluntnose minnow	.	0.1	.	.	.	.
River carpsucker	.	.	.	.	0.1	.
Quillback carpsucker	.	.	.	2.7	0.6	.
Northern hogsucker	0.1	0.1	.	.	.	.
Silver redhorse	.	.	.	.	1.2	.
Shorthead redhorse	0.1	0.2	.	0.1	0.1	0.2
River redhorse	0.1	0.1	0.1	.	.	.
Black redhorse	1.1	1.9	.	.	0.5	.
Golden redhorse	0.3	0.2	0.1	0.5	2.0	0.1
Channel catfish	.	0.1	.	1.0	0.3	.
Flathead catfish	0.2	0.1	.	.	0.5	.
White bass	.	.	.	1.2	0.2	0.1
Striped bass	0.1	.	.	0.2	0.4	0.3
Rock bass	0.1	.	0.5	.	.	0.8
Bluegill	12.1	10.9	29.4	0.1	.	.
Longear sunfish	0.3	.	.	.	.	.
Smallmouth bass	4.7	1.7	1.5	0.1	0.1	0.7
Spotted bass	1.1	1.5	1.5	0.1	0.5	0.2
Largemouth bass	1.5	1.3	0.5	.	.	.
White crappie	.	.	.	0.2	0.5	.
Black crappie	0.2	0.3	.	0.3	1.3	.
Logperch	1.9	4.9	1.1	.	.	.
Sauger	.	.	.	0.1	0.2	.
Walleye	0.1	0.1	0.1	2.3	2.1	5.3
Freshwater drum	0.1	0.1	.	0.1	0.5	0.6
Brook silverside	0.5	1.0	0.1	.	.	.
Total	31.4	29.7	36.9	13.1	16.0	11.3
Number of samples	15	15	15	10	10	10
Number collected	471	446	554	131	160	113
Species collected	23	22	13	17	20	11

Table 21. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Nottely, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Gizzard shad	0.1	0.1	4.3	2.1
Hybrid shad	0.3	.	3.1	.
Goldfish	.	0.2	.	.
Common carp	2.1	1.6	2.6	1.8
Northern hogsucker	0.2	0.1	.	.
White catfish	.	.	0.4	0.1
Yellow bullhead	.	.	.	0.2
Brown bullhead	0.1	0.1	0.3	.
Channel catfish	0.1	0.3	0.8	0.9
Snail bullhead	.	.	.	0.2
Flathead catfish	0.1	0.2	0.8	0.4
White bass	.	0.1	2.5	3.2
Striped bass	.	.	0.4	3.0
Striped x white bass	.	.	.	0.3
Warmouth	2.3	.	0.2	.
Redbreast sunfish	0.8	0.1	.	.
Green sunfish	6.9	0.7	.	.
Bluegill	45.1	27.7	.	.
Hybrid sunfish	0.5	0.1	.	.
Smallmouth bass	1.2	0.3	.	2.8
Spotted bass	15.9	3.9	1.2	3.3
Largemouth bass	1.1	0.7	0.4	0.3
Black crappie	3.1	0.9	5.9	0.3
Yellow perch	0.5	0.3	.	.
Walleye	.	.	1.5	0.7
Total	80.4	37.3	24.4	19.6
Number of samples	15	15	10	10
Number collected	1206	559	244	196
Species collected	17	17	14	15

Table 22. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Parksville - ocoee no 1, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Forebay	Gill Netting Forebay
Gizzard shad	0.4	.
Hybrid shad	0.3	.
Rainbow trout	0.1	.
Common carp	0.1	.
Northern hogsucker	0.1	.
Channel catfish	.	1.0
Flathead catfish	.	0.1
Warmouth	0.3	.
Green sunfish	0.3	.
Bluegill	20.6	.
Longear sunfish	0.3	.
Redear sunfish	0.3	.
Largemouth bass	3.5	2.2
White crappie	.	0.1
Black crappie	.	0.1
Yellow perch	1.3	1.7
Sauger	.	0.1
Brook silverside	78.5	.
Total	106.0	5.3
Number of samples	15	10
Number collected	1590	53
Species collected	13	7

Table 23. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Pickwick, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Electrofishing Embayment	Gill Netting Transition	Gill Netting Forebay	Gill Netting Embayment
Chestnut lamprey	0.1	0.1	0.4	0.2	.	.	.
Spotted gar	.	0.1	0.1	0.1	0.1	.	0.1
Longnose gar	0.1	.	0.1	0.1	.	.	.
Skipjack herring	3.2	0.1	0.1	0.5	0.3	1.5	0.8
Gizzard shad	30.5	11.4	32.6	60.4	5.6	9.8	17.4
Threadfin shad	53.8	20.9	9.5	76.1	3.1	0.1	7.2
Hybrid shad	0.1	.	0.1	.	.	9.7	.
Mooneye	0.1	.	.	.	.	.	.
Common carp	5.6	0.9	2.1	1.5	0.1	0.1	0.3
Golden shiner	0.1	1.7	.	.	.	0.2	.
Emerald shiner	.	3.2	6.7	.	.	.	.
Spotfin shiner	0.9	1.7	2.1	0.3	.	.	.
Mimic shiner	.	4.9	.	.	.	.	.
Pugnose minnow	.	3.1	.	0.4	.	.	.
Bullhead minnow	.	0.1	.	.	.	.	.
River carpsucker	.	.	.	.	0.1	.	.
Quillback carpsucker	.	.	.	.	.	.	0.5
Blue sucker	0.1	.	.	.	.	.	.
Northern hogsucker	0.3	.	.	0.1	.	.	.
Smallmouth buffalo	2.3	0.1	0.1	0.7	0.1	.	0.2
Bigmouth buffalo	.	.	0.1	.	.	.	.
Black buffalo	.	.	.	.	.	0.2	.
Spotted sucker	0.1	3.7	2.6	1.8	0.7	0.6	2.9
Silver redhorse	.	.	.	.	.	.	0.2
Shorthead redhorse	0.7	0.1	.	0.2	0.1	.	.
River redhorse	0.3	0.1	.	0.1	0.3	.	0.1
Black redhorse	1.2	0.3	.	0.2	0.2	.	.
Golden redhorse	0.2	.	.	2.4	.	.	0.5
Blue catfish	1.4	0.1	.	.	0.5	0.1	1.2
Black bullhead	.	.	.	.	.	.	0.1
Channel catfish	5.4	1.0	0.9	0.5	0.9	1.4	0.6
Flathead catfish	0.1	.	0.1	.	0.2	0.3	0.3
Blackspotted topminnow	.	.	0.3	.	.	.	.
White bass	2.2	.	.	0.2	.	0.3	0.1
Yellow bass	2.5	0.1	0.1	1.2	0.7	3.1	5.7
Striped x white bass	0.2	.	.	.	.	.	.
Rock bass	0.3	.	.	.	.	.	.
Warmouth	.	0.1	.	.	.	0.1	0.1
Green sunfish	.	.	1.0	.	.	.	.
Bluegill	16.9	9.5	16.0	10.5	0.2	0.3	0.4
Longear sunfish	3.0	23.7	23.0	11.2	.	0.1	.
Redear sunfish	1.7	3.7	2.2	1.6	0.5	0.3	.
Hybrid sunfish	0.1	.	.	.	.	.	.
Smallmouth bass	3.0	1.3	4.0	1.3	0.3	0.1	.
Spotted bass	0.6	0.3	0.4	0.1	0.2	0.1	0.1
Largemouth bass	1.7	2.1	2.9	4.2	0.1	0.1	0.2
White crappie	0.1	0.1	0.2	.	0.1	.	.
Black crappie	0.1	0.1	.	.	.	.	.
Yellow perch	.	0.1	.	.	.	.	.
Logperch	0.1	1.3	0.5	1.1	.	.	.
Sauger	0.1	0.1	0.1	0.1	1.0	0.4	1.6
Freshwater drum	5.7	.	1.2	0.5	0.6	0.5	1.2
Striped mullet	.	0.1	.	.	.	.	.
Brook silverside	0.2	0.9	0.7	1.5	.	.	.
Inland silverside	.	0.1	0.5	0.3	.	.	.
Total	144.9	97.1	110.7	179.3	16.0	29.4	41.8
Number of samples	15	15	15	15	10	10	10
Number collected	2173	1456	1660	2690	160	294	418
Species collected	38	35	30	30	23	22	23

Table 24. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on South Holston, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Gizzard shad	8.1	3.5	5.6	4.3
Threadfin shad	.	0.1	.	.
Goldfish	.	.	.	0.2
Common carp	1.7	1.1	2.9	1.2
Spotfin shiner	20.5	78.5	.	.
Bluntnose minnow	0.1	4.1	.	.
River carpsucker	.	.	0.6	.
Quillback carpsucker	.	.	3.3	0.3
Northern hogsucker	0.1	0.1	.	.
Silver redhorse	.	0.1	.	.
Shorthead redhorse	.	.	0.3	.
River redhorse	0.1	.	0.2	.
Black redhorse	0.4	.	.	.
Golden redhorse	.	0.1	0.2	.
Channel catfish	0.1	.	0.8	0.2
Flathead catfish	.	0.1	0.7	0.4
White bass	.	0.1	4.6	2.0
Rock bass	.	0.5	.	0.4
Warmouth	0.1	0.2	.	.
Bluegill	8.1	17.8	0.1	0.1
Smallmouth bass	1.3	4.7	1.1	0.5
Largemouth bass	1.1	1.0	0.7	0.1
White crappie	.	.	.	0.1
Black crappie	0.3	0.3	1.3	1.5
Logperch	1.1	.	.	.
Walleye	.	.	2.9	2.3
Total	43.0	112.1	25.3	13.6
Number of samples	15	15	10	10
Number collected	645	1682	253	136
Species collected	14	16	15	14

Table 25. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Tellico, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Skipjack herring	.	.	2.5	5.5
Alewife	.	.	0.1	0.6
Gizzard shad	2.5	2.9	4.0	3.1
Threadfin shad	.	0.1	.	.
Hybrid shad	0.1	0.2	0.4	1.0
Mooneye	.	.	.	0.1
Common carp	2.1	1.4	1.4	0.6
Spotfin shiner	5.6	22.3	.	.
Northern hogsucker	0.1	0.2	.	0.1
Smallmouth buffalo	0.8	0.7	1.2	0.7
Bigmouth buffalo	.	0.1	.	.
Black buffalo	0.5	0.1	0.2	0.3
Spotted sucker	0.4	0.1	0.1	.
Golden redhorse	.	.	0.2	.
Blue catfish	.	.	0.1	0.1
Channel catfish	0.1	0.1	1.5	1.1
Flathead catfish	.	0.3	.	0.1
White bass	.	0.1	1.9	3.8
Yellow bass	.	.	1.5	2.3
Striped bass	.	.	0.3	0.1
Striped x white bass	.	.	0.1	.
Warmouth	0.2	0.1	.	.
Redbreast sunfish	1.3	1.4	.	.
Green sunfish	0.1	0.3	.	.
Bluegill	12.8	26.3	.	0.4
Redear sunfish	0.1	.	.	.
Hybrid sunfish	0.1	.	.	.
Smallmouth bass	1.5	2.1	0.2	0.7
Spotted bass	0.8	0.1	.	.
Largemouth bass	0.6	2.6	0.6	0.1
White crappie	.	.	0.1	0.1
Black crappie	0.1	.	.	0.3
Yellow perch	0.1	0.3	.	0.4
Logperch	0.6	0.5	.	.
Sauger	.	.	.	0.2
Walleye	.	.	1.0	0.1
Freshwater drum	0.1	0.2	0.4	0.4
Brook silverside	9.2	10.0	.	.
Total	39.8	72.4	17.8	22.2
Number of samples	15	15	10	10
Number collected	597	1086	178	222
Species collected	23	24	20	24

Table 26. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Tims Ford, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Longnose gar	.	0.1	.	0.4
Gizzard shad	3.3	0.5	2.0	1.4
Common carp	4.0	1.2	0.3	0.5
Spotfin shiner	12.1	9.1	.	.
River carpsucker	.	.	.	0.1
Quillback carpsucker	.	.	2.6	0.5
Smallmouth buffalo	0.3	.	1.6	0.6
Spotted sucker	0.2	.	.	.
Silver redhorse	.	.	0.1	.
Black redhorse	0.1	0.1	.	0.4
Golden redhorse	0.4	.	0.1	.
Channel catfish	0.4	0.1	0.7	0.6
Flathead catfish	0.3	1.2	0.2	0.2
White bass	0.1	0.1	1.4	0.6
Yellow bass	.	.	4.1	2.3
Striped bass	.	.	0.9	1.5
Rock bass	.	0.1	.	.
Warmouth	.	0.1	.	.
Green sunfish	6.7	5.4	.	.
Bluegill	28.5	77.5	0.3	0.1
Longear sunfish	.	0.4	.	.
Smallmouth bass	3.2	5.3	0.2	0.7
Spotted bass	.	0.1	.	.
Largemouth bass	0.9	0.3	0.4	.
Black crappie	0.1	.	.	.
Logperch	0.7	2.9	.	.
Walleye	0.1	.	2.1	2.2
Freshwater drum	0.1	.	0.1	.
Brook silverside	1.5	.	.	.
Total	63.1	104.4	17.1	12.1
Number of samples	15	15	10	10
Number collected	946	1566	171	121
Species collected	19	17	16	15

Table 27. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Watauga, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Gizzard shad	1.7	0.3	1.0	2.0
Common carp	0.5	0.4	0.8	0.5
Silver shiner	.	0.3	.	.
Spotfin shiner	3.5	2.2	.	.
Bluntnose minnow	0.5	0.6	.	.
Northern hogsucker	.	0.1	.	.
Shorthead redhorse	.	0.1	.	.
Black redhorse	0.1	0.1	.	.
Golden redhorse	0.1	.	.	.
Yellow bullhead	0.1	.	.	.
Channel catfish	.	.	.	0.2
Flathead catfish	.	0.1	0.5	0.4
Rock bass	0.3	5.7	0.4	0.5
Bluegill	28.2	25.9	.	.
Smallmouth bass	2.6	2.5	2.5	0.4
Spotted bass	0.5	.	0.4	.
Largemouth bass	2.0	0.7	0.1	.
Walleye	.	0.7	9.1	1.4
Total	40.1	39.7	14.8	5.4
Number of samples	15	15	10	10
Number collected	602	596	148	54
Species collected	12	14	8	7

Table 28. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Watts Bar, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow Clinch	Electrofishing Inflow Tennessee	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Longnose gar	.	0.6	.	.	.	.
Skipjack herring	12.1	0.7	1.1	0.1	5.5	6.5
Gizzard shad	27.1	12.5	8.3	5.5	0.7	1.5
Threadfin shad	32.9	264.0	27.9	1.0	.	.
Hybrid shad	.	.	.	.	.	0.3
Mooneye	.	0.1	.	.	.	.
Common carp	1.5	2.1	2.1	1.9	0.2	.
Golden shiner	.	.	0.1	0.9	.	.
Emerald shiner	1.2	1.1	42.6	109.2	.	.
Spotfin shiner	.	1.3	13.9	3.8	.	.
Steelcolor shiner	.	0.5	4.3	2.3	.	.
Striped shiner	0.5	.	.	.	.	.
Bluntnose minnow	0.5	.	4.6	0.1	.	.
Quillback carpsucker	.	.	.	.	0.1	.
Northern hogsucker	0.3	1.1	.	0.5	.	.
Smallmouth buffalo	0.1	0.7	0.1	0.1	0.1	.
Spotted sucker	0.4	1.0	1.3	0.1	.	.
Shorthead redhorse	.	0.1	.	.	.	.
Black redhorse	2.3	0.9	.	.	.	.
Golden redhorse	1.7	0.7	.	.	.	.
Blue catfish	.	0.1	.	.	1.4	0.4
Channel catfish	0.1	0.9	0.2	0.1	0.6	0.3
Flathead catfish	.	.	.	0.2	0.7	0.7
White bass	3.3	2.9	0.2	0.2	0.8	1.1
Yellow bass	1.4	0.8	.	.	2.4	0.8
Striped bass	0.1	0.1	.	0.1	0.3	0.1
Striped x white bass	.	0.1	.	.	.	0.4
Rock bass	0.1	.	.	.	.	.
Warmouth	0.1	.	0.1	.	.	.
Redbreast sunfish	0.1	0.1	0.1	0.5	.	.
Green sunfish	.	0.2	0.3	0.3	.	.
Bluegill	4.3	6.9	30.5	28.7	0.2	0.3
Longear sunfish	.	.	0.1	.	.	.
Redear sunfish	0.7	0.1	4.1	3.1	.	0.2
Smallmouth bass	0.1	0.5	4.3	1.8	.	0.3
Spotted bass	0.5	1.5	.	0.5	.	0.3
Largemouth bass	1.9	3.7	4.7	3.0	0.1	0.1
White crappie	.	0.8	0.5	.	0.4	.
Black crappie	.	0.2	0.2	0.1	.	.
Yellow perch	0.9	0.9	0.2	0.3	.	.
Logperch	0.4	11.2	2.1	0.2	.	.
Sauger	.	0.1	.	.	3.5	0.6
Freshwater drum	0.3	0.3	0.6	0.3	0.5	0.1
Banded sculpin	0.2	.	.	.	.	.
Brook silverside	0.5	.	0.2	0.4	.	.
Total	95.5	318.5	154.8	165.2	17.5	14.0
Number of samples	15	15	15	15	10	10
Number collected	1432	4777	2322	2478	175	140
Species collected	29	34	27	28	16	17

Table 29. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Wheeler, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Transition	Electrofishing Forebay	Gill Netting Transition	Gill Netting Forebay
Chestnut lamprey	0.2	0.1	.	.	.
Spotted gar	0.5	0.1	0.1	.	.
Longnose gar	1.3	.	.	.	.
Bowfin	0.1	.	.	.	.
Skipjack herring	6.3	8.8	1.3	0.3	6.1
Gizzard shad	15.9	13.4	41.0	2.4	3.3
Threadfin shad	2.1	26.7	.	.	1.5
Common carp	1.4	0.3	0.1	.	.
Golden shiner	.	0.1	.	0.1	.
Emerald shiner	4.9	5.8	0.6	.	.
Ghost shiner	.	0.1	.	.	.
Steelcolor shiner	.	.	0.1	.	.
River carpsucker	0.1	.	.	.	.
Quillback carpsucker	0.1	.	.	.	.
Northern hogsucker	.	0.1	.	.	.
Smallmouth buffalo	1.4	0.1	0.1	0.3	.
Bigmouth buffalo	0.1	0.1	.	.	.
Black buffalo	.	.	.	0.2	.
Spotted sucker	0.2	0.6	2.1	0.1	0.6
Silver redhorse	0.1	.	.	.	.
Shorthead redhorse	0.1	.	.	.	.
Black redhorse	0.4	0.1	0.1	0.1	0.1
Golden redhorse	1.4	.	0.1	.	.
Blue catfish	0.8	0.3	.	.	0.1
Channel catfish	2.3	0.7	0.5	0.8	0.7
Flathead catfish	.	0.1	.	0.3	0.5
White bass	0.8	0.3	.	0.1	.
Yellow bass	22.1	2.0	.	1.0	0.7
Striped x white bass	.	.	0.1	0.2	0.3
Warmouth	.	1.3	.	.	0.3
Green sunfish	0.1	1.1	.	.	.
Bluegill	13.3	25.0	28.5	0.6	0.1
Longear sunfish	0.8	2.5	1.5	.	.
Redear sunfish	1.7	4.2	3.1	0.4	0.4
Hybrid sunfish	.	.	0.1	.	.
Smallmouth bass	0.3	0.8	1.5	.	0.2
Spotted bass	5.3	0.3	0.1	0.1	0.2
Largemouth bass	2.1	2.5	3.0	0.1	0.1
White crappie	0.1	0.1	.	.	0.1
Black crappie	0.5	.	.	.	.
Logperch	1.5	.	0.3	.	.
Sauger	0.1	0.3	.	0.9	0.8
Freshwater drum	0.9	1.7	1.7	0.3	0.7
Brook silverside	.	0.5	.	.	.
Inland silverside	.	0.1	.	.	.
Total	89.3	100.2	85.7	8.3	16.8
Number of samples	15	15	15	10	10
Number collected	1340	1503	1286	83	168
Species collected	34	32	21	18	19

Table 30. Species listing and catch per unit effort at the transition during fall electrofishing and gill netting on Wilson, 1994 (electrofishing effort = 300 meters of shoreline and gill netting effort = net-nights).

Comman name	Electrofishing Inflow	Electrofishing Forebay	Gill Netting Forebay
Chestnut lamprey	0.1	0.1	0.1
Spotted gar	0.1	0.1	0.1
Longnose gar	0.1	.	.
Bowfin	0.1	.	.
Skipjack herring	0.1	0.1	1.4
Gizzard shad	36.5	31.3	1.9
Threadfin shad	.	.	0.5
Hybrid shad	.	.	0.1
Common carp	0.3	.	.
Golden shiner	0.1	0.1	.
Emerald shiner	4.4	0.1	.
Spotfin shiner	0.6	.	.
Smallmouth buffalo	.	0.1	.
Bigmouth buffalo	0.3	0.1	.
Spotted sucker	1.5	0.6	0.2
Black redhorse	1.1	0.1	.
Golden redhorse	1.0	.	.
Blue catfish	0.1	.	1.8
Channel catfish	4.1	0.7	0.1
Flathead catfish	0.3	0.2	0.3
White bass	0.3	0.8	.
Yellow bass	.	.	0.4
Striped bass	0.1	.	.
Warmouth	0.1	.	.
Green sunfish	0.1	0.5	.
Bluegill	26.9	24.5	0.2
Longear sunfish	1.4	2.9	.
Redear sunfish	2.5	1.5	0.5
Smallmouth bass	3.3	3.3	0.3
Spotted bass	0.1	.	1.0
Largemouth bass	5.9	3.5	0.5
White crappie	0.1	.	0.1
Black crappie	0.1	.	.
Logperch	.	0.5	.
Sauger	.	0.1	1.1
Freshwater drum	1.4	0.6	0.7
Brook silverside	.	8.1	.
Inland silverside	0.1	0.1	.
Total	93.1	79.9	11.3
Number of samples	15	15	10
Number collected	1396	1198	113
Species collected	31	24	19