Tennessee Valley Authority

Water Management

AQUATIC ECOLOGICAL HEALTH DETERMINATIONS FOR TVA RESERVOIRS--1997

An Informal Summary of 1997 Vital Signs Monitoring Results
and Ecological Health Determination Methods

Prepared by Monitoring Team

Primary Authors/Editors:

Don L. Dycus and Dennis L. Meinert

April 1998

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Section 1. Reservoir Monitoring -- Overview of Approach, Methods, and 1997 Results

Introduction

The Tennessee Valley Authority (TVA) began a program to systematically monitor the ecological condition of its reservoirs in 1990 to complement a Stream Monitoring Program begun in 1986. Previously, reservoir studies had been confined to reservoir specific assessments to meet specific needs as they arose. These two monitoring programs were combined with TVA's fish tissue and bacteriological studies to form an integrated program (Vital Signs Monitoring) 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. Ecological monitoring activities provide the necessary information from key physical, chemical, and biological indicators to evaluate conditions in streams and reservoirs 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 document focuses on how TVA performs the overall ecological health rating for reservoirs. It summarizes 1996 data as an example of the mechanics and index values resulting from the rating system.

Each year, the reservoir ecological health rating system is reviewed seeking areas in need of improvements. Initially, numerous improvements were made based on experienced gained from working with this new system and input from other professionals. These changes were described in previous documents parallel this one. Each year progressively fewer changes have been needed. No changes were instituted for evaluation of 1996 results (Dycus and Meinert, 1997). For the 1997 results, only changes were incorporated and these were associate only with the benthic macroinvertebrate community. These changes are described in Section 6.

Study Design Considerations

Study design was based on several fundamental premises or assumptions. 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 of the basic study design decisions TVA made in developing this program. Vital signs monitoring activities focus on (1) physical/chemical characteristics of water; (2) 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 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. Embayments, another important type of reservoir area, also were 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 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 this monitoring effort.

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 was conducted in late autumn/early winter (November and December). The problem with spring benthos sampling is that results were 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 5 "Benthic Macroinvertebrate Community", and in the 1995 iteration if this document (Dycus and Meinert, 1996)

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 requiring special attention. Tied closely to development of reference conditions is the issue of **classification**--grouping only those water bodies 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 systems and those objectives must considered.

Reference Conditions--In absence of using reference sites to determine characteristics or expectations representative of good-fair-poor conditions, other approaches must be used. These include 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 many indicators because of spatial and temporal variations within and among 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 close to a hundred feet. This leaves best observed conditions or professional judgment as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. Initially, TVA's approach was to use best observed conditions to define good, fair, and poor ranges for each ecological indicator's metrics. This is still the basic approach used but experience has shown the best results can be obtained by adjusting scoring for selected metrics using professional judgment. Two requisites for this approach are an extensive database to determine reference conditions for each metric and substantial experience with both the environmental indicators and the types of reservoirs under consideration. Details of this approach to developing reference conditions are provided latter in this document.

Reservoir Classification -- 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. 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 differed among the various indicators. 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 "best expected conditions" 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. One class includes the reservoirs on the Tennessee River plus the 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 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 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. See Section 2 for details.

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 an intermediate 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) can result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment. Sec Section 3 for details.

Prior to 1995, the **sediment quality** scoring criteria used a combination of two characteristics: sediment toxicity tests and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs. In 1995, 1996, and 1997 only sediment analyses for metals, pesticides, and PCBs were used. Sediment toxicity tests were discontinued primarily because of budget reductions, but also because frequent changes in toxicity testing methods made year-to-year comparisons difficult. See Section 4 for details.

For the **benthic macroinvertebrate** and **fish** communities, scoring criteria were developed from the existing data base on TVA reservoirs as described above and in Sections 5 and 6. Seven metrics or characteristics were used to evaluate the benthic macroinvertebrate community (see Section 5) and 12 were used for the fish assemblage (see Section 6).

The ecological health scoring process is designed such that four of the indicators (DO, chlorophyll-a, benthos, and fish) are given equal weights and assigned a rating ranging from 1 (poor) to 5 (excellent). The other indicator, sediment quality, is given only half the weight of the other indicators and assigned a rating ranging from 0.5 (poor) to 2.5 (excellent). (Note: Prior to 1995, sediment quality had been rated on the full 1 to 5 range, same as the other indicators. But, discontinuance of sediment toxicity testing, which had contributed half the sediment quality rating, resulted in the rating for this indicator being reduced by one half). Ratings for the five indicators are summed for each site. Thus, the maximum total rating for a sample site would be 22.5 (all indicators excellent) and the minimum 4.5 (all indicators poor).

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. It is necessary to use a percentage basis because the number of sites monitored varies according to reservoir size and configuration. Only one site, the forebay, is sampled in small tributary reservoirs, and up to four sites (forebay, transition zone, inflow, and embayment) are sampled in selected run-of-the-river reservoirs. Also, the number of indicators varies from three at run-of-river inflow sites to five at the other types of sites. Chlorophyll and sediment quality are excluded 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. As a result, the number of scoring possibilities may be as few as 5 indicator ratings for a small reservoir sampled only at the forebay. Or, as many as 18 indicator ratings for a large reservoir sampled at the forebay, transition zone, inflow, and embayment. The total score for the small reservoir would be 22.5 if all indicators rated excellent, whereas, the total score for the large reservoir would be 82.5 if all indicators rated excellent. Hence, using a percentage basis allows easier comparison among reservoirs. Specific information for each reservoir (number of locations and indicators monitored) is in Table 1.

This approach provides a potential range of scores from 20 to 100 percent and applies to all reservoirs regardless of the number of indicators or sample sites. To complete the ecological health scoring process, the 20-100 percent scoring range must be divided into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results for each year are plotted, examined for apparent groupings, and compared to previous years.

2. Next, the groupings are compared to a trisection of the overall scoring range and to known, a priori conditions for each reservoir, focusing on reservoirs with known poor conditions.

3. Ranges representing good, fair, and poor conditions are then established. A final fine-tuning of scoring ranges is occasionally needed (adjusted either 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.

This ecological health scoring process has been in use for six years. Each year, slight modifications were made in the original evaluation process and the numerical rating 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 changed slightly over the years as outlined below (note: there were no changes between 1995, 1996,and 1997):

	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
1995	<52	52-72	>72	<57	57-72	>72
1996	<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. Fort Loudoun Reservoir, the example used, has five aquatic health indicators at two locations and two indicators at another location.

Reservoir Ecological Conditions--1997 Results

Meteorology and Hydrology - Meteorological conditions (sunlight, cloud cover, and the amount, frequency, and seasonal distribution of rainfall) significantly affect the observed hydrology (flows and retention times) and ecological conditions in reservoirs. As meteorology vary from year to year, so to its effects on reservoir hydrology and ecology.

Figure 1 shows the relative flow contributed by each of the major tributary rivers to the Tennessee River. Water quality characteristics vary greatly among major tributaries to the Tennessee River because of differences in geology, rainfall, and land use patterns among watersheds. For example, the French Broad and Holston rivers are moderately hard and rich in nutrients; 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, especially in phosphorus.

Numerous meteorological extremes occurred in 1997 and many records were set. Air temperatures were warmer than normal in January, February, and March; in February and March temperatures averaged about 5°F warmer than normal (Figure 2). Temperatures were much cooler than normal during April, May , and June, with April temperatures the seventh coolest on record (103 years). In fact, average temperatures in April were slightly lower than in March. The period July through October had near normal air temperatures.

Rainfall in the Tennessee Valley for the year 1997 was about 3 inches below normal - 48.3 inches versus a long term (100 year) average of 51.6 inches. Nearly all of the deficit was in the eastern half of the Valley, with near average rainfall in the west. However, the rain was not evenly distributed throughout the year (Figures 3 and 3a). Significant rainfall events occurred in March, June, and September; other months had normal or below normal rainfall. March was the wettest month of the year with 7.3 inches (32% above normal), and June was the fifth wettest June in 106 years of record. As a result, runoff (and stream flow) in the Tennessee Valley was high from January through June, but about normal during the naturally low flow summertime period (Figure 4 and 4a).

Interestingly, despite the 3 inch rainfall deficit for 1997, runoff for the year was actually about 3.5 inches higher than normal, due to the intensity and timing of rainfall events. Runoff is greatest in high intensity rainfall events, especially if the ground is already saturated and spring growth of foliage has not yet occurred. Foliage increases surface area which enhances evaporation, and significant amounts of water move back to the atmosphere via plant transpiration (evapo-transpiration).

The naturally low summertime runoff (Figure 4a) usually results in reduced stream flows which in turn decrease flows in the receiving reservoirs and thereby increase retention times. Retention time has a direct influence on physical, chemical, and biological (ecological) conditions in reservoirs. Some of these effects are stressful to aquatic life. For example, lower reservoir flows allow stronger thermal stratification to develop. This in turn limits mixing of the water column diminishing reaeration and causing lower dissolved oxygen concentrations in bottom waters. Naturally warmer summer water temperatures further lower oxygen concentrations due to lower solubility of oxygen and higher rates of respiration and decomposition. In addition, low stream flows help to diminish turbidity and increase water clarity. In reservoirs in which algal productivity is not nutrient limited (such as the main stem Tennessee River reservoirs), greater water clarity means more light available for photosynthesis and higher algal populations.

Meteorological conditions in 1997 set the stage for some unusual conditions in TVA reservoirs. The cool spring delayed warming of reservoir waters and many spring spawning fishes either failed to spawn or had only a marginally successful spawn. Autumn sampling of the fish assemblage revealed fewer young-of-year than normal. The heavy rains in March washed large amounts of nutrients into Valley streams and reservoirs that resulted in increased chlorophyll levels as water clarity improved in April and May. The June rains replenished these nutrients. Coupled with the lower flows and clearer water of summer, this resulted in some of the highest chlorophyll levels seen since this monitoring program began in 1990. These results are further discussed below.

Physical/Chemical/Biological Conditions in 1997 – Four of the five aquatic indicators used to evaluate each reservoir's ecological condition were similar or better in 1997 compared to past years. Only the trophic status indicator (chlorophyll levels) showed "poorer" conditions (higher concentrations).

Overall, comparing 1997results for each of the aquatic ecosystem indicators with the range of values from previous years show the following:

- DO rated the same or improved in all 17 reservoirs monitored ;
- Sediment quality was the same or better in 16 of 17 reservoirs;
- Benthos communities were the same or improved in 15 of 17 reservoirs; and
- Fish assemblages were the same or improved in 13 of 17 reservoirs.
- Chlorophyll rated poorer (levels higher than the upper range value) in 8 of 17 reservoirs;

Chlorophyll levels were measured monthly from April through October at 31 locations on 17 reservoirs during 1997. Those results were compared with the range of chlorophyll concentrations found in previous years (generally 1991 through 1996). Only one location had a seasonal mean which was lower than the lowest seasonal mean previously measured for that location. Fifteen of the 31 locations had seasonal mean concentrations which fell within their respective range. The remaining 15 locations had seasonal means which exceeded the highest mean ever measured for that location. For the 15 locations with higher than normal chlorophyll levels, 11 were in tributary reservoirs and only 4 were in mainstream reservoirs.

Phytoplankton productivity in TVA reservoirs is usually limited by a combination of three factors – nutrients, light, and retention time. In tributary reservoirs retention time is rarely a limiting factor because they have such a large volume relative to their inflow rate, which creates long retention times (100 - 300 days, see Table 5 in Section 1). Longer retention times allow suspended particles to settle, increasing water clarity. As a result, light availability, which often limits algal productivity in main stream reservoirs, is rarely a problem during the summer in tributary reservoirs. Consequently, nutrient availability usually is the limiting factor in tributary reservoirs. The rainfall in 1997 followed a "boom or bust" pattern. When it rained, it rained a lot (e.g., March and June), then extended periods passed until the next downpour. This pattern enhances algal productivity in tributary reservoirs with long retention times because it tends to replenish nutrients. However, it sometimes has the opposite effect in main stream reservoirs because of decreased light availability and decreased retention times due to increased flows. This is thought to be the most plausible explanation for the increased chlorophyll concentrations found mostly in the tributary reservoirs during 1997.

In summary, ecological indicator ratings were generally about the same or improved for DO, sediment quality, benthos, and fish and poorer for chlorophyll in 1997 compared to previous years. Data and ratings for each of these indicators are summarized in Sections 2 through 6 of this document.

Reservoir Ecological Health Scores for 1997 -- Combining all the aquatic ecosystem indicator ratings to determine the overall ecological health for each of the 17 reservoirs sampled in 1997 shows the following:

- 6 of the 17 rated good (4 mainstream reservoirs and 2 tributary reservoirs);
- 6 of the 17 rated fair (2 mainstream reservoirs and 4 tributary reservoirs); and
- 5 of the 17 rated poor (all tributary reservoirs).

The ecological health ratings for all reservoirs sampled in 1996 and/or 1997 are presented by classification unit in Table 3 and Figure 5. Main stem reservoirs scored higher (as in previous years) than any other class of reservoirs, while none of the reservoirs in the Interior Plateau Ecoregion scored better than fair. Comparisons of reservoir ecological health ratings with previous years (Table 4) shows that 10 of the 17 reservoirs sampled in 1997 scored within two points of their long term average, 3 scored higher, and 4 scored lower than their long term average.

A brief summary of Vital Signs Monitoring results for each reservoir in 1997 is provided in Appendix A. Differences between 1997 and previous years 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 the time they were originally reported) and based on the latest (1997) scoring methods.

Important physical and operational characteristics of reservoirs and the dams that control them are summarized in Table 5.

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Table 1. Reservoir Vital Signs Monitoring Activities, 1997

Reservoir	River Mile	Sampling Schedule (Monthly or Annual)				
		Water Chemistry	Sediment Quality		Benthos	Fish
			Toxicity	Chemistry		
Kentucky	TRM 23.0	M	A	A	A	A
	TRM 85.0[S,B,F]	M	A	A	A	A
	TRM 200-206[B,F]	-	-	-	A	A
	Big Sandy 7.4	M	A	A	A	A
Pickwick	TRM 207.3	M	A	A	A	A
	TRM 230.0	M	A	A	A	A
	TRM 253-259	-	-	-	A	A
	Bear Creek 8.4	M	A	A	A	A
Wilson	TRM 260.8	M	A	A	A	A
	TRM 273-274	-	-	-	A	A
Wheeler	TRM 277.0	M	A	A	A	A*#
	TRM 295.9	M	A	A	A	A*#
	TRM 347-348	-	-	-	A	A*#
	Elk River 6.0	M	A	A	A	A*#
Guntersville	TRM 350.0	M	A	A	A	A
	TRM 375.2	M	A	A	A	A
	TRM 420-424	-	-	-	A	A
Nickajack	TRM 425.5	M	A	A	A	A**
	TRM 469-470	-	-	-	A	A**
Chickamuaga	TRM 472.3	M	A	A	A	A***
	TRM 490.5	M	A	A	A	A***
	TRM 518-529	-	-	-	A	A***
	Hiwassee 8.5	M	A	A	A	A***
Watts Bar	TRM 531/532.5	M	A	A	A	A
	TRM 560.8	M	A	A	A	A
	TRM 600-601	-	-	-	A	A
	CRM 19-22	-	-	-	A	A
Fort Loudoun	TRM 605.5[S,B,F]	M	A	A	A	A
	TRM 624.6	M	A	A	A	A****
	TRM 652	-	-	-	A	A
Tellico	LTRM 1.0	M	A	A	A	A*
	LTRM 15.0	M	A	A	A	A*
Melton Hill	CRM 24.0	M	A	A	A	A
	CRM 45.0	M	A	A	A	A
	CRM 59-66	-	-	-	A	A
Norris	CRM 80.0	M	A	A	A	A*
	CRM 125.0	M	A	A	A	A*
	PRM 30.0	M	A	A	A	A*

Footnotes: Shadded areas -- not sampled in 1997

(M)-Monthly, April - October (A)-Annually

(vsigns97.xls-5/20/97)

Reservoir	River Mile	Sampling Schedule (Monthly or Annual)				
		Water Chemistry	Sediment Quality		Benthos	Fish
			Toxicity	Chemistry		
Cherokee	HRM 53/55.0	M	A	A	A	A
	HRM 76.0	M	A	A	-	A
Douglas	FBRM 33/34.5	M	A	A	A	A*
	FBRM 51.0[B,F]	M	A	A	A	A*
Ft.Pat Henry	SFHR 8.7[S]	M	A	A	A	A*
Boone	SFHR19.0[S,B,F]	M	A	A	A	A*
	SFHR 27.0	M	A	A	A	A*
	WRM 6.5	M	A	A	A	A*
South Holston	SFHR 51.0	M	A	A	A	A
	SFHR 62.5	M	A	A	A	A
Watauga	WRM 37.4	M	A	A	A	A
	WRM 45.5	M	A	A	A	A
Fontana	LTRM 62.0	M	A	A	-	A
	LTRM 81.5	M	A	A	A	A
	TkRM 3.0	M	A	A	A	A
Apalachia	HiRM 67.0	M	A	A	A	A*
Hiwassee	HiRM 77/77.5	M	A	A	A	A
	HiRM 85.0	M	A	A	A	A
Chatuge	HiRM 122.0	M	A	A	A	A
	Shooting Cr 1.5	M	A	A	A	A
Nottely	NRM 23.5	M	A	A	A	A*
	NRM 31.0[B,F]	M	A	A	A	A*
Blue Ridge	ToRM 54.1	M	A	A	A	A*
Ocoee No.1	ORM 12.5	M	A	A	A	A***
Tims Ford	ERM 135.0	M	A	A	A	A
	ERM 150.0	M	A	A	A	A
Bear Creek	BCM 75.0	M	A	A	A	A
L. Bear Creek	LBCM 12.5[S,B,F]	M	A	A	A	A
Cedar Creek	CCM 25.2	M	A	A	A	A
Normandy	DRM 249.5	M	A	A	A	A
Beech	BRM 36.0	M	A	A	A	A

Footnotes: S,B,F = QA resample sites -- S=Sediments; B=Benthos; F=Fish

*Fish Tissue Site - 5 CHC and 5 LMB; # More detail to follow about Wheeler fish tissue:

**Fish Tissue Site - 5 CHC, 5 LMB, 5 STB; ***Fish Tissue Site - 5 CHC

****Fish Tissue Site - 10 CHC

Table 2. Computional Method for Evaluation of Reservoir Health; Fort Loudoun Reservoir -- 1997 (Run-of-the-River Reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition	Inflow	Forebay	Transition	Inflow
Chlorophyll-a				1.2 (poor)	1.0 (poor)	No Rating
Summer Average, ug/l	15.7	16.2	No Sample			
Maximum Concentration	21.0	23.0	No Sample			
Dissolved Oxygen				5.0 (good)	5.0 (good)	No Rating
Percent less than 2 mg/l :						
X-Sectional Area	0 (5)	0 (5)	No Sample			
Bottom X-Sectional Length	0 (5)	0 (5)	No Sample			
Sediment Quality				1.5 (fair)	1.5 (fair)	No Rating
Metals/Pesticides/PCBs	chlordane	chlordane	No Sample			
Benthic Community				2 (fair)	4 (good)	2 (poor)
Total Score - Seven Metrics	17	29	13			
Fish Community				4 (fair)	3 (fair)	2 (poor)
Total Score - Twelve Metrics	42	37	22			
	Sampling Location Sum			13.7 of 22.5	14.5 of 22.5	4 of 10
	Reservoir Sum			32.2 of 55 (58%)		
	Overall Reservoir Evaluation			"fair"		

Overall Reservoir Evaluation Key:

Less than 52 % -- poor (red)
52 % to 72 % -- fair (yellow)
Greater than 72 % -- good (green)

Table 3. Ecological Health Scores for Reservoirs Monitored in 1996 and 1997 (All Scoring Based on the Latest, 1997, Criteria)

Reservoir	1995 Score/Rating	1996 Score/Rating	1997 Score/Rating
Reservoir Class: Mainstream Reservoirs			
Kentucky	72 - Good	NS	78 - Good
Pickwick	NS	73 - Good	NS
Wilson	NS	75 - Good	NS
Wheeler	69 - Fair	NS	76 - Good
Guntersville	NS	86 - Good	NS
Nickajack	92 - Good	NS	88 - Good
Chickamauga	79 - Good	NS	88 - Good
Watts Bar	NS	70 - Fair	
Ft. Loudoun	49 - Poor	52 - Fair	58 - Fair
Tellico	53 - Fair	NS	62 - Fair
Melton Hill	NS	73 - Good	NS
Reservoir Class: Ridge and Valley Ecoregion			
Norris	61 - Fair	NS	64 - Fair
Douglas	45 - Poor	NS	54 - Poor
Cherokee	51 - Poor	49 - Poor	NS
Ft. Pat. Henry	51 - Poor	59 - Fair	56 - Poor
Boone	52 - Poor	NS	55 - Poor
South Holston	NS	55 - Poor	NS
Watauga	NS	72 - Good	NS
Reservoir Class: Blue Ridge Ecoregion			
Apalachia	NS	NS	73-Good
Hiwassee	NS	62 - Fair	NS
Chatuge	NS	84 - Good	NS
Blue Ridge	89 - Good	NS	82 - Good
Parksville	71 - Fair	NS	71 - Fair
Nottely	49 - Poor	NS	48 - Poor
Fontana	72 - Good	62 - Fair	NS
Reservoir Class: Interior Plateau Ecoregion			
Tims Ford	56 - Fair	53 - Poor	NS
Normandy	59 - Fair	69 - Fair	NS
Bear	46 - Poor	47 - Poor	42 - Poor
Little Bear	64 - Fair	64 - Fair	64 - Fair
Cedar	60 - Fair	68 - Fair	69 - Fair
Beech	46 - Poor	51 - Poor	NS

Table 4. Reservoir Ecological Health Scores 1991 - 1997

Watershed/ Reservoir	Area (Acres)	Res. Eco. Health Rating, as reported							Res. Eco. Health on 1997 Criteria							1993-97
		1991	1992	1993	1994	1995	1996	1997	1991*	1992*	1993*	1994	1995	1996	1997	Averag
Kentucky Res. Watershed																
Kentucky Reservoir	160,300	77	88	75	71	74	N/A	78	69	87	81	75	72	N/A	78	77
Beech Reservoir	900	N/A	N/A	65	56	46	51	N/A	N/A	N/A	69	54	46	51	N/A	55
Duck River Watershed																
Normandy Reservoir	3,200	N/A	N/A	56	68	59	69	N/A	N/A	N/A	62	64	59	69	N/A	64
Pickwick/Wilson Watershed																
Pickwick Reservoir	43,100	77	75	73	84	N/A	73	N/A	77	80	70	82	N/A	73	N/A	75
Wilson Reservoir	15,500	60	68	71	71	N/A	75	N/A	58	67	76	73	N/A	75	N/A	75
Bear Creek Resrvoir	700	N/A	N/A	60	56	46	47	42	N/A	N/A	64	60	46	47	42	52
Little Bear Creek Res.	1,600	N/A	N/A	64	64	69	64	64	N/A	N/A	68	69	64	64	64	66
Cedar Creek Reservoir	4,200	N/A	N/A	56	80	60	64	69	N/A	N/A	64	72	60	68	69	67
Wheeler/Elk Watershed																
Wheeler Reservoir	67,100	89	80	72	75	69	N/A	76	70	76	72	74	69	N/A	76	73
Tims Ford Reservoir	10,600	N/A	60	58	58	56	53	N/A	N/A	63	60	58	56	53	N/A	57
Guntersville/Sequatchie WS																
Guntersville Reservoir	67,900	66	83	78	83	N/A	86	N/A	84	85	79	83	N/A	86	N/A	83
Nickajack/Chickamauga																
Nickajack Reservoir	10,400	89	83	88	90	92	N/A	88	87	81	87	91	92	N/A	88	90
Chickamauga Res.	35,400	90	73	83	87	81	N/A	88	83	88	86	86	79	N/A	88	85
Hiwassee River Watershed																
Hiwassee Reservoir	6,100	82	69	58	68	N/A	62	N/A	72	71	69	62	N/A	62	N/A	64
Chatuge Reservoir	7,100	60	56	67	77	N/A	84	N/A	59	79	79	72	N/A	84	N/A	78
Nottely Reservoir	4,200	60	60	64	56	47	N/A	48	60	61	62	56	49	N/A	48	54
Blue Ridge Reservoir	3,300	87	73	72	86	84	N/A	82	87	83	91	80	89	N/A	82	86
Ocoee No. 1 Reservoir	1,900	47	53	52	60	71	N/A	71	74	74	67	67	71	N/A	71	69
Apalachia	1,100							73							73	73

* 1991, 1992, and 1993 are scored on 1997 criteria for 4 of the 5 indicators. A change in processing of benthic macroinvertebrate samples beginning in 1994 prevents appropriate scoring of the earlier results on the latter criteria.

Table 4. cont. Reservoir Ecological Health Score 1991 - 1997

Watershed/ Reservoir	Area (Acres)	Res. Eco Health Rating, as reported 1991	1992	1993	1994	1995	1996	1997	Res. Eco. Health on 1997 Criteria 1991*	1992*	1993*	1994	1995	1996	1997	1993-97 Average
Watts Bar/Ft. Loud./Mel. Hill																
Watts Bar Reservoir	39,000	69	71	68	79	N/A	68	N/A	72	79	76	73	N/A	70	N/A	73
Fort Loudoun Reservoir	14600	60	53	58	61	49	52	58	63	63	56	64	49	52	58	56
Melton Hill Reserovir	5700	80	67	68	72	N/A	73	N/A	67	65	66	75	N/A	73	N/A	71
Clinch/Powell Watershed																
Norris Reservoir	34200	57	67	67	69	60	N/A	64	71	72	69	65	61	N/A	64	65
L' Tenn. River Watershed																
Tellico Reservoir	15,900	48	48	63	71	53	N/A	62	61	57	63	74	53	N/A	62	63
Fontana Reservoir	10,600	N/A	N/A	64	67	72	62	N/A	N/A	N/A	71	75	72	62	N/A	70
French Broad River WS																
Douglas Reservoir	30,400	42	56	58	64	45	N/A	54	60	54	60	62	45	N/A	54	55
Holston River Watershed																
Cherokee Reservoir	30300	50	53	64	53	51	49	N/A	57	57	66	48	51	49	N/A	54
Fort Pat. Henry Res.	900	N/A	N/A	72	60	51	59	56	N/A	N/A	86	56	51	59	56	62
Boone Reservior	4300	51	64	59	59	49	N/A	55	53	63	58	56	52	N/A	55	55
South Holston Res.	7600	60	57	65	66	N/A	55	N/A	63	59	66	66	N/A	55	N/A	62
Watauga Reservor	6,400	80	57	61	65	N/A	72	N/A	75	72	63	63	N/A	72	N/A	66

* 1991, 1992, and 1993 are scored on 1997 criteria for 4 of the 5 indicators. A change in processing of benthic macroinvertebrate samples beginning in 1994 prevents appropriate scoring of the earlier results on the latter criteria.

Table 5. 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 POR (thru 97) Flow (cfs)	Average Jan-Dec 97 Flow (cfs)	Average Jan-Dec 97 Residence Time[a] (days)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	67,230	69,611	20.6
Pickwick	32,820	52.7	43.1	84	924	6	55,921	64,207	7.3
Wilson	30,750	15.5	15.5	108	634	3	52,403	61,552	5.2
Wheeler	29,590	74.1	67.1	66	1,050	6	50,526	60,470	8.8
Guntersville	24,450	75.7	67.9	65	1,018	2	41,698	49,001	10.5
Nickajack	21,870	46.3	10.7	60	241	0	37,141	39,484	3.1
Chickamauga	20,790	58.9	35.4	83	628	7	34,887	38,899	8.1
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,672	30,715	16.6
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,892	22,943	8.0
Melton Hill	3,343	44.0	5.7	69	120	0	5,123	5,470	11.1
Tellico	2,627	33.2	16.5	80	415	6	6,213[d]	7,823[d]	
Tributary River Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,287	4,653	221.0
Douglas	4,541	43.1	30.4	127	1,408	48	6,793	6,763	105.0
Cherokee	3,428	54.0	30.3	163	1,481	28	4,599	4,864	153.6
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,680	2,612	5.2
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,573	2,461	38.7
South Holston	703	23.7	7.6	239	658	33	990	1,003	330.7
Watauga	468	16.3	6.4	274	569	26	720	706	406.3
Fontana	1,571	29.0	10.6	460	1,420	64	3,949	5,196	137.8
Hiwassee	968	22.2	6.1	255	422	45	2,064	2,486	85.6
Chatuge	189	13.0	7.1	124	234	10	463	484	243.8
Nottely	214	20.2	4.2	167	170	24	419	450	190.5
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,426	1,501	28.6
Blue Ridge	232	11.0	3.3	156	193	36	615	666	146.1
Tims Ford	529	34.2	10.6	143	530	12	983	1,195	223.6
Bear Creek	232	16.0	0.7	74	10	11[e]	405	588	8.6
Cedar Creek	179	9.0	4.2	79	94	14[e]	312	451	105.1
Little Bear Creek	61	7.1	1.6	82	45	12[e]	109	152	149.3
Normandy	195	17.0	3.2	83	110	11	340	424	130.8
Beech	16	5.3	0.9	32	11	1[e]	--	--	--

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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: Environmental Compliance, Water Management, TVA (Knoxville, TN), 1998.

Figure 1. Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

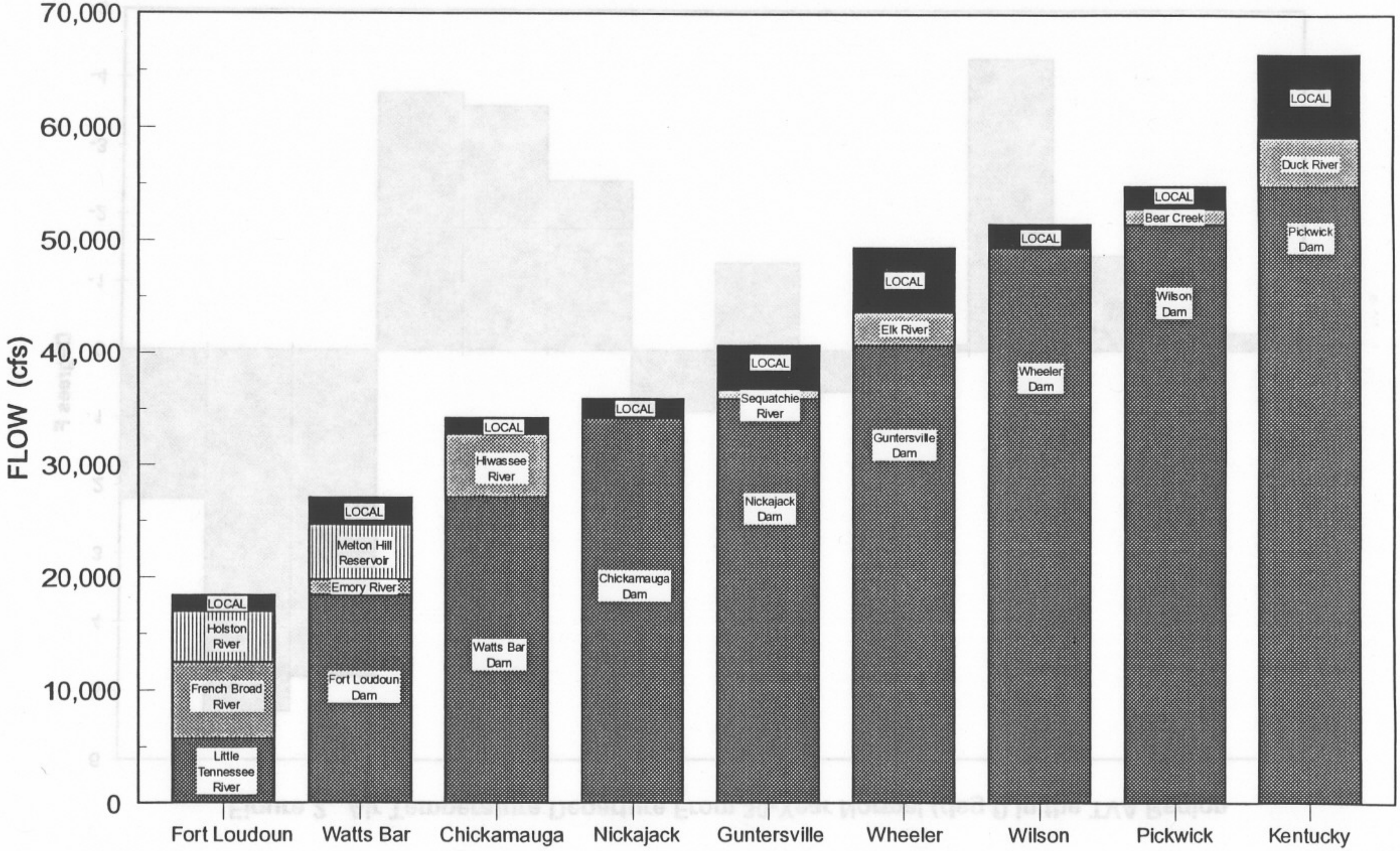


Figure 2. Air Temperature Departure From 30-Year Normal (deg f) in the TVA Region

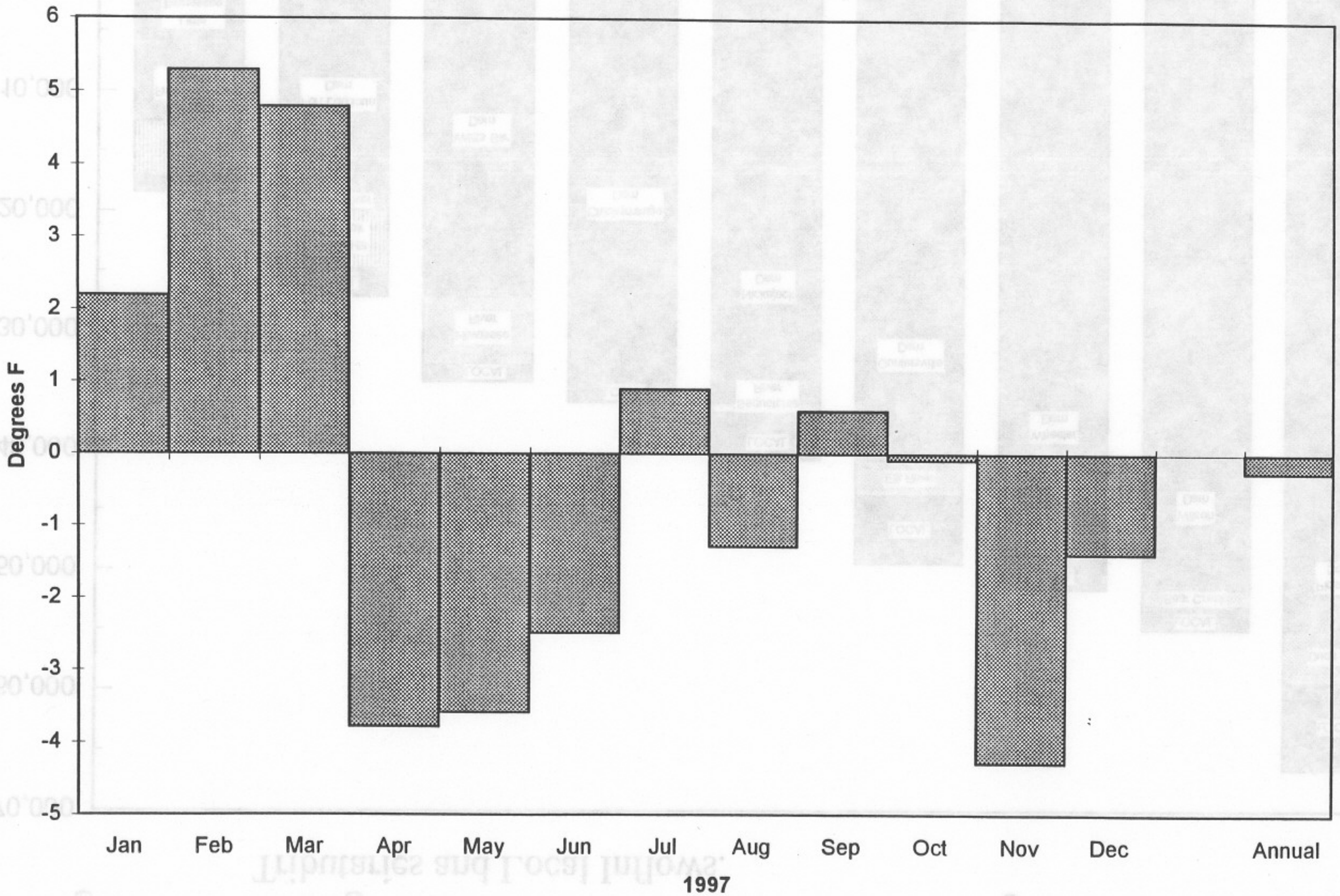


Figure 3. PRECIPITATION DEPARTURES FROM LONG-TERM MEAN (1897-1996) FOR THE TENNESSEE RIVER BASIN

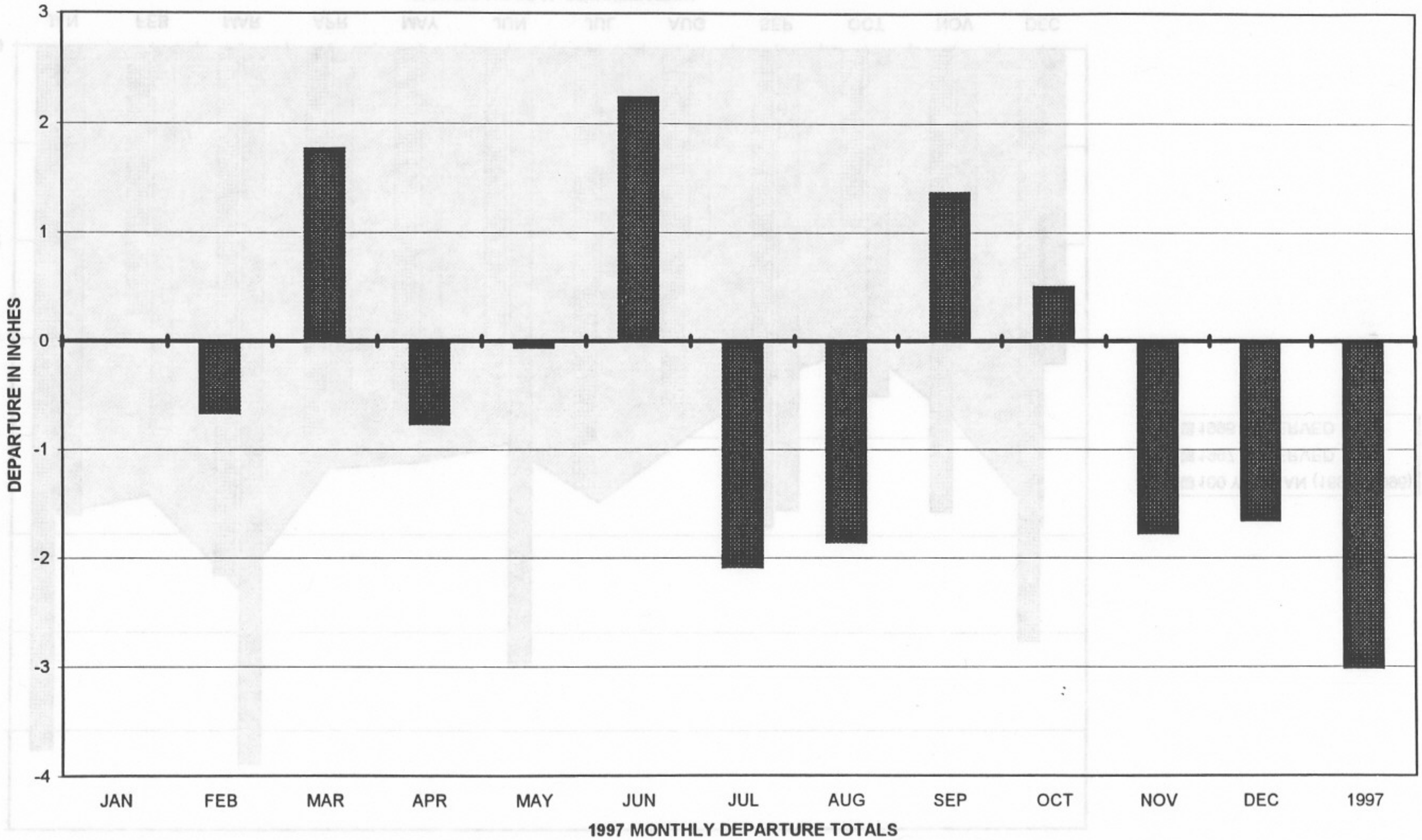


Figure 3a. PRECIPITATION FOR THE TENNESSEE RIVER BASIN

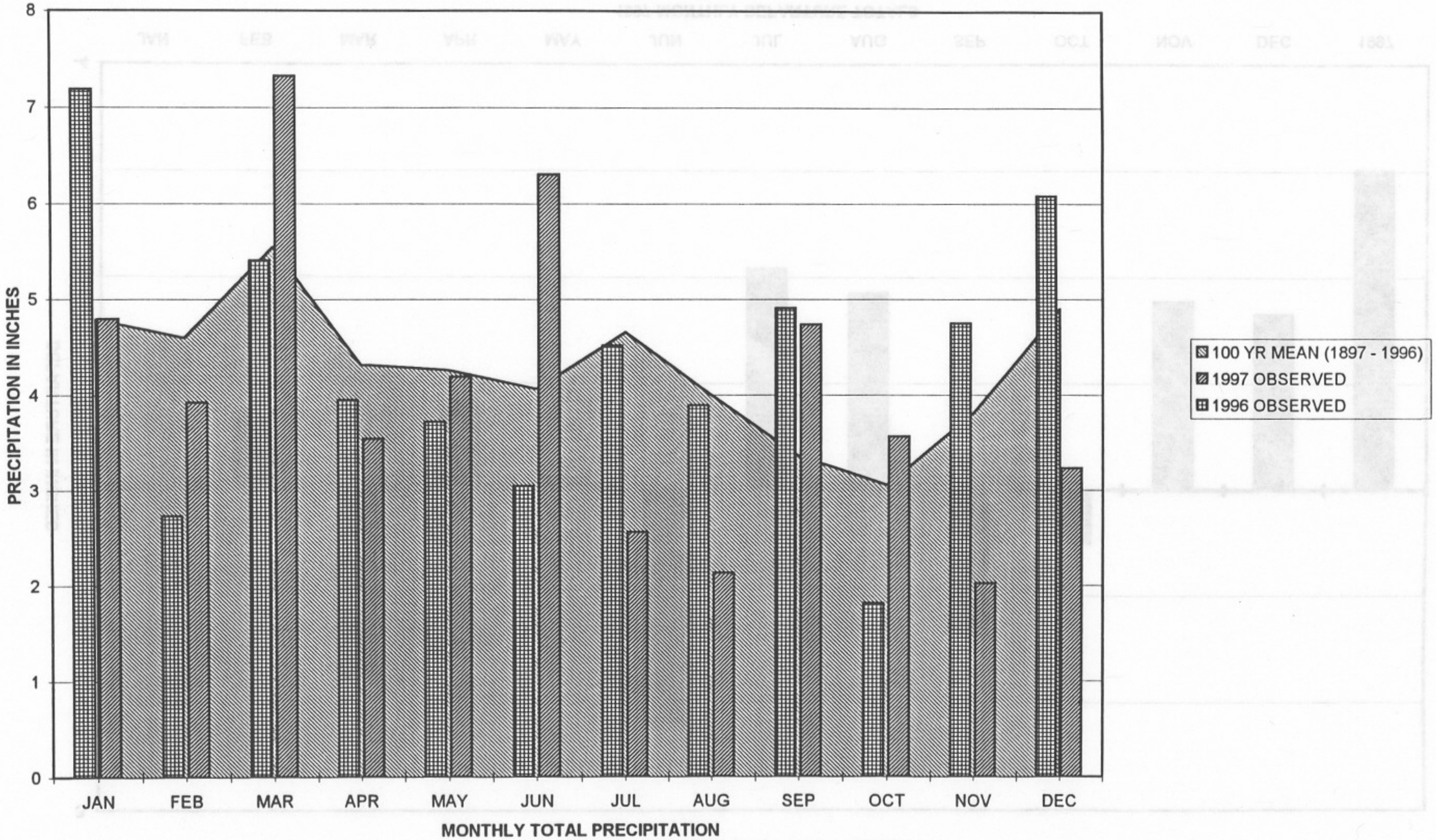


Figure 4. RUNOFF DEPARTURES FROM LONG-TERM MEAN (1897-1996) FOR THE TENNESSEE RIVER BASIN ABOVE KENTUCKY DAM

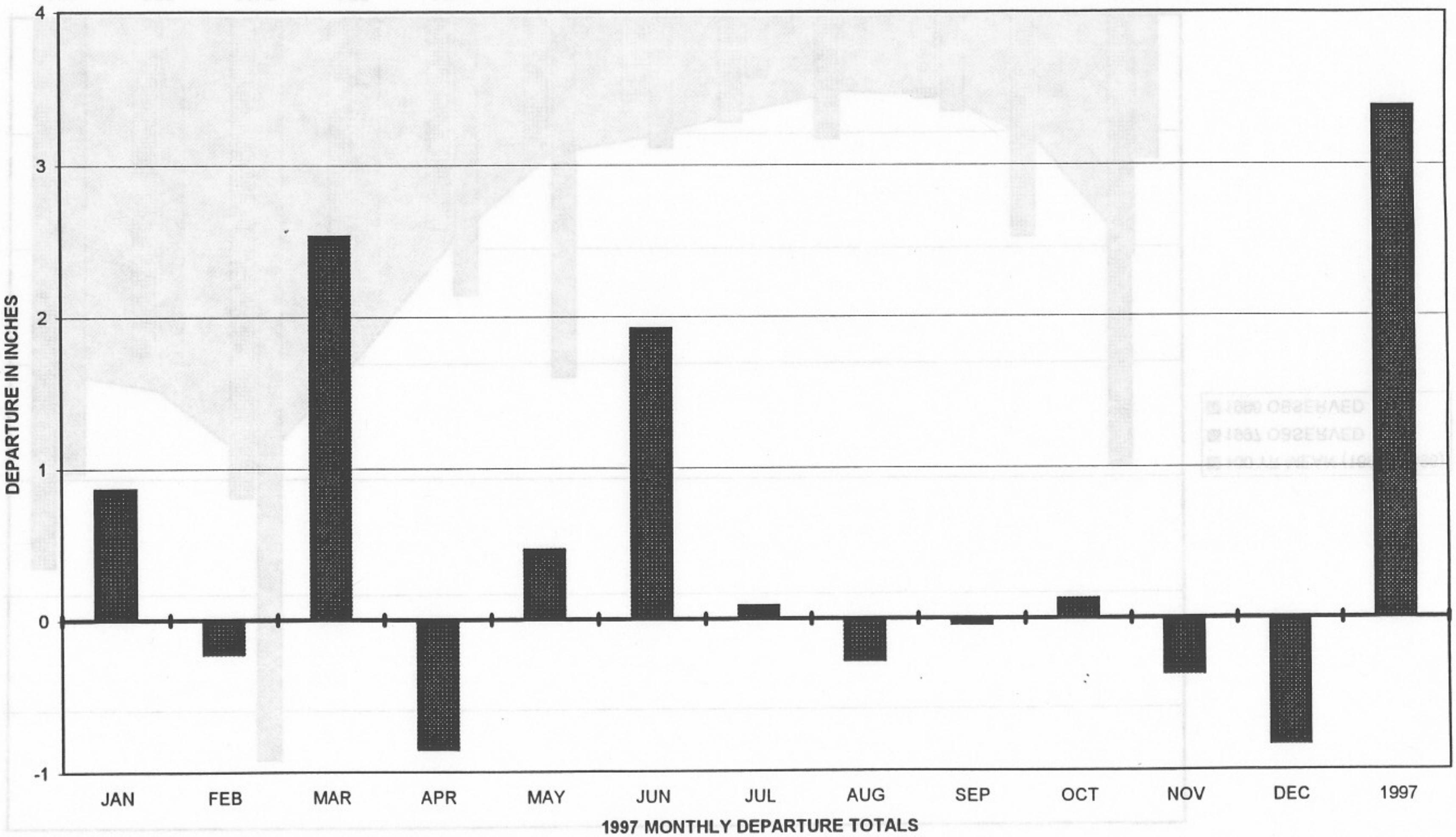


Figure 4a. RUNOFF ABOVE KENTUCKY DAM

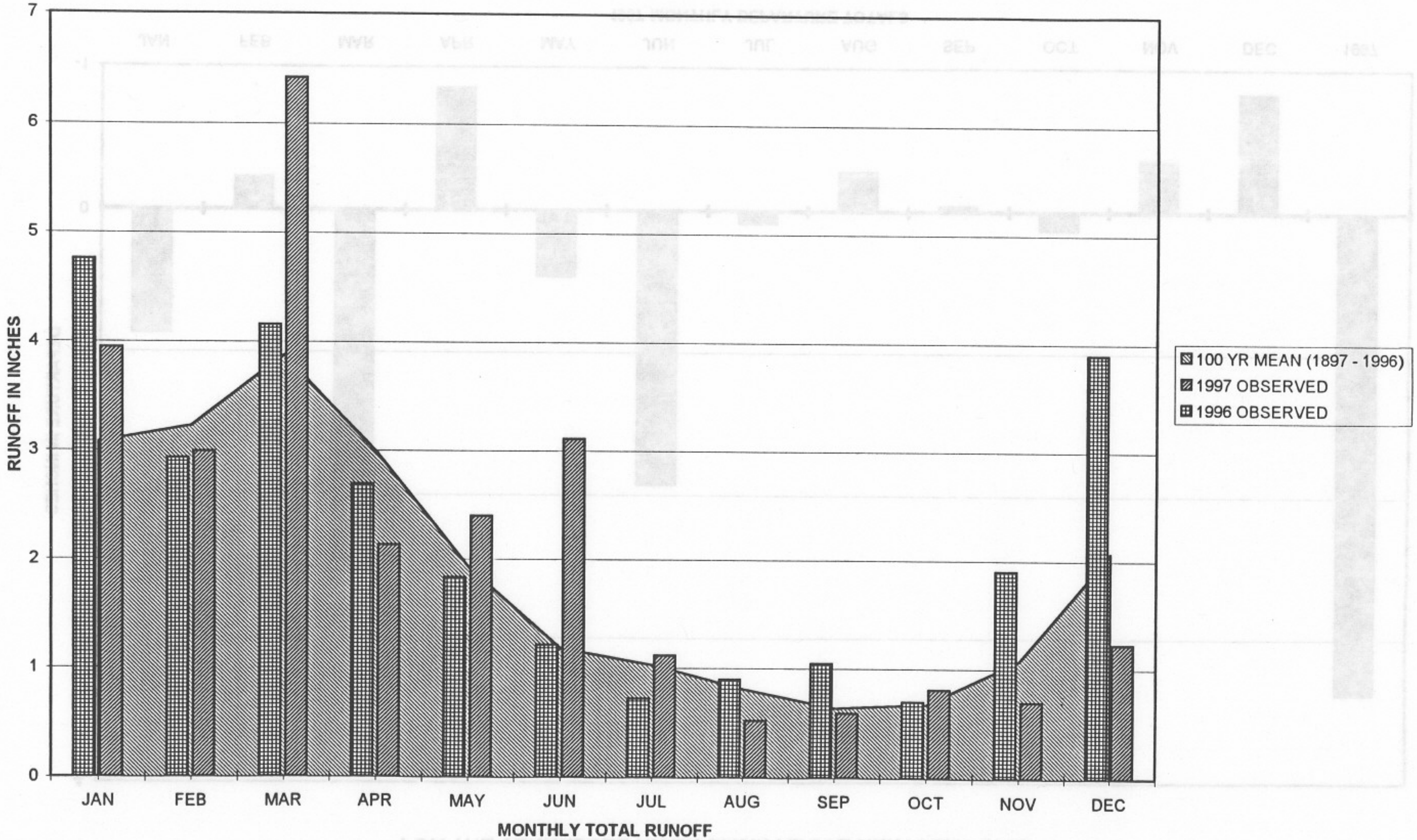
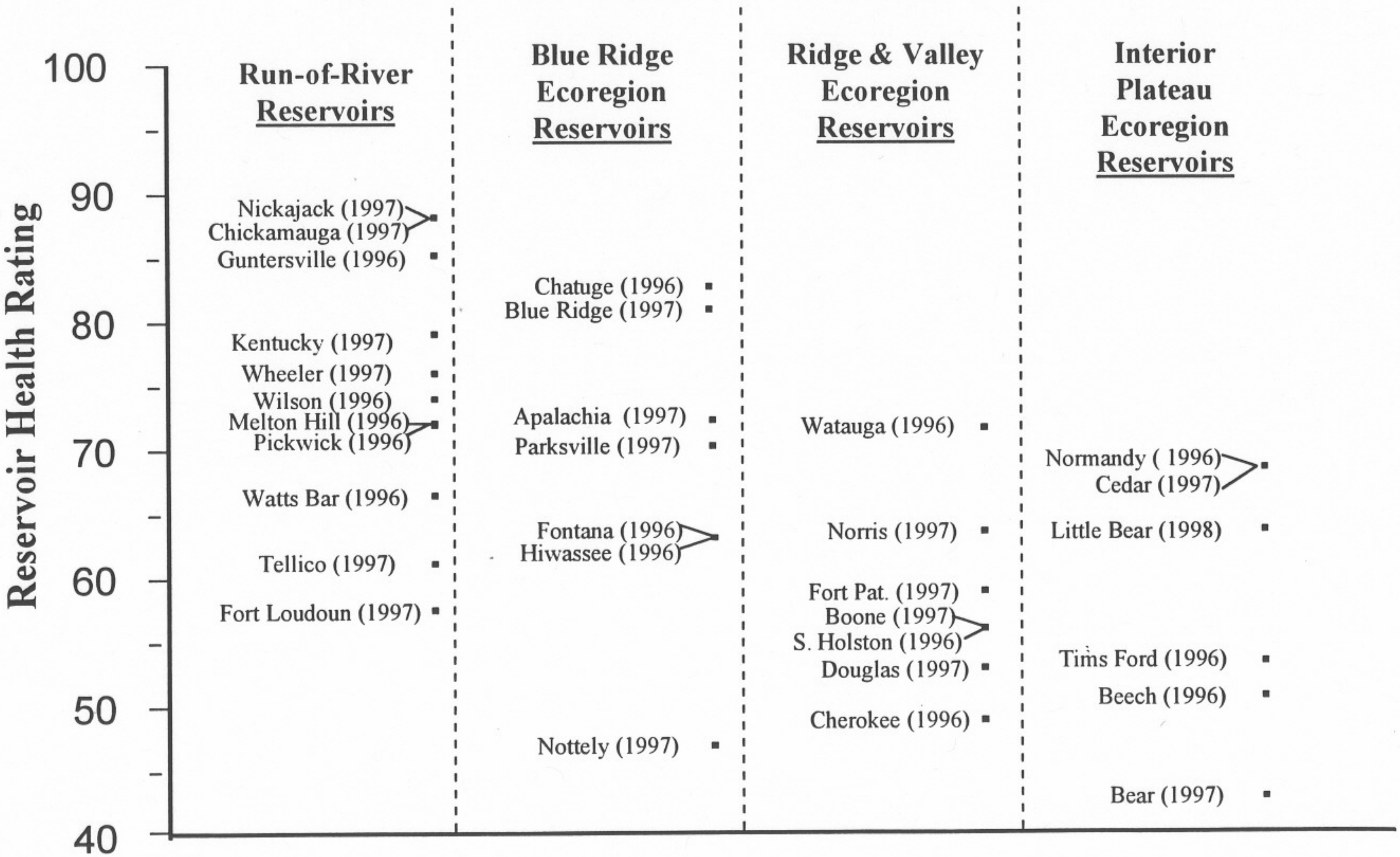


Figure 5. 1996/7 Ecological Health Summary

Reservoirs were sampled in the year in parenthesis



Section 2. Dissolved Oxygen (DO)

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 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 health, 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, 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.

Data Collection Methods

DO data were collected monthly during the summer (April-October) of 1997, concurrently with chlorophyll and other physical/chemical samples. The 1997 sampling scheme included collection of physical/chemical water quality variables at 30 locations on 17 reservoirs. (See Table 1 in Section 1 for specific location sampled in each reservoir.) Water quality sampling, as described in Table 2 included, in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and photic zone (defined as twice the Secchi depth or 4-meters, whichever is greater) composite chlorophyll-a samples. In addition, on three occasions during the summer (beginning-, mid-, and end- of the summer growing season), photic zone composite samples for nutrient analyses (total phosphorus, ammonia-nitrogen, nitrate+nitrite-nitrogen, and organic nitrogen) were also collected. Water quality profiles and sampling were conducted over the original river channel at the reservoir's maximum depth at each location. Physical/chemical water quality sampling was not conducted at most reservoir inflow locations because many of these locations are free flowing (or tailwater areas of upstream dams) and are more representative of riverine processes (and the upstream reservoir), rather than conditions in the reservoir being assessed.

Two specific QA/QC activities were incorporated into the reservoir physical/chemical water sampling. These were: (1) collection and analysis of triplicate sets of water samples once during the year at seven locations to assess sample collection and handling, laboratory analysis, and natural sample variability; and (2) preparation and analysis of ten sets of nutrient container bottle blanks (when the nutrient samples were collected) to assess the degree of contamination associated with the nutrient sample bottles.

DO Rating Scheme

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 measurements. (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 (WC_{DO}) rating and the bottom DO rating (B_{DO}):

$$\textbf{DO Rating} = 0.5\,(\textbf{WC}_{DO}\ \textbf{rating} + \textbf{B}_{DO}\ \textbf{rating}),\ \text{where:}$$

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) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L. (See Figure 1).

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 1997 Monitoring

Table 1 summarizes DO results for each location monitored in 1997. 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 B for each sample location during the 1997 sampling season.

References

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.

Table 1. 1997 Dissolved Oxygen Results -- Vital Signs Monitoring Data

(using average minimum winter pool elevations)

Reservoir	+-------Dissolved Oxygen-------						Final DO Rating
	+----Water Column DO----+			+-------Bottom DO-------+			
	Less than 5.0 mg/l ? (@ 1.5 meters)	Percent of X-Section <2.0 mg/l	Rating	Bottom DO 0 mg/l ?	Percent of B-L @ MP < 2.0 mg/l	Rating	
RUN-OF-THE-RIVER RESERVOIRS							
Kentucky							
Forebay(TRM 23.0)	No	0.0	5	No	0.0	5	5
T-Zone(TRM 85.0)	No	0.0	5	No	0.0	5	5
Inflow(TRM 200-206)	No		5			-	5
Embay(BSRM 7.4)	No	0.0	5	No	0.0	5	5
Pickwick							
Forebay(TRM 207.3)							
T-Zone(TRM 230.0)							
Inflow(TRM 253-259)							
Embay(BCM 8.4)							
Wilson							
Forebay(TRM 260.8)							
Inflow(TRM 273-274)							
Wheeler							
Forebay(TRM 277.0)	No	0.0	5	No	0.0	5	5
T-Zone(TRM 295.9)	No	0.0	5	No	0.0	5	5
Inflow(TRM 347-348)	No	-	5	-	-	-	5
Embay(ERM 6.0)	No	11.1	1	No	31.6	1	1
Guntersville							
Forebay(TRM 350.0)							
T-Zone(TRM 375.2)							
Inflow(TRM 420-424)							
Nickajack							
Forebay(TRM 425.5)	No	0.0	5	No	0.0	5	5
Inflow(TRM 469-470)	No		5	No		-	5
Chickamauga							
Forebay(TRM 472.3)	No	0.0	5	No	0.0	5	5
T-Zone(TRM 490.5)	No	0.0	5	No	0.0	5	5
Inflow(TRM 518-529)	Yes 4.1	-	4	-	-	-	4
Embay(HRM 8.5)	No	0.0	5	No	0.0	5	5
Watts Bar							
Forebay(TRM 531.0)							
T-Zone(TRM 560.8)							
Inflow(TRM 600-601)							
Inflow(CRM 19-22)							

Table 1. 1997 Dissolved Oxygen Results -- 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	Rating	Dissolved Oxygen: Bottom DO: Bottom DO 0 mg/l ?	Dissolved Oxygen: Bottom DO: Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**
Fort Loudoun							
Forebay(TRM 605.5)	No	0.0	5	No	0.0	5	5
T-Zone(TRM 624.6)	No	0.0	5	No	0.0	5	5
Tellico							
Forebay(LTRM 1.0)	No	3.7	5	No	16.2	3	4
T-Zone(LTRM 15.0)	No	0.0	5	No	0.0	5	5
Melton Hill							
Forebay(CRM 24.0)							
T-Zone(CRM 45.0)							
TRIBUTARY RESERVOIRS							
Norris							
Forebay(CRM 80.0)	No	22.6	1	Yes	37.3	1	1
CRM 125.0	No	26.8	1	Yes	63.7	1	1
PRM 30.0	No	19.0	1	Yes	55.0	1	1
Cherokee							
Forebay(HRM 55.0)							
HRM 77.0							
Douglas							
Forebay(FBRM 34.5)	Yes 4.4	33.8	1	Yes	66.8	1	1
FBRM 51.0	No	21.1	1	Yes	203.0	1	1
Ft. Patrick Henry							
Forebay(SFHRM 8.7)	No	0.0	5	No	0.0	5	5
Boone							
Forebay(SFHRM 19.0	No	4.4	5	Yes	9.8	3	4
SFHRM 27.0	No	4.0	5	No	2.9	4	4.5
WRM 6.5	No	0.0	5	No	0.0	5	5
South Holston							
Forebay(SFHRM 51.0)							
SFHRM 62.5							
Watauga							
Forebay(WRM 37.4)							
WRM 45.5							

Table 1. 1997 Dissolved Oxygen Results -- 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)	Water Column DO: Percent of X-Section <2.0 mg/l	Rating	Bottom DO: Bottom DO 0 mg/l ?	Bottom DO: Percent of B-L @ MP < 2.0 mg/l	Rating	**Final DO Rating**	
Fontana								[N
Forebay(LTRM 62.0)								
LTRM 81.5								
TkRM 3.0								
Blue Ridge								[N
Forebay(ToRM 54.1)	No	0.4	5	No	10.6	3	4	
Apalachia								[N
Forebay(HiRM 67.0)	No	1.8	5	No	19.9	3	4	
Hiwassee								
Forebay(HiRM 77.0)								
HIRM 85.0								
Nottely								[N
Forebay(NRM 23.5)	No	13.8	1	Yes	28.4	1	1	
NRM 31.0	No	11.1	1	Yes	39.5	1	1	
Chatuge								
Forebay(HiRM 122.0)								
Shooting Cr 1.5								
Ocoee #1								[N
Forebay(ORM12.5)	No	0.0	5	No	0.0	5	5	
Tims Ford								
Forebay(ERM 135.0)								
ERM 150.0								
Normandy								
Forebay(DRM 249.5)								
Bear Creek								
Forebay(BCM 75.0)	No	20.4	1	Yes	49.1	1	1	
Little Bear Creek								
Forebay(LBCM 12.5)	No	38.9	1	Yes	71.7	1	1	
Cedar Creek								
Forebay(25.2)	No	30.6	1	Yes	68.0	1	1	
Beech								
Forebay(BRM 36.0)								

Shaded monitoring locations were not sampled in 1997.

Table 2

RESERVOIR "VITAL SIGNS" WATER QUALITY MONITORING
WATER QUALITY MEASUREMENTS -- 1997

Samples/ Measurements	Depths(s)[a] (meters)	Container	Preservation/Handling
		FIELD - each survey	
Secchi disc	(record depth)	--	--
Temp, pH, DO, cond	0.3, 1.5, 4, etc.	in situ[b]	--
Chlorophyll[c]	S_c	1-L cubitainer	Immediately add 1 mL of $MgCO_3$ suspension, place on ice, filter within three hours
		LABORATORY - April, June, and August surveys[d]	
Nutrients -- (phosphorus, ammonia, nitrate + nitrite, organic nitrogen)	S_c	250-mL	Add 1 mL of 1 + 4 H_2SO_4, place on ice
Blanks[e] and Triplicates[f]		(same containers as above -- for nutrients)	
		AQUATIC BIOLOGICAL - each survey	
Algal Assemblage	S_c	125-mL, dark bottle	Add 2-mL of Lugol's solution
Zooplankton Tow[g]	Bottom to Surface tow	250-mL	Add approx. 20mL buffered formalin per 250 mL of sample
		SEDIMENT - July survey	
Sediment[h] (metals, PCBs, and pesticides)	Top 3cm composite	1 - 1 liter glass wide mouth bottle	Immediately place on ice

a. S_c - indicates a surface composite sample.

b. Hydrolab measurements of temperature, pH, DO, and conductivity will be made at the depths shown and at 2-meter intervals (4-meter intervals on tributary reservoirs) to the bottom of the reservoir. Measurements will be made at intermediate depths any time the temperature changes by more than 2°C or the DO changes by more than 1 mg/L from the previous measurement.

c. Recommended chlorophyll filters -- Whatman GF/C, 47 mm, 1.2 μm pore size, MFR No.1822-047.

d. Nutrients are only collected on the first survey -- April ; third survey -- June; and fifth survey -- August.

e. Ten sets of nutrient container blank bottles will be collected – three (or 4) on each of the three surveys when nutrients samples are collected.

f. Triplicate samples - Three separate and distinct samples will be collected, once during the year, at the seven locations.

g. Zooplankton net should be retrieved at a constant rate of 0.5 to 0.7 meters per second. (Duplicate samples collected from all forebay locations in August.)

h. All sediment samples (and duplicates at six locations) will be collected in July.

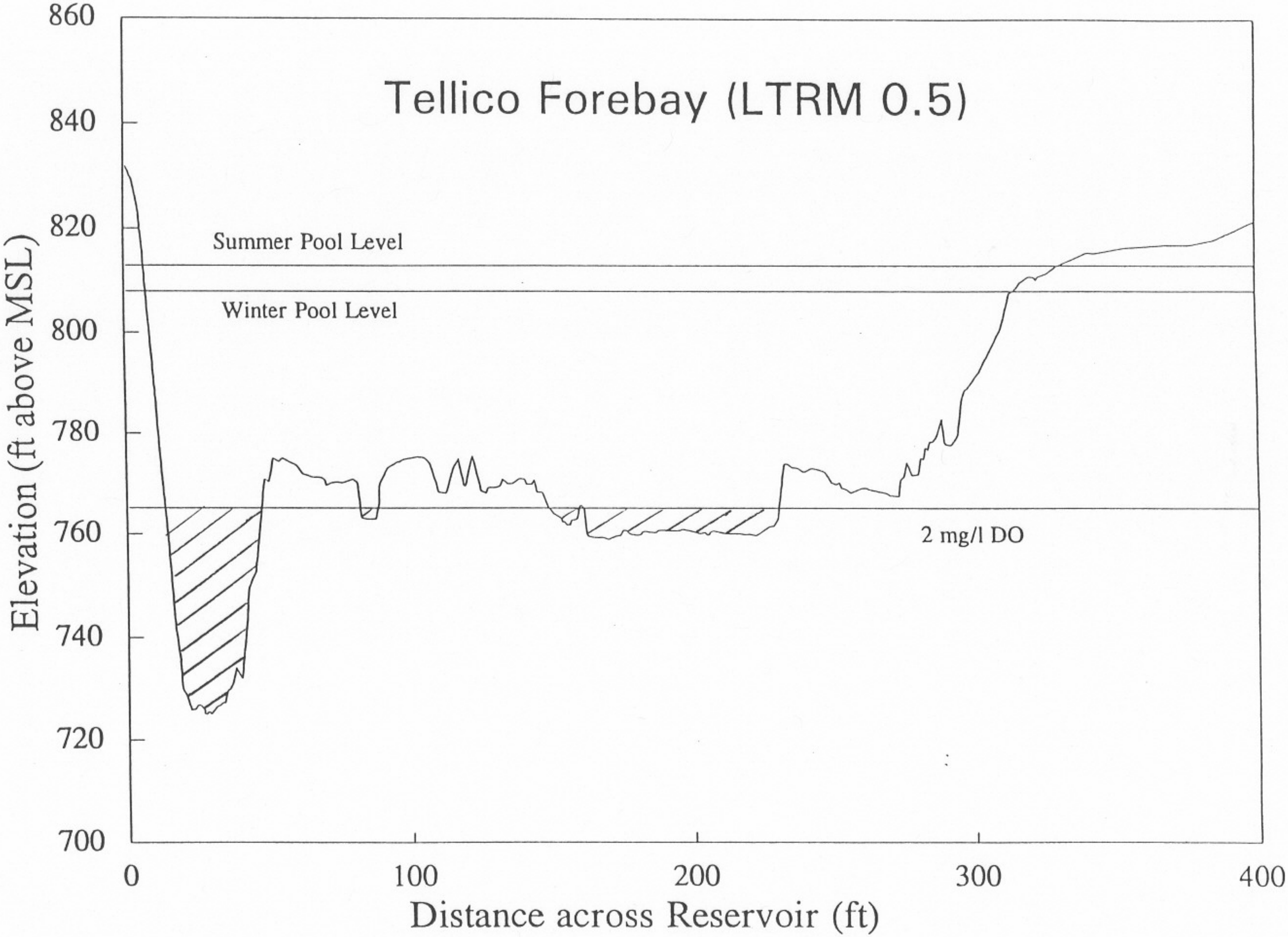


Figure 1. Cross-sectional Area of Tellico Reservoir Forebay Showing the Area with DO Less Than 2.0 mg/l.

Section 3. Chlorophyll and Nutrients

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 anthropogenic sources and 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 oligotrophic 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. For those reservoirs in watersheds with naturally low nutrient levels, the primary concern is early identification of cultural eutrophication. Appropriate actions can then be taken to control the nutrient loadings and 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 may be lowered when such conditions are found.

<u>Data Collection Methods</u>

Photic zone (defined as twice the Secchi depth or 4-meters, whichever is greater) composite chlorophyll-a samples were collected monthly (April-October). Concurrent with the collection of the chlorophyll samples, algal and zooplankton samples were collected for screening and semi-qualitative examination of the plankton community assemblage. In addition, <u>in-situ</u> water column profiles of temperature, dissolved oxygen, pH, conductivity; and Secchi depth measurements were also made each month. Finally, on three of the monthly surveys (April, June and August), the photic zone composite samples were also analyzed for nutrient levels (total phosphorus, ammonia-nitrogen, nitrate+nitrite-nitrogen, and organic nitrogen) to support reservoir trophic state assessments.

In 1997, physical/chemical water quality variables were measured at the 31 locations on 17 reservoirs shown in Table 1, Section 1. Additional details on collection methods are given in <u>Data Collection Methods</u>, Section 2 and Table 2-Section 2.

Chlorophyll Rating Scheme

Chlorophyll ratings at each sampling location were based on the average summer concentration of monthly, composite photic zone samples collected from April through October (or September), using the criteria shown in Figure 1.

Results from 1997 Monitoring

Table 1 summarizes chlorophyll results for each location monitored in 1997. 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. Table 2 is a statistical summary of the physical/chemical and nutrient quality data for each location monitored during the summer of 1997.

References

Carlson, R.E., 1977. "A Trophic State Index for Lakes." Limnology and Oceanography, 22:361-369.

Table 1

1997 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	RiverMile	Lab Chlorophyll-a Results		Lab Chlorophyll-a Average	Rating
April 09	Apalachia-FB	HIWASSEE RIVER 67.0	3	3		
May 14	Apalachia-FB	HIWASSEE RIVER 67.0	2	2		
June 18	Apalachia-FB	HIWASSEE RIVER 67.0	1	1		
July 16	Apalachia-FB	HIWASSEE RIVER 67.0	5	5		
August 12	Apalachia-FB	HIWASSEE RIVER 67.0	3	3		
September 17	Apalachia-FB	HIWASSEE RIVER 67.0	5	5		
October 23	Apalachia-FB	HIWASSEE RIVER 67.0	2	2		
					3.00	5.0
April 07	Bear-FB	BEAR CREEK 75.0	12	12		
May 06	Bear-FB	BEAR CREEK 75.0	7	7		
June 10	Bear-FB	BEAR CREEK 75.0	47	*		
July 08	Bear-FB	BEAR CREEK 75.0	25	25		
August 11	Bear-FB	BEAR CREEK 75.0	32	*		
September 08	Bear-FB	BEAR CREEK 75.0	38	*		
October 21	Bear-FB	BEAR CREEK 75.0	28	28		
					18.00 *	1.0
April 10	BlueRidge-FB	TOCCOA RIVER 54.1	2	2		
May 15	BlueRidge-FB	TOCCOA RIVER 54.1	2	2		
June 19	BlueRidge-FB	TOCCOA RIVER 54.1	2	2		
June 19	BlueRidge-FB	TOCCOA RIVER 54.1	3	triplicate		
June 19	BlueRidge-FB	TOCCOA RIVER 54.1	2	triplicate		
July 17	BlueRidge-FB	TOCCOA RIVER 54.1	2	2		
August 14	BlueRidge-FB	TOCCOA RIVER 54.1	3	3		
September 18	BlueRidge-FB	TOCCOA RIVER 54.1	3	3		
October 24	BlueRidge-FB	TOCCOA RIVER 54.1	2	2		
					2.29	5.0
April 16	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	5	5		
May 22	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	8	8		
June 26	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	14	14		
July 24	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	16	16		
August 21	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	22	22		
September 23	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	22	22		
October 21	Boone-MRH	SOUTH FORK HOLSTON RIVER 27.0	17	17		
					14.86	1.6
April 16	Boone-MRW	WATAUGA RIVER 6.5	10	10		
May 22	Boone-MRW	WATAUGA RIVER 6.5	13	13		
June 26	Boone-MRW	WATAUGA RIVER 6.5	16	16		
July 24	Boone-MRW	WATAUGA RIVER 6.5	17	17		
August 21	Boone-MRW	WATAUGA RIVER 6.5	18	18		
September 23	Boone-MRW	WATAUGA RIVER 6.5	29	29		
October 21	Boone-MRW	WATAUGA RIVER 6.5	13	13		
					16.57	1.0
April 16	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	5	5		
May 22	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	7	7		
June 25	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	10	10		
July 24	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	11	11		
August 21	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	28	28		
September 23	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	13	13		
October 21	Boone FB	SOUTH FORK HOLSTON RIVER 19.0	13	13		
					12.43	2.8
April 07	Cedar-FB	CEDAR CREEK 25.2	4	4		
May 06	Cedar-FB	CEDAR CREEK 25.2	5	5		
June 10	Cedar-FB	CEDAR CREEK 25.2	8	8		
July 08	Cedar-FB	CEDAR CREEK 25.2	11	11		
August 11	Cedar-FB	CEDAR CREEK 25.2	5	5		
August 11	Cedar-FB	CEDAR CREEK 25.2	5	triplicate		
August 11	Cedar-FB	CEDAR CREEK 25.2	6	triplicate		
September 08	Cedar-FB	CEDAR CREEK 25.2	4	4		
October 21	Cedar-FB	CEDAR CREEK 25.2	3	3		
					5.71	5.0
April 07	Chick-EMB	HIWASSEE RIVER 8.5	2	2		
May 13	Chick-EMB	HIWASSEE RIVER 8.5	3	3		
June 17	Chick-EMB	HIWASSEE RIVER 8.5	5	5		
June 17	Chick-EMB	HIWASSEE RIVER 8.5	4	triplicate		
June 17	Chick-EMB	HIWASSEE RIVER 8.5	5	triplicate		
July 15	Chick-EMB	HIWASSEE RIVER 8.5	5	5		

Table 1
1997 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	RiverMile	Lab Chlorophyll-a Results		Lab Chlorophyll-a Average	Rating
August 12	Chick-EMB	HIWASSEE RIVER 8.5	4	4		
September 16	Chick-EMB	HIWASSEE RIVER 8.5	4	4		
					3.83	4.8
April 08	Chick-FB	TENNESSEE RIVER 472.3	9	9		
May 13	Chick-FB	TENNESSEE RIVER 472.3	15	15		
June 17	Chick-FB	TENNESSEE RIVER 472.3	6	6		
July 15	Chick-FB	TENNESSEE RIVER 472.3	13	13		
August 12	Chick-FB	TENNESSEE RIVER 472.3	9	9		
September 16	Chick-FB	TENNESSEE RIVER 472.3	8	8		
					10.00	4.0
April 07	Chick-TZ	TENNESSEE RIVER 490.5	11	11		
May 13	Chick-TZ	TENNESSEE RIVER 490.5	9	9		
June 17	Chick-TZ	TENNESSEE RIVER 490.5	6	6		
July 15	Chick-TZ	TENNESSEE RIVER 490.5	13	13		
August 12	Chick-TZ	TENNESSEE RIVER 490.5	4	4		
September 16	Chick-TZ	TENNESSEE RIVER 490.5	3	3		
					7.67	5.0
April 16	Douglas-FB	FRENCH BROAD 33/34.5	12	12		
May 21	Douglas-FB	FRENCH BROAD 33/34.5	18	18		
June 25	Douglas-FB	FRENCH BROAD 33/34.5	36	*		
July 23	Douglas-FB	FRENCH BROAD 33/34.5	5	5		
August 20	Douglas-FB	FRENCH BROAD 33/34.5	13	13		
August 20	Douglas-FB	FRENCH BROAD 33/34.5	13	triplicate		
August 20	Douglas-FB	FRENCH BROAD 33/34.5	14	triplicate		
September 22	Douglas-FB	FRENCH BROAD 33/34.5	7	7		
October 20	Douglas-FB	FRENCH BROAD 33/34.5	2	2		
					9.50 *	3.3
April 16	Douglas-MR	FRENCH BROAD 51.0	16	16		
May 21	Douglas-MR	FRENCH BROAD 51.0	36	*		
June 25	Douglas-MR	FRENCH BROAD 51.0	19	19		
July 23	Douglas-MR	FRENCH BROAD 51.0	17	17		
August 20	Douglas-MR	FRENCH BROAD 51.0	24	24		
September 22	Douglas-MR	FRENCH BROAD 51.0	27	27		
October 20	Douglas-MR	FRENCH BROAD 51.0	13	13		
					19.33 *	1.0
April 14	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	12	12		
May 19	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	20	20		
June 25	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	18	18		
July 21	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	21	21		
August 18	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	16	16		
September 25	Ft. Loudoun-FB	TENNESSEE RIVER 605.5	7	7		
					15.67	1.2
April 14	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	16	16		
May 19	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	17	17		
June 25	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	13	13		
July 21	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	23	23		
August 18	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	19	19		
September 25	Ft. Loudoun-TZ	TENNESSEE RIVER 624.6	9	9		
					16.17	1.0
April 16	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	17	17		
May 21	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	7	7		
June 25	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	7	7		
July 23	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	15	15		
August 20	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	14	14		
September 22	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	31	*		
October 20	Ft.Pat Henry-FB	SOUTH FORK HOLSTON RIVER 8.7	12	12		
					12.00 *	2.0
April 10	Kentucky-EMB	BIG SANDY 7.4	21	21		
April 10	Kentucky-EMB	BIG SANDY 7.4	20	triplicate		
April 10	Kentucky-EMB	BIG SANDY 7.4	20	triplicate		
May 08	Kentucky-EMB	BIG SANDY 7.4	22	22		
June 12	Kentucky-EMB	BIG SANDY 7.4	23	23		
July 15	Kentucky-EMB	BIG SANDY 7.4	23	23		
August 14	Kentucky-EMB	BIG SANDY 7.4	40	*		
September 11	Kentucky-EMB	BIG SANDY 7.4	57	*		
					22.25 *	1.0

Table 1
1997 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	RiverMile	Lab Chlorophyll-a Results		Lab Chlorophyll-a Average	Rating
April 09	Kentucky-FB	TENNESSEE RIVER 23.0	22	22		
May 07	Kentucky-FB	TENNESSEE RIVER 23.0	6	6		
June 11	Kentucky-FB	TENNESSEE RIVER 23.0	22	22		
July 14	Kentucky-FB	TENNESSEE RIVER 23.0	22	22		
August 13	Kentucky-FB	TENNESSEE RIVER 23.0	24	24		
September 10	Kentucky-FB	TENNESSEE RIVER 23.0	17	17		
					18.83	1.0
April 10	Kentucky-TZ	TENNESSEE RIVER 85.0	14	14		
May 08	Kentucky-TZ	TENNESSEE RIVER 85.0	5	5		
June 12	Kentucky-TZ	TENNESSEE RIVER 85.0	4	4		
July 15	Kentucky-TZ	TENNESSEE RIVER 85.0	7	7		
August 14	Kentucky-TZ	TENNESSEE RIVER 85.0	7	7		
September 11	Kentucky-TZ	TENNESSEE RIVER 85.0	3	3		
					6.67	5.0
April 07	L.Bear-FB	LITTLE BEAR CREEK 12.5	6	6		
May 06	L.Bear-FB	LITTLE BEAR CREEK 12.5	5	5		
June 10	L.Bear-FB	LITTLE BEAR CREEK 12.5	10	10		
July 08	L.Bear-FB	LITTLE BEAR CREEK 12.5	14	14		
August 11	L.Bear-FB	LITTLE BEAR CREEK 12.5	8	8		
September 08	L.Bear-FB	LITTLE BEAR CREEK 12.5	5	5		
October 21	L.Bear-FB	LITTLE BEAR CREEK 12.5	3	3		
					7.29	5.0
April 08	Nickajack-FB	TENNESSEE RIVER 425.5	3	3		
May 12	Nickajack-FB	TENNESSEE RIVER 425.5	7	7		
June 16	Nickajack-FB	TENNESSEE RIVER 425.5	3	3		
July 15	Nickajack-FB	TENNESSEE RIVER 425.5	3	3		
August 11	Nickajack-FB	TENNESSEE RIVER 425.5	1	1		
September 15	Nickajack-FB	TENNESSEE RIVER 425.5	5	5		
					3.67	4.7
April 15	Norris-FB	CLINCH RIVER 80.0	10	10		
May 20	Norris-FB	CLINCH RIVER 80.0	5	5		
June 24	Norris-FB	CLINCH RIVER 80.0	3	3		
July 22	Norris-FB	CLINCH RIVER 80.0	5	5		
August 19	Norris-FB	CLINCH RIVER 80.0	3	3		
September 24	Norris-FB	CLINCH RIVER 80.0	3	3		
October 22	Norris-FB	CLINCH RIVER 80.0	2	2		
					4.43	5.0
April 15	Norris-MRC	CLINCH RIVER125.0	3	3		
April 15	Norris-MRC	CLINCH RIVER125.0	3	duplicate		
May 20	Norris-MRC	CLINCH RIVER125.0	8	8		
June 24	Norris-MRC	CLINCH RIVER125.0	4	4		
July 22	Norris-MRC	CLINCH RIVER125.0	7	7		
August 19	Norris-MRC	CLINCH RIVER125.0	5	5		
September 24	Norris-MRC	CLINCH RIVER125.0	3	3		
October 22	Norris-MRC	CLINCH RIVER125.0	10	10		
					5.71	5.0
April 15	Norris-MRP	POWELL RIVER 30.0	6	6		
May 20	Norris-MRP	POWELL RIVER 30.0	5	5		
June 24	Norris-MRP	POWELL RIVER 30.0	7	7		
July 22	Norris-MRP	POWELL RIVER 30.0	7	7		
August 19	Norris-MRP	POWELL RIVER 30.0	5	5		
September 23	Norris-MRP	POWELL RIVER 30.0	8	8		
October 21	Norris-MRP	POWELL RIVER 30.0	6	6		
					6.29	5.0
April 10	Nottely-FB	NOTTELY RIVER 23.5	7	7		
May 15	Nottely-FB	NOTTELY RIVER 23.5	4	4		
June 19	Nottely-FB	NOTTELY RIVER 23.5	23	23		
July 17	Nottely-FB	NOTTELY RIVER 23.5	4	4		
August 14	Nottely-FB	NOTTELY RIVER 23.5	3	3		
September 18	Nottely-FB	NOTTELY RIVER 23.5	5	5		
October 24	Nottely-FB	NOTTELY RIVER 23.5	5	5		
					7.29	1.6
April 10	Nottely-MR	NOTTELY RIVER 31.0	15	15		
May 15	Nottely-MR	NOTTELY RIVER 31.0	17	17		
June 19	Nottely-MR	NOTTELY RIVER 31.0	18	18		
July 17	Nottely-MR	NOTTELY RIVER 31.0	11	11		
August 14	Nottely-MR	NOTTELY RIVER 31.0	10	10		
September 18	Nottely-MR	NOTTELY RIVER 31.0	7	7		

Table 1
1997 Chlorophyll-a Results -- Vital Signs Reservoir Monitoring Data

Date	Location	RiverMile	Lab Chlorophyll-a			Rating
			Results		Average	
October 24	Nottely-MR	NOTTELY RIVER 31.0	12	12		
					12.86	1.0
April 09	Ocoee-FB	OCOEE RIVER12.5	1	1		
May 14	Ocoee-FB	OCOEE RIVER12.5	1	1		
June 18	Ocoee-FB	OCOEE RIVER12.5	5	5		
July 16	Ocoee-FB	OCOEE RIVER12.5	1	1		
August 12	Ocoee-FB	OCOEE RIVER12.5	1	1		
August 12	Ocoee-FB	OCOEE RIVER12.5	1	duplicate		
September 17	Ocoee-FB	OCOEE RIVER12.5	1	1		
October 23	Ocoee-FB	OCOEE RIVER12.5	1	1		
					1.57	5.0
April 14	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	6	6		
May 19	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	9	9		
June 25	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	12	12		
July 21	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	6	6		
August 18	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	7	7		
September 25	Tellico-FB	LITTLE TENNESSEE RIVER 1.0	9	9		
					8.17	1.0
April 14	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	5	5		
May 19	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	6	6		
June 25	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	7	7		
July 21	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	3	3		
August 18	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	6	6		
September 25	Tellico-TZ	LITTLE TENNESSEE RIVER 15.0	6	6		
					5.50	3.0
April 08	Wheeler-EMB	ELK RIVER 6.0	7	7		
April 08	Wheeler-EMB	ELK RIVER 6.0	7	triplicate		
April 08	Wheeler-EMB	ELK RIVER 6.0	7	triplicate		
May 05	Wheeler-EMB	ELK RIVER 6.0	9	9		
June 09	Wheeler-EMB	ELK RIVER 6.0	4	4		
July 07	Wheeler-EMB	ELK RIVER 6.0	41	*		
August 12	Wheeler-EMB	ELK RIVER 6.0	41	*		
September 08	Wheeler-EMB	ELK RIVER 6.0	35	*		
					6.67 *	2.0
April 08	Wheeler-FB	TENNESSEE RIVER 277.0	23	23		
May 05	Wheeler-FB	TENNESSEE RIVER 277.0	4	4		
June 09	Wheeler-FB	TENNESSEE RIVER 277.0	5	5		
July 07	Wheeler-FB	TENNESSEE RIVER 277.0	6	6		
August 12	Wheeler-FB	TENNESSEE RIVER 277.0	22	22		
September 08	Wheeler-FB	TENNESSEE RIVER 277.0	16	16		
					12.67	2.7
April 08	Wheeler-TZ	TENNESSEE RIVER 295.9	3	3		
May 05	Wheeler-TZ	TENNESSEE RIVER 295.9	2	2		
June 09	Wheeler-TZ	TENNESSEE RIVER 295.9		1		
July 07	Wheeler-TZ	TENNESSEE RIVER 295.9	3	3		
August 12	Wheeler-TZ	TENNESSEE RIVER 295.9	4	4		
September 08	Wheeler-TZ	TENNESSEE RIVER 295.9	9	9		
					3.67	4.7

* Indicates one (or more) chlorophyll-a results equaled or exceeded 30 ug/L

Shading indicates ratings for samples collected in nutrient limited watersheds

Table 2
1997 Vital Signs Reservoir Monitoring Summary

	Kentucky Forebay (TRM 23.0)				Kentucky Transition (TRM 85.0)				Kentucky Embay (Big Sandy 7.4)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	71	22.2	14.2	30.9	54	22.5	15.4	28.9	39	21.9	13.9	28.5
Dissolved Oxygen (mg/L)	71	7.9	3.1	10.8	54	7.3	5.5	9.8	39	6.9	2.4	9.4
pH (s.u.)	71	7.9	7.2	9.1	54	7.5	7.0	8.0	39	7.3	7.0	7.7
Conductivity (us/cm)	71	145	131	175	54	158	139	183	39	80	45	106
Organic N (mg/L)	3	0.377	0.230	0.490	3	0.377	0.260	0.600	3	0.520	0.450	0.570
Ammonia N (mg/L)	3	0.010	0.010	0.010	3	0.060	0.040	0.100	3	0.040	0.010	0.100
Nitrate+Nitrite N (mg/L)	3	0.213	0.020	0.380	3	0.290	0.160	0.440	3	0.010	0.010	0.010
Total Nitrogen (mg/L)	3	0.600	0.440	0.740	3	0.727	0.530	1.080	3	0.570	0.470	0.650
Total Phosphorus (mg/L)	3	0.060	0.050	0.080	3	0.063	0.060	0.070	3	0.040	0.030	0.050
TN / TP Ratio	3	10.2	8.8	12.4	3	11.7	8.1	18.0	3	14.8	11.8	19.7
Chlorophyll-a (ug/L)	6	18.8	6.0	24.0	6	6.7	3.0	14.0	6	31.0	21.0	57.0
Secchi Depth (m)	6	1.1	0.9	1.8	6	1.0	0.9	1.3	6	0.8	0.5	1.3

	Wheeler Forebay (TRM 277.0)				Wheeler Transition (TRM 295.9)				Wheeler Embayment (ERM 6.0)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	55	22.8	16.4	29.1	33	22.6	15.9	27.7	35	21.5	15.2	28.3
Dissolved Oxygen (mg/L)	55	7.4	3.3	10.3	33	7.5	6.3	9.0	35	7.2	0.9	15.3
pH (s.u.)	55	7.7	7.2	8.6	33	7.6	7.4	8.0	35	7.9	7.3	9.2
Conductivity (us/cm)	55	163	131	205	33	158	134	182	35	210	190	236
Organic N (mg/L)	3	0.263	0.120	0.410	3	0.200	0.130	0.240	3	0.403	0.220	0.540
Ammonia N (mg/L)	3	0.027	0.010	0.050	3	0.047	0.030	0.070	3	0.090	0.020	0.200
Nitrate+Nitrite N (mg/L)	3	0.293	0.030	0.530	3	0.343	0.170	0.620	3	0.427	0.010	0.660
Total Nitrogen (mg/L)	3	0.583	0.460	0.660	3	0.590	0.480	0.790	3	0.920	0.750	1.160
Total Phosphorus (mg/L)	3	0.057	0.030	0.070	3	0.040	0.030	0.060	3	0.200	0.090	0.310
TN / TP Ratio	3	12.5	6.6	22.0	3	15.3	13.2	16.7	3	5.6	3.7	9.4
Chlorophyll-a (ug/L)	6	12.7	4.0	23.0	6	3.7	1.0	9.0	6	22.8	4.0	41.0
Secchi Depth (m)	6	1.2	0.6	1.6	6	1.3	0.5	1.8	6	0.7	0.3	1.1

	Nickajack Forebay (TRM 425.5)			
	N	Mean	Min	Max
Temperature (deg C)	62	22.6	15.5	27.7
Dissolved Oxygen (mg/L)	62	7.3	5.0	9.9
pH (s.u.)	62	7.5	7.3	7.9
Conductivity (us/cm)	62	160	129	185
Organic N (mg/L)	3	0.140	0.060	0.250
Ammonia N (mg/L)	3	0.050	0.030	0.070
Nitrate+Nitrite N (mg/L)	3	0.283	0.190	0.430
Total Nitrogen (mg/L)	3	0.473	0.410	0.520
Total Phosphorus (mg/L)	3	0.033	0.020	0.050
TN / TP Ratio	3	16.8	8.2	26.0
Chlorophyll-a (ug/L)	6	3.7	1.0	7.0
Secchi Depth (m)	6	1.5	0.8	2.0

	Chickamauga Forebay (TRM 472.3)				Chickamauga Transition (TRM 490.5)				Chickamauga Embay (HiRM 8.5)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	62	23.0	15.5	29.9	45	22.1	15.4	29.2	33	19.8	15.4	26.0
Dissolved Oxygen (mg/L)	62	7.5	4.6	10.4	45	7.4	4.5	10.4	33	8.3	7.4	9.1
pH (s.u.)	62	7.6	7.3	8.5	45	7.6	7.3	8.4	33	7.4	7.2	7.7
Conductivity (us/cm)	62	160	134	185	45	163	133	193	33	125	110	154
Organic N (mg/L)	3	0.207	0.090	0.300	3	0.177	0.090	0.260	3	0.177	0.060	0.300
Ammonia N (mg/L)	3	0.027	0.010	0.040	3	0.027	0.010	0.040	3	0.040	0.030	0.060
Nitrate+Nitrite N (mg/L)	3	0.253	0.190	0.370	3	0.267	0.210	0.370	3	0.170	0.140	0.220
Total Nitrogen (mg/L)	3	0.487	0.450	0.540	3	0.470	0.430	0.510	3	0.387	0.340	0.480
Total Phosphorus (mg/L)	3	0.083	0.030	0.190	3	0.093	0.030	0.210	3	0.080	0.040	0.140
TN / TP Ratio	3	12.0	2.4	18.0	3	10.2	2.0	15.7	3	6.7	2.4	12.0
Chlorophyll-a (ug/L)	6	10.0	6.0	15.0	6	7.7	3.0	13.0	6	3.8	2.0	5.0
Secchi Depth (m)	6	1.3	0.8	1.8	6	1.2	0.8	1.6	6	0.8	0.4	1.2

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1997 Vital Signs Reservoir Monitoring Summary

	Fort Loudoun Forebay (TRM 605.5)				Fort Loudoun Transition (TRM 624.6)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	78	21.5	14.1	31.3	62	21.2	14.3	28.4
Dissolved Oxygen (mg/L)	78	7.2	2.8	13.8	62	8.1	5.8	13.0
pH (s.u.)	78	7.8	7.2	9.1	62	7.9	7.5	9.0
Conductivity (us/cm)	78	191	100	229	62	210	165	232
Organic N (mg/L)	3	0.343	0.230	0.440	3	0.290	0.140	0.460
Ammonia N (mg/L)	3	0.017	0.010	0.030	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.263	0.070	0.470	3	0.400	0.170	0.520
Total Nitrogen (mg/L)	3	0.623	0.540	0.710	3	0.700	0.640	0.790
Total Phosphorus (mg/L)	3	0.033	0.030	0.040	3	0.033	0.020	0.040
TN / TP Ratio	3	19.1	15.5	23.7	3	23.1	16.0	33.5
Chlorophyll-a (ug/L)	6	16.0	9.0	21.0	5	17.6	13.0	23.0
Secchi Depth (m)	6	1.3	1.3	1.5	6	0.9	0.8	1.1

	Tellico Reservoir (LTRM 1.0)				Tellico Reservoir (LTRM 15.0)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	96	17.3	11.5	30.1	71	18.0	12.2	30.2
Dissolved Oxygen (mg/L)	96	6.0	0.2	10.7	71	8.3	2.7	10.5
pH (s.u.)	96	7.0	6.4	8.7	71	7.1	6.7	8.0
Conductivity (us/cm)	96	52	29	130	71	33	22	58
Organic N (mg/L)	3	0.140	0.040	0.260	3	0.157	0.050	0.210
Ammonia N (mg/L)	3	0.013	0.010	0.020	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.093	0.060	0.150	3	0.067	0.040	0.100
Total Nitrogen (mg/L)	3	0.247	0.190	0.350	3	0.233	0.160	0.280
Total Phosphorus (mg/L)	3	0.012	0.008	0.020	3	0.008	0.006	0.010
TN / TP Ratio	3	26.1	9.5	43.8	3	30.4	20.0	43.3
Chlorophyll-a (ug/L)	6	7.7	6.0	12.0	5	5.4	3.0	7.0
Secchi Depth (m)	6	1.8	1.3	2.1	6	1.8	1.1	2.3

	Norris Reservoir (CRM 80.0)				Norris Reservoir (CRM 125.0)				Norris Reservoir (PRM 30.0)			
	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	154	16.6	7.3	30.7	99	19.7	10.8	31.1	108	19.6	10.4	31.3
Dissolved Oxygen (mg/L)	154	5.7	0.1	12.4	99	5.4	0.1	12.1	108	5.6	0.1	14.6
pH (s.u.)	154	7.9	7.3	9.0	99	8.0	7.2	8.9	108	8.0	7.3	8.9
Conductivity (us/cm)	154	250	209	311	99	276	241	343	108	296	230	410
Organic N (mg/L)	3	0.207	0.180	0.220	3	0.230	0.190	0.290	3	0.230	0.150	0.320
Ammonia N (mg/L)	3	0.010	0.010	0.010	3	0.010	0.010	0.010	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.187	0.010	0.410	3	0.247	0.010	0.560	3	0.247	0.010	0.620
Total Nitrogen (mg/L)	3	0.403	0.240	0.640	3	0.487	0.310	0.760	3	0.487	0.340	0.780
Total Phosphorus (mg/L)	3	0.007	0.004	0.010	3	0.008	0.007	0.010	3	0.013	0.010	0.020
TN / TP Ratio	3	55.1	41.3	64.0	3	56.3	44.3	76.0	3	43.0	17.0	78.0
Chlorophyll-a (ug/L)	7	4.4	2.0	10.0	7	5.7	3.0	10.0	7	6.3	5.0	8.0
Secchi Depth (m)	7	2.7	1.8	4.5	7	2.6	1.0	4.3	7	2.5	1.8	3.0

	Douglas Reservoir (FBRM 34.5)				Douglas Reservoir (FBRM 51.0)			
	N	Mean	Min	Max	N	Mean	Min	Max
Temperature (deg C)	107	20.7	11.7	29.9	74	21.9	13.4	30.3
Dissolved Oxygen (mg/L)	107	5.1	0.1	31.0	74	6.1	0.1	13.9
pH (s.u.)	107	7.7	6.8	10.0	74	8.0	6.9	9.9
Conductivity (us/cm)	107	143	117	188	74	150	119	212
Organic N (mg/L)	3	0.320	0.280	0.380	3	0.330	0.290	0.350
Ammonia N (mg/L)	3	0.010	0.010	0.010	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.150	0.010	0.430	3	0.133	0.010	0.360
Total Nitrogen (mg/L)	3	0.480	0.320	0.720	3	0.473	0.370	0.660
Total Phosphorus (mg/L)	2	0.020	0.009	0.030	3	0.023	0.010	0.030
TN / TP Ratio	2	29.8	24.0	35.6	3	24.0	13.0	37.0
Chlorophyll-a (ug/L)	7	13.3	2.0	36.0	7	21.7	13.0	36.0
Secchi Depth (m)	7	1.5	1.0	2.3	7	1.2	0.9	1.5

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1997 Vital Signs Reservoir Monitoring Summary

Fort Patrick Henry(SFHRM 8.7)

	N	Mean	Min	Max
Temperature (deg C)	67	16.8	11.3	27.0
Dissolved Oxygen (mg/L)	67	8.6	3.1	15.3
pH (s.u.)	67	8.1	7.3	9.3
Conductivity (us/cm)	67	206	173	243
Organic N (mg/L)	3	0.250	0.190	0.280
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.570	0.440	0.720
Total Nitrogen (mg/L)	3	0.830	0.730	1.010
Total Phosphorus (mg/L)	3	0.020	0.020	0.020
TN / TP Ratio	3	41.5	36.5	50.5
Chlorophyll-a (ug/L)	7	14.7	7.0	31.0
Secchi Depth (m)	7	1.6	1.0	2.8

Boone Reservoir (SFHRM19.0)

	N	Mean	Min	Max
Temperature (deg C)	134	16.7	9.3	28.6
Dissolved Oxygen (mg/L)	134	6.7	0.1	13.0
pH (s.u.)	134	8.0	7.3	9.3
Conductivity (us/cm)	134	191	143	249
Organic N (mg/L)	3	0.337	0.190	0.460
Ammonia N (mg/L)	3	0.017	0.010	0.030
Nitrate+Nitrite N (mg/L)	3	0.273	0.010	0.630
Total Nitrogen (mg/L)	3	0.627	0.500	0.830
Total Phosphorus (mg/L)	3	0.020	0.020	0.020
TN / TP Ratio	3	31.3	25.0	41.5
Chlorophyll-a (ug/L)	7	12.4	5.0	28.0
Secchi Depth (m)	7	1.6	0.9	2.5

Boone Reseroir (SFHRM 27.0)

	N	Mean	Min	Max
Temperature (deg C)	89	18.1	11.2	28.0
Dissolved Oxygen (mg/L)	89	8.1	1.1	13.3
pH (s.u.)	89	8.1	7.5	9.0
Conductivity (us/cm)	89	245	204	317
Organic N (mg/L)	3	0.343	0.190	0.510
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.323	0.020	0.560
Total Nitrogen (mg/L)	3	0.677	0.540	0.760
Total Phosphorus (mg/L)	3	0.020	0.020	0.020
TN / TP Ratio	3	33.8	27.0	38.0
Chlorophyll-a (ug/L)	7	15.6	8.0	22.0
Secchi Depth (m)	7	1.6	1.0	2.3

Boone Reservoir (WRM 6.5)

	N	Mean	Min	Max
Temperature (deg C)	87	17.6	10.9	28.1
Dissolved Oxygen (mg/L)	87	8.7	2.5	13.1
pH (s.u.)	87	8.2	7.3	9.3
Conductivity (us/cm)	87	156	116	196
Organic N (mg/L)	3	0.357	0.280	0.450
Ammonia N (mg/L)	3	0.023	0.010	0.050
Nitrate+Nitrite N (mg/L)	3	0.310	0.060	0.750
Total Nitrogen (mg/L)	3	0.690	0.470	1.080
Total Phosphorus (mg/L)	3	0.027	0.020	0.030
TN / TP Ratio	3	29.0	15.7	54.0
Chlorophyll-a (ug/L)	7	15.9	5.0	29.0
Secchi Depth (m)	7	1.4	1.0	1.8

Apalachia Reervoir (HiRM 67.0)

	N	Mean	Min	Max
Temperature (deg C)	101	16.5	9.7	26.4
Dissolved Oxygen (mg/L)	101	6.9	0.2	10.6
pH (s.u.)	101	6.8	6.3	7.4
Conductivity (us/cm)	101	25	19	54
Organic N (mg/L)	3	0.077	0.030	0.120
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.090	0.050	0.120
Total Nitrogen (mg/L)	3	0.177	0.160	0.190
Total Phosphorus (mg/L)	3	0.037	0.005	0.100
TN / TP Ratio	3	23.3	1.9	36.0
Chlorophyll-a (ug/L)	7	3.0	1.0	5.0
Secchi Depth (m)	7	3.1	1.5	4.1

Nottely Reservoir (NRM 23.5)

	N	Mean	Min	Max
Temperature (deg C)	123	17.1	8.9	29.1
Dissolved Oxygen (mg/L)	123	5.4	0.1	13.0
pH (s.u.)	123	6.7	6.0	9.5
Conductivity (us/cm)	123	25	21	53
Organic N (mg/L)	3	0.150	0.060	0.230
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.060	0.010	0.160
Total Nitrogen (mg/L)	3	0.220	0.180	0.250
Total Phosphorus (mg/L)	3	0.011	0.002	0.020
TN / TP Ratio	3	42.2	11.5	90.0
Chlorophyll-a (ug/L)	7	7.3	3.0	23.0
Secchi Depth (m)	7	1.8	1.3	3.3

Nottely Reservoir (NRM 31.0)

	N	Mean	Min	Max
Temperature (deg C)	79	18.9	12.1	29.2
Dissolved Oxygen (mg/L)	79	5.9	0.1	12.1
pH (s.u.)	79	6.9	6.1	9.5
Conductivity (us/cm)	79	28	22	90
Organic N (mg/L)	3	0.173	0.100	0.260
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.053	0.010	0.140
Total Nitrogen (mg/L)	3	0.237	0.180	0.280
Total Phosphorus (mg/L)	3	0.014	0.002	0.030
TN / TP Ratio	3	42.1	8.3	90.0
Chlorophyll-a (ug/L)	7	12.9	7.0	18.0
Secchi Depth (m)	7	1.5	0.6	2.5

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Table 2
1997 Vital Signs Reservoir Monitoring Summary

Blue Ridge Reservoir (ToRM 54.1)

	N	Mean	Min	Max
Temperature (deg C)	126	18.2	8.5	29.0
Dissolved Oxygen (mg/L)	126	6.7	0.2	10.2
pH (s.u.)	126	6.6	6.0	8.4
Conductivity (us/cm)	126	16	14	34
Organic N (mg/L)	3	0.060	0.020	0.080
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.030	0.010	0.060
Total Nitrogen (mg/L)	3	0.100	0.090	0.110
Total Phosphorus (mg/L)	3	0.008	0.002	0.020
TN / TP Ratio	3	30.4	4.5	50.0
Chlorophyll-a (ug/L)	7	2.3	2.0	3.0
Secchi Depth (m)	7	3.7	2.8	5.4

Ocoee No. 1 (ORM 12.5)

	N	Mean	Min	Max
Temperature (deg C)	113	15.8	7.7	27.1
Dissolved Oxygen (mg/L)	113	8.0	4.3	10.4
pH (s.u.)	113	6.7	6.2	7.3
Conductivity (us/cm)	113	44	35	53
Organic N (mg/L)	3	0.063	0.020	0.120
Ammonia N (mg/L)	3	0.013	0.010	0.020
Nitrate+Nitrite N (mg/L)	3	0.053	0.040	0.060
Total Nitrogen (mg/L)	3	0.130	0.090	0.190
Total Phosphorus (mg/L)	3	0.017	0.005	0.040
TN / TP Ratio	3	18.6	2.8	38.0
Chlorophyll-a (ug/L)	7	1.6	1.0	5.0
Secchi Depth (m)	7	3.3	0.7	5.5

Bear Creek Forebay (BCM 75.0)

	N	Mean	Min	Max
Temperature (deg C)	72	20.2	12.8	29.3
Dissolved Oxygen (mg/L)	72	5.0	0.1	10.1
pH (s.u.)	72	6.8	6.2	7.5
Conductivity (us/cm)	72	57	32	230
Organic N (mg/L)	3	0.353	0.110	0.580
Ammonia N (mg/L)	3	0.023	0.010	0.050
Nitrate+Nitrite N (mg/L)	3	0.167	0.010	0.470
Total Nitrogen (mg/L)	3	0.543	0.440	0.600
Total Phosphorus (mg/L)	3	0.030	0.020	0.040
TN / TP Ratio	3	19.7	14.7	29.5
Chlorophyll-a (ug/L)	7	27.0	7.0	47.0
Secchi Depth (m)	7	1.0	0.3	1.5

Little Bear Creek Forebay (LBCM 12.5)

	N	Mean	Min	Max
Temperature (deg C)	94	18.3	11.6	28.4
Dissolved Oxygen (mg/L)	94	4.4	0.1	9.9
pH (s.u.)	94	7.3	6.7	8.5
Conductivity (us/cm)	94	99	75	159
Organic N (mg/L)	3	0.193	0.090	0.300
Ammonia N (mg/L)	3	0.013	0.010	0.020
Nitrate+Nitrite N (mg/L)	3	0.103	0.010	0.290
Total Nitrogen (mg/L)	3	0.310	0.210	0.400
Total Phosphorus (mg/L)	3	0.017	0.010	0.020
TN / TP Ratio	3	20.8	10.5	32.0
Chlorophyll-a (ug/L)	7	6.9	3.0	11.0
Secchi Depth (m)	7	1.9	1.5	2.4

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

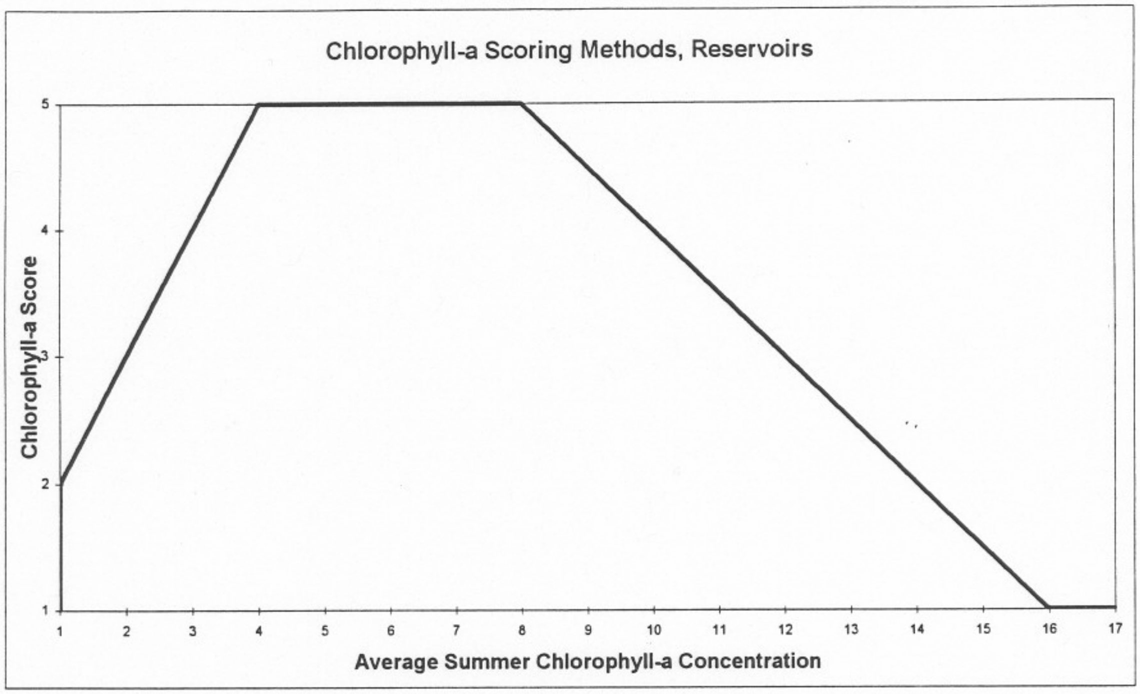
Table 2
1997 Vital Signs Reservoir Monitoring Summary

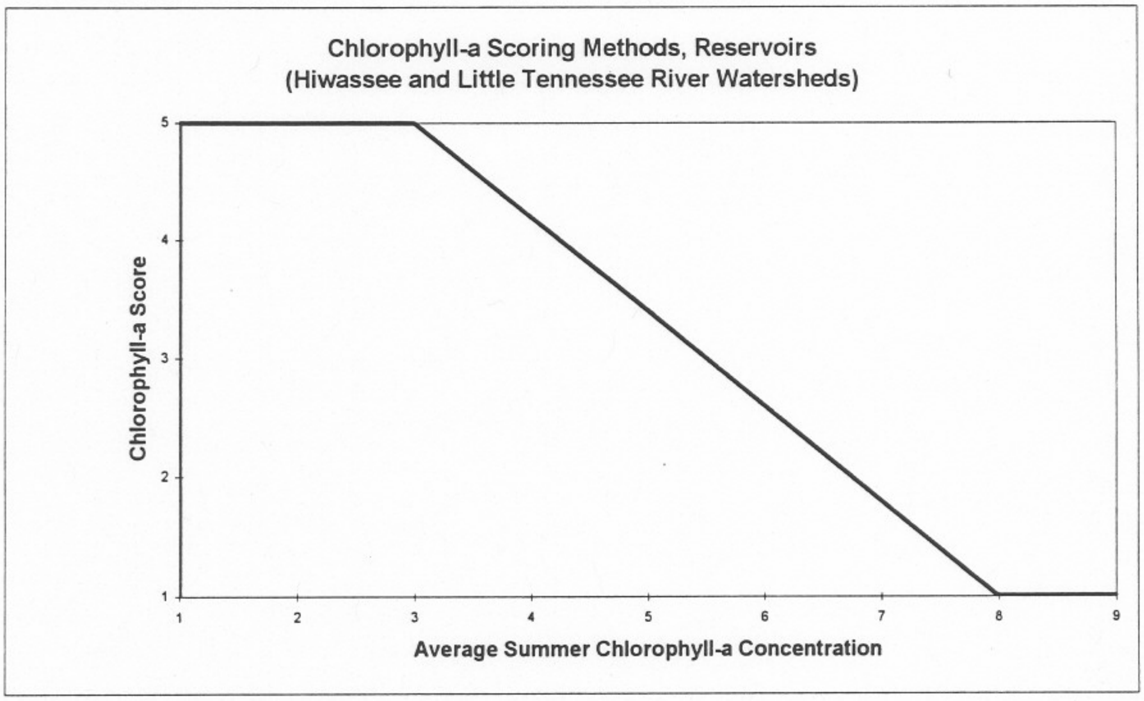
Cedar Creek Forebay (CCM 25.2)

	N	Mean	Min	Max
Temperature (deg C)	88	19.8	14.1	28.2
Dissolved Oxygen (mg/L)	88	4.2	0.1	9.5
pH (s.u.)	88	7.7	7.1	8.7
Conductivity (us/cm)	88	211	185	250
Organic N (mg/L)	3	0.190	0.060	0.310
Ammonia N (mg/L)	3	0.010	0.010	0.010
Nitrate+Nitrite N (mg/L)	3	0.087	0.010	0.240
Total Nitrogen (mg/L)	3	0.287	0.220	0.330
Total Phosphorus (mg/L)	3	0.017	0.010	0.020
TN / TP Ratio	3	19.8	11.0	33.0
Chlorophyll-a (ug/L)	7	6.1	3.0	14.0
Secchi Depth (m)	7	1.6	1.0	2.7

(If a duplicate/triplicate sample is collected at a sampling location, only the first sample (D1 or T1) of the duplicate/triplicate is used to determine the mean, minimum, and maximum values.)

Figure 1





Chlorophyll-a Rating -- The chlorophyll-a rating at each sampling location is based on the average summer concentration (of monthly photic zone composite samples). 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.

* 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, the chlorophyll-a rating is decreased one unit.

Section 5. 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 a free-flowing river. 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 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. 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 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 later in this section.

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 31 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

- Apalachia
- 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 its results were excluded in developing scoring ranges for this class because its 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 data base must exist and decisions made as to how best to separate data for each metric into the three scoring ranges of good, fair, and poor. TVA's approach is, for each metric, to first omit outliers (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.

Sample Collection Methods

Benthic macroinvertebrate samples were collected in the late fall/early winter (November-December) at 36 locations on 17 TVA reservoirs in 1997 (Table 1, Section 1). This was the third year for sample collection to occur during the late fall/early winter time frame. Previous to 1995, sample collection had occurred during late winter/early spring (February-March). The problem with using late winter/early spring benthic macroinvertebrate information is that the results are an indication of the conditions which existed during the summer and autumn of 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 for a particular year because Vital Signs monitoring results are summarized and reported on a calendar year cycle. Benthos sampling was initially conducted in late winter/early spring because the required reporting date of mid-January did not allow sample 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 most of the problems resulting from late winter/early spring sampling and would improve the contribution of this important community to the overall reservoir evaluation. The basis for these changes is documented in Section 4, Appendix A of Dycus, 1995. Evaluation of data resulting from use of these methods is discussed in Dycus and Meinert, 1996 (summarizing 1995 results) and Dycus and Meinert, 1997 (summarizing 1996 results).

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, counted, and identified to either family or order level as appropriate (i.e., the lowest practical in the field). Samples were then transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution.

The Quality Control (QC) element of the benthic macroinvertebrate evaluation includes two components. One examines how the final benthic score is affected by the change from full laboratory processing to field processing. The other examines the reproducibility of benthic macroinvertebrate sampling results. To fulfill the first component, samples from 7 sites (about 20% of the sampling locations) were processed in the field (described above) and later sent to the benthic laboratory for full processing as in previous years (sorted and quantified at the lowest practical taxon). Benthic scores were developed for both sets of sample results and compared. To examine the reproducibility of the collection and analysis procedure, the same 7 sites selected above were sampled a second time. This was achieved by collecting the 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. In this effort, both sets of samples were field processed and benthic scores developed and compared for each set of samples. All classes of reservoirs and types of locations (i.e., forebay, transition zone, embayment, and inflow) were included in the QC effort. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request.

Benthic Community Rating Scheme

Seven community characteristics (or metrics), were used to evaluate the benthic community in 1997, same as in 1995 and 1996. This is a change from previous years when 8 were used. The Percent Chironomid metric was dropped, because it "penalized" a site if there was an abundance of chironomids, which may or may not be tolerant of pollution depending on the species.

1. **Taxa richness**—The average total number of taxa per sample at each site. Taxa generally means Family or Order level because samples are processed in the field. For chironomids, taxa refers to obviously different organisms (i.e., separated by body size, head capsule size and shape, color, etc.). An increase in taxa richness indicates better conditions than low taxa richness.
2. **EPT**—The average number of Ephemeroptera, Plecoptera, and Trichoptera taxa per sample at each site. Higher diversity of these taxa indicates good water quality and other habitat conditions in streams. A similar use is incorporated here despite expected lower numbers of these organisms in reservoirs than in streams.
3. **Long-lived species**—The proportion of samples with at least one long-lived organism (Corbicula, Hexagenia, mussels, and snails) present. The presence of long-lived taxa is indicative of conditions which allow long-term survival.

4. **Percentage as Tubificidae**—The average percentage of tubificids in each sample at each site. A higher proportion indicates poor water quality.
5. **Percentage as dominant taxa**—The average percentage of the two most abundant taxa in each sample. This was calculated by selecting the two most abundant taxa in a sample, summing the number of individuals in those two taxa, dividing that sum by the total number of animals in the sample, and converting to a percentage. Often, the most abundant taxa differed among the 10 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.
6. **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.
7. **Proportion of samples with no organisms present**—Proportion 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 empty sample was assigned a score of three, and any site with two or more empty samples received a score of one. Sites with no empty samples were assigned a score of five.

Scoring Criteria for each of the seven metrics were developed using the four years of Vital Signs monitoring which provide results from samples processed in the field (1994 - 1997). Scoring ranges were developed as follows:

- Individual criteria were developed for each type of sampling location (forebay, transition zone/mid-reservoir, 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 and observations on the entire data base were used to adjust the cutoffs for the range of each metric.

Scoring criteria which resulted from these efforts are detailed by reservoir class for each metric in Table 1. Two versions of Table 1 (a and b) are provided. Table 1a provides scoring ranges for results from field processed samples. Sample results for 1997, as well as results from field processed samples for 1994, 1995, and 1996, were scored against these criteria. Table 1b provides scoring criteria used in previous years (1991 - 1994) for results from lab processed samples. Results for laboratory processed samples collected for QC purposes in 1997 were scored using these criteria.

Sample results at each site were scored using the appropriate scoring ranges for each metric and assigned the following ratings -- 5 (good), 3 (fair), or 1 (poor) if they fell in the top, middle, or bottom group, respectively. Numerical ratings for the seven metrics were then summed. This resulted in a minimum score of 7 if all metrics at a site were poor, and a maximum score of 35 if all metrics were excellent.

One use of the benthic macroinvertebrate score is to help establish the overall ecological health score for a reservoir as described in Section 1. The benthic macroinvertebrate community is one of five 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	7-12	13-18	19-23	24-29	30-35
Community Condition	Very Poor	Poor	Fair	Good	Excellent
Contribution to Reservoir Ecological Health Score	1	2	3	4	5

Benthic community results along with results from the other four indicators and overall ecological health scores for each reservoir are used to keep the public informed on the conditions of Tennessee Valley reservoirs. In publications intended for the public, 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 necessitates dividing scores for each indicator into three ranges. The benthic macroinvertebrate scores are categorized as follows:

Benthic Community Score	7-16	17-26	27-35
Color	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1997 Monitoring

Results and Scores

Results from 1997 benthos sampling are summarized for each sample location, separated by reservoir class and reservoir zone in Table 2. This table includes final benthic scores, ratings for each of the seven metrics, and the data for each metric which drove the rating. Results for 1994, 1995, and 1996 are also included in Table 2. All results in Table 2 are from field-processed samples. Results for lab-processed (QC) samples for 1997 are in Table 3. Appendix C provides mean density for each taxon at each location in 1997; first for field-processed samples, followed by lab-processed samples.

Table 4 provides benthic community scores for 1994 through 1997 at all monitoring locations. Scores shown are for field processed samples based on the latest (1997) scoring criteria. This table provides an "apples to apples" comparison through time. The 1997 scores for most locations (20 of 36) fell within the range of scores previously observed. Interestingly, of the remaining 16 locations, 12 had scores two to four points higher than previously found and only 4 had scores lower than seen before. The consistency of comparable or higher scores in 1997 is interesting and encouraging. This will bear watching in the future to see if this represents a possible trend or simply a "blip" in the data.

Evaluation of QC Results

As described earlier, QC efforts for benthic macroinvertebrates includes two components -- one is aimed at evaluating implications of developing scores for the benthic community based on field processed samples begun in 1995 and continued in 1996 and 1997, rather than on lab processed samples as in previous years. (Note: In 1994 all samples were processed in both the field and lab but reported only for the lab. Beginning in 1995 the protocol changed to all field processing with only a subset of samples sent to the lab for verification.) Results (scores and metric ratings) from lab processed samples for this QC component in 1997 are in Table 3. They are not reported in Table 2 because different scoring criteria are used for lab processed samples, as discussed above.

The other QC component deals with how well the benthic scores can be repeated and is accomplished by collecting a second set of samples at selected locations. Results of this component for 1994, 1995, 1996, and 1997 are provided in Table 2 and identified with a "Q".

Determination of acceptable differences for QC results is an important issue and must consider study design and planned use of results. Given that the primary use of these results is to help evaluate the overall condition of a reservoir, the acceptable difference was defined in terms of impact on the Reservoir Ecological Health Score. The Reservoir Ecological Health Score is developed by summing the points (ratings) for the five indicators (chlorophyll, DO, sediment quality, benthos, and fish assemblage) and expressing as a percentage of the maximum points possible see Section 1. The benthic macroinvertebrate community contributes from 1 to 5 points to the Reservoir Ecological Health Score. A benthic community score between 7-12 contributes 1 point; 13-18 2 points; 19-23 3 points;

24-29 4 points; and 30-35 5 points. For reservoirs with only one sample location, a shift of 1 point changes the Reservoir Ecological Health Score 4.4 percent, a shift of 2 points results in an 8.8 percent change, etc. The former was deemed acceptable but the latter unacceptable. Therefore, for both components of the benthos QC effort, the difference in contribution between the original sample and the QC sample should be no more than 1 point.

When this reasoning is applied to the benthic score itself, replicate scores for QC sample sets should be no more than 6 points apart. Differences greater than this could cause a 2 point shift in the benthic community contribution to Ecological Health Score.

QC Results: Comparison of scores – field processed samples versus lab processed samples in 1997

Run-of-the-River Reservoirs	Benthic Community Scores		
	Field Score	Lab Score	Difference
Fort Loudoun Forebay	19 (Fair)	15 (Poor)	-4
Kentucky Transition Zone	35 (Excellent)	31 (Excellent)	-4
Kentucky Inflow	23 (Fair)	23 (Fair)	0
Tributary Reservoirs	Field Score	Lab Score	Difference
Blue Ridge Ecoregion			
Nottely Mid-reservoir	27 (Good)	21 (Fair)	-6
Ridge and Valley Ecoregion			
Douglas Forebay	19 (Fair)	15 (Poor)	-4
Boone Forebay	13(Poor)	21 (Fair)	+8
Interior Plateau Ecoregion			
Little Bear Forebay	15 (Poor)	15 (Poor)	0

Note: Field processed samples are scored on expectations appropriate for that level of taxonomic discernment as shown in Table 1a; whereas lab processed samples are scored on a different set of expectations appropriate for that level of discernment as shown in Table 1b.

Differences in all but one sample set were less than the desired maximum of 6. The maximum observed difference between scores from field processed and lab processed samples was 8 (1 set) and the minimum was 0 (2 sets). The mean difference (1.4) for the seven "paired" scores and associated 95 percent confidence interval (± 4.4) provide a range (-3.0 to 5.9) just below the desired maximum of 6. Scores for the 1997 samples tended to be higher based on the field derived results than the lab derived results. For example, no difference in scores was found at two locations, higher scores for field processes samples at four locations, and higher scores in lab processed samples in only one of the seven sample locations.

This observation differs from that found in previous years. For the 1994 - 1996 results there was a bias toward higher scores from the samples when processed in the lab – of the 95 sample sets, 49 (52%) of the pairs had higher scores for laboratory samples, 21 (22%) had higher scores for field processed samples, and the remaining 25 (26%) had identical scores. (Note: Most of these results are for 1994 because all samples for that year were processed in both the field and the lab, whereas, in 1995 and 1996 all samples were processed in the field and only QC samples were processed in the lab.) The bias of lower scores for field processed samples compared to the score which would have been obtained had the samples been processed in the lab was recognized as a concern and reported in Dycus and Meinert (1997) because scores from field processed samples could have been providing an overly conservative evaluation of the benthos (i.e., the community may be in better condition than indicated by the score). The cause(s) of this bias was investigated prior to scoring of 1997 results. Each metric was examined to determine if it consistently contributed to the bias. Only one metric (Zero Samples) consistently rated higher for lab processed samples than for field processed samples. Prior to 1997, the scoring criteria used for this metric was the same for both field processed samples and lab processed samples – only two rating possibilities existed (either 1 or 5). If one or more of the 10 samples at a site contained no animals, the metric received a rating of 1. If all 10 samples at a site contained at least a single animal, a rating of 5 was given. For 1997, this metric was changed for field processed samples – to received a rating of 1, a site had to have two or more samples which contained no animals; a rating of 3 was given to sites which had a single sample containing no animals; and a site with no "zero" samples received a rating of 5 (Table 1).

Results for paired scores for 1997 are encouraging, but it is important to remember that this is only a small data set (7 paired scores). Results from this component of the QC effort will continue to be examined each year to determine if additional changes to scoring criteria are needed.

QC Results: Scores for original samples compared to scores for repeat sampling in 1997

Run-of-the-River Reservoirs	Benthic Community Scores		
	Field Score Original	Field Score Repeat	Difference
Fort Loudoun Forebay	17 (Poor)	19 (Fair)	2
Kentucky Transition Zone	35 (Excellent)	35 (Excellent)	0
Kentucky Inflow	25 (Good)	23 (Fair)	2
Tributary Reservoirs			
Blue Ridge Ecoregion			
Nottely Mid-reservoir	19 (Fair)	27 (Good)	8

Ridge and Valley Ecoregion

	Field Score Original	Field Score Repeat	Difference
Douglas Forebay	19 (Fair)	19 (Fair)	0
Boone Forebay	9 (Very Poor)	13 (Poor)	4

Interior Plateau Ecoregion

Little Bear Forebay	11 (Very Poor)	15 (Poor)	4

Note: + and - signs are not provided for these differences because there is no basis for bias – neither would be expected to be higher or lower than the other; therefore, the absolute rather than the relative difference should be considered.

Scores from most paired sample sets compared favorably. Replicate sample sets from two sites had identical scores, and scores from replicate sample sets at four sites differed by 4 points or less. Only one set of samples had scores which differed by more than 6 points. Scores for the two sample sets from the mid-reservoir site on Nottely differed by 8 points (Table 2). The mean difference (2.9) for all QC sites in 1997 and associated 95 percent confidence limits (± 2.6) provide a range (0.3 - 5.5) which does not include 6. The difference in scores between the original and repeat sample sets in 1997 was smaller than in 1995 and 1996 and comparable to 1994:

Year	Maximum Observed Difference	Mean	95% CL	Lower Limit	Upper Limit
1994	12	2.3	± 2.0	0.3	4.3
1995	8	4.0	± 2.2	1.8	6.2
1996	12	4.5	± 3.7	0.8	8.2
1997	8	2.9	± 2.6	0.3	5.5

Results from the paired sample sets from the Nottely Mid-reservoir QC site bear further examination. The difference of 8 points between the replicate set of samples was due to the occurrence of a single large (> 10mm) mayfly in one sample from the repeat sample set. Occurrence of this one individual influenced four metrics (EPT, Long-lived Species, Total Abundance excluding Chironomidae and Tubificidae, and Percentage as Dominant Taxa). This situation highlights one of the issues surrounding use of benthic macroinvertebrates as indicators in tributary reservoirs. Expectations for the benthic community in these reservoirs is quite low. Great depth and low dissolved oxygen often severely limit existence of a truly good benthic macroinvertebrate community in these reservoirs. As previously discussed, the approach taken in this program is to compare communities within each class of reservoir. To this end, scoring criteria for each metric or community characteristic have been developed by trisecting the observed range of values using the best observed condition for that metric as "good" and the lowest as "poor." For example, Table 1a shows that a forebay sample site on a reservoir within the Blue Ridge Ecoregion which had no EPT would rate 1, if it had only one EPT taxon out of the 10 samples collected it would rate 3, and if it more than one EPT taxa, it would rate 5. Similar "nominal" expectations exist for several other metrics for reservoirs in the Blue Ridge Ecoregion as well as for tributary reservoirs in other ecoregions.

Initially, this monitoring program did not include benthos in tributary reservoirs because their value as a meaningful indicator in these reservoirs was questionable, but little data existed to verify or refute this assumption. Because the benthos had proven to be a valuable indicator in the run-of-the-river reservoirs, the decision was made to evaluate the usefulness of these organisms in tributary reservoirs. Initial sampling revealed somewhat surprising results when at least some benthic taxa were found in nearly all samples, even those from the greatest depths of reservoirs with known oxygen problems. Additionally, samples from near shore often had greater diversity. Based on these observations, some hope existed that the benthos might prove to be a meaningful indicator and a data base began to be established from which scoring criteria could be developed. At this point in 1997 the data base is fairly well established and scoring criteria have been developed. As discussed above, close examination of the scoring criteria reveals that even the "best" benthos in a tributary reservoir is actually poor by any other standards. In itself, this does not rule out these organisms as valuable indicators. However, when presence/absence of one organisms can cause a significant shift in the overall score, some action or correction is necessary. Determinations about how to handle this situation were in process at the time this document was being prepared. Since no decision had been reached by publication date, results from the benthos were included for all reservoirs. Adjustments may be made later. The types of adjustments being considered include:

- changing metrics – the seven metrics currently in use are the same as the run-of-the-river reservoirs, other metrics might be more appropriate for tributary reservoirs;
- changing scoring criteria – the same metrics might be valid but a different approach to determining what represents "good, fair, or poor" conditions might be used;
- changing sample collection methods – rather than using the transect method used on the R-O-R, possibly collect samples only from the near shore area;
- discontinue using benthos as an indicator in some or all tributary reservoirs – this group of organisms may have no value as an environmental indicator in most or all tributary reservoirs and as such sampling should be discontinued.

Reference

Dycus, D.L., 19 . "Aquatic Ecological Health Determinations for TVA Reservoirs--1994. An Informal Summary of 1994 Vital Signs Monitoring Results and Ecological Health Determination Methods." April 1995.

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Table 1a. Scoring Criteria for Benthic Macroinvertebrate Community; Field Processed Samples, 1997 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	<2	2-4	>4	<2.3	2.3-4.6	>.4.6	<2.3	2.3-4.6	>4.6
EPT	<.3	.3-.6	>.6	<.3	.3-.6	>.6	<.7	.7-1.3	>1.3
Long-lived	<.3	.3-.6	>.6	<.3	.3-.6	>.6	<.3	.3-.6	>.6
Percent Tubificids	>34	17-34	<17	>34	17-34	<17	>34	17-34	<17
Dominance	>93	84-93	>84	>93	84-93	>84	>93	84-93	>84
Non Chi. and Tub. Density	<100	100-200	>200	<250	250-500	>500	<233	233-466	>466
Zero Samples	>.1	.1	0	>1	1	0	>1	1	0

Blue Ridge Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	<1.3	1.3-2.4	>2.4	-	-	-	<.8	.8-1.6	>1.6
EPT	<.1	.1-.2	>.2	-	-	-	<.1	.1	>.1
Long-lived	<.1	.1	>.1	-	-	-	<.1	.1	>.1
Percent Tubificids	>66	33-66	<33	-	-	-	>56	28-56	<28
Dominance	>96.6	93.3-96.6	<93.3	-	-	-	>96.6	93.3-96.6	<93.3
Non Chi. and Tub. Density	<5.5	5.5-11.3	>11.3	-	-	-	<3	3-6	>6
Zero Samples	>.1	.1	0	-	-	-	>1	1	0

Table 1a. Cont', Scoring Criteria for Benthic Macroinvertebrate Community; Field Processed Samples, 1997 Reservoir Vital Signs Monitoring

Interior Plateau Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	<1.3	1.3-2.6	>2.6	-	-	-	-	-	-
EPT	<.1	.1-.2	>.2	-	-	-	-	-	-
Long-lived	<.1	.1	>.1	-	-	-	-	-	-
Percent Tubificids	>66	33-66	<33	-	-	-	-	-	-
Dominance	>96.6	93.3-96.6	<93.3	-	-	-	-	-	-
Non Chi. and Tub. Density	<10	10-20	>20	-	-	-	-	-	-
Zero Samples	>.1	.1	0	-	-	-	-	-	-

Ridge and Valley Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Reservoir		
	1	3	5				1	3	5
Taxa Richness	<.8	.8-1.6	>1.6	-	-	-	<1.2	1.2-2.3	>2.3
EPT	<.1	.1	>.1	-	-	-	<.1	.1	>.1
Long-lived	<.1	.1	>.1	-	-	-	<.1	.1	>.1
Percent Tubificids	>66	33-66	<33	-	-	-	>66	33-66	<33
Dominance	>96.6	93.3-96.6	<93.3	-	-	-	>96.6	93.3-96.6	<93.3
Non Chi. and Tub. Density	<21	21-43	>43	-	-	-	<8	8-16	>16
Zero Samples	>.1	.1	0	-	-	-	>1	1	0

Table 1b. Scoring Criteria for Benthic Macroinvertebrate Community; Lab Processed Samples, 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 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 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 1b. Cont', Scoring Criteria for Benthic Macroinvertebrate Community; Lab Processed Samples, Reservoir Vital 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 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	≥.1	-	0	-	-	-	-	-	-

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 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	≥.1	-	0	-	-	-	0	-	1

Table 2. Results and Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs --Forebay Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
Chickamauga		472.3	94	33	5.3	5	1	5	1	5	13.8	5	82.3	5	151.7	3	0	5
Chickamauga	Q	472.3	94	31	5.9	5	1	5	0.5	3	26.3	3	78.6	5	298.3	5	0	5
Chickamauga		472.3	95	31	4.3	5	0.9	5	0.4	3	14.9	5	85.3	3	310.0	5	0	5
Chickamauga		472.3	97	33	5.5	5	0.9	5	0.3	3	6.1	5	81.7	5	353.3	5	0	5
Fort Loudoun		605.5	94	13	3	3	0.1	1	0.1	1	34.6	1	99.3	1	7.6	1	0	5
Fort Loudoun		605.5	95	13	3.2	3	0.1	1	0.1	1	43.1	1	96.5	1	11.7	1	0	5
Fort Loudoun		605.5	96	11	2.9	3	0.1	1	0.1	1	38.0	1	99.5	1	3.3	1	0.1	3
Fort Loudoun		605.5	97	17	3.2	3	0.4	3	0.4	3	38.0	1	99.3	1	30.0	1	0	5
Fort Loudoun	Q	605.5	97	19	2.7	3	0.3	3	0.3	3	20.6	3	99.0	1	41.7	1	0	5
Guntersville		350	94	27	4.9	5	1	5	0.6	3	20.0	3	86.6	3	143.3	3	0	5
Guntersville		350	96	35	6	5	1	5	0.8	5	12.8	5	72.6	5	246.7	5	0	5
Kent. Big Sandy		7.4	94	19	6.2	5	0.2	1	0	1	5.9	5	94.1	1	60.0	1	0	5
Kent. Big Sandy		7.4	95	19	4.9	5	0.1	1	0	1	8.7	5	93.5	1	78.3	1	0	5
Kent. Big Sandy		7.4	97	23	5.6	5	0.5	3	0.1	1	2.4	5	93.7	1	128.3	3	0	5
Kentucky		23	94	27	6	5	0.9	5	0.2	1	25.6	3	81.0	5	173.3	3	0	5
Kentucky		23	95	27	4.4	5	0.7	5	0.2	1	17.4	3	85.4	3	523.3	5	0	5
Kentucky		23	97	29	6	5	0.7	5	0	1	7.2	5	86.3	3	328.3	5	0	5
Melton Hill		24	94	19	3.5	3	0.4	3	0.5	3	15.0	5	94.0	1	18.3	1	0.1	3
Melton Hill		24	96	17	2.4	3	0.3	3	0.4	3	18.1	3	98.3	1	18.3	1	0.1	3
Melton Hill	Q	24	96	21	2.5	3	0.3	3	0.5	3	11.0	5	94.0	1	28.3	1	0	5
Nickajack		425.5	94	33	4.8	5	0.8	5	1.5	5	4.5	5	82.8	5	138.3	3	0	5
Nickajack	Q	425.5	94	33	4.8	5	0.9	5	1.1	5	11.3	5	82.4	5	151.7	3	0	5
Nickajack		425.5	95	33	4.2	5	0.9	5	0.8	5	16.3	5	76.3	5	171.7	3	0	5
Nickajack	Q	425.5	95	29	3.9	3	0.9	5	0.6	3	14.9	5	82.8	5	196.7	3	0	5
Nickajack		425.5	97	35	5.9	5	1	5	1	5	6.3	5	81.9	5	331.7	5	0	5
Pick. Bear Cr.		8.4	94	17	5	5	0	1	0	1	20.5	3	99.6	1	3.3	1	0	5
Pick. Bear Cr.		8.4	96	17	4.3	5	0.1	1	0	1	20.8	3	96.5	1	13.3	1	0	5
Pickwick		207.3	94	31	4.9	5	0.5	3	0.5	3	12.2	5	78.8	5	213.3	5	0	5
Pickwick		207.3	96	31	5	5	0.6	3	0.9	5	14.5	5	84.4	3	228.3	5	0	5
Tellico		1	94	7	0.8	1	0	1	0	1	55.6	1	100.0	1	0.0	1	0.4	1
Tellico		1	95	7	0.9	1	0	1	0	1	61.9	1	100.0	1	1.7	1	0.3	1
Tellico		1	97	9	1.8	1	0.1	1	0.1	1	28.5	3	98.1	1	11.7	1	0.2	1
Watts Bar		531	94	17	3.8	3	0.2	1	0.3	3	24.0	3	92.0	3	20.0	1	0.1	3
Watts Bar		531	96	13	3	3	0.1	1	0.1	1	32.7	3	95.2	1	10.0	1	0.1	3
Watts Bar	Q	531	96	15	3.1	3	0.2	1	0.4	3	44.4	1	94.8	1	10.0	1	0	5
Wheeler		277	94	19	4.8	5	0.4	3	0	1	19.1	3	93.1	1	41.7	1	0	5
Wheeler		277	95	17	3	3	0.2	1	0	1	15.7	5	95.9	1	21.7	1	0	5
Wheeler		277	97	23	4.8	5	0.6	3	0	1	10.0	5	88.7	3	80.0	1	0	5
Wilson		260.8	94	19	4.6	5	0	1	0	1	9.1	5	94.1	1	78.3	1	0	5
Wilson		260.8	96	15	3.8	3	0	1	0	1	40.4	1	90.1	3	21.7	1	0	5

Table 2. Results and Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Transition Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
Chick. Hiw. R.		8.5	94	19	2.9	3	0.5	3	0.6	3	21.7	3	89.4	3	203.3	1	0.1	3
Chick. Hiw. R.	Q	8.5	94	17	2.6	3	0.4	3	0.4	3	39.2	1	85.2	3	61.7	1	0.1	3
Chick. Hiw. R.		8.5	95	29	5.5	5	0.9	5	0.9	5	33.8	3	75.9	5	166.7	1	0	5
Chick. Hiw. R.		8.5	97	25	5.9	5	0.6	3	0.8	5	37.0	1	78.4	5	191.7	1	0	5
Chickamauga		490.5	94	33	5.7	5	0.9	5	1	5	10.8	5	70.8	5	373.3	3	0	5
Chickamauga	Q	490.5	94	33	5.5	5	1	5	1	5	5.0	5	73.7	5	480.0	3	0	5
Chickamauga		490.5	95	29	5.4	5	0.9	5	0.9	5	23.0	3	74.6	5	170.0	1	0	5
Chickamauga		490.5	97	33	5.9	5	1	5	0.7	5	10.4	5	69.7	5	428.3	3	0	5
Fort Loudoun		624.6	94	21	3.9	3	0.4	3	0.4	3	28.6	3	92.8	3	21.7	1	0	5
Fort Loudoun		624.6	95	29	4.9	5	0.7	5	0.7	5	15.3	5	86.2	3	76.7	1	0	5
Fort Loudoun		624.6	96	23	4.6	3	0.4	3	0.4	3	12.7	5	91.0	3	83.3	1	0	5
Fort Loudoun		624.6	97	29	5.5	5	1	5	1	5	12.4	5	89.2	3	140.0	1	0	5
Guntersville		375.2	94	35	6.3	5	1	5	1	5	7.4	5	78.8	5	610.0	5	0	5
Guntersville		375.2	96	35	5.5	5	1	5	0.8	5	4.1	5	82.7	5	733.3	5	0	5
Kentucky	Q	85	94	33	5.8	5	0.9	5	0.8	5	14.7	5	79.7	5	253.3	3	0	5
Kentucky		85	94	33	5.3	5	1	5	0.8	5	9.9	5	81.0	5	255.0	3	0	5
Kentucky		85	95	29	3.9	3	1	5	0.9	5	1.6	5	85.8	3	433.3	3	0	5
Kentucky	Q	85	97	35	6.1	5	1	5	0.8	5	13.3	5	76.6	5	760.0	5	0	5
Kentucky		85	97	35	6.4	5	1	5	1	5	3.7	5	76.9	5	790.0	5	0	5
Melton Hill		45	94	19	3.2	3	0.3	3	0.3	3	26.0	3	96.7	1	8.3	1	0	5
Melton Hill		45	96	19	3.2	3	0.4	3	0.4	3	41.8	1	90.8	3	26.7	1	0	5
Pickwick		230	94	31	6	5	1	5	0.8	5	18.4	3	74.6	5	294.8	3	0	5
Pickwick	Q	230	96	35	5.2	5	0.9	5	0.9	5	3.5	5	80.2	5	758.3	5	0	5
Pickwick		230	96	35	5.2	5	1	5	0.8	5	3.7	5	83.7	5	871.7	5	0	5
Tellico		15	94	15	1.5	1	0.3	3	0.3	3	11.3	5	100.0	1	6.7	1	0.2	1
Tellico	Q	15	95	13	1.3	1	0.2	1	0.2	1	8.3	5	100.0	1	3.3	1	0.1	3
Tellico		15	95	17	2	1	0.4	3	0.4	3	33.8	3	99.0	1	10.0	1	0	5
Tellico		15	97	9	1.8	1	0	1	0.2	1	32.6	3	100.0	1	8.3	1	0.2	1
Watts Bar		560.8	94	29	4.5	3	0.9	5	1	5	2.7	5	90.2	3	356.7	3	0	5
Watts Bar		560.8	96	27	4.2	3	0.9	5	0.9	5	1.0	5	89.7	3	148.3	1	0	5
Wheeler		295.9	94	33	5.6	5	1	5	0.8	5	10.4	5	77.3	5	316.7	3	0	5
Wheeler		295.9	95	27	3.3	3	1	5	0.6	3	6.6	5	82.2	5	131.7	1	0	5
Wheeler		295.9	97	33	5.9	5	1	5	1	5	10.1	5	79.5	5	393.3	3	0	5
Wheeler Elk R.		6	97	17	6	5	0.1	1	0	1	52.0	1	92.3	3	80.0	1	0	5
Wheeler Elk R.		6	94	15	4.6	3	0.1	1	0	1	28.4	3	98.9	1	8.3	1	0	5
Wheeler Elk R.		6	95	13	2.8	3	0	1	0	1	54.5	1	95.2	1	10.0	1	0	5
Wheeler Elk R.	Q	6	95	15	3.5	3	0	1	0	1	45.2	1	90.4	3	25.0	1	0	5

Table 2. Results and Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Run-of-River Reservoirs -- Inflow Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
Chickamauga		518	94	23	2.6	3	1.0	5	0.0	1	5.3	5	95.7	1	411.7	3	0	5
Chickamauga	Q	518	95	25	4.5	3	0.9	5	0.3	1	2.9	5	79.5	5	155.5	1	0	5
Chickamauga		518	95	31	6.4	5	0.9	5	1.0	3	3.5	5	68.1	5	249.1	3	0	5
Chickamauga		518	97	27	5.5	5	1.0	5	0.5	1	1.5	5	84.8	3	345.6	3	0	5
Fort Loudoun		652	94	7	1.2	1	0.1	1	0.0	1	40.5	1	99.2	1	10.9	1	0.3	1
Fort Loudoun		652	95	11	1.7	1	0.0	1	0.0	1	25.0	3	94.7	1	19.1	1	0.1	3
Fort Loudoun		652	96	7	1.4	1	0.0	1	0.0	1	59.9	1	97.1	1	11.7	1	0.2	1
Fort Loudoun		652	97	13	2.4	3	0.1	1	0.2	1	24.3	3	90.9	3	73.3	1	0.2	1
Guntersville		420	94	25	3.3	3	0.9	5	0.1	1	2.0	5	87.3	3	281.8	3	0	5
Guntersville		420	96	29	4.7	5	1.0	5	0.5	1	3.1	5	84.1	3	629.1	5	0	5
Kentucky		15	94	25	5.4	5	1.0	5	0.7	3	18.1	3	86.4	3	214.5	1	0	5
Kentucky		200	94	27	5.2	5	0.9	5	0.4	1	12.7	5	75.8	5	80.9	1	0	5
Kentucky		200	95	23	3.1	3	0.8	5	0.0	1	0.6	5	88.3	3	92.7	1	0	5
Kentucky		200	97	25	4.2	3	0.9	5	0.6	1	12.0	5	78.0	5	113.6	1	0	5
Kentucky	Q	200	97	23	4.3	3	0.8	5	0.3	1	5.5	5	86.8	3	170.9	1	0	5
Melton Hill		58.8	94	11	1.2	1	0.0	1	0.0	1	9.0	5	100.0	1	0.0	1	0.2	1
Melton Hill		58.8	96	7	1.5	1	0.1	1	0.2	1	40.0	1	98.4	1	5.5	1	0.2	1
Nickajack	Q	469	94	31	5.8	5	1.0	5	2.1	5	0.0	5	85.3	3	457.3	3	0	5
Nickajack		469	94	35	7.6	5	1.0	5	2.4	5	0.5	5	82.2	5	693.6	5	0	5
Nickajack		469	95	35	8.5	5	1.0	5	2.2	5	2.1	5	79.7	5	1086.4	5	0	5
Nickajack		469	97	35	7	5	1.0	5	1.7	5	1.6	5	82.3	5	1420.0	5	0	5
Pickwick		253.2	94	25	4.2	3	0.4	3	1.0	3	5.4	5	79.7	5	95.5	1	0	5
Pickwick	Q	253.2	94	21	3.6	3	0.6	3	0.5	1	10.4	5	91.4	3	183.6	1	0	5
Pickwick		253.2	96	23	3.8	3	0.7	5	0.6	1	0.7	5	85.4	3	131.8	1	0	5
Watts Bar		19	94	15	1.8	1	0.3	3	0.2	1	0.0	5	96.1	1	38.2	1	0.1	3
Watts Bar		19	96	15	1.4	1	0.1	1	0.0	1	7.0	5	99.0	1	43.6	1	0	5
Watts Bar		600	94	19	2.9	3	0.2	1	0.2	1	4.3	5	89.9	3	65.5	1	0	5
Watts Bar		600	96	15	2.5	3	0.0	1	0.6	1	0.2	5	89.2	3	77.3	1	0.2	1
Wheeler		347	94	31	6.1	5	0.9	5	1.0	3	0.9	5	68.7	5	308.2	3	0	5
Wheeler		347	95	25	4.5	3	1.0	5	0.1	1	0.4	5	86.0	3	407.3	3	0	5
Wheeler		347	97	31	5.2	5	1.0	5	0.7	3	1.1	5	91.9	3	610.0	5	0	5
Wilson		273	94	29	5.5	5	1.0	5	0.6	1	1.9	5	80.4	5	359.7	3	0	5
Wilson	Q	273	96	31	5.2	5	1.0	5	0.9	3	0.5	5	85.4	3	1295.0	5	0	5
Wilson		273	96	27	4.2	3	1.0	5	0.6	1	0.2	5	90.8	3	1730.0	5	0	5

Table 2. Results and Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sampling Location.

Blue Ridge Ecoregion -- Forebay and Mid-Reservoir Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																		
Apalachia		67	96	21	2.4	3	0	1	0	1	51.7	3	94.3	3	18.3	5	0	5
Apalachia		67	97	19	1.6	3	0	1	0	1	49.1	3	98.9	1	15.0	5	0	5
Blue Ridge		54.1	94	17	1.5	3	0	1	0	1	40.5	3	94.8	3	15.0	5	0.5	1
Blue Ridge	Q	54.1	94	29	2.7	5	0.2	5	0.4	5	38.7	3	90.5	5	105.0	5	0.2	1
Blue Ridge		54.1	95	31	3.5	5	0.3	5	0.3	5	47.4	3	84.6	5	161.7	5	0.1	3
Blue Ridge		54.1	97	29	4	5	0.1	3	0.1	3	35.1	3	91.2	5	341.7	5	0	5
Chatuge		1.5	94	17	1.9	3	0.1	3	0.1	3	23.4	5	98.6	1	4.2	1	0.2	1
Chatuge		1.5	96	25	1.5	3	0.3	5	0.3	5	40.4	3	98.3	1	6.7	3	0	5
Chatuge		122	94	17	1.5	3	0	1	0.2	3	45.1	3	100.0	1	5.0	1	0	5
Chatuge	Q	122	96	9	0.9	1	0	1	0	1	64.3	3	100.0	1	1.7	1	0.3	1
Chatuge		122	96	21	1.6	3	0.1	3	0.2	3	34.1	3	100.0	1	8.3	3	0	5
Fontana		62	95	7	0.6	1	0	1	0	1	86.7	1	100.0	1	3.3	1	0.6	1
Fontana		62	96	7	0.2	1	0	1	0	1	66.7	1	100.0	1	0.0	1	0.9	1
Hiwassee		77	94	7	0.3	1	0	1	0	1	66.7	1	100.0	1	0.0	1	0.7	1
Hiwassee		77	96	11	1	1	0	1	0	1	75.0	1	99.2	1	25.0	5	0.2	1
Nottely		23.5	94	13	1.7	3	0	1	0	1	41.5	3	100.0	1	0.0	1	0.1	3
Nottely		23.5	95	15	2.6	5	0	1	0	1	40.4	3	100.0	1	0.0	1	0.1	3
Nottely		23.5	97	15	2.2	3	0	1	0	1	46.4	3	100.0	1	0.0	1	0	5
Parksville	Q	12.5	94	7	0.4	1	0	1	0	1	100.0	1	100.0	1	0.0	1	0.6	1
Parksville		12.5	94	7	0.8	1	0	1	0	1	82.5	1	100.0	1	3.3	1	0.3	1
Parksville	Q	12.5	95	11	1	1	0	1	0	1	69.1	1	98.0	1	15.0	5	0.3	1
Parksville		12.5	95	19	1.5	3	0	1	0	1	63.4	3	96.7	1	18.3	5	0	5
Parksville		12.5	97	19	1.4	3	0	1	0.1	3	50.4	3	100.0	1	23.3	5	0.1	3
Watauga		37.4	94	11	0.5	1	0.1	3	0	1	60.0	3	100.0	1	1.8	1	0.5	1
Watauga		37.4	96	9	1.2	1	0	1	0	1	69.5	1	100.0	1	6.7	3	0.4	1
MID-RESERVOIR																		
Fontana		3	94	13	1.9	5	0	1	0	1	39.1	3	100.0	1	0.0	1	0.2	1
Fontana		3	96	9	1.2	3	0	1	0	1	96.2	1	100.0	1	0.0	1	0.3	1
Fontana		81.5	94	15	2	5	0	1	0	1	28.2	3	100.0	1	0.0	1	0.1	3
Fontana		81.5	96	11	1.2	3	0	1	0	1	96.1	1	100.0	1	0.0	1	0.1	3
Hiwassee		85	94	9	1	3	0	1	0	1	63.0	1	100.0	1	0.0	1	0.5	1
Hiwassee	Q	85	94	9	1.3	3	0	1	0	1	93.7	1	100.0	1	0.0	1	0.4	1
Hiwassee		85	96	11	1.5	3	0	1	0	1	90.0	1	99.6	1	3.3	3	0.4	1
Nottely		31	94	29	2.6	5	0.2	5	0.2	5	8.2	5	99.0	1	5.5	3	0	5
Nottely	Q	31	94	31	2.2	5	0.3	5	0.4	5	2.9	5	99.3	1	9.1	5	0	5
Nottely		31	95	13	1.2	3	0	1	0	1	37.4	3	100.0	1	1.7	1	0.1	3
Nottely	Q	31	95	19	1.3	3	0.1	3	0.1	3	24.4	5	95.8	3	1.7	1	0.2	1
Nottely	Q	31	97	27	3.4	5	0.1	3	0.1	3	16.9	5	96.1	3	3.3	3	0	5
Nottely		31	97	19	2.9	5	0	1	0	1	15.5	5	99.2	1	1.7	1	0	5
Watauga	Q	45.5	94	15	1.3	3	0	1	0	1	7.3	5	100.0	1	1.7	1	0.1	3
Watauga		45.5	94	19	1.6	3	0	1	0	1	16.8	5	98.7	1	151.7	5	0.1	3
Watauga		45.5	96	13	1.8	5	0	1	0	1	32.4	3	100.0	1	0.0	1	0.3	1
Watauga	Q	45.5	96	17	2.1	5	0	1	0	1	23.7	5	100.0	1	5.0	3	0.2	1

Table 2. Results and Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Ridge and Valley Ecoregion Tributary Reservoirs -- Forebay and Mid-Reservoir Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																		
Boone		19	94	15	2.4	5	0	1	0	1	86.4	1	98.6	1	1.7	1	0	5
Boone		19	95	11	1.1	3	0	1	0	1	99.6	1	100.0	1	1.7	1	0.1	3
Boone		19	97	9	1.4	3	0	1	0	1	90.0	1	100.0	1	3.3	1	0.2	1
Boone	Q	19	97	13	1.5	3	0.1	3	0	1	78.0	1	100.0	1	1.7	1	0.1	3
Cherokee		53	94	21	2.4	5	0.1	3	0.1	3	43.7	3	99.6	1	3.3	1	0	5
Cherokee		53	95	15	2.2	5	0	1	0	1	51.5	3	100.0	1	0.0	1	0.1	3
Cherokee		53	96	15	1.9	5	0	1	0	1	55.6	3	100.0	1	0.0	1	0.1	3
Douglas		33	94	15	2.2	5	0	1	0	1	56.6	3	100.0	1	0.0	1	0.1	3
Douglas		33	95	9	1.5	3	0	1	0	1	81.5	1	100.0	1	0.0	1	0.2	1
Douglas		33	97	17	2.5	5	0	1	0	1	47.2	3	100.0	1	0.0	1	0	5
Ft Pat Henry		8.7	94	17	2.3	5	0	1	0	1	54.8	3	99.6	1	1.7	1	0	5
Ft Pat Henry		8.7	95	15	1.9	5	0	1	0	1	72.6	1	100.0	1	0.0	1	0	5
Ft Pat Henry		8.7	96	19	1.8	5	0.1	3	0	1	61.0	3	100.0	1	3.3	1	0	5
Ft Pat Henry		8.7	97	15	2.5	5	0	1	0	1	55.2	3	100.0	1	0.0	1	0.1	3
Norris		80.4	94	19	1.3	3	0.2	5	0	1	77.4	1	99.0	1	40.9	3	0	5
Norris		80.4	95	23	1.2	3	0.3	5	0.1	3	73.0	1	100.0	1	65.0	5	0	5
Norris	Q	80.4	95	21	1.1	3	0.2	5	0	1	78.9	1	100.0	1	101.7	5	0	5
Norris		80.4	97	19	2.2	5	0.1	3	0.1	3	68.7	1	97.7	1	8.3	1	0	5
South Holston		51	94	17	1.3	3	0.2	5	0.1	3	73.5	1	96.6	3	4.5	1	0.3	1
South Holston	Q	51	96	7	0.7	1	0	1	0	1	85.7	1	100.0	1	0.0	1	0.3	1
South Holston		51	96	7	0.5	1	0	1	0	1	73.7	1	100.0	1	3.3	1	0.6	1
Tims Ford		135	94	9	0.8	3	0	1	0	1	92.5	1	100.0	1	0.0	1	0.4	1
Tims Ford		135	95	9	0.9	3	0	1	0	1	81.3	1	100.0	1	0.0	1	0.2	1
Tims Ford		135	96	9	0.9	3	0	1	0	1	80.0	1	100.0	1	0.0	1	0.2	1
MID-RESERVOIR																		
Boone		6.5	94	13	2	3	0	1	0	1	76.7	1	100.0	1	0.0	1	0	5
Boone		6.5	95	13	1.3	3	0.1	3	0	1	83.9	1	100.0	1	1.7	1	0.1	3
Boone		6.5	97	17	2.4	5	0.1	3	0	1	74.5	1	98.8	1	1.7	1	0	5
Boone		27	94	15	2.2	3	0	1	0	1	47.6	3	99.7	1	0.9	1	0	5
Boone		27	95	13	1.7	3	0	1	0	1	60.5	3	100.0	1	0.0	1	0.1	3
Boone		27	97	13	2.1	3	0.1	3	0	1	57.1	3	99.5	1	1.7	1	0.3	1
Cherokee		76	96	15	2.3	3	0	1	0	1	13.6	5	100.0	1	0.0	1	0.1	3
Douglas		51	94	17	2.1	3	0	1	0	1	27.9	5	100.0	1	0.0	1	0	5
Douglas		51	95	15	1.9	3	0	1	0	1	36.1	3	100.0	1	0.0	1	0	5
Douglas	Q	51	97	19	3.6	5	0	1	0	1	14.8	5	100.0	1	0.0	1	0	5
Douglas		51	97	19	3.1	5	0	1	0	1	9.3	5	99.7	1	3.3	1	0	5
Norris		30	94	27	3.9	5	0.1	3	0.1	3	40.3	3	95.7	3	28.3	5	0	5
Norris		30	95	19	1.9	3	0	1	0	1	39.7	3	90.8	5	23.3	5	0.2	1
Norris		30	97	23	4.2	5	0	1	0	1	25.7	5	97.1	1	25.0	5	0	5
Norris		125	94	29	3.1	5	0.2	5	0.2	5	22.9	5	98.8	1	11.7	3	0	5
Norris		125	95	21	2.8	5	0	1	0	1	30.9	5	96.5	3	13.3	3	0.1	3
Norris		125	97	21	3.6	5	0	1	0	1	21.8	5	97.0	1	18.3	5	0.1	3
South Holston		62.5	94	19	2.7	5	0	1	0	1	30.9	5	99.3	1	1.8	1	0	5
South Holston		62.5	96	7	0.8	1	0	1	0	1	66.7	1	100.0	1	0.0	1	0.3	1
Tims Ford		150	94	11	0.7	1	0	1	0	1	25.0	5	100.0	1	0.0	1	0.4	1
Tims Ford		150	95	7	0.6	1	0	1	0	1	66.7	1	100.0	1	0.0	1	0.4	1
Tims Ford		150	96	7	0.9	1	0	1	0	1	76.1	1	100.0	1	0.0	1	0.4	1

Table 2. Results for Ratings for Individual Metrics and Final Benthic Scores. Separated by Reservoir Class and Type of Sample Location.

Interior Plateau Tributary Reservoirs -- Forebay Sites

RESERVOIR		Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZEROS	
Bear Creek		75	94	19	1.8	3	0	1	0.1	3	4.1	5	100.0	1	3.3	1	0	5
Bear Creek		75	95	17	1.8	3	0	1	0	1	14.6	5	100.0	1	0.0	1	0	5
Bear Creek		75	96	17	1.6	3	0	1	0	1	7.3	5	100.0	1	0.0	1	0	5
Bear Creek		75	97	11	1.3	3	0	1	0	1	47.9	3	100.0	1	0.0	1	0.2	1
Beech		36	94	31	4.3	5	0.1	3	0.3	5	11.9	5	96.5	3	23.3	5	0	5
Beech		36	95	23	3.1	5	0.1	3	0.1	3	11.0	5	98.7	1	6.7	1	0	5
Beech	Q	36	96	25	3.1	5	0.1	3	0.2	3	4.2	5	98.2	1	23.3	5	0.1	3
Beech		36	96	35	3.7	5	0.3	5	0.4	5	4.8	5	93.0	5	38.3	5	0	5
Cedar Creek		25.2	94	29	2.4	3	0.2	5	0.3	5	25.7	5	96.5	3	31.7	5	0.1	3
Cedar Creek		25.2	95	11	1.2	1	0	1	0	1	5.7	5	100.0	1	0.0	1	0.3	1
Cedar Creek		25.2	96	19	1.6	3	0.1	3	0.1	3	31.8	5	100.0	1	3.3	1	0.1	3
Cedar Creek		25.2	97	15	1.5	3	0	1	0	1	13.9	5	100.0	1	0.0	1	0.1	3
Little Bear Cr		12.5	94	21	2.2	3	0.1	3	0.2	3	65.7	3	99.3	1	10.0	3	0	5
Little Bear Cr	Q	12.5	94	21	1.9	3	0.1	3	0.1	3	76.7	1	99.7	1	30.0	5	0	5
Little Bear Cr		12.5	95	17	3.9	5	0.1	3	0.1	3	72.1	1	100.0	1	1.7	1	0.1	3
Little Bear Cr		12.5	96	17	1.4	3	0.2	5	0	1	83.6	1	96.9	1	15.0	3	0.1	3
Little Bear Cr		12.5	97	11	1.3	3	0	1	0	1	86.9	1	100.0	1	0.0	1	0.1	3
Little Bear Cr	Q	12.5	97	15	1.7	3	0	1	0.1	3	90.1	1	99.4	1	1.7	1	0	5
Normandy		250	94	15	1.4	3	0	1	0	1	47.1	3	100.0	1	0.0	1	0	5
Normandy		250	95	7	0.9	1	0	1	0	1	73.4	1	100.0	1	0.0	1	0.3	1
Normandy	Q	250	95	7	0.7	1	0	1	0	1	81.7	1	100.0	1	0.0	1	0.4	1
Normandy		250	96	13	1.7	3	0	1	0	1	66.3	1	99.3	1	1.7	1	0	5

Table 3. Results and Ratings for individual Metrics and Final Benthic Score for Samples for QA/QC from Lab Processed Samples.

Class	Reservoir	Mile	Year	Score	TAXA		LLIVED		EPT		PTUBI		DOMN		TOTNONCT		ZERO	
MAIN	Kentucky -TZ	85	97	31	7.1	3	1	5	1.0	3	10.0	5	74.0	5	756.7	5	0	5
MAIN	Kentucky -INF	200	97	23	5.3	3	0.8	3	0.9	3	3.3	5	74.8	3	207.3	1	0	5
MAIN	Fort Loudoun -FB	605.5	97	15	4.6	3	0.3	1	0.4	1	24.7	3	94.9	1	56.7	1	0	5
BR	Nottely -MR	31	97	21	3.8	3	0.1	1	0.2	3	21.4	5	94.9	3	21.7	1	0	5
IP	Little Bear Cr. -FB	12.5	97	15	1.6	1	0	1	0.1	1	92.0	5	99.3	1	3.3	1	0	5
RV	Boone -FB	19	97	21	3.0	5	0.1	1	0.0	1	80.8	1	96.3	3	121.7	5	0	5
RV	Douglas -MR	51	97	15	2.9	1	0	1	0.0	1	20.4	5	100	1	0.0	1	0	5

Table 4. Benthic Community Scores for 1994 through 1997 Based on Samples Collected in Late Autumn/Early Winter and Field Processed Samples

Run-of-the-River Reservoirs

Reservoir		Mile	1994*	1995*	1996*	1997*
Chickamauga	Forebay	472.3	33	31	.	33
Chickamauga	Inflow	518	23	31	.	27
Chickamauga	Embayment	8.5	19	29	.	25
Chickamauga	Transition	490.5	33	29	.	33
Fort Loudoun	Forebay	605.5	13	13	11	17
Fort Loudoun	Inflow	652	7	11	7	13
Fort Loudoun	Transition	624.6	21	29	23	29
Guntersville	Forebay	350	27	.	35	.
Guntersville	Inflow	420	25	.	29	.
Guntersville	Transition	375.2	35	.	35	.
Kentucky	Embayment	7.4	19	19	.	23
Kentucky	Forebay	23	27	27	.	29
Kentucky	Inflow	200	27	23	.	25
Kentucky	Transition	85	33	29	.	35
Melton Hill	Forebay	24	19	.	17	.
Melton Hill	Inflow	58.8	11	.	7	.
Melton Hill	Transition	45	19	.	19	.
Nickajack	Forebay	425.5	33	33	.	35
Nickajack	Inflow	469	35	35	.	35
Pickwick	Embayment	8.4	17	.	17	.
Pickwick	Forebay	207.3	31	.	31	.
Pickwick	Inflow	253.2	25	.	23	.
Pickwick	Transition	230	31	.	35	.
Tellico	Forebay	1	7	7	.	9
Tellico	Transition	15	15	17	.	9
Watts Bar	Forebay	531	17	.	13	.
Watts Bar	Inflow	19	15	.	15	.
Watts Bar	Inflow	600	19	.	15	.
Watts Bar	Transition	560.8	29	.	27	.
Wheeler	Forebay	277	19	17	.	23
Wheeler	Inflow	347	31	25	.	31
Wheeler	Embayment	6	15	13	.	17
Wheeler	Transition	295.9	33	27	.	33
Wilson	Forebay	260.8	19	.	15	.
Wilson	Inflow	273	29	.	27	.

* Note: Results for all years are scored on 1997 scoring protocols. Scores for 1991 - 1993 are excluded from this table because they are based on lab processed results.

Table 4. Cont.'

Blue Ridge Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*
Apalachia	Forebay	67	.	.	21	19
Blue Ridge	Forebay	54.1	17	31	.	29
Chatuge	Forebay	1.5	17	.	25	.
Chatuge	Forebay	122	17	.	21	.
Fontana	Forebay	62	.	7	7	.
Fontana	Mid-reservoir	3	13	.	9	.
Fontana	Mid-reservoir	81.5	15	.	11	.
Hiwassee	Forebay	77	7	.	11	.
Hiwassee	Mid-reservoir	85	9	.	11	.
Nottely	Forebay	23.5	13	15	.	15
Nottely	Mid-reservoir	31	29	13	.	19
Parksville	Forebay	12.5	7	19	.	19
Watauga	Forebay	37.4	11	.	9	.
Watauga	Mid-reservoir	45.5	19	.	13	.

Interior Plateau Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*
Bear Creek	Forebay	75	19	17	17	11
Beech Lake	Forebay	36	31	23	35	.
Cedar Creek	Forebay	25	29	11	19	15
Little Bear Cr.	Forebay	12.5	21	17	17	11
Normandy	Forebay	249.5	15	7	13	.

Ridge and Valley Ecoregion

Reservoir		Mile	1994*	1995*	1996*	1997*
Boone	Forebay	19	15	11	.	9
Boone	Mid-reservoir	27	15	13	.	13
Boone	Mid-reservoir	6.5	13	13	.	17
Cherokee	Forebay	53	21	15		15
Cherokee	Mid-reservoir	76	.	.	15	.
Douglas	Forebay	33	15	9	.	17
Douglas	Mid-reservoir	51	17	15	.	19
Fort Pat. Henry	Forebay	8.7	17	15	19	15
Norris	Forebay	80.4	19	23	.	19
Norris	Mid-reservoir	30	27	19	.	23
Norris	Mid-reservoir	125	29	21	.	21
South Holston	Forebay	51	17	.	7	.
South Holston	Mid-reservoir	62.5	19	.	7	.
Tims Ford	Forebay	135	9	9	.	9
Tims Ford	Mid-reservoir	150	11	7	.	7

* Note: Results for all years are scored on 1997 scoring protocols. Scores for 1991 - 1993 are excluded from this table because they are based on lab processed results.

Section 4.0. 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 áll biological organisms (EPA, 1992). Prior to 1995, TVA's approach used two sediment assessment methods--one biological (toxicity tests), the other chemical (direct chemcial analysis of sediments)--to evaluate sediment quality. In 1995 only sediment chemical analysis of heavy metals, pesticides, and PCBs was used. The primary reason for excluding toxicity tests in 1995 was budget reductions. Another important reason was that toxicity testing protocols had changed often during the four years they had been part of this monitoring program. Test media had changed from sediment elutriate to sediment pore water. Test procedures/organisms had changed from Microtox®, to Microtox® plus Rototox®, and later to Rototox® plus 24-hour acute test using Ceriodaphnia. Protocols were to change again in 1995 to the newly approved EPA methods using whole sediments and amphipods and midge larvae.

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 and pesticides should not be present. In this situation, there is no need for classification because the same conditions are desired for all reservoirs.

Sediment Collection Methods

Sediment samples were collected during the summer of 1997 from 31 locations, i.e., the forebays and transition zones (or mid-reservoir) of 6 run-of-river reservoirs and 11 tributary reservoirs as shown in Table 1 of Section 1. In addition, 5 of the 31 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the 5 sites. Replicate samples were handled and processed independently. Results from these 6 sets of replicates were used to assess field methods consistency, variations in laboratory physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment. 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. Samples were placed on ice immediately after collection and compositing, and were shipped or carried to the laboratory where they were analyzed for 13 metals and 26 selected trace organics (organochlorine pesticides and PCBs), as shown in Tables 1 and 1a.

Sediment Rating Scheme

Prior to 1995, sediment quality evaluations were based on both results of toxicity tests (S_{TOX}) and chemical analysis (S_{CHM}). Between 1990 and 1994, the Sediment Quality Rating for a sample was the average rating of the sample's toxicity and its sediment chemistry:

$$\textbf{Sediment Quality Rating} = 0.5\,(S_{TOX}\ \textbf{rating} + S_{CHM}\ \textbf{rating}).$$

Since both the sediment toxicity rating and the sediment chemistry rating can range from 1 (poor quality) to 5 (excellent quality), this resulted in an final, Sediment Quality Rating ranging from 1 (poor quality) to 5 (excellent quality) for a given reservoir location. To arrive at an overall ecological health score for a reservoir location, this Sediment Quality Rating was then combined with ratings for the other four indicators (DO, chlorophyll, benthos, and fish). Together, all five indicators carried equal weight and each indicator could range from 1 to 5. This methodology is described in more detail in Section 1.

With the elimination of sediment toxicity testing in 1995, it was decided that the Sediment Quality Rating (based only on the results of chemical analyses) should not carry equal weight with the other four ecological indicators. It was decided that the Sediment Quality Rating would be revised and carry only half the weight as the other four indicators of ecological health, and equal one half the sediment chemistry rating:

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

Consequently, the revised Sediment Quality Rating ranges from 1 (poor quality) to 2.5 (excellent quality), and as a result carries only one-half the weight as the other four indicators.

The sediment chemistry rating was developed as follows:

S_{CHM} (Sediment Chemistry) Rating--Sediment samples were analyzed for heavy metals, organochlorine pesticides, and PCBs. Sediment chemistry ratings were based on:

- concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (Tables 1 and 1a); and
- detectable amounts of PCBs or pesticides (Tables 1 and 1a).

Each sampling location's sediment chemistry was rated as follows:

Sediment Chemistry 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, and PCBs) and guidelines are listed in Tables 1 and 1a.

Results from 1997 Monitoring

Table 2 provides sediment chemistry rating, Final Sediment Quality Rating, and comments for each location examined in 1997. Table 3 presents the actual sediment chemistry data which resulted in the sediment chemistry rating for each location.

References

Environmental Protection Agency, 1992. Sediment Classification Methods Compendium. EPA 823-R-92-006, USEPA, Washington, D.C.

Environmental Protection Agency, 1977. "Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments." USEPA, Region V, Chicago.

Table 1

Physical/Chemical Measurements of Sediment, Reservoir Vital Signs Monitoring, 1997

Description, units	Detection Limits (dry weight)	Sediment Quality Guidelines[a]
Metals		
Aluminum, mg/kg	5 mg/kg	--
Arsenic, mg/kg	0.5 mg/kg	15 mg/kg
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/kg	10 mg/kg	--
Chromium, mg/kg	5 mg/kg	75 mg/kg[b]
Copper, mg/kg	1 mg/kg	50 mg/kg[b]
Iron, mg/kg	1 mg/kg	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/kg	1 mg/kg	--
Manganese, mg/kg	0.5 mg/kg	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	1 mg/kg	300 mg/kg
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
α-Endosulfan, µg/kg	10 µg/kg	10 µg/kg
β-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	25 µg/kg	25 µg/kg
PCB-1232, µg/kg	25 µg/kg	25 µg/kg
PCB-1242, µg/kg	25 µg/kg	25 µg/kg
PCB-1248, µg/kg	25 µg/kg	25 µg/kg
PCB-1254, µg/kg	25 µg/kg	25 µg/kg
PCB-1260, µg/kg	25 µg/kg	25 µg/kg
PCB-1016, µg/kg	25 µg/kg	25 µg/kg
PCB's, Total, µg/kg	25 µg/kg	25 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 1a

Analytical Methodology for Vital Signs Sediments, 1997

Parameter	Reference	Method Description	Minimum Detectable Concentration
Pesticides/PCBs:	EPA, SW 846: Methods 3550A & 8080A	CH_2CL_2, Kuderna-Danish/Mercury (KD/Hg), Gas Chromatograph/Electron Capture (GC/EC)	
Pesticides			10 ug/Kg
Toxaphene			500 ug/Kg
PCB's			25 ug/Kg
Metals:	EPA, SW 846: Methods 3050A & 6010A	HNO_3, Inductively Coupled Argon Plasma (ICAP)	
Iron			1 mg/Kg
Manganese			0.5 mg/Kg
Calcium			10 mg/Kg
Magnesium			1 mg/Kg
Copper			1 mg/Kg
Zinc			1 mg/Kg
Aluminum			5 mg/Kg
Nickel			5 mg/Kg
Cadmium			0.5 mg/Kg
Chromium			5 mg/Kg
Lead			5 mg/Kg
Arsenic:	EPA, SW 846: Method 7060A	HNO_3, Atomic Absorption Spectrophotometry (AAS), Heated Graphite Atomizer (HGA)	0.5 mg/Kg
Mercury:	EPA, SW 846: Method 7471A	$HNO_3/KMNO_4$, Cold Vapor (CV)--AAS	0.10 mg/Kg
Residue: (Solids)	EPA, SW 846: Method 3550A	Gravimetry	
Total			0.1 %
Volatile			0.1 %

Reference:

Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW 846, United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC 20460, Third Edition, Updates I, II, and IIA, September 1994.

Table 2

1997 Sediment Ratings -- Vital Signs Reservoir Monitoring

Sediment Quality Rating = 0.5 (SED CHM)

Chemistry
5 - no analytes
3 - 1 or 2 analytes
1 - 3 or more analytes

Toxicity
5 - no toxicity
3 - some toxicity
1 - significant toxicity

No Toxicity Testing in 1997

Reservoir	Mile	Comment	Collection Date yy	mm	dd	# Pest.	# Metals	SED-CHM RATING	SED-TOX RATING	FINAL SEDIMENT QUALITY RATING	COMMENTS (ppb, dry weight)
Kentucky	TRM 23.0		97	7	14	0	0	5		2.5	
	TRM 85.0	Dup-1	97	7	15	0	0	5		2.5	
		Dup-2	97	7	15	0	0	5		2.5	
	Big Sandy 7.4		97	7	15	0	0	5		2.5	
Wheeler	TRM 277.0		97	7	7	0	0	5		2.5	
	TRM 295.9		97	7	7	0	0	5		2.5	
	Elk River 6.0		97	7	7	0	0	5		2.5	
Nickajack	TRM 425.5		97	7	15	1	0	3		1.5	PCB-1260=26
Chickamauga	TRM 472.3		97	7	15	0	1	3		1.5	Cu=62
	TRM 490.5		97	7	15	0	0	5		2.5	
	Hiwassee 8.5		97	7	15	0	0	5		2.5	
Fort Loudoun	TRM 605.5	Dup-1	97	7	21	2	0	3		1.5	PCB-1260=27, Chlordane=16
		Dup-2	97	7	21	2	0	3		1.5	PCB-1260=37, Chlordane=16
	TRM 624.6		97	7	21	2	0	3		1.5	PCB-1260=32, Chlordane=18
Tellico	LTRM 1.0		97	7	21	0	0	5		2.5	
	LTRM 15.0		97	7	21	0	0	5		2.5	
Norris	CRM 80.0		97	7	22	0	2	3		1.5	Arsenic=23, Pb=65
	CRM 125.0		97	7	22	0	0	5		2.5	
	PRM 30.0		97	7	22	0	3	1 (2)		0.5 (1)	Cu=50, Pb=77,Nickel=80
Douglas	FBRM 33/34.5		97	7	23	0	0	5		2.5	
		Precision	97	7	23	0	0	5		2.5	
	FBRM 51.0				23	0	0	5		2.5	
Ft.Pat Henry	SFHR 8.7	Dup-1	97	7	23	1	0	3		1.5	Chlordane=22
		Dup-2	97	7	23	1	0	3		1.5	Chlordane=20

Table 2

1997 Sediment Ratings -- Vital Signs Reservoir Monitoring

Chemistry
5 - no analytes
3 - 1 or 2 analytes
1 - 3 or more analytes

Toxicity	
5 - no toxicity	No Toxicity Testing in 1997
3 - some toxicity	
1 - significant toxicity	

Sediment Quality Rating = 0.5 (SED CHM)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	# Pest.	# Metals	SED-CHM RATING	SED-TOX RATING	FINAL SEDIMENT QUALITY RATING	COMMENTS (ppb, dry weight)
Boone	SFHR 19.0	Dup-1	97	7	24	1	0	3		1.5	Chlordane=22
		Dup-2	97	7	24	1	0	3		1.5	Chlordane=19
	SFHR 27.0		97	7	24	2	0	3		1.5	Chlordane=27
	WRM 6.5		97	7	24	1	2	1 (2)		0.5 (1)	Chlordane=38,Cu=52,Zn=300
Apalachia	HiRM 67.0		97	7	16	0	0	5		2.5	
Nottely	NRM 23.5		97	7	17	0	0	5		2.5	
	NRM 31.0		97	7	17	0	0	5		2.5	
Blue Ridge	ToRM 54.1		97	7	17	0	0	5		2.5	
Ocoee No. 1	ORM 12.5		97	7	16	1	4	0		0.0	PCB-1254=130,Arsenic=33, Cu=1300,Pb=530,Zn=1100
		Precision	97	7	16	1	4	0		0.0	PCB-1254=150,Arsenic=35, Cu=1400,Pb=570,Zn=1200
Bear Creek	BCM 75.0		97	7	8	0	0	5		2.5	
L. Bear Creek	LBCM 12.5	Dup-1	97	7	8	0	0	5		2.5	
		Precision	97	7	8	0	0	5		2.5	
		Dup-2	97	7	8	0	0	5		2.5	
Cedar Creek	CCM 25.2		97	7	8	0	0	5		2.5	

Shaded (Duplicate/Precision) samples were not used to determine the Sediment Quality Ratings

Table 3

1997 Vital Signs Reservoir Monitoring Sediment Data

Metals (mg/kg, dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ALUMINUM	ARSENIC	CADMIUM	CALCIUM	CHROMIUM	COPPER	IRON	LEAD	MAGNESIUM	MANGANESE	MERCURY	NICKEL	ZINC

Kentucky	TRM 23.0		97	7	14	25000	6.8	< 0.5	4000	26	20	39000	14	3100	2700	0.16	24	100
	TRM 85.0	Dup-1	97	7	15	14000	4.8	< 0.5	2900	15	10	21000	< 5.	1900	1600	< 0.10	14	58
		Dup-2	97	7	15	17000	5.3	< 0.5	2800	18	12	23000	< 5.	2200	1800	0.1	14	65
	Big Sandy 7.4		97	7	15	19000	11	< 0.5	1800	16	12	39000	11	1700	3000	< 0.10	15	57
Wheeler	TRM 277.0		97	7	7	27000	9	< 0.5	4200	26	26	40000	22	2500	3100	0.15	28	140
	TRM 295.9		97	7	7	14000	5.2	0.55	2300	18	19	23000	16	2400	1900	0.11	16	96
	Elk River 6.0		97	7	7	20000	5.6	< 0.5	8400	16	12	28000	6.5	2500	2200	< 0.10	20	66
Nickajack	TRM 425.5		97	7	15	25000	7.9	< 0.5	3000	26	38	38000	34	3300	3400	0.31	22	220
Chickamauga	TRM 472.3		97	7	15	32000	9.4	< 0.5	2900	31	62	48000	36	3800	5200	0.43	29	290
	TRM 490.5		97	7	15	24000	6.6	0.7	2800	25	28	36000	24	3200	3200	0.32	23	200
	Hiwassee 8.5		97	7	15	8900	2.9	< 0.5	920	11	24	16000	7	1500	680	0.3	5	240
Fort Loudoun	TRM 605.5	Dup-1	97	7	21	25000	7	< 0.5	4200	27	28	43000	24	3600	2700	0.1	22	210
		Dup-2	97	7	21	22000	7.3	< 0.5	4000	25	26	42000	20	3400	2800	0.14	20	200
	TRM 624.6		97	7	21	19000	5.3	0.5	7000	23	29	38000	30	5100	2400	0.14	18	250
Tellico	LTRM 1.0		97	7	21	25000	8.2	< 0.5	1600	20	20	42000	17	2000	3300	< 0.10	20	94
	LTRM 15.0		97	7	21	26000	7.2	< 0.5	1400	25	23	47000	25	2800	4400	0.12	18	94
Norris	CRM 80.0		97	7	22	22000	23	< 0.5	3800	22	24	42000	65	2200	5700	0.2	26	110
	CRM 125.0		97	7	22	17000	6.1	< 0.5	8600	20	23	36000	22	4000	1300	< 0.10	26	120
	PRM 30.0		97	7	22	22000	8.8	8.8	7700	38	50	36000	77	4400	1500	0.12	80	210
Douglas	FBRM 33/34.5		97	7	23	32000	4.2	< 0.5	2600	35	28	53000	16	4100	860	0.12	25	160
		Precision	97	7	23	30000	4.5	< 0.5	2600	34	28	53000	20	4100	870	0.13	23	150
	FBRM 51.0				23	20000	2	0.6	1800	25	20	28000	16	3600	470	< 0.10	16	140
Ft.Pat Henry	SFHR 8.7	Dup-1	97	7	23	21000	5.8	< 0.5	4700	27	38	36000	18	3900	1600	0.15	20	170
		Dup-2	97	7	23	25000	7.4	< 0.5	4700	30	39	37000	24	4200	1600	0.19	23	190
Boone	SFHR 19.0	Dup-1	97	7	24	37000	9.1	< 0.5	5400	32	34	56000	18	5100	1400	0.15	26	190
		Dup-2	97	7	24	36000	10	< 0.5	6000	34	34	50000	21	4900	1400	0.15	27	200

Table 3

1997 Vital Signs Reservoir Monitoring Sediment Data

Metals (mg/kg, dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ALUMINUM	ARSENIC	CADMIUM	CALCIUM	CHROMIUM	COPPER	IRON	LEAD	MAGNESIUM	MANGANESE	MERCURY	NICKEL	ZINC

	SFHR 27.0		97	7	24	15000	4.9	< 0.5	26000	22	25	28000	32	3800	1100	0.13	18	100
	WRM 6.5		97	7	24	30000	6.3	< 0.5	6200	29	52	43000	29	5800	990	0.17	22	300
Apalachia	HiRM 67.0		97	7	16	61000	5.8	< 0.5	700	34	31	67000	16	3700	1200	0.12	24	120
Nottely	NRM 23.5		97	7	17	55000	3.1	< 0.5	760	30	26	48000	< 5.	2900	510	< 0.10	14	81
	NRM 31.0		97	7	17	50000	2.2	< 0.5	900	35	28	39000	< 5.	4600	450	< 0.10	18	98
Blue Ridge	ToRM 54.1		97	7	17	52000	3.4	< 0.5	400	32	28	60000	14	3300	360	0.1	15	87
Ocoee No. 1	ORM 12.5		97	7	16	58000	33	2	1500	31	1300	96000	530	3400	2500	0.24	20	1100
		Precision	97	7	16	58000	35	1.8	1600	32	1400	100000	570	3600	2600	0.25	22	1200
Bear Creek	BCM 75.0		97	7	8	24000	6.4	< 0.5	1600	24	13	34000	12	2400	1600	< 0.10	21	74
L. Bear Creek	LBCM 12.5	Dup-1	97	7	8	25000	10	< 0.5	2300	32	12	41000	6.5	1800	940	< 0.10	22	110
		Precision	97	7	8	23000	8.8	< 0.5	2200	29	12	36000	11	1600	890	< 0.10	24	96
		Dup-2	97	7	8	13000	6.1	< 0.5	1600	18	8	25000	17	940	700	< 0.10	14	62
Cedar Creek	CCM 25.2		97	7	8	22000	9.2	< 0.5	6100	26	10	37000	< 5.	2100	1500	< 0.10	20	72

Results for Metals Digestion Blank No. 01/97 (97/10613):						< 5.	< 0.5	< 0.5	< 10.	< 5.	< 1.	< 1.	< 5.	< 1.	< 0.5	< 0.10	< 5.	< 1.
Results for Sediment Reference Material (97/10614):																		
	VS-ERA 232-01/97	Reported Values				4845	101.6	92	2005	134	86.5	10500	78.5	1350	215	2.89	105	74.1
		Percent Recovery,%				108	99	103	101	101	98	137	91	114	115	101	110	73
		Certified Values																
		Approx. 95% C.I.																

Table 3

1997 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCBs (ug/kg, dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ALDRIN	Benzene Hexachloride (BHC) ALPHA	BETA	DELTA	GAMMA	CHLORDANE	DIELDRIN	DDT's p,p DDT	p,p DDD	p,p DDE	Endosulfan ALPHA	BETA	SULFATE	ENDRIN
Kentucky	TRM 23.0		97	7	14	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	TRM 85.0	Dup-1	97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Dup-2	97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	Big Sandy 7.4		97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Wheeler	TRM 277.0		97	7	7	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	TRM 295.9		97	7	7	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	Elk River 6.0		97	7	7	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Nickajack	TRM 425.5		97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Chickamauga	TRM 472.3		97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	TRM 490.5		97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	Hiwassee 8.5		97	7	15	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Fort Loudoun	TRM 605.5	Dup-1	97	7	21	< 10.	< 10.	< 10.	< 10.	< 10.	16	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Dup-2	97	7	21	< 10.	< 10.	< 10.	< 10.	< 10.	16	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	TRM 624.6		97	7	21	< 10.	< 10.	< 10.	< 10.	< 10.	18	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Tellico	LTRM 1.0		97	7	21	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	LTRM 15.0		97	7	21	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Norris	CRM 80.0		97	7	22	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	CRM 125.0		97	7	22	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	PRM 30.0		97	7	22	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Douglas	FBRM 33/34.5		97	7	23	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Precision	97	7	23	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	FBRM 51.0				23	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Ft.Pat Henry	SFHR 8.7	Dup-1	97	7	23	< 10.	< 10.	< 10.	< 10.	< 10.	22	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Dup-2	97	7	23	< 10.	< 10.	< 10.	< 10.	< 10.	20	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.

Table 3
1997 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCBs (ug/kg, dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ALDRIN	Benzene Hexachloride (BHC) ALPHA	BETA	DELTA	GAMMA	CHLORDANE	DIELDRIN	DDT's p,p DDT	p,p DDD	p,p DDE	Endosulfan ALPHA	BETA	SULFATE	ENDRIN
Boone	SFHR 19.0	Dup-1	97	7	24	< 10.	< 10.	< 10.	< 10.	< 10.	22	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Dup-2	97	7	24	< 10.	< 10.	< 10.	< 10.	< 10.	19	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	SFHR 27.0		97	7	24	< 10.	< 10.	< 10.	< 10.	< 10.	27	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	WRM 6.5		97	7	24	< 10.	< 10.	< 10.	< 10.	< 10.	38	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Apalachia	HiRM 67.0		97	7	16	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Nottely	NRM 23.5		97	7	17	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
	NRM 31.0		97	7	17	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Blue Ridge	ToRM 54.1		97	7	17	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Ocoee No. 1	ORM 12.5		97	7	16	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Precision	97	7	16	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Bear Creek	BCM 75.0		97	7	8	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
L. Bear Creek	LBCM 12.5	Dup-1	97	7	8	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Precision	97	7	8	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
		Dup-2	97	7	8	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Cedar Creek	CCM 25.2		97	7	8	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Results for Extraction Blank No. 01/97 (97/10612):						< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.	< 10.
Results for Matrix Spikes:																			
VS-BOFB-0797 (97/10657)		Percent Recovery, %									118								
VS-TLFB-0797 (97/10658)		Percent Recovery, %				77	--	--	--	94	--	82	78	--	--	--	--	--	86

Table 3

1997 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCB's (ug/kg dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ENDRIN ALDEHYDE	HEPTACHLOR	HEPTACHLOR EPOXIDE	Polychlorinated Biphenyls (PCB's) 1221	1232	1242	1248	1254	1260	1016	TOTAL	METHOXYCHLOR	TOXAPHENE
Kentucky	TRM 23.0		97	7	14	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	TRM 85.0	Dup-1	97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Dup-2	97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	Big Sandy 7.4		97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Wheeler	TRM 277.0		97	7	7	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	TRM 295.9		97	7	7	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	Elk River 6.0		97	7	7	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Nickajack	TRM 425.5		97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	26	< 25.	26	< 10.	< 500.
Chickamauga	TRM 472.3		97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	TRM 490.5		97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	Hiwassee 8.5		97	7	15	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Fort Loudoun	TRM 605.5	Dup-1	97	7	21	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	27	< 25.	27	< 10.	< 500.
		Dup-2	97	7	21	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	37	< 25.	37	< 10.	< 500.
	TRM 624.6		97	7	21	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	32	< 25.	32	< 10.	< 500.
Tellico	LTRM 1.0		97	7	21	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	LTRM 15.0		97	7	21	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Norris	CRM 80.0		97	7	22	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	CRM 125.0		97	7	22	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	PRM 30.0		97	7	22	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Douglas	FBRM 33/34.5		97	7	23	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Precision	97	7	23	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	FBRM 51.0				23	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Ft.Pat Henry	SFHR 8.7	Dup-1	97	7	23	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Dup-2	97	7	23	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.

Table 3

1997 Vital Signs Reservoir Monitoring Sediment Data

Organochlorine Pesticides and PCB's (ug/kg dry weight)

Reservoir	Mile	Comment	Collection Date yy	mm	dd	ENDRIN ALDEHYDE	HEPTACHLOR	HEPTACHLOR EPOXIDE	PCB's 1221	PCB's 1232	PCB's 1242	PCB's 1248	PCB's 1254	PCB's 1260	PCB's 1016	PCB's TOTAL	METHOXYCHLOR	TOXAPHENE
Boone	SFHR 19.0	Dup-1	97	7	24	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Dup-2	97	7	24	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	SFHR 27.0		97	7	24	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	37	< 25.	37	< 10.	< 500.
	WRM 6.5		97	7	24	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Apalachia	HiRM 67.0		97	7	16	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Nottely	NRM 23.5		97	7	17	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
	NRM 31.0		97	7	17	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Blue Ridge	ToRM 54.1		97	7	17	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Ocoee No. 1	ORM 12.5		97	7	16	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	130	< 25.	< 25.	130	< 10.	< 500.
		Precision	97	7	16	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	150	< 25.	< 25.	150	< 10.	< 500.
Bear Creek	BCM 75.0		97	7	8	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
L. Bear Creek	LBCM 12.5	Dup-1	97	7	8	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Precision	97	7	8	< 10.	< 10.	< 10.	< 25.	< 25.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
		Dup-2	97	7	8	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.
Cedar Creek	CCM 25.2		97	7	8	< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 10.	< 500.

		ENDRIN ALDEHYDE	HEPTACHLOR	HEPTACHLOR EPOXIDE	PCB's 1221	PCB's 1232	PCB's 1242	PCB's 1248	PCB's 1254	PCB's 1260	PCB's 1016	PCB's TOTAL	METHOXYCHLOR	TOXAPHENE
Results for Extraction Blank No. 01/97 (97/10612):		< 10.	< 10.	< 10.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.	< 25.		< 10.	< 500.
Results for Matrix Spikes:														
VS-OCFB-0797 (97/10656)	Percent Recovery, %				--	--	--	--	--	94	--			
VS-TLFB-0797 (97/10658)	Percent Recovery, %	--	101	--									--	--

Section 6. Fish Community

Philosophical Approach/Background

Many of the same considerations discussed for the benthic macroinvertebrate community (Section 5) 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 often has found 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 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., water depth, water level fluctuation, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability, and depth of withdrawal for discharge) 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 expectations for each metric, 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 conditions. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided later 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, i.e., those in the same ecoregion and 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. Fish assemblage expectations for each metric (discussed later) have been developed for each of these four reservoir categories.

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
- Tims Ford

Tributary Reservoirs:
Ridge and Valley Ecoregion

- Cherokee
- Fort Patrick Henry
- Boone
- South Holston
- Norris
- Douglas

Tributary Reservoirs:
Blue Ridge Ecoregion

- Fontana
- Apalachia
- 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 through November 1997). Only one or two zones were sampled on reservoirs where zones were indistinguishable. Location of collection sites in 1997 are identified in Section 1, 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 12.7 cm) 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. Field data loggers were used to record all sampling results.

Reservoir Fish Assemblage Index (RFAI)

The 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 (i.e., expectations or reference 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. One way to help alleviate this problem is to use several years of results from reservoirs within a class. This not only helps establish baseline conditions for each reservoir, but also has the desirable effect of increasing the data base from which scoring criteria can be developed. However, care must be taken to keep this time period as short as possible; otherwise, constantly changing criteria will prevent recognition of improvements or degradation, if they occur. This potential problem was realized as this monitoring program was being conceived. As a result, it was decided that the maximum desired period to establish baseline conditions and provide the data base to develop scoring criteria would be five years, assuming variations of low, normal, and high flows were experienced in that time frame. This proved to be the case. In practice, scoring criteria for RAFI metrics were reevaluated each year from 1990 through 1994 as new data were added. Scoring criteria have not been adjusted since 1994.

In developing scoring criteria, 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 1.

Scoring criteria are used to separate results for each metric into three categories assumed to represent relative degrees of condition of the fish assemblage ranging from good to poor. Each category has a corresponding value: good = 5; fair = 3; and poor = 1. The sum of the 12 metrics constitutes the RFAI score.

Scoring criteria were applied differently to results from the two collections methods (electrofishing and experimental gill netting) depending on the type metric. For the taxa richness, reproductive composition, and fish health metrics, 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.

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

Fish assemblage results along with results from the other four indicators and overall the ecological health score for each reservoir are used to keep the public informed on the conditions of Tennessee Valley reservoirs. In publications intended for the public, 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	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1997 Monitoring

RFAI scores for 1990 through 1997 are summarized by reservoir class and type of location in Table 2. (Note: 10 electrofishing runs were used in 1990 - 1992 and 15 were used in 1993 - 1997.) Appendix D summarizes results and ratings for individual metrics and final RFAI scores for each sample location based on 1997 data. Appendix E provides mean catch per effort by species for electrofishing and gill netting efforts at each location in 1997.

Slightly less than 20 percent of the locations (6 randomly selected sites) were revisited for Quality Control purposes. These 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 QC sample set was 10. A difference greater than this could cause the RAFI to change two categories (e.g., very poor-1 point to fair-3 points or fair-3 points to good-5 points). A shift of two categories in the RFAI could cause a change of 2 points contributed to the overall Reservoir Ecological Health Score. For reservoirs with only one sample location, a 2 point change translates into a change of 8.8 percent change in the Ecological Health Score, which was deemed unacceptable.

Scores Derived from Repeat (QC) Sampling Compared to Scores from the Initial Sampling in 1997.

Run-of-the-River Reservoirs[a]	Initial Score	QC Score	Difference
Ft. Loudoun Forebay	42 (Good)	39 (Fair)	3
Kentucky Transition Zone	44 (Good)	44 (Good)	0
Kentucky Inflow	38 (Fair)	52 Excellent)	14
Tributary Reservoirs			
Blue Ridge Ecoregion			
Nottely Mid-reservoir	43 (Good)	43 (Good)	0
Ridge and Valley Ecoregion			
Boone Forebay	32 (Fair)	35 (Fair)	3
Interior Plateau Ecoregion			
Little Bear Forebay	52 (Excellent)	46 (Good)	6

The maximum observed difference in RAFI scores between the original and repeat collection efforts was 14 (1 sample set). Otherwise, the remaining 5 sample sets were well under the desired maximum of 10. The mean difference for all reservoirs and associated 95 percent confidence limits were 4.3 $\pm$5.5 (-1.2 - 9.8). The difference in scores between the original and repeat sample sets was greater in 1997 than in 1994, 1995. Mean differences in 1997 were similar to those found in 1996, although variability was greater in 1997 resulting in broader confidence limits:

Year	Maximum Observed Difference	Mean	95% CL	Lower Limit	Upper Limit
1994	10	2.6	± 1.8	0.8	4.3
1995	6	3.1	± 1.9	1.2	5.0
1996	12	4.4	± 3.5	0.8	8.0
1997	14	4.3	± 5.5	-1.2	9.8

Scores from the two sample sets from each QC location in 1997 were tested using a t-test for paired comparisons at $\alpha = 0.05$ with the null hypothesis that the mean difference between each pair of scores did not exceed 0. The test failed to detect a significant difference (Table 4).

Despite the slightly increased variation in paired RAFI scores in 1997, these results indicate acceptable reproducibility for fish assemblage sampling.

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