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Tennessee Valley Authority

Water Management

AQUATIC ECOLOGICAL HEALTH DETERMINATIONS FOR TVA RESERVOIRS--1994

An Informal Summary of 1994 Vital Signs Monitoring Results
and Ecological Health Determination Methods

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Section 1. Reservoir Monitoring -- Overview of Approach, Methods, and 1994 Results

Introduction

The Tennessee Valley Authority (TVA) began its Stream Monitoring Program in 1986 to evaluate major tributaries of the Tennessee River. A parallel program, Reservoir Monitoring, was begun in 1990. The combined Stream and Reservoir Monitoring efforts consolidated these newly-developed activities with existing activities to form an integrated program that is part of TVA's comprehensive Clean Water Initiative.

Objectives of TVA's monitoring efforts are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee River tributaries and reservoirs and to provide screening level information for describing how well these water resources meet the "fishable" and "swimmable" goals of the Clean Water Act. Vital Signs monitoring activities provide the necessary information from key physical, chemical, and biological indicators to evaluate the ecological health of each stream or reservoir and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions. Periodic monitoring of toxic contaminants in fish and bacteriological sampling at recreation areas provides information for evaluating whether Tennessee Valley waters are fishable and swimmable.

This paper focuses on how TVA performs the overall ecological health rating for reservoirs. It summarizes 1994 data as an example of the mechanics and index values resulting from the rating system.

Study Design Considerations

Several fundamental premises or assumptions were formulated to aid the study design process. These included:

1. Ecological health evaluations must be based on information on physical, chemical, and biological components of the ecosystem;

2. Monitoring program design must be considered dynamic and flexible, rather than rigid and static, and must allow adoption of new environmental monitoring techniques as they develop to meet specific needs;

3. Monitoring methods must provide current, useful information to resource managers;

4. Monitoring must be sustained for several years to document the status of the river/reservoir system, determine its year-to-year variability, and track results of water quality improvement efforts; and

5. Addressing specific cause/effect mechanisms is not the primary purpose of monitoring. While monitoring may provide information to identify cause/effect relationships, more detailed assessment investigations usually are required.

With these premises in mind, TVA's challenge has been to develop a sustainable monitoring effort that collects the right kinds of physical, chemical, and biological data to provide enough information to reliably characterize ecological health. Study design must carefully consider selection of important ecological indicators, representative sampling locations, and frequency of sampling, all in light of available resources. Following are some the basic study design decisions TVA made in developing this program. The four main activities of the program focus on (1)physical/chemical characteristics of water; (2)acute toxicity and physical/chemical characteristics of sediment; (3)benthic macroinvertebrate community sampling; and (4) fish assemblage sampling.

Ecological Indicators-- Physical, chemical, and biological indicators were selected to provide information from various habitats or ecological compartments on the health of that particular habitat or compartment. For example, in reservoirs the open water or pelagic area was represented by physical and chemical characteristics of water (including chlorophyll) in midchannel. The shoreline or littoral area was evaluated by sampling the fish community. The bottom or benthic compartment was evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments and acute toxicity testing of pore water); and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

Sampling Locations--Three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam. Overbanks, basically the floodplain which was inundated when the dam was built, were included in transition zone and forebay areas. Another important reservoir area, embayments, also was considered. Previous studies (Meinert, Butkus, and McDonough, 1992) have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with little influence from the main body of the reservoir. Although these are important areas, monitoring the ecological health of hundreds of embayments is beyond the scope of this program. As a result, only four, large

embayments (all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres) were included in the Vital Signs Monitoring Program.

Sampling Frequency--Sampling frequencies (indexing periods) must consider the expected temporal variation for each indicator. Physical and chemical components vary significantly in the short term so they are monitored monthly from spring to fall. Biological indicators better integrate long-term variations and are sampled once each year. Fish assemblage sampling is conducted in autumn (September-November). From 1990 through 1994 benthic macroinvertebrate sampling was conducted in early spring (February-April) to avoid aquatic insect emergence. Beginning in 1995, sampling will be conducted in late autumn/early winter (November and December). The problem with spring sampling is that results are reflective of conditions from the previous year. This caused evaluations for this indicator to be out of synch with those from the other indicators. This change is more thoroughly discussed in Section 4 "Benthic Macroinvertebrate Community."

Data Evaluation Considerations

Selection of data evaluation techniques is also of primary importance in study design considerations. Like most evaluations, results for ecological integrity studies must be compared to some reference or yard stick to determine if monitoring results are indicative of good, fair, or poor conditions. In streams this is usually accomplished by studying a site that has had little or preferably no alterations due to human activities. Observations at that site provide the reference conditions or expectations of what represents a site with good/excellent ecological health. Given that reservoirs are not natural systems, this approach is not possible. Developing reference conditions for reservoirs represents a more difficult task and requires special attention. Tied closely to development of reference conditions is the issue of classification--grouping only those waterbodies which are expected to have similar characteristics and thus correctly allow an "apples to apples" comparison. In streams, important considerations include comparable stream size, gradient, ecoregion, etc. Similar considerations apply to reservoirs but the list is longer because reservoirs are managed or controlled systems and those objectives must be taken into consideration.

Reference Conditions--It is not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to determine characteristics or expectations of a "natural" reservoir because reservoirs are manmade systems. Other approaches must be used such as: historical or preimpoundment conditions, predictive models,

best observed conditions, or professional judgment. Preimpoundment conditions are inappropriate because of significant habitat alterations. For the most part, models are of limited value for a large variety of indicators because of such great spatial and temporal variations within and between reservoirs. Spatial variation exists within in the multiple zones (e.g., forebay, transition zone, inflow, and embayments) of a reservoir. Further, each zone responds differently to different stimuli. Temporal variations are introduced because reservoirs are controlled systems with planned annual drawdowns in elevations ranging from only a few feet to several hundred feet. This leaves best observed conditions or professional judgment as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment is the best approach. Use of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

Reservoir Classification -- Implications of reservoir classification issues to environmental indicator evaluation had to be considered in developing the study design. This was accomplished by examining the following fundamental question separately for each indicator--Should reservoir ecological health evaluations be based on:

(1) ideal conditions (for example, a very low DO concentration is an unacceptable ecological condition); or

(2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir (for example, very low DO concentrations are acceptable in many tributary reservoirs because of water management practices, withdrawal schemes, stratification, etc.)?

The answer to this question was the same for some indicators but differed for others. For DO and Sediment Quality, ideal conditions should be expected. That is, poor DO is unacceptable regardless of type of reservoir or dam operation. Sediments should not have high concentrations of metals, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota. In this situation, there is no need for classification because the same conditions are desired for all reservoirs. For chlorophyll, benthos, and fish the latter approach was used. As such, reservoirs must be grouped or stratified because the same conditions do not exist for all reservoirs. The classification scheme that has evolved for chlorophyll is actually a combination of the two approaches--examination of the "natural" nutrient level in the watershed and then a conceptual/subjective decision made as to the concentrations indicative of good, fair, and poor conditions. Two classes of reservoirs were developed -- reservoirs in watersheds draining nutrient poor soils, primarily those in the Blue Ridge Ecoregion (i.e., expected oligotrophic reservoirs); and reservoirs in watersheds draining soils which are not nutrient poor (i.e., expected mesotrophic reservoirs).

For the benthic macroinvertebrate and fish communities, reservoirs were divided into four classes. The reservoirs on the Tennessee River plus two navigable reservoirs on tributaries to the Tennessee River. This group of reservoirs has relatively short retention times and little winter drawdown. The remaining tributary reservoirs were separated by ecoregion into three classes: those in the Blue Ridge Ecoregion, those in the Ridge and Valley Ecoregion, and those on the Interior Plateau Ecoregion.

Reservoir classification issues are further discussed in subsequent sections as they apply to specific environmental indicators.

Ecological Health Rating Methods

There are no official or universally accepted guidelines or criteria upon which to base an evaluation of the health or integrity of the aquatic ecosystem within reservoirs. Consequently, an evaluation methodology had to be developed to assess overall ecological health or condition of reservoirs included in TVA's Vital Signs program. The ecological health evaluation system combines both biological and physical/chemical information to examine reservoir and stream health. Five aquatic ecosystem indicators are used -- dissolved oxygen, chlorophyll-a, sediment quality, benthic macroinvertebrates, and fish community.

Detailed descriptions of scoring criteria for each environmental indicator are provided in other sections. A brief overview is provided here to assist in understanding how individual ratings contribute to the overall ecological health score for a reservoir. Dissolved oxygen scoring criteria attempt a multidimensional approach that includes considering dissolved oxygen levels both in the water column and near the bottom of the reservoir. The DO scoring criteria necessarily are complicated because of the combined effects of flow regulation and the potential for oxygen depletion in the hypolimnion.

Chlorophyll scoring criteria were developed separately for each of the two classes of reservoirs based on geologic and soil characteristics and professional experience with reservoirs in the TVA region. Reservoirs expected to be oligotrophic received highest ratings at low chlorophyll concentrations. Reservoirs expected to be mesotrophic received highest ratings for a range of concentrations. Experience has shown that below a threshold level of chlorophyll (about 2-3 ug/l), primary production may be insufficient to support an active, biologically healthy food chain. In addition, chlorophyll concentrations above a higher threshold (about 10 ug/l) result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment.

The sediment quality scoring criteria uses a combination of two characteristics: sediment toxicity to test organisms; and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs.

For the benthic macroinvertebrate and fish community indicators, scoring criteria were developed from the existing data base on TVA reservoirs. Appropriate community characteristics or metrics were selected for each community (8 metrics for benthic macroinvertebrates and 12 metrics for fish). Data for each metric/community characteristic (e.g., number of taxa, abundance, etc.) were ranked and divided into good, fair, and poor groupings. Data for the current year of monitoring (e.g., 1994) were then compared to these criteria and scored accordingly. Scores for each metric were then summed to obtain a score for that community. This approach is valid if the data base is sufficiently large and if it can be safely assumed that the data base covers the full spectrum of good to poor conditions.

The first step in determining an overall reservoir health score is to sum the ratings for all indicators (ranging from 1-poor to 5-excellent) at a sample site. The number of indicators monitored at each site varies. Generally, all five indicators are included; however, this is not always the case. For example, chlorophyll and sediment quality are not monitored at the inflows on run-of-the-river reservoirs because <u>in situ</u> plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. The number of sites per reservoir also varies from one (the forebay) in small tributary reservoirs to four (forebay, transition zone, inflow, and embayment) in

selected run-of-the-river reservoirs. As a result, the number of individual ratings vary from five to 18 for the 30 reservoirs monitored in 1994. Specific information on what indicators were sampled in each reservoir is in Table 1.

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum potential ratings for that reservoir, and expressed as a percentage. For example, a small reservoir with only one sample site, the minimum health evaluation would be 20 percent (all five indicators rated poor-1 for a total score of 5 divided by the maximum possible total of 25) and the maximum would be 100 percent (all five indicators rated good-5). This same range of 20 to 100 percent applies to all reservoirs regardless of the number of sample sites, and the same calculation process is used.

The next step is to divide the 20-100 percent scoring range into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results are plotted and examined for apparent groupings.
2. Groupings are compared to known, a priori conditions (focusing on reservoirs with known poor conditions), and good-fair and fair-poor boundaries were established subjectively.
3. The groupings are compared to a trisection of the overall scoring range. A scoring range is adjusted up or down a few percentage points to ensure a reservoir with known conditions falls within the appropriate category. This is done only in circumstances where a nominal adjustment is necessary.

These methods have been in use for four years. Each year slight modifications are made in the original evaluation process and the numerical scoring criteria for each of the five ecological health indicators based on experience gained from working with this process, review of the evaluation scheme by other state and federal professionals, and results of another year of monitoring,

As a result, scoring ranges have changed slightly over the years as outlined below

	Run-of-the-river reservoirs			Tributary, storage reservoirs		
	Poor	Fair	Good	Poor	Fair	Good
1991	<53	53-72	>72	<57	57-72	>72
1992	<53	53-72	>72	<57	57-72	>72
1993	<52	52-71	>71	<57	57-71	>71
1994	<52	52-72	>72	<57	57-72	>72

The difference in the poor scoring range between the two types of reservoirs is due to the fact that two storage reservoirs with known poor conditions rated slightly higher than the boundary for the

lower (poor) grouping on the run-of-the-river reservoirs. Hence, the high end of the lower scoring range for storage reservoirs was shifted upward from 52 to 56 percent to accommodate these reservoirs with known poor conditions.

An example that illustrates the overall reservoir health evaluation methodology is presented in Table 2. Wilson Reservoir, the example used, has five aquatic health indicators at one location and three indicators at another location.

Ecological Health Ratings--1994 Results

Experience has shown rainfall and runoff have a significant impact on the ecological conditions in TVA reservoirs. Both were above the long-term average for the Tennessee Valley in 1994 (Figures 1 and 2, respectively). Figure 3 shows the relative contribution of each of the major tributary rivers to flow rates in Tennessee River reservoirs.

Physical and operational characteristics of reservoirs and the dams that control them are also important in evaluating ecological condition. Table 3 summarizes a number of attributes of the reservoirs included in the Vital Signs Monitoring program.

A brief summary of Vital Signs Monitoring results for each reservoir in 1994 is provided in Appendix A. Differences between 1994 and 1993 results are discussed and explained to the extent possible. Appendix A also includes ecological health scores for all years for which Vital Signs Monitoring data exist. Scores are provided as reported (calculated based on the methods in use at that time) and based on the 1994 scoring methods. These scores are also listed for each reservoir in Table 4.

The ecological score for each reservoir in 1994 is presented by classification unit in Figure 4. Run-of-river reservoirs clearly scored higher than any other class. Six fell in the "good" category, four in the upper end of the "fair" range, one in the middle of the "fair" range, and none "poor". For the tributary reservoirs, scores tended to be higher for reservoirs in the Blue Ridge Ecoregion--two were "good", three "fair", and one "poor". Tributary reservoirs in the Ridge and Valley Ecoregion had no "good" scores--six were in the "fair" range and one in the "poor" range. One reservoir in the Interior Plateau Ecoregion was "good", three "fair", and two "poor".

The relative contribution of each environmental indicator to the overall score in 1994 for a reservoir is given for the run-of-river reservoirs in Figure 5 and for tributary reservoirs in Figure 6. Low ratings for certain indicators are obvious. In the run-of-river reservoirs low ratings for the benthic macroinvertebrate community are obvious for Ft. Loudoun, Melton Hill, and Tellico Reservoirs. Low rating for DO are apparent for several tributary reservoirs, especially those in the Interior Plateau

Ecoregion. Minimal DO ratings (i.e., a rating of 1 for all sample locations) occurred in Norris and Cherokee Reservoirs in the Ridge and Valley Ecoregion and for all six reservoirs in the Interior Plateau Ecoregion. None of the reservoirs in the Blue Ridge Ecoregion had minimal DO ratings. Probably low primary productivity rates due to naturally low nutrient levels account for better DO conditions in the latter group of reservoirs. As would be expected based on this line of logic, the reservoir with the highest chlorophyll concentrations among reservoirs in the Blue Ridge Ecoregion (Nottely Reservoir) had the poorest DO conditions.

Figures 7 - 11 further examine the influence of each environmental indicator on overall reservoir scores. Each figure plots the overall reservoir score based on all five indicators and the score with one indicator deleted. These scores were also tested with a Paired T-test to quantitatively test for differences between overall scores based on all five indicators and scores with one indicator deleted. Tests were conducted separately for each ecoregion. Test results should be used only as an indication of possible statistical significance because these are proportional ratings, not actual data, and because no transformation was used prior to testing. Results are summarized below and on Figures 7-11:

	Mean Difference In Reservoir Scores With All Five Indicators Vs Score With One Deleted			
Indicator Deleted	Run-of-River Reservoirs	Ridge and Valley Reservoirs	Blue Ridge Reservoirs	Interior Plateau Reservoirs
DO	-4.3***	4.1	-1.6	10.9***
Chlorophyll	0.6	-1.1	-4.5*	-4.9*
Sediment Qual.	-1.5**	-4.6**	1.1	-4.5*
Benthic Macro.	3.7*	3.6**	6.6***	0.9
Fish	1.3	-1.3	-1.6	-2.4

* Significant at $\alpha = 0.1$; ** Significant at $\alpha = 0.05$; *** Significant at $\alpha = 0.01$

Figure 7 plots these total scores on 1994 data with DO deleted. The previously discussed influence of DO on overall scores for reservoirs in the Interior Plateau Ecoregion is readily apparent. Scores for all six reservoirs in that ecoregion would be almost 10 percentage points higher if DO were excluded. The opposite is the case for the Run-of-River reservoirs -- most reservoir scores would decrease slightly. Scores for most tributary reservoirs in the Ridge and Valley Ecoregion would be higher if DO were excluded. It is not possible to fully explain the consistency of very poor DO conditions in the Interior Plateau tributary reservoirs. One important consideration is that 5 of the 6 reservoirs are water storage

projects; only Tims Ford has hydroelectric generators. This affects water retention time and withdrawal depth, both have significant implications to DO conditions.

Figure 8 plots total scores with Chlorophyll deleted. Trends are not obvious. This is possibly due to the importance of localized conditions of land use and nutrient enrichment on individual reservoirs over riding natural regional conditions.

Figure 9 plots scores with Sediment Quality deleted. A listing of these changes is in Table 5. It is important to consider implications of these changes because plans at the time this text was prepared were to exclude Sediment Quality testing in 1995 due to budget constraints. Although small in most cases, scores for 23 of the 30 reservoirs monitored would be lower if Sediment Quality were excluded. Six of these 23 would decrease by 5 or more percentage points. The greatest decrease (11%) would be for Beech Reservoir which had mostly poor or fair ratings, so excluding sediments would cause the score to drop substantially. Only four reservoirs would have a higher score if Sediment Quality were excluded. Two of these (Parksvile and Fontana) would decrease by 5 or more percentage point. Parksville would have the greatest improvement (+15%). Sediment Quality problems there include very high concentrations of several metals, high concentrations of PCBs, and toxicity to test animals. Problems in Fontana Reservoir were high chlordane and toxicity.

Figure 10 plots total reservoir scores with Benthic Macroinvertebrates deleted. Tributary reservoirs in the Blue Ridge and Ridge and Valley Ecoregions, as well as the upper most Run-of-River reservoirs, would have mostly higher scores if benthos were excluded. Benthos ratings were mostly low in these reservoirs, so excluding them would result in a higher overall score. There is no obvious reason for this trend. There is a great variety of reservoir depths, substrate types, drawdown depths, and dam management strategies among these reservoirs.

Figure 11 plots overall scores with and without Fish ratings. Few substantial differences are apparent.

References

Meinert, DL., S.R. Buttus, and T.A. McDonough. 1992. Chickamauga Reservoir Embayment Study - 1990. TVA/WR-92/28

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

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

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

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

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

Table 2 Computational Method For Evaluation of Reservoir Health

Wilson Reservoir - 1994 (Run-of-the-river reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:		No Samples	Tailrace DOs	3.5 (fair)	No Rating	5 (good)
Less Than 2 mg/L (Summer Avg.)						
% of X-Sectional Area	0.4 (5)	-	-			
% of X-Sectional Bottom Length	10.7 (2)*	-	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m Yes/No	No	-	No			
Chlorophyll-a, µg/L:		No Samples	No Samples	3 (fair)	No Rating	No Rating
Summertime Average	13.5	-	-			
Maximum Concentration	30.0	-	-			
Sediment Quality:		No Samples	No Samples	3.0 (fair)	No Rating	No Rating
Toxicity	Rating = 1					
Ceriodaphnia Survival	Yes-0% sur.	-	-			
Rotifer Survival	Yes-30% sur.	-	-			
Chemistry	Rating = 5					
Metals/NH3/pesticides	None	-	-			
Benthic Community:		No Samples		2 (poor)	No Rating	5 (excellent)
Dominance	1		5			
Tubificidae	5		3			
Chironomidae	1		5			
EPT	1		3			
Long-lived	1		5			
Taxa richness	1		5			
Zero in sample	5		5			
Non-tolerant density	1		3			
Total	20	-	34			
Fish Community:		No Samples		4 (good)	No Rating	3 (fair)
RFAI	45		40			
Rating	4		3			
		-				
		Sampling Location Sum		15.5 of 25	--	13 of 15
		Reservoir Sum		28.5 of 40 [71%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

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

Table 3

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1994[a] (days)	Average CY 1994 Reservoir Flow (cfs)
				Run-of-the-River Reservoirs					
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	16.6	86,463
Pickwick	32,820	52.7	43.1	84	924	6	54,900	5.9	79,148
Wilson	30,750	15.5	15.5	108	634	3	51,500	4.2	76,182
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	7.3	72,927
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	8.3	61,766
Nickajack	21,870	46.3	10.4	60	241	0	35,900	2.3	52,487
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	6.2	50,663
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	12.6	40,393
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	6.5	28,147
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	8.1	7,451
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	24.2	8,638[d]
				Tributary River Reservoirs					
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	165.6	6,211
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	78.8	9,009
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	117.9	6,335
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	4.3	3,189
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	30.2	3,151
South Holston	703	23.7	7.6	239	658	33	976	264.1	1,256
Watauga	468	16.3	6.4	274	569	26	714	345.2	831
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	130.0	5,509
Hiwassee	968	22.2	6.1	255	422	45	2,020	74.5	2,855
Chatuge	189	13.0	7.0	124	234	10	459	217.7	542
Nottely	214	20.2	4.2	167	170	24	416	183.1	468
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	26.9	1,592
Blue Ridge	232	11.0	3.3	156	193	36	614	171.0	569
Tims Ford	529	34.2	10.6	143	530	12	940	194.1	1,377
Bear Creek	232	16.0	0.7	74	10	11[e]	380	9.8	513
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	121.8	389
Little Bear Creek	61	7.1	1.6	82	45	12[e]	101	170.6	133
Normandy	195	17.0	3.2	83	110	11	320	116.3	477
Beech	16	5.3	0.9	32	11	1[e]	14	--	--

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a. Estimates based on normal maximum summer pool.
b. ***Tennessee River and Reservoir System Operation and Planning Review,*** Final EIS, TVA/RDG/EQS--91/1, 1990.
c. Major/minor arms of reservoir.
d. Estimated flow based on releases from Chilhowee Dam (POR avg.= 4770cfs), and adjusted based on the additional drainage area between Chilhowee Dam (1977 sq miles) and Tellico Dam (2627 sq miles).
e. Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

Data Source: Hydrologic Data Management (Knoxville, TN), Systems Engineering, TVA, 1994.

(vs-rea94.tbl)

Table 4. Reservoir Ecological Health Scores 1991 - 1994

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

Table 4. cont. Reservoir Ecological Health Score 1991 - 1994

Watershed/	Area	Eco Health Rating, as reported				Eco Health on 1994 Criteria				Three-yr
Reservoir	(Acres)	1991	1992	1993	1994	1991	1992	1993	1994	Average
Watts Bar/Ft. Loud./Mel. Hill										
Watts Bar Reservoir	39,000	69	71	68	79	71	76	74	79	76
Fort Loudoun Reservoir	14600	60	53	58	61	63	59	60	61	60
Melton Hill Reserovir	5700	80	67	68	72	72	66	69	72	69
Clinch/Powell Watershed										
Norris Reservoir	34200	57	67	67	69	73	76	71	69	72
L' Tenn. River Watershed										
Tellico Reservoir	15,900	48	48	63	71	54	48	57	71	59
Fontana Reservoir	10,600	N/A	N/A	64	67	N/A	N/A	71	67	69
French Broad River WS										
Douglas Reservoir	30,400	42	56	58	64	60	52	58	64	58
Holston River Watershed										
Cherokee Reservoir	30300	50	53	64	53	62	60	64	53	59
Fort Pat. Henry Res.	900	N/A	N/A	72	60	N/A	N/A	80	60	70
Boone Reservior	4300	51	64	59	59	52	63	61	59	61
South Holston Res.	7600	60	57	65	66	63	63	69	66	66
Watauga Reservor	6,400	80	57	61	65	77	72	63	65	67

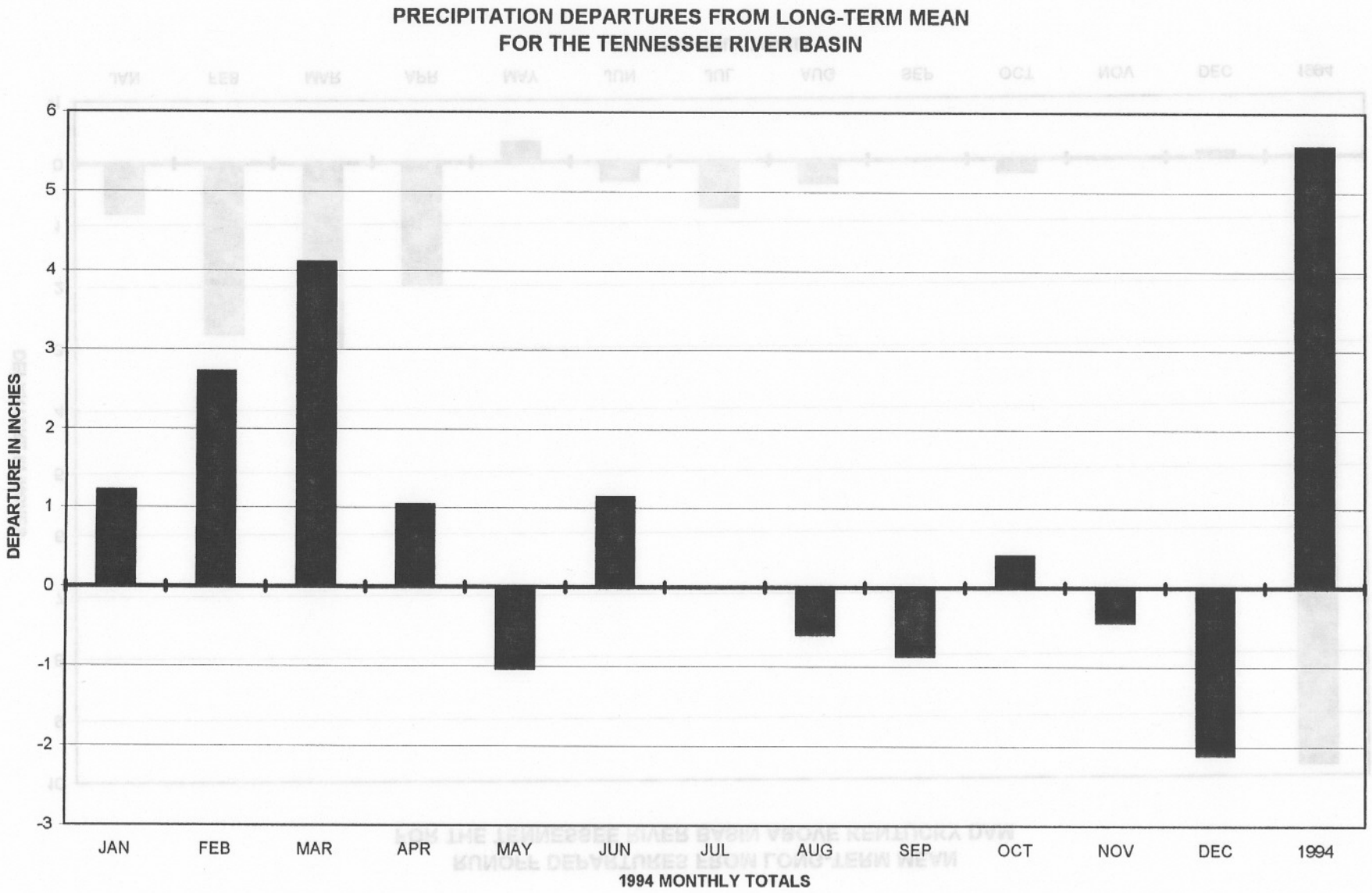
Table 5. Reservoir Ecological Health Scores for 1994--With and Without Sediment Quality

Reservoir	1994 Rating/Score	1994 Rating/Score Without Sediment	Difference
Kentucky	Fair - 71	Fair - 69	-2 pts
Pickwick	Good - 84	Good - 81	-3 pts
Wilson	Fair - 71	Good - 73	+2 pts
Wheeler	Good - 75	Good - 73	-2 pts
Guntersville	Good - 83	Good - 82	-1 pt
Nickajack	Good - 90	Good - 89	-1 pt
Chickamauga	Good - 87	Good - 87	0
Watts Bar	Good - 79	Good - 79	0
Fort Loudoun	Fair - 61	Fair - 57	-4 pts
Melton Hill	Fair - 72	Fair - 68	-4 pts
Tellico	Fair - 71	Fair - 71	0
Norris	Fair - 69	Fair - 65	-4 pts
Douglas	Fair - 64	Fair - 63	-1 pt
Cherokee	Poor - 53	Poor - 43	-10 pts
Fort Patrick Henry	Fair - 60	Poor - 55	-5 pts
Boone	Fair - 59	Fair - 58	-1 pt
South Holston	Fair - 66	Fair - 58	-8 pts
Watauga	Fair - 65	Fair - 64	-1 pt
Fontana	Fair - 67	Good - 75	+8 pts
Hiwassee	Fair - 68	Fair - 60	-8 pts
Chatuge	Good - 77	Good - 76	-1 pt
Nottely	Poor - 56	Poor - 53	-3 pts

Table 5. Cont.'

Reservoir	1994 Rating/Score	1994 Rating/Score Without Sediment	Difference
Blue Ridge	Good - 86	Good - 83	-3 pts
Parksville	Fair - 60	Good - 75	+15 pts
Tims Ford	Fair - 58	Poor - 55	-3 pts
Normandy	Fair - 68	Fair - 60	-8 pts
Bear Creek	Poor - 56	Poor - 55	-1 pt
Little Bear	Fair - 64	Fair - 65	+1 pt
Cedar Creek	Good - 80	Good - 75	-5 pts
Beech	Poor - 56	Poor - 45	-11 pts

FIGURE 1



RAIN_RUN.XLS,Chart17

Prepared by Edward A. Thornton 1/23/95

FIGURE 2

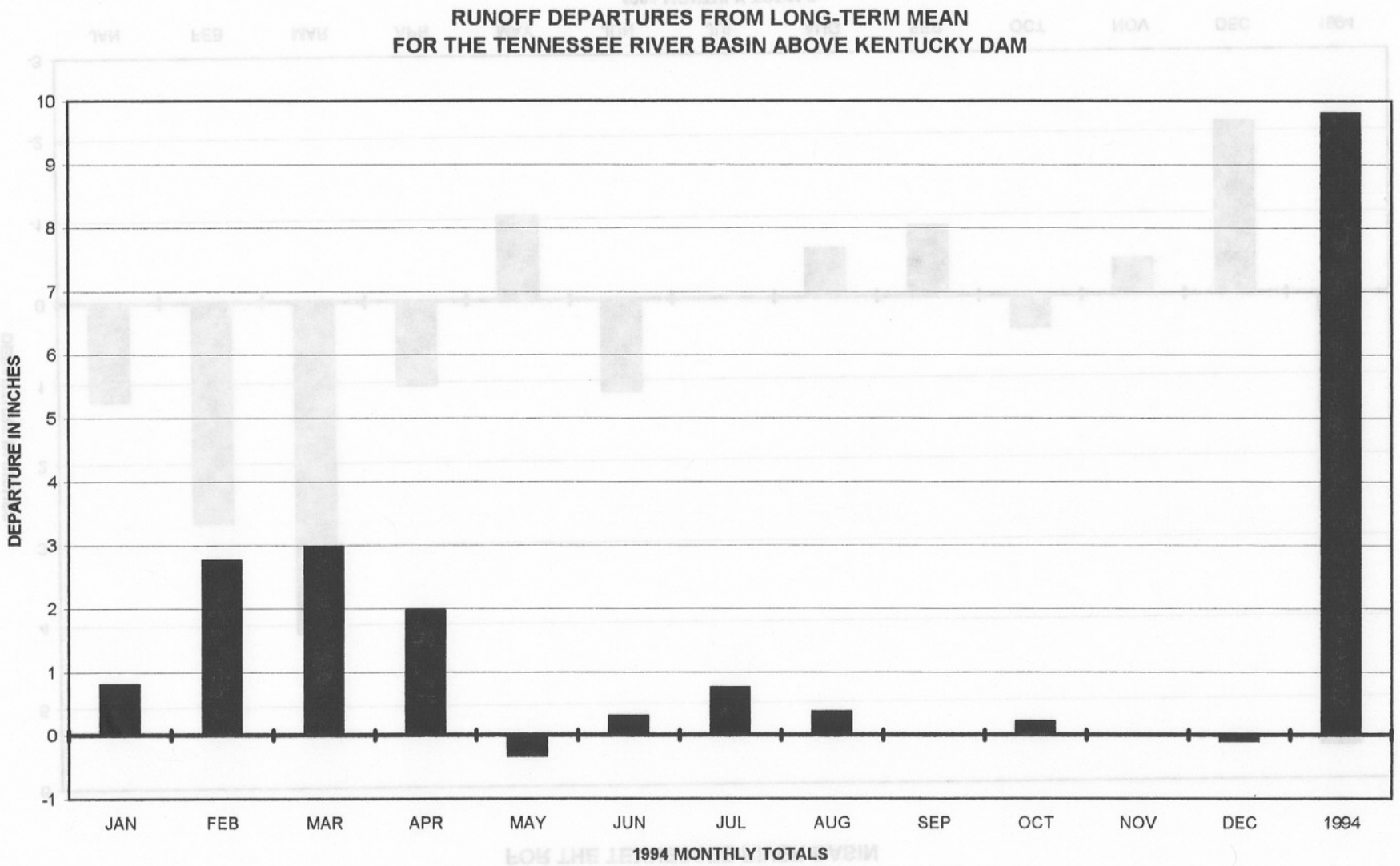

RUNOFF DEPARTURES FROM LONG-TERM MEAN
FOR THE TENNESSEE RIVER BASIN ABOVE KENTUCKY DAM
DEPARTURE IN INCHES
10
9
8
7
6
5
4
3
2
1
0
-1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1994
1994 MONTHLY TOTALS

Figure 3. Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

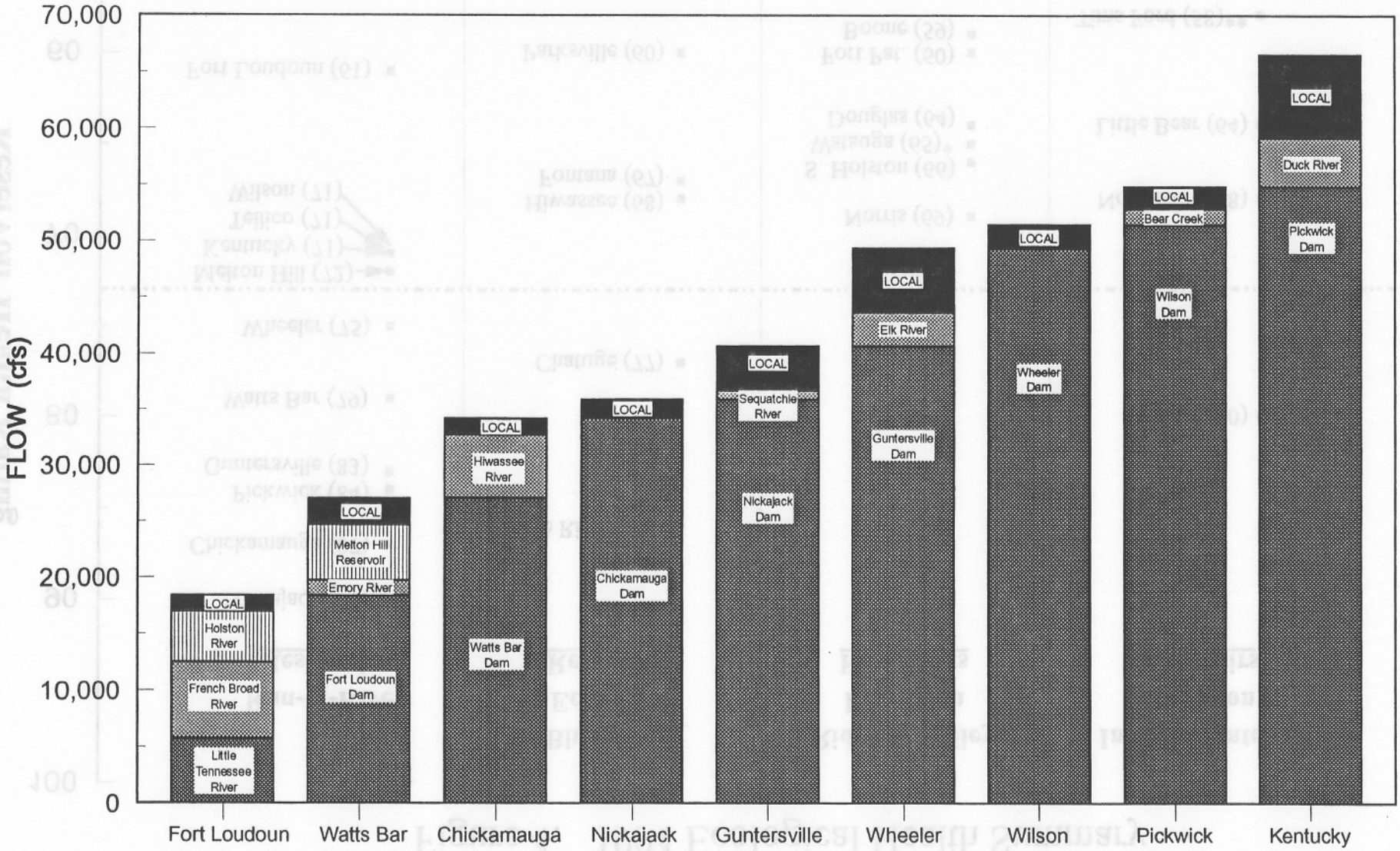
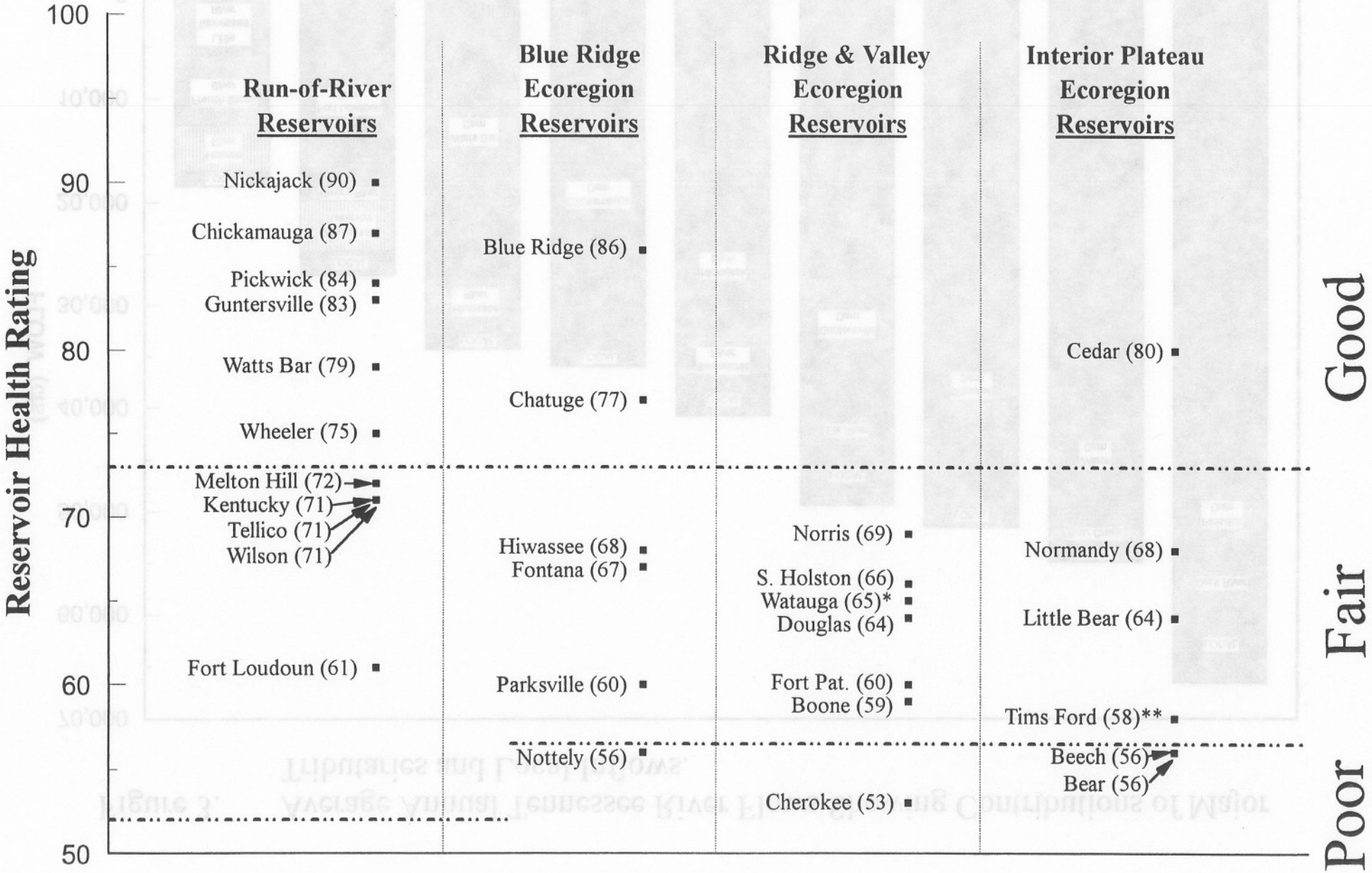


Figure 4. 1994 Ecological Health Summary



* Benthos & Fish compared to Blue Ridge Ecoregion resrevoirs although Watauga physically within Ridge & Valley Ecoregion.

** Benthos & Fish compared to Ridge & Valley Ecoregion reservoirs although Tims Ford pl[illegible]ly within Interior Plateau Ecoregion.

Figure 5. Overall Ecological Health of Run-of-the-River Reservoirs in the Tennessee Valley in 1994. (Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

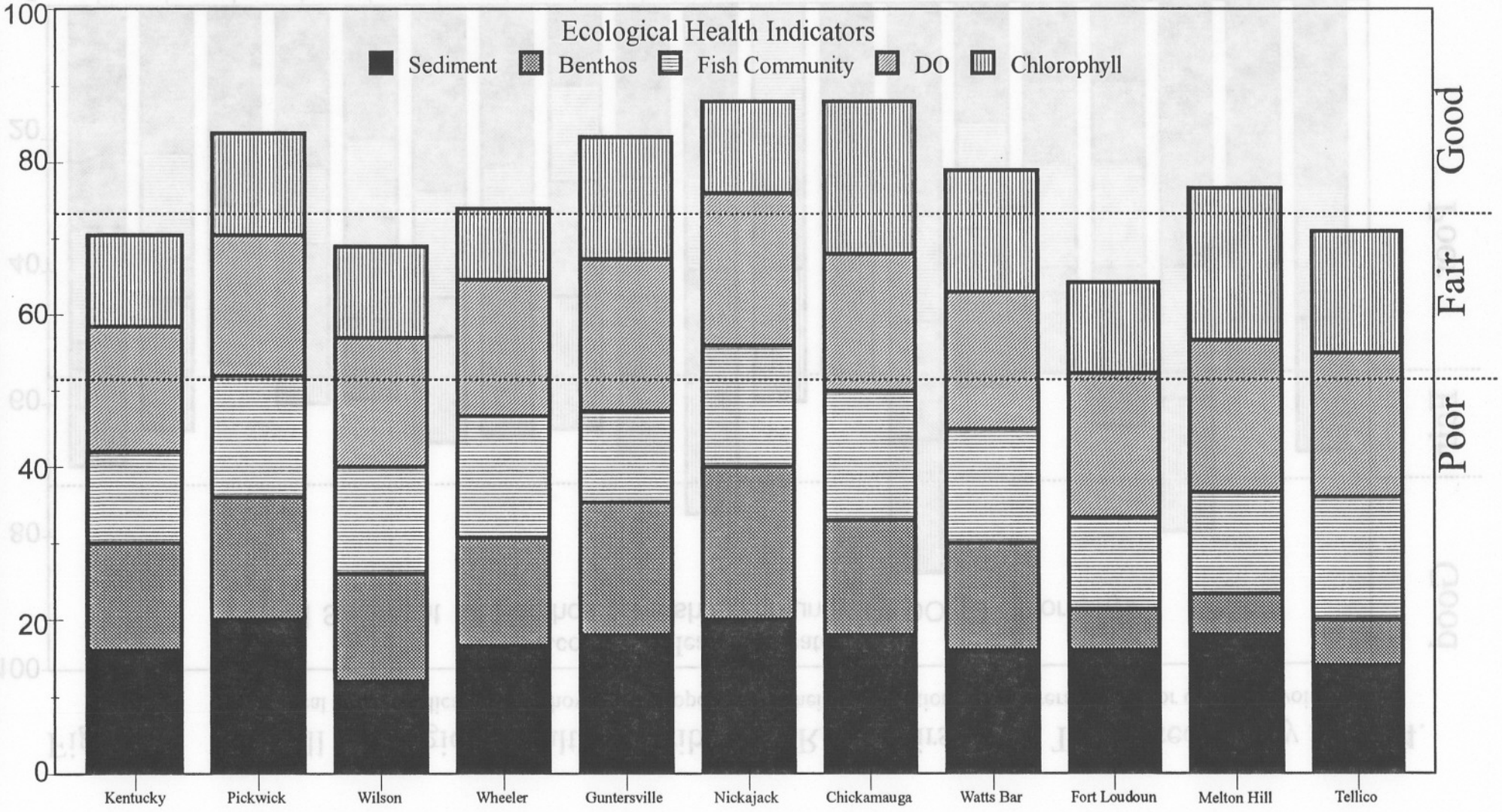


Figure 6. Overall Ecological Health of Tributary Reservoirs in the Tennessee Valley in 1994.

(Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

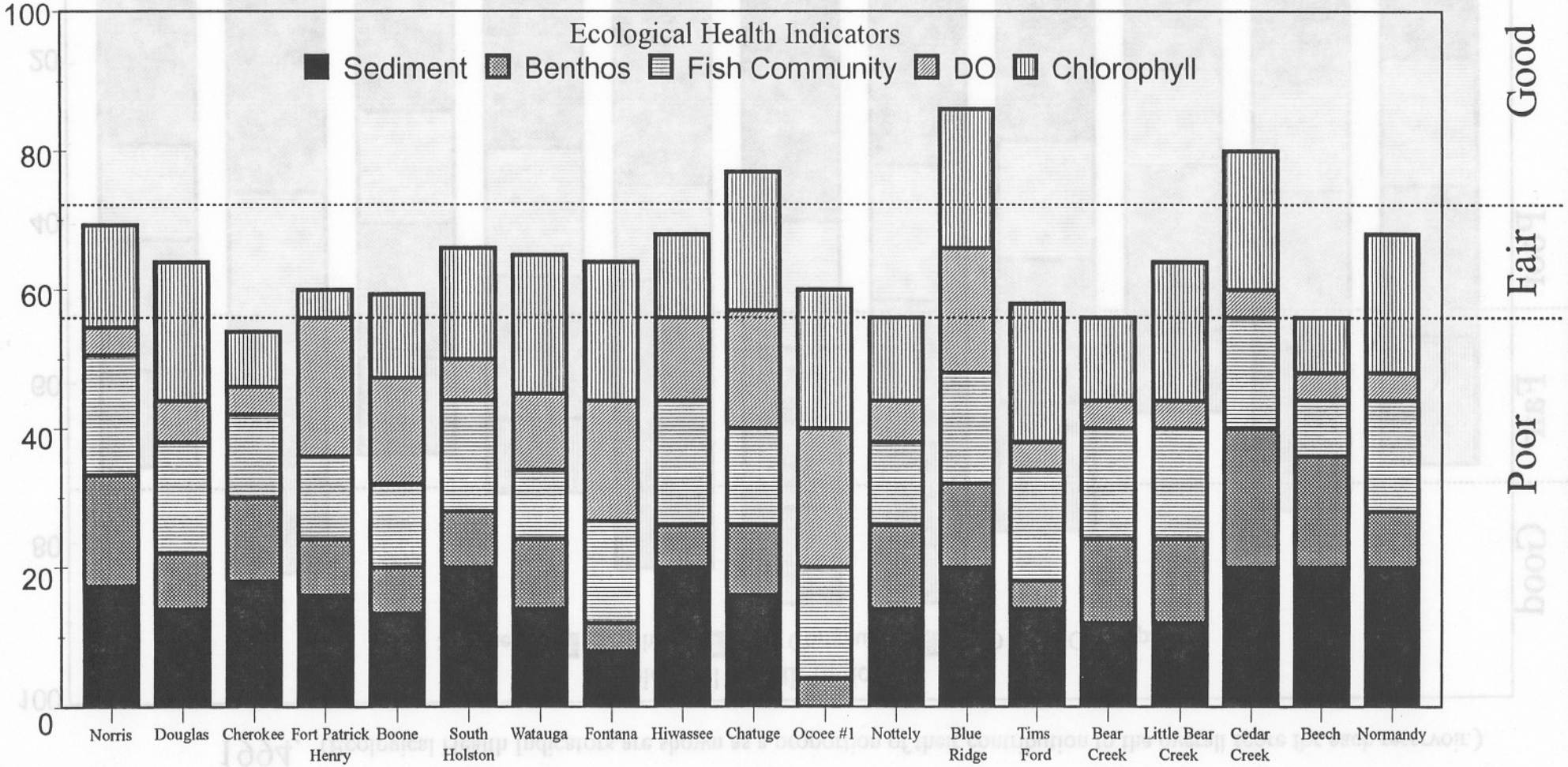
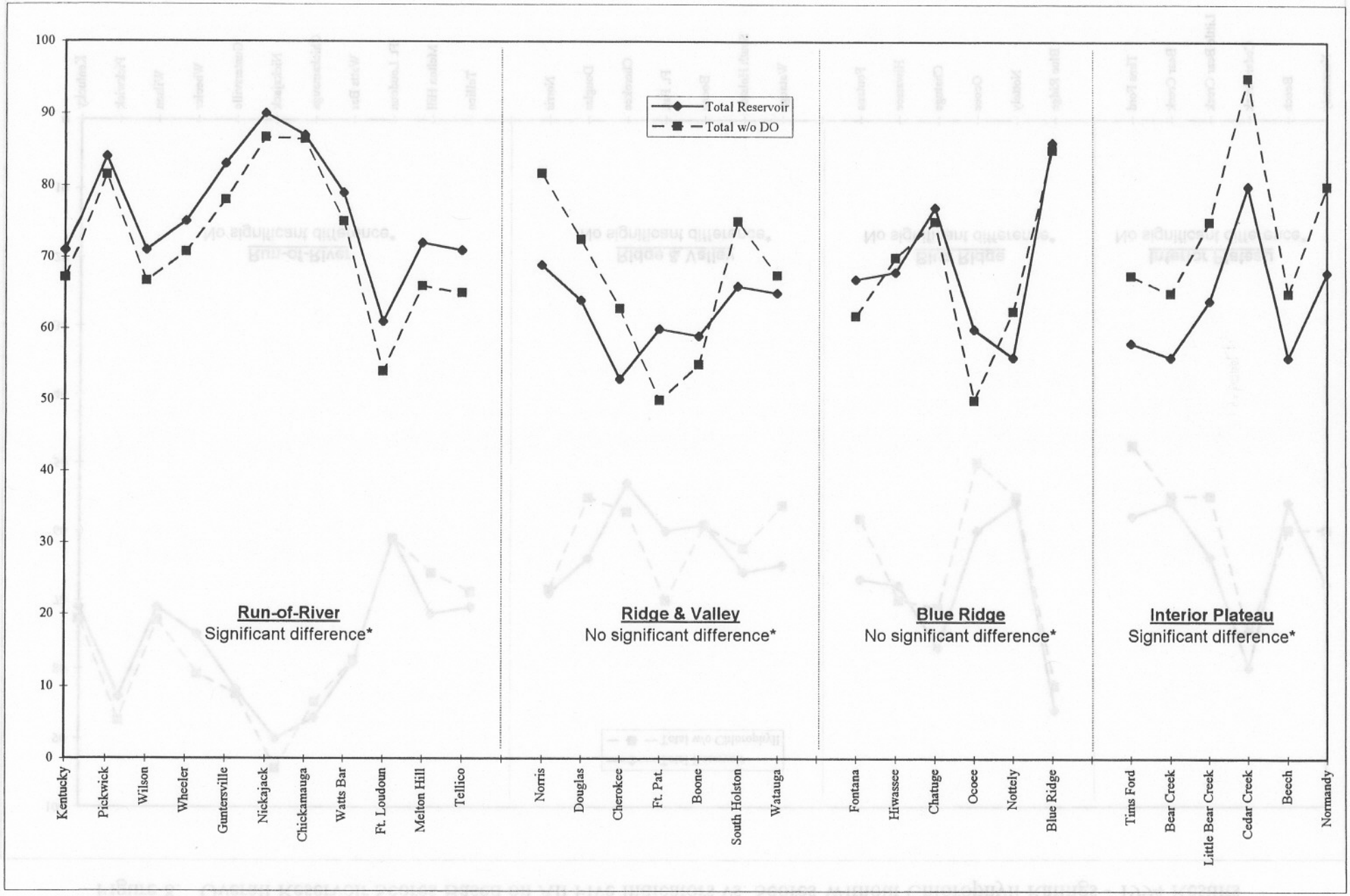
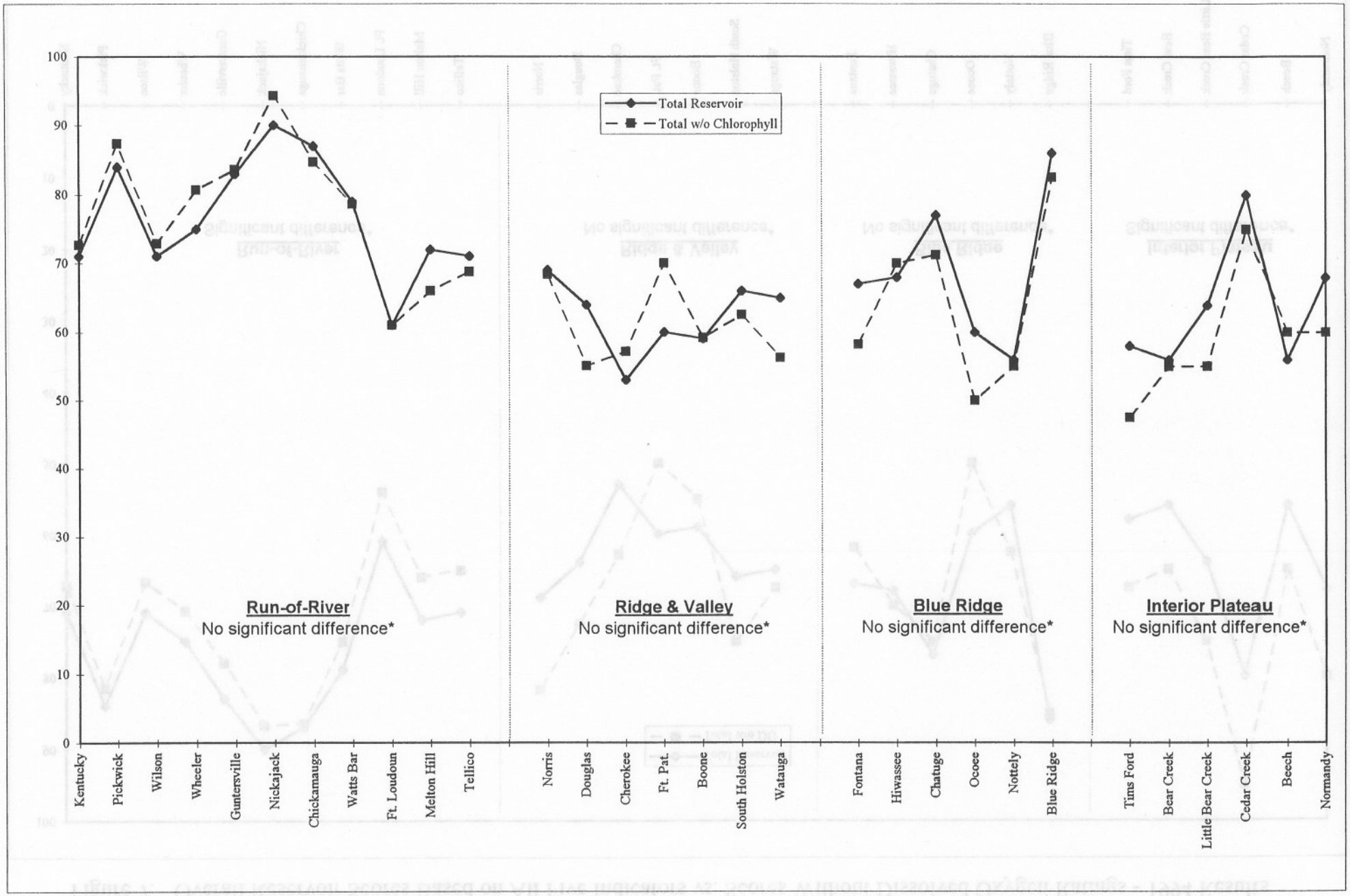


Figure 7. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Dissolved Oxygen Ratings - 1994 Results



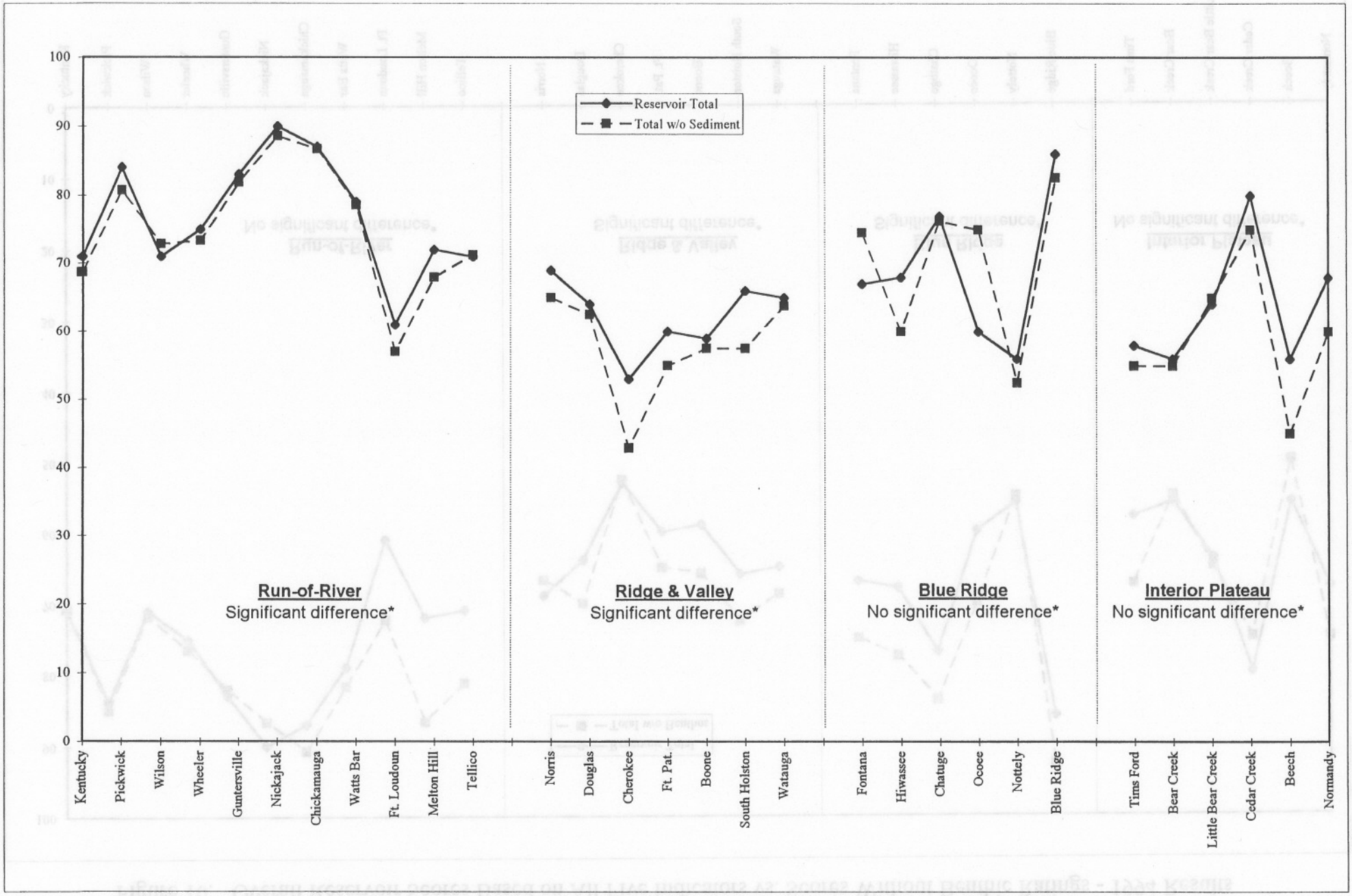
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 8. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Chlorophyll Ratings - 1994 Results



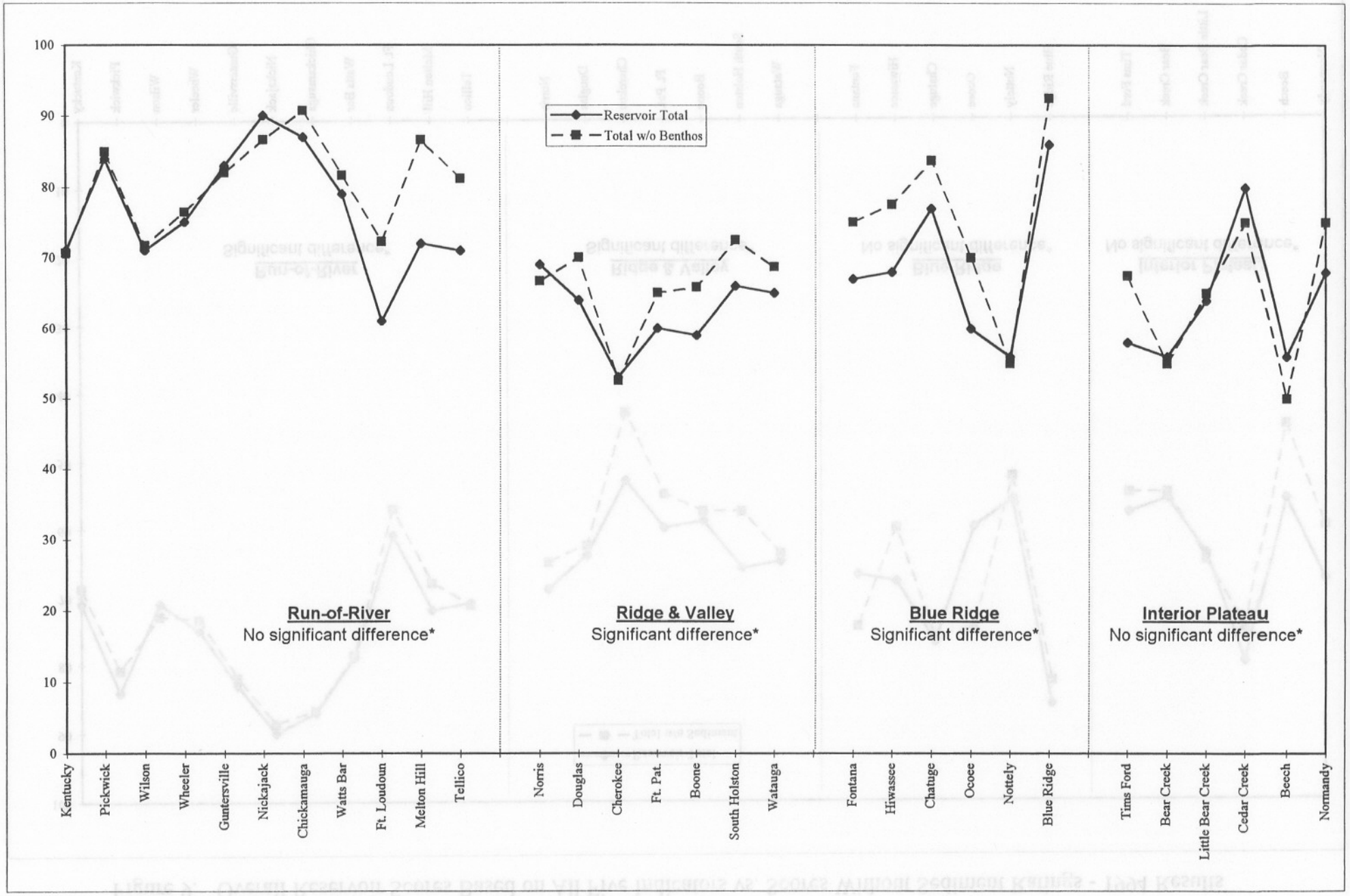
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indic[illegible]sible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 9. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Sediment Ratings - 1994 Results



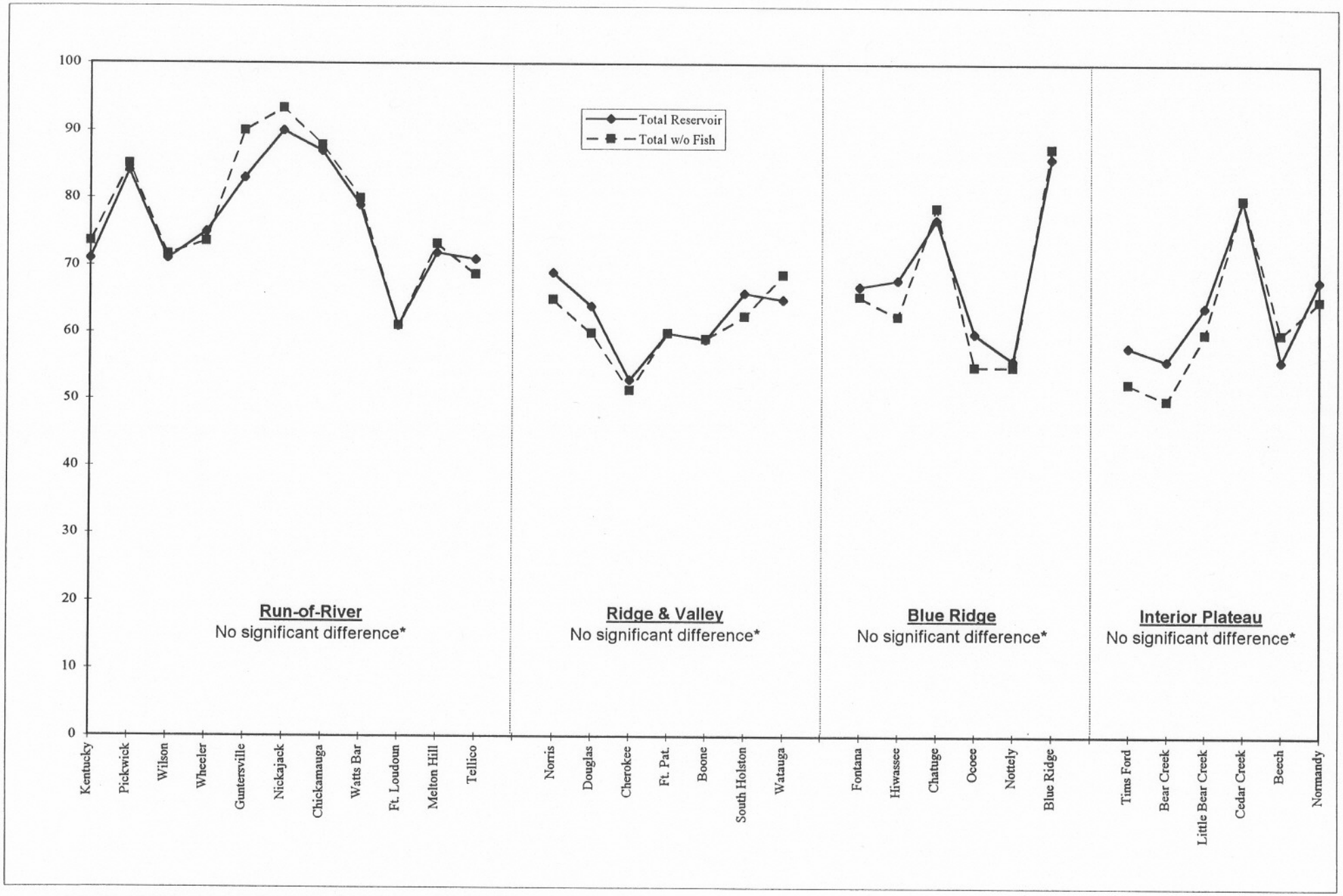
* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 10. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Benthic Ratings - 1994 Results



* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indica[illegible]sible differences between reservoir scores with and without individual ratings (α=0.05).

Figure 11. Overall Reservoir Scores Based on All Five Indicators vs. Scores Without Fish Ratings - 1994 Results



* Although plotted data are percentages and were not Arc-sin transformed, Paired T-tests were performed to indicate possible differences between reservoir scores with and without individual ratings (α=0.05).

Section 2. Dissolved Oxygen (DO) and Chlorophyll

Dissolved Oxygen

Philosophical Approach/Background

Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about the nature of a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are below saturation in the metalimnion and hypolimnion of a reservoir or lake. This hypolimnetic and metalimnetic oxygen depletion is a common, but undesirable, occurrence in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia not only promotes the biochemical release of phosphorus which affects trophic conditions, but also promotes the release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, many of these reduced chemicals can cause chronic or acute toxicity to benthos.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions exist. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish

species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish growth and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

A question fundamental to reservoir ecological health evaluation as well as reservoir classification issues is -- should reservoir ecological health evaluations be based on (1) ideal conditions, for example, very low DO concentrations represent an unacceptable ecological condition; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir, for example, very low DO concentrations are acceptable in many tributary reservoirs because of withdrawal schemes, stratification, etc. The approach selected for this program is -- poor DO is unacceptable regardless of type of reservoir or dam operation. Hence, reservoirs were not separated into classes for DO evaluations/expectations because the expectation was the same for all reservoirs.

Data Collection Methods

DO data were collected concurrently with chlorophyll and other physical/chemical samples. Collection methods for these efforts are described in the subsection entitled Data Collection Methods--Physical/Chemical Characteristics of Water (following the subsection on Chlorophyll Rating Scheme).

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 concentrations. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.) The final DO rating is the average of the water column DO rating and the bottom DO rating:

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

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location*
<5%	5 (good);
≥5% but ≤10%	3 (fair);
>10%	1 (poor).

*Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows.

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length* (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

*The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Results from 1994 Monitoring

Table 2 summarizes DO and chlorophyll results for each location monitored in 1994. The summary of DO results includes information on water column and bottom DO measurements and the final DO rating.

Isopleths for dissolved oxygen and temperature are provided in Appendix A for each sample location during the 1994 sampling season.

Chlorophyll

Philosophical Approach/Background

Algae are the base of the aquatic food chain; consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977).

Generally, lower chlorophyll concentrations in the oligotrophic range are thought of being indicative of good water quality conditions. Conversely, high chlorophyll concentrations are usually considered indicative of cultural eutrophication. However, care must be taken not to over generalize. For example, it would be inappropriate to expect all reservoirs in the Tennessee Valley to have low chlorophyll concentrations because some reservoirs are in watersheds which have nutrient rich, easily erodable soils. Most watersheds in the Tennessee Valley provide sufficient nutrients to expect chlorophyll concentrations in the mesotrophic range, even in absence of cultural etrophication. However, two watersheds in the Tennessee Valley have soils (and consequently waters) with naturally low nutrient levels--the Little Tennessee and Hiwassee. The streams and rivers in these watersheds drain the Blue Ridge Ecoregion which is largely characterized by thin soils and is underlain mostly with hard crystalline and metasedimentary rocks.

Obviously, development of appropriate expectations is a critical step in evaluating implications of chlorophyll concentrations on the ecological health of a reservoir. The range of concentrations which are considered indicative of good, fair, and poor conditions must be tailored to reservoirs within each watershed based on knowledge of background or natural conditions. This leads to separating reservoirs into classes based upon these conditions.

The classification scheme used to develop expectations for chlorophyll in Tennessee Valley reservoirs was based on the "natural" nutrient level in a watershed. Professional judgment was used to select concentrations considered indicative of good, fair, and poor conditions. Based on this approach, reservoirs were placed into one of two classes for chlorophyll expectations -- those expected to be oligotrophic because they are in watersheds with naturally low nutrient concentrations and those expected to be mesotrophic because the are in watersheds which naturally have greater nutrient availability. The reservoirs expected to be ologotrophic are those in the Blue Ridge Ecoregion. Included in this group are those in the Hiwassee River drainage--Hiwassee, Chatuge, Nottely, Blue Ridge, and Parksville reservoirs and those in the Little Tennessee River drainage--Tellico and Fontana.

Results from 1994 Monitoring

Table 2 summarizes DO and chlorophyll results for each location monitored in 1994. The summary of chlorophyll results includes the average chlorophyll concentration for the monitoring season, the maximum observed chlorophyll concentration, and the Final Chlorophyll-a Rating.

References

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

Hutchinson, G. Evelyn, 1975. A Treatise on Limnology, Volume 1, Part 2 - Chemistry of Lakes, J. Wiley and Sons, New York.

Masters, A., and T.A. McDonough, April 1993. TVA Water Management, Chattanooga, Tennessee, Personal Communication.

Data Collection Methods--Physical/Chemical Characteristics of Water

In 1994, physical/chemical water quality variables were measured at a total of 57 sampling locations on 30 reservoirs. Three specific QA/QC measures were incorporated in the reservoir physical/chemical water sampling activities. These included: (1) collection and analysis of triplicate sets of water samples once during the year at all forebay sampling locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling.

The water quality monitoring activities on the Vital Signs reservoirs followed a "basic" (11 run-of-the-river reservoirs) or a "limited" (19 tributary reservoirs) sampling strategy (Table 1). Physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system.

Basic--Monitoring on the run-of-the-river reservoirs included monthly water quality surveys (April through September) at forebays and transition zones. Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone (defined as twice the Secchi depth) composite chlorophyll-a samples; and photic zone composite and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids. Physical/chemical water quality sampling was not conducted at most run-of-the-river reservoir inflows because most of these locations are tailwater areas of upstream dams; water quality characteristics there are more representative of processes in the upstream reservoir.

Limited--Tributary storage reservoirs were sampled monthly (April through October) for a smaller list of parameters. The approach was the same as for the run-of-the-river reservoirs, except that no fecal coliform, color, or suspended solids samples were collected, and only photic zone composites for nutrients and organic carbon samples were collected and only in April and August. The April and August

nutrient samplings were designed to provide information on nutrient concentrations available at the beginning of the growing season, then near the end of the growing season. Forebays were sampled on all these reservoirs, and mid-reservoir locations were sampled on all but the smaller reservoirs.

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	–	–	–	A	–
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes
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a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

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

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

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

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

TABLE 2

1994 Vital Signs Monitoring Data (using average minimum winter pool elevations)

Reservoir	Dissolved Oxygen: Water Column DO: Less than 5.0 mg/l ? (@ 1.5 meters)	Dissolved Oxygen: Water Column DO: Percent of X-Section < 2.0 mg/l	Dissolved Oxygen: Water Column DO: Rating	Dissolved Oxygen: Bottom DO: Bottom DO 0 mg/l ?	Dissolved Oxygen: Bottom DO: Percent of B-L @ MP < 2.0 mg/l	Dissolved Oxygen: Bottom DO: Rating	Dissolved Oxygen: Final DO Rating	Chlorophyll-a: Average	Chlorophyll-a: Maximum	Chlorophyll-a: Final Chlor-a Rating	Comments
RUN-OF-THE-RIVER RESERVOIRS											
Kentucky											
Tailrace(TRM 22.3)	No	–	5	–	–	–	5	–	–	–	
Forebay(TRM 23.0)	No	0.9	5	No	2.8	4	4.5	10.5	18	3	
T-Zone(TRM 85.0)	No	0	5	No	0	5	5	7.3	13	5	
Inflow(TRM 200-206)	No	–	5	–	–	–	5	–	–	–	
Embay(BSRM 7.4)	No	8.2	3	Yes	21.3	1	2	19.4	33	1	
Pickwick											
Forebay(TRM 207.3)	No	0	5	No	0	5	5	11.2	31	2	
T-Zone(TRM 230.0)	No	0	5	No	0	5	5	7.7	22	5	
Inflow(TRM 253-259)	Yes 4.8	–	4	–	–	–	4	–	–	–	
Embay(BCM 8.4)	No	0.8	5	No	1.6	4	4.5	13.3	20	3	
Wilson											
Forebay(TRM 260.8)	No	0.4	5	Yes	10.7	2	3.5	13.5	30	3	
Inflow(TRM 273-274)	No	–	5	–	–	–	5	–	–	–	
Wheeler											
Forebay(TRM 277.0)	No	0	5	No	0	5	5	14.8	24	3	
T-Zone(TRM 295.9)	No	0	5	No	0	5	5	2.2	3	3	
Inflow(TRM 347-348)	No	–	5	–	–	–	5	–	–	–	
Embay(ERM 6.0)	No	6.3	3	No	20.0	3	3	19.0	35	1 *	*[Rating lowered to 1, 2 values above 30ug/l]
Guntersville											
Forebay(TRM 350.0)	No	0	5	No	0	5	5	6.7	15	5	
T-Zone(TRM 375.2)	No	0	5	No	0	5	5	2.7	5	3	
Inflow(TRM 420-424)	No	–	5	–	–	–	5	–	–	–	
Nickajack											
Forebay(TRM 425.5)	No	0	5	No	0	5	5	2.7	3	3	
Inflow(TRM 469-470)	No	–	5	–	–	–	5	–	–	–	
Chickamauga											
Forebay(TRM 472.3)	No	0	5	No	0	5	5	8.2	13	5	
T-Zone(TRM 490.5)	No	0	5	No	0	5	5	5.3	10	5	
Inflow(TRM 518-529)	Yes 3.7	–	3	–	–	–	3	–	–	–	
Embay(HRM 8.5)	No	0	5	No	0	5	5	3.2	4	5	
Watts Bar											
Forebay(TRM 531.0)	No	2.7	5	Yes	8.9	3	4	11.0	19	3	
T-Zone(TRM 560.8)	No	0	5	No	0	5	5	9.3	14	5	
Inflow(TRM 600-601)	Yes 4.7	–	4	–	–	–	4	–	–	–	
Inflow(CRM [illegible]-22)	No	–	5	–		–	5	–	–	–	

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	Water Column DO: Rating	Bottom DO: Bottom DO 0 mg/l ?	Bottom DO: Percent of B-L @ MP < 2.0 mg/l	Bottom DO: Rating	Final DO Rating	Chlorophyll-a: Average	Chlorophyll-a: Maximum	Final Chlor-a Rating	Comments
RUN-OF-THE-RIVER RESERVOIRS (continued)											
Fort Loudoun											
Forebay(TRM 605.5)	No	0.6	5	No	7.6	4	4.5	10.8	16	3	
T-Zone(TRM 624.6)	No	0	5	No	0	5	5	10.3	16	3	
Tellico								[Nutrient limited watershed]			
Forebay(LTRM 1.0)	No	2.5	5	No	9.2	4	4.5	5.0	8	3	
T-Zone(LTRM 15.0)	No	0	5	No	0	5	5	3.8	6	5	
Melton Hill											
Forebay(CRM 24.0)	No	0	5	No	0	5	5	7.8	13	5	
T-Zone(CRM 45.0)	No	0	5	No	0	5	5	4.2	9	5	
TRIBUTARY RESERVOIRS											
Norris											
Forebay(CRM 80.0)	No	20.3	1	No	42.0	1	1	2.3	5	3	
CRM 125.0	No	27.0	1	Yes	63.8	1	1	2.7	6	3	
PRM 30.0	No	21.4	1	Yes	54.1	1	1	3.3	7	5	
Cherokee											
Forebay(HRM 53.0)	No	23.8	1	Yes	49.5	1	1	11.6	17	3	
HRM 76.0	No	30.6	1	Yes	62.7	1	1	16.7	26	1	
Douglas											
Forebay(FBRM 33.0)	Yes 4.8	26.8	1	Yes	61.3	1	1	7.6	18	5	
FBRM 51.0	No	6.1	3	No	171.7	1	2	9.9	15	5	
Ft. Patrick Henry											
Forebay(SFHRM 8.7)	No	0	5	No	0	5	5	15.9	25	1	
Inflow(SFHRM 18.5)	Yes 3.8	–	3	–	–	–	3	–	–	–	
Boone											
Forebay(SFHRM 19.0)	No	3.2	5	No	4.5	4	4.5	8.7	11	5	
SFHRM 27.0	No	16.5	1	No	12.8	3	2	16.7	29	1	
WRM 6.5	No	0	5	No	0	5	5	13.3	24	3	
South Holston											
Forebay(SFHRM 51.0)	No	9.8	3	No	32.5	1	2	2.9	5	3	
SFHRM 62.5	No	25.2	1	Yes	61.7	1	1	7.3	12	5	
Watauga											
Forebay(WRM 37.4)	No	2.5	5	No	18.6	3	4	4.7	7	5	
WRM 45.5	No	13.4	1	No	20.8	2	1.5	6.3	8	5	

TABLE 2 (Cont'd)

1994

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	Water Column DO: Rating	Bottom DO: Bottom DO 0 mg/l ?	Bottom DO: Percent of B-L @ MP < 2.0 mg/l	Bottom DO: Rating	Final DO Rating	Chlorophyll-a: Average	Chlorophyll-a: Maximum	Final Chlor-a Rating	Comments
TRIBUTARY RESERVOIRS (continued)											
Fontana								[Nutrient limited watershed]			
Forebay(LTRM 62.0)	No	1.0	5	No	6.5	4	4.5	2.1	4	5	
LTRM 81.5	No	0	5	No	0	5	5	3.6	7	5	
TkRM 3.0	No	2.2	5	No	23.4	2	3.5	3.0	5	5	
Blue Ridge								[Nutrient limited watershed]			
Forebay(ToRM 54.1)	No	0.1	5	No	1.2	4	4.5	2.6	4	5	
Hiwassee								[Nutrient limited watershed]			
Forebay(HiRM 77.0)	No	8.9	3	Yes	46.8	1	2	6.0	22	3	
HIRM 85.0	No	1.0	5	No	15.1	3	4	5.0	9	3	
Nottely								[Nutrient limited watershed]			
Forebay(NRM 23.5)	No	26.0	1	No	59.7	1	1	5.4	13	3	
NRM 31.0	No	7.4	3	Yes	46.3	1	2	6.7	13	3	
Chatuge								[Nutrient limited watershed]			
Forebay(HiRM 122.0)	No	3.8	5	No	9.9	4	4.5	2.4	3	5	
Shooting Cr 1.5	No	2.7	5	No	15.2	3	4	2.4	4	5	
Ocoee #1								[Nutrient limited watershed]			
Forebay(ORM12.5)	No	0	5	No	0	5	5	2.0	3	5	
Tims Ford											
Forebay(ERM 135.0)	No	46.0	1	Yes	76.3	1	1	6.4	11	5	
ERM 150.0	No	39.4	1	Yes	70.9	1	1	6.3	11	5	
Normandy											
Forebay(DRM 249.5)	No	47.2	1	Yes	88.9	1	1	5.9	8	5	
Bear Creek											
Forebay(BCM 75.0)	No	23.5	1	Yes	66.4	1	1	12.1	24	3	
Little Bear Creek											
Forebay(LBCM 12.5)	No	42.1	1	Yes	83.1	1	1	6.9	14	5	
Cedar Creek											
Forebay(25.2)	No	33.0	1	Yes	78.6	1	1	3.7	7	5	
Beech											
Forebay(BRM 36.0)	No	46.4	1	No	77.6	1	1	12.8	72	2	

~~(13-28-94)~~
(1-5-95)

1994--River Performance Report – Quality of the Water Resource

Dissolved Oxygen Rating – The Dissolved Oxygen (DO) rating at each sampling location is based on both summer water column and bottom water DO concentrations. (The summer time period is April through September for the 11 Run-of-the-River reservoirs, and May through October for the 19 Tributary reservoirs.) The Final DO Rating is the average of the the water column DO rating and the bottom DO rating:

Final DO Rating = 0.5 (Water Column DO rating + Bottom DO rating)

-- The Water Column DO rating is based on a six month summertime average of the percent of the reservoir cross-sectional area (at the location where sampling is conducted) that has a DO concentration less than 2.0 mg/l, as follow:

Average Cross-Sectional Area (DO less than 2mg/L)	Sampling Location Water Column Rating
< 5 %	(good) – 5
5–10 %	(fair) – 3
> 10 %	(poor) – 1

+ In addition, if the DO is ever less than 5 mg/L at the 1.5 meter depth, the location's water column DO rating is decreased as follows:

Minimum DO at 1.5 meter depth	Sampling Location DO Rating Change
4–4.9 mg/L	Lower 1 unit (e.g., 5 to 4)
3–3.9 mg/L	Lower 2 units (e.g., 5 to 3)
2–2.9 mg/L	Lower 3 units (e.g., 5 to 2)
etc.	etc.

-- The Bottom DO rating is based on a six month summertime average of the percent of the reservoir cross-sectional bottom length (at the location where sampling is conducted), that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length (DO less than 2mg/L)	Sampling Location Bottom Water Rating
0 %	(good) – 5
0–10 %	– 4
10–20 %	(fair) – 3
20–30 %	– 2
> 30 %	(poor) – 1

+ The average percent X-sectional length is computed on the basis of the total X-sectional length at average minimum winter pool elevation. In addition, if anoxic conditions (i.e., 0 mg/l DO) are observed at the bottom, the bottom DO rating is decreased one unit, with a minimum rating of 1.

Ratings - 94

< 3 Red

3 to 4 Yellow

> 4 green

(Chl-a, DO, Sediment)

Chlorophyll-a Rating – The chlorophyll-a rating at each sampling location is based on the average summer concentration, as shown below. (If triplicate samples are collected at a sampling location, only the median value of the triplicate is used in the calculation of the summer average and the maximum.) If a monthly chlorophyll-a sample has a concentration that exceeds 30 ug/l, the value is not included in the calculation of the summer average, however, the final chlorophyll-a rating is decreased one unit, (i.e. 5 to 4, or 4 to 3, etc.) for each sample that exceeds 30 ug/l.

Average Summer Chlorophyll-a Concentration	Rating
< 3 ug/L*	(fair) – 3
3 – 10 ug/L	(good) – 5
10 – 15 ug/L	(fair) – 3
> 15 ug/L	(poor) – 1

Average Summer Chlorophyll-a Concentration (Nutrient Limited Watersheds)	Rating
< 4 ug/L	(good) – 5
4 – 7 ug/L	(fair) – 3
> 7 ug/L	(poor) – 1

* If nutrients are present (e.g. total phosphorus greater than about 0.01 mg/L and nitrate+nitrite-nitrogen greater than about 0.05 mg/L) but chlorophyll-a concentrations are generally low (e.g. < 3ug/L), other limiting or inhibiting factors (e.g., high streamflows, turbidity, toxicity, etc.) must be considered. When these conditions exist, chlorophyll-a is rated 2 (poor).

Section 3.0. Sediment Quality

Philosophical Approach/Background

Contaminated bottom sediments can have direct adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. There are many sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). TVA's approach combines two sediment assessment methods--one biological, the other chemical--to evaluate sediment quality.

A fundamental question concerning implications of sediment quality on overall reservoir ecological health is essentially a classification issue -- should reservoir ecological health evaluations be based on: (1) ideal conditions; for example, sediments should not have high concentrations of metals compared to background, should have no or at most very low concentrations of pesticides, and should not pose a toxic threat to biota; or (2) the best conditions expected for a reservoir given the environmental and operational characteristics of the dam/reservoir; for example, high concentrations of reduced metals are acceptable in tributary reservoirs due to anoxic conditions resulting from long retention times and thermal stratification. The approach taken for these studies accepts only ideal conditions. That is, metal concentrations should not be elevated, pesticides should not be present, and there should be no toxicity. In this situation, there is no need for classification because the same conditions are desired for all reservoirs.

Sediment Collection and Toxicity Testing Methods

Annual sediment samples and near-bottom water samples were collected during the summer of 1994 from 57 locations, i.e., the forebays and transition zones (or mid-reservoir) of the 11 mainstream reservoirs and 19 tributary reservoirs as shown in Table 1. In addition, ten of the 57 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the ten sites. Replicate samples were handled and processed independently. Results from these ten sets of replicates were used to assess field methods consistency, variations in laboratory toxicity and physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment and Kemmerer or Isco water samplers were used to collect the near-bottom water. Each sediment sample was a composite of at least three subsamples independently collected at each

sampling location from the original stream channel bed. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency, and split into two fractions: one fraction for acute toxicity testing, and one fraction for physical/chemical analyses. Samples were placed on ice immediately after collection, compositing, and splitting, and were shipped or carried to the appropriate laboratory. One split from each sampling location and the sample of near-bottom water were shipped to the Toxicity Testing Laboratory (TTL) for toxicity testing; the other split at each sampling location was shipped or carried to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute Toxicity Testing--Within 36 hours of collection, all sediment samples were screened for toxicity using Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. Organisms were exposed to undiluted interstitial (pore) water from the sediment and near bottom water. Interstitial water was obtained by refrigerated centrifugation of sediment. Control water consisted of Moderately Hard Reconstituted Water, MHRW (TVA, 1992), (hardness of 80-100 mg/L as $CaCO_3$) enriched with 10 percent Tennessee River water from TTL's experimental channels for the daphnid test and MHRW adjusted to pH=7.5 using HCl for the rotifer test. All samples were aerated to bring dissolved oxygen levels to near saturation (8.4 mg/L at 25°C) before testing. Water chemistry (temperature, DO, pH, conductivity, alkalinity, and hardness) was measured for all samples and controls. After centrifugation of the sediment, pore water samples were collected and preserved and sent to the Environmental Chemistry Laboratory for un-ionized ammonia analysis. Four replicates of five individuals each were used in both tests. Rotifer (24-hr) and daphnid (48-hr) acute toxicity was reported if average survival in the four replicates was significantly reduced (95 percent probability) from the control.

Physical/Chemical Characteristics--Splits of the same sediment samples used in the toxicity testing were analyzed for 13 metals, un-ionized ammonia (in pore water), total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs, Table 2).

Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in TVA technical report (Moses, Simbeck, and Wade, 1995).

Sediment Rating Scheme

TVA's scoring criterion is based on ratings for the toxicity of sediment pore water (S_{TOX}) to test organisms, and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia. The final sediment quality score or rating is the average of these two ratings:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating), where:

S_{TOX} (Sediment Toxicity) Rating--Sediment toxicity is evaluated using both Rotox® (rotifer Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. The acute toxicity evaluations entail the exposure of these organisms (zooplankton) to interstitial pore water from sediment. The survival rates of the organisms are based on the average survival in four replicates of five individuals each, compared to a control. If average survival is significantly reduced (95 percent probability) from the control, the sample is considered to be toxic. Sampling locations are rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good)	Survival not significantly different than control and greater than or equal to 80 percent for both species, (i.e., no significant toxicity);
3 (fair)	Survival not significantly different from control, but less than 80 percent survival for either species; or
1 (poor)	Survival of either organism significantly less than control, (i.e., significant toxicity).

S_{CHM} (Sediment Chemistry) Rating--Splits of the same sediment used in the sediment toxicity testing are analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings are based on: (a) concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (Table 2); (b) detectable amounts of PCBs or pesticides; and (c) concentrations of un-ionized ammonia in pore water above 200 μg NH_3/L. Each sampling location is rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

* Analytes (i.e., heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in Table 2.

Results from 1994 Monitoring

Table 3 provides sediment chemistry rating, sediment toxicity rating, and Final Sediment Quality Rating for each location examined in 1994. Table 4 summarizes sediment toxicity data which resulted in the sediment toxicity rating for each location. Table 5 sediment chemistry data which resulted in the sediment chemistry rating for each location.

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.

Moses, J., D. Simbeck, and D. Wade. 1995. "Acute Toxicity Screening of Stream Water and Sediment Using Daphnids (Ceriodaphnia dubia) and Rotifers [Rotox™], Stream Vital Signs Monitoring, Summer 1994." TVA Water Management (in preparation).

Tennessee Valley Authority, 1992. "Aquatic Research Laboratory Quality Assurance Program and Standard Operating Procedures Manual." TVA, Division of Water Resources.

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes

a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

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

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

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

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

Table 2
Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Metals and Ammonia		
Aluminum, mg/g	1 mg/g	--
Arsenic, mg/kg	1 mg/kg	8 mg/kg[b]
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/g	0.5 mg/g	--
Chromium, mg/kg	10 mg/kg	75 mg/kg[b]
Copper, mg/kg	2 mg/kg	50 mg/kg[b]
Iron, mg/g	1 mg/g	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/g	0.5 mg/g	--
Manganese, mg/g	0.1 mg/g	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	10 mg/kg	300 mg/kg
Un-ionized Ammonia (in pore water), $\mu g\ NH_3/l$	10 $\mu g/l$	200 $\mu g/l$
Solids		
Total solids, %	0.1%	--
Total volatile solids, %	0.1%	--
Particle size, <0.062 mm diameter, %	0.1%	--
Particle size, <0.125 mm diameter, %	0.1%	--
Particle size, <0.50 mm diameter, %	0.1%	--
Particle size, <2.0 mm diameter, %	0.1%	--
Organochlorine Pesticides and PCB's		
Aldrin, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
α-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
β-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
γ-Benzene Hexachloride (Lindane), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
δ-Benzene Hexachloride (BHC), $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
Chlordane, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
Dieldrin, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
p,p DDT, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
p,p DDD, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$
p,p DDE, $\mu g/kg$	10 $\mu g/kg$	10 $\mu g/kg$

Table 2.3 (continued)

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Organochlorine Pesticides and PCB's (continued)		
α-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
ß-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
Endosulfan Sulfate, μg/kg	10 μg/kg	10 μg/kg
Endrin, μg/kg	10 μg/kg	10 μg/kg
Endrin Aldehyde, μg/kg	10 μg/kg	10 μg/kg
Heptachlor, μg/kg	10 μg/kg	10 μg/kg
Heptachlor Epoxide, μg/kg	10 μg/kg	10 μg/kg
Methoxychlor, μg/kg	10 μg/kg	10 μg/kg
PCB-1221, μg/kg	100 μg/kg	100 μg/kg
PCB-1232, μg/kg	100 μg/kg	100 μg/kg
PCB-1242, μg/kg	100 μg/kg	100 μg/kg
PCB-1248, μg/kg	100 μg/kg	100 μg/kg
PCB-1254, μg/kg	100 μg/kg	100 μg/kg
PCB-1260, μg/kg	100 μg/kg	100 μg/kg
PCB-1016, μg/kg	100 μg/kg	100 μg/kg
PCBs, Total, μg/kg	100 μg/kg	100 μg/kg
Toxaphene, μg/kg	500 μg/kg	500 μg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

TABLE 3

SEDIMENT RATINGS
1994 RESERVOIR VITAL SIGNS DATA

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

SEDIMENT QUALITY =
0.5(CHEMISTRY + TOXICITY)

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

Reservoir	Mile	Comment	Collection Date yy	mm	dd		CHEMISTRY RATING		TOXICITY RATING	SEDIMENT QUALITY RATING
Kentucky	TRM 23.0	Dup–1	94	7	25	5	5	1	3	4.0
		Dup–2	94	7	25	5		5		
Kentucky	TRM 85.0		94	7	25		5		5	5.0
Kentucky	BSRM 7.4		94	7	26		5		1	3.0
Pickwick	TRM 207.3		94	8	3		5		5	5.0
Pickwick	TRM 230.0	Dup–1	94	8	3	5	5	5	5	5.0
		Dup–2	94	8	3	5		5		
Pickwick	BCM 8.4		94	8	3		5		5	5.0
Wilson	TRM 260.8		94	7	26		5		1	3.0
Wheeler	TRM 277.0	Dup–1	94	6	27	5	5	3	2	3.5
		Dup–2	94	6	27	5		1		
Wheeler	TRM 295.9	Dup–1	94	6	27	3	3	5	5	4.0
		Dup–2	94	6	27	3		5		
Wheeler	ERM 6.0		94	7	26		5		5	5.0
Guntersville	TRM 350.0		94	8	29		3		5	4.0
Guntersville	TRM 375.2		94	8	29		5		5	5.0
Nickajack	TRM 425.5		94	6	7		5		5	5.0
Chickamauga	TRM 472.3	Dup–1	94	5	25	3	2	5	5	3.5
		Dup–2	94	5	25	1		5		
Chickamauga	TRM 490.5		94	5	25		5		5	5.0
Chickamauga	HiRM 8.5		94	5	25		5		5	5.0
Watts Bar	TRM 531.0		94	6	1		3		5	4.0
Watts Bar	TRM 560.8	Dup–1	94	6	1	3	3	5	5	4.0
		Dup–2	94	6	1	3		5		
Fort Loudoun	TRM 605.5		94	6	20		3		5	4.0
Fort Loudoun	TRM 624.6	Dup–1	94	6	20	3	3	5	5	4.0
		Dup–2	94	6	20	3		5		
Tellico	LTRM 1.0		94	7	13		5		1	3.0
Tellico	LTRM 15.0	Dup–1	94	7	13	5	5	5	3	4.0
		Dup–2	94	7	13	5		1		
Melton Hill	CRM 24.0	Dup–1	94	8	29	5	5	5	5	5.0
		Dup–2	94	8	29	5		5		
Melton Hill	CRM 45.0		94	8	29		3		5	4.0
Norris	CRM 80.0		94	6	6		3		5	4.0
Norris	CRM 125.0		94	6	7		5		5	5.0
Norris	PRM 30.0		94	6	7		3		5	4.0
Douglas	FBRM 33.0		94	6	21		5		5	5.0
Douglas	FBRM 51.0		94	6	21		3		1	2.0

TABLE 3 (Cont'd)

SEDIMENT RATINGS
1994 RESERVOIR VITAL SIGNS DATA

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

SEDIMENT QUALITY =
0.5(CHEMISTRY + TOXICITY)

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

Reservoir	Mile	Comment	Collection Date yy	mm	dd	CHEMISTRY RATING		TOXICITY RATING		SEDIMENT QUALITY RATING
Cherokee	HRM 53.0	Dup–1	94	7	18	5	5	5	5	5.0
		Dup–2	94	7	18	5		5		
Cherokee	HRM 76.0		94	7	18		3		5	4.0
Ft Pat Henry	SFHRM 8.7		94	6	22		3		5	4.0
Boone	SFHRM 19.0		94	6	22		3		3	3.0
Boone	SFHRM 27.0		94	6	22		3		5	4.0
Boone	WRM 6.5		94	6	22		1		5	3.0
South Holston	SFHRM 51.0		94	7	12		5		5	5.0
South Holston	SFHRM 62.5		94	7	12		5		5	5.0
Watauga	WRM 37.4		94	8	22		5		1	3.0
Watauga	WRM 45.5		94	8	22		3		5	4.0
Fontana	LTRM 62.0		94	8	22		3		1	2.0
Fontana	LTRM 81.5		94	8	22		3		1	2.0
Fontana	TkRM 3.0		94	8	22		3		1	2.0
Hiwassee	HiRM 77.0		94	7	12		5		5	5.0
Hiwassee	HiRM 85.0		94	7	12		5		5	5.0
Chatuge	HiRM 122.0		94	5	24		3		5	4.0
Chatuge	SCM 1.5		94	5	24		3		5	4.0
Nottely	NRM 23.5		94	8	17		5		3	4.0
Nottely	NRM 31.0		94	8	17		5		1	3.0
Ocoee #1	ORM 12.5		94	6	6		1		1	1.0
Blue Ridge	ToRM 54.1		94	6	20		5		5	5.0
Tims Ford	ERM 135.0		94	8	23		3		1	2.0
Tims Ford	ERM 150.0		94	8	23		~~3~~ 5		5	~~4.0~~ 5
Normandy	DRM 249.5		94	8	23		5		5	5.0
Bear Creek	BCM 75.0		94	8	17		5		1	3.0
L. Bear Creek	LBCM 12.5		94	8	17		5		1	3.0
Cedar Creek	CCM 25.2		94	8	17		5		5	5.0
Beech	BRM 36.0		94	5	31		5		5	5.0

(sedrat94.wk1 – 1/19/95)

1994 SEDIMENT QUALITY RATINGS/EVALUSTIONS

Sediment Quality - Ratings for reservoir sediment quality were based both on biological toxicity testing (S_{TOX}) and chemical analysis of sediment for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia (S_{CHM}). The final sediment quality rating at each sampling location was the average of these two ratings, as follows:

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

* *Sediment Toxicity (S_{TOX}) Rating* -- Reservoir sediment toxicity was evaluated with both Ceriodaphnia dubia and Branchionus calyciflorus by examining these organisms survival rates (compared to a control) when exposed to sediment interstitial pore water. Each sampling location was rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good) --	Survival of both organisms not significantly different than control and greater than or equal to 80% for both species *(i.e. no significant toxicity).
3 (fair) --	Survival of both organism not significantly different from control, but less than 80% survival for either species; or
1 (poor) --	Survival of either organism significantly less than control, (i.e. significant toxicity);

* *Sediment Chemistry (S_{CHM}) Rating* -- Splits of the same sediment used in the sediment toxicity testing were analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings were based on: (a.) concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines; (b.) detectable amounts of pesticides or PCBs; and (c.) concentrations of un-ionized ammonia in pore water above 200 ug NH3/L. Each sampling location was rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceeding guidelines;
3 (fair)	One or two analytes exceeding guidelines;
1 (poor)	Three or more exceeding guidelines.

* Analytes (i.e. heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in table 1.

TABLE 4

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
BASIC					
Kentucky	TRM 23.0 (A)	FB	1	Toxicity to dapnids	3
	TRM 23.0 (B)	FB	5	No toxicity	
	TRM 85.0	TZ	5	No toxicity	5
	BSRM 7.4	EMB	1	Toxicity to dapnids	1
Pickwick	TRM 207.3	FB	5	No toxicity	5
	TRM 230.0 (A)	FB	5	No toxicity	5
	TRM 230.0 (B)	TZ	5	No toxicity	
	BCM 8.4	EMB	5	No toxicity	5
Wilson	TRM 260.8	FB	1	Toxicity to both species	1
Wheeler	TRM 277.0 (A)	FB	3	Rotifer survival 60%	2
	TRM 277.0 (B)	FB	1	Toxicity to both species	
	TRM 295.9 (A)	TZ	5	No toxicity	5
	TRM 295.9 (B)	TZ	5	No toxicity	
	ElRM 6.0	EMB	5	No toxicity	5
Guntersville	TRM 350.0	FB	5	No toxicity	5
	TRM 375.2	TZ	5	No toxicity	5
Nickajack	TRM 425.5	FB	5	No toxicity	5
Chickamauga	TRM 472.3 (A)	FB	5	No toxicity	5
	TRM 472.3 (B)	FB	5	No toxicity	
	TRM 490.5	TZ	5	No toxicity	5
	HiRM 8.5	EMB	5	No toxicity	5
Watts Bar	TRM 531.0	FB	5	No toxicity	5
	TRM 560.8 (A)	TZ	5	No toxicity	5
	TRM 560.8 (B)	TZ	5	No toxicity	

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
Ft. Loudoun	TRM 605.5	FB	5	No toxicity	5
	TRM 624.6 (A)	TZ	5	No toxicity	5
	TRM 624.6 (B)	TZ	5	No toxicity	
Melton Hill	CRM 24.0 (A)	FB	5	No toxicity	5
	CRM 24.0 (B)	FB	5	No toxicity	
	CRM 45.0	TZ	5	No toxicity	5
Tellico	LTRM 1.0	FB	1	Toxicity to both species	1
	LTRM 15.0 (A)	TZ	5	No toxicity	3
	LTRM 15.0 (B)	TZ	1	Toxicity to daphnids	
TRIBUTARY					
Norris	CRM 80.0	FB	5	No toxicity	5
	CRM 125.0	TZ	5	No toxicity	5
	PRM 30.0	TZ	5	No toxicity	5
Cherokee	HoRM 53.0 (A)	FB	5	No toxicity	5
	HoRM 53.0 (B)	FB	5	No toxicity	
	HoRM 76.0	TZ	5	No toxicity	5
Douglas	FBRM 33.0	FB	5	No toxicity	5
	FBRM 51.0	TZ	1	Toxcity to rotifers	1
Fort Pat Henry	SFHRM 8.7	FB	5	No toxicity	5
Boone	SFHRM 19.0	FB	3	Rotifer survival 75%	3
	SFHRM 27.0	TZ	5	No toxicity	5
	WRM 6.5	TZ	5	No toxicity	5

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
S. Holston	SFHRM 51.0	FB	5	No toxicity	5
	SFHRM 62.5	TZ	5	No toxicity	5
Watauga	WRM 37.4	FB	1	Toxicity to both species	1
	WRM 45.5	FB	5	No toxicity	5
Fontana	LTRM 62.0	FB	1	Toxicity to both species	1
	LTRM 81.5	TZ	1	Toxicity to daphnids	1
	TkRM 3.0	TZ	1	Toxicity to daphnids	1
Hiwassee	HiRM 77.0	FB	5	No toxicity	5
	HiRM 85.0	TZ	5	No toxicity	5
Chatuge	HiRM 122.0	FB	5	No toxicity	5
	SCM 1.5	FB	5	No toxicity	5
Nottely	NoRM 23.5	FB	3	Daphnid survival 60%	3
	NoRM 31.0	TZ	1	Toxicity to rotifers	1
Ocoee No. 1	ORM 12.5	FB	1	Toxicity to dapnids	1
Blue Ridge	ToRM 54.1	FB	5	No toxicity	5
Tims Ford	ElRM 135.0	FB	1	Toxicity to both species	1
	ElRM 150.0	TZ	5	No toxicity	5
Bear Creek	BCM 75.0	FB	1	Toxicity to both species	1
Cedar Creek	CCM 25.2	FB	5	No toxicity	5

TABLE 4 (Cont'd)

RiverPulse Ratings, Sediment Toxicity
Reservoir Vital Signs Monitoring, Summer 1994

Reservoir	River Mile	Zone	Rating	Reason	Final Rating
L. Bear Creek	LBCM 12.5	FB	1	Toxicity to daphnids	1
Beech	BRM 36.0	FB	5	No toxicity	5
Normandy	DRM 249.5	FB	5	No toxicity	5

Good = 5 (No toxicity to either species, survival for both species ≥ 80%)
Fair = 3 (No toxicity to either species, however survival of at least one species < 80%)
Poor = 1 (Toxicity to at least one species)

TABLE 5

SEDIMENT CHEMISTRY
1994 RESERVOIR VITAL SIGNS DATA

Reservoir	Mile	Comment	Collection Date yy	mm	dd	Metals, mg/kg (dry weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	ZINC	AMMONIA (ug/l)	CHLORDANE (ug/kg)	DDT (ug/kg)	TOTAL PCB (ug/kg)
Kentucky	TRM 23.0	Dup-1	94	7	25	7.6	0.5 K	28	14	18	0.18	20	110	36	10 K	10 K	25 K
		Dup-2	94	7	25	7.0	0.5 K	30	12	18	0.17	21	110	34	10 K	10 K	25 K
		Precision	94	7	25	7.2	0.5 K	28	12	20	0.17	19	100		10 K	10 K	25 K
Kentucky	TRM 85.0		94	7	25	9.0	0.5 K	26	10	16	0.17	16	93	14	10 K	10 K	25 K
Kentucky	BSRM 7.4		94	7	26	12.0	0.5 K	25	8	22	0.12	17	78	26	10 K	10 K	25 K
Pickwick	TRM 207.3		94	8	3	7.2	0.5 K	36	26	35	0.75	26	150	15	10 K	10 K	25 K
Pickwick	TRM 230.0	Dup-1	94	8	3	7.6	0.5 K	22	10	21	0.74	11	90	14	10 K	10 K	25 K
		Dup-2	94	8	3	6.8	0.5 K	19	10	19	0.72	10	88	25	10 K	10 K	25 K
Pickwick	BCM 8.4		94	8	3	8.9	0.5 K	26	6	20	0.10 K	16	82	15	10 K	10 K	25 K
Wilson	TRM 260.8		94	7	26	8.7	0.5 K	38	22	37	0.15	30	160	43	10 K	10 K	25 K
Wheeler	TRM 277.0	Dup-1	94	6	27	7.6	0.5 K	31	24	30	0.16	29	160	50	10 K	10 K	25 K
		Dup-2	94	6	27	7.0	0.6	32	25	28	0.15	30	160	39	10 K	10 K	25 K
Wheeler	TRM 295.9	Dup-1	94	6	27	3.9	0.5 K	22	17	16	0.13	18	110	23	10 K	50	25 K
		Dup-2	94	6	27	4.8	0.5 K	26	20	21	0.14	20	130	24	10 K	50	25 K
Wheeler	ERM 6.0		94	7	26	5.0	0.5 K	23	5	20	0.10	22	68	26	10 K	10 K	25 K
Guntersville	TRM 350.0		94	8	29	8.2	0.6	45	29	54	0.62	34	320	34	10 K	10 K	60
Guntersville	TRM 375.2		94	8	29	4.8	0.5 K	20	12	26	0.23	21	160	21	10 K	10 K	25 K
		Precision	94	8	29	4.6	0.5 K	23	11	28	0.24	20	150		10 K	10 K	25 K
Nickajack	TRM 425.5		94	6	7	7.0	0.6	32	38	56	0.25	26	250	23	10 K	10 K	25 K
Chickamauga	TRM 472.3	Dup-1	94	5	25	7.8	0.5 K	33	58	46	0.38	31	280	1	10 K	10 K	25 K
		Dup-2	94	5	25	8.5	0.6	31	63	50	0.38	30	320	1	10 K	10 K	50
		Precision	94	5	25	7.4	0.5	33	62	52	0.37	30	320		10 K	10 K	25 K
Chickamauga	TRM 490.5		94	5	25	6.0	0.5 K	28	30	33	0.25	22	240	1	10 K	10 K	25 K
Chickamauga	HiRM 8.5		94	5	25	2.7	0.5 K	28	46	16	0.10 K	16	200	2	10 K	10 K	25 K
Watts Bar	TRM 531.0		94	6	1	12.0	0.5 K	36	34	34	0.43	30	200	31	10 K	10 K	60
Watts Bar	TRM 560.8	Dup-1	94	6	1	8.4	0.6	24	27	28	0.53	21	160	16	10 K	10 K	40
		Dup-2	94	6	1	8.8	0.6	30	32	33	0.57	27	190	12	10 K	10 K	30
Fort Loudoun	TRM 605.5		94	6	20	8.1	0.7	33	30	38	0.11	24	280	82	10 K	10 K	40
		Precision	94	6	20	7.8	0.6	35	29	36	0.11	26	270		10 K	10 K	40
Fort Loudoun	TRM 624.6	Dup-1	94	6	20	5.6	1.0	28	29	34	0.12	20	310	78	10 K	10 K	40
		Dup-2	94	6	20	5.7	0.9	29	30	36	0.12	22	300	66	10 K	10 K	40
Tellico	LTRM 1.0		94	7	13	10.0	0.5 K	32	23	29	0.12	22	130	50	10 K	10 K	25 K
Tellico	LTRM 15.0	Dup-1	94	7	13	7.0	0.5 K	25	22	22	0.13	16	110	22	10 K	10 K	25 K
		Dup-2	94	7	13	7.0	0.5 K	24	18	22	0.12	14	94	13	10 K	10 K	25 K
Melton Hill	CRM 24.0	Dup-1	94	8	29	11.0	0.5 K	27	31	44	0.12	26	130	120	10 K	10 K	25 K
		Dup-2	94	8	29	12.0	0.6	27	31	44	0.13	26	130	110	10 K	10 K	25 K
Melton Hill	CRM 45.0		94	8	29	6.8	0.5 K	20	26	38	0.10	21	120	62	10 K	10 K	40
Norris	CRM 80.0		94	6	6	27.0	1.2	28	36	94	0.12	30	150	41	10 K	10 K	25 K
Norris	CRM 125.0		94	6	7	6.3	0.5	28	28	39	0.10 K	27	130	39	10 K	10 K	25 K
Norris	PRM 30.0		94	6	7	8.8	0.5	24	28	52	0.10 K	26	160	39	10	10 K	25 K
		Precision	94	6	7	8.8	0.5	24	27	52	0.10 K	27	160		10 K	10 K	25 K
Douglas	FBRM 33.0		94	6	21	6.3	0.5 K	32	24	33	0.10 K	16	110	12	10 K	10 K	25 K
Douglas	FBRM 51.0		94	6	21	2.7	0.6	33	28	33	0.10 K	18	160	37	20	10 K	25 K
Cherokee	HRM 53.0	Dup-1	94	7	18	9.3	0.5 K	35	40	38	0.18	27	150	65	10 K	10 K	25 K
		Dup-2	94	7	18	9.8	0.5 K	36	44	38	0.20	29	160	49	10 K	10 K	25 K
Cherokee	HRM 76.0		94	7	18	7.3	0.5 K	32	54	38	0.42	26	150	92	10 K	10 K	25 K

TABLE 5 (Cont'd)

SEDIMENT CHEMISTRY
1994 RESERVOIR VITAL SIGNS DATA

Reservoir	Mile	Comment	Collection Date yy	mm	dd	Metals, mg/kg (dry weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	ZINC	AMMONIA (ug/l)	CHLORDANE (ug/kg)	DDT (ug/kg)	PCB (ug/kg)
Ft Pat Henry	SFHRM 8.7		94	6	22	7.0	0.5 K	30	45	35	0.10 K	18	200	120	30	10 K	30
Boone	SFHRM 19.0		94	6	22	8.1	0.5 K	34	39	44	0.10	21	170	96	30	10 K	40
Boone	SFHRM 27.0		94	6	22	5.0	0.5 K	27	30	38	0.11	16	110	140	40	10 K	25 K
Boone	WRM 6.5		94	6	22	5.8	0.5	33	54	55	0.13	20	280	71	30	10 K	50
South Holston	SFHRM 51.0		94	7	12	7.6	0.5 K	26	29	40	0.10 K	16	78	27	10 K	10 K	25 K
South Holston	SFHRM 62.5		94	7	12	5.8	0.5 K	29	23	38	0.12	18	96	29	10 K	10 K	25 K
		Precision	94	7	12	5.1	0.5 K	31	23	37	0.12	19	100		10 K	10 K	25 K
Watauga	WRM 37.4		94	8	22	7.6	0.5 K	27	28	38	0.10 K	28	98	37	10 K	10 K	25 K
Watauga	WRM 45.5		94	8	22	5.2	0.5 K	29	25	38	0.10 K	26	140	12	20	10 K	25 K
Fontana	LTRM 62.0		94	8	22	5.0	0.5 K	40	40	36	0.10 K	34	140	20	20	10 K	25 K
Fontana	LTRM 81.5		94	8	22	2.0	0.5 K	50	42	30	0.10 K	34	150	8	30	10 K	25 K
Fontana	TkRM 3.0		94	8	22	2.1	0.5 K	47	24	17	0.10 K	32	120	9	30	10 K	25 K
Hiwassee	HiRM 77.0		94	7	12	4.8	0.5 K	41	40	40	0.10	23	120	29	10 K	10 K	25 K
Hiwassee	HiRM 85.0		94	7	12	3.0	0.5 K	38	36	34	0.10	22	120	19	10 K	10 K	25 K
Chatuge	HiRM 122.0		94	5	24	2.8	0.5 K	60	50	24	0.10 K	27	80	8	10 K	10 K	25 K
Chatuge	SCM 1.5		94	5	24	3.0	0.5 K	81	58	32	0.10 K	45	84	12	10 K	10 K	25
Nottely	NRM 23.5		94	8	17	2.4	0.5 K	37	33	21	0.10 K	20	96	14	10 K	10 K	25 K
Nottely	NRM 31.0		94	8	17	3.0	0.5 K	47	38	26	0.10 K	26	120	25	10 K	10 K	25 K
Ocoee #1	ORM 12.5		94	6	6	38.0	3.5	40	1700	1200	0.23	18	1300	8	10 K	10 K	240
Blue Ridge	ToRM 54.1		94	6	20	3.4	0.5 K	42	43	44	0.10 K	19	110	1	10 K	10 K	25 K
Tims Ford	ERM 135.0		94	8	23	11.0	0.5 K	20	17	33	0.10 K	56	77	68	10 K	10 K	25 K
		Precision	94	8	23	11.0	0.5 K	22	18	31	0.10 K	62	84		10 K	10 K	25 K
Tims Ford	ERM 150.0		94	8	23	9.8	0.5 K	33	16	34	0.10 K	32	90	46	10 K	10 K	25 K
Normandy	DRM 249.5		94	8	23	8.0	0.5 K	20	21	34	0.10 K	33	76	36	10 K	10 K	25 K
Bear Creek	BCM 75.0		94	8	17	6.8	0.5 K	29	16	22	0.10 K	26	80	100	10 K	10 K	25 K
L. Bear Creek	LBCM 12.5		94	8	17	9.8	0.5 K	38	14	28	0.11	28	120	61	10 K	10 K	25 K
Cedar Creek	CCM 25.2		94	8	17	8.3	0.5 K	25	10	17	0.10 K	20	68	35	10 K	10 K	25 K
Beech	BRM 36.0		94	5	31	12.0	0.6	28	20	35	0.10 K	16	70	5	10 K	10 K	25 K
			Number			74	74	74	74	74	74	74	74	67	74	74	74
			Max			38.0	3.5	81	1700	1200	0.75	62	1300	140	40	50	240
			Min			2.0	0.5 K	19	5	16	0.10 K	10	68	1	10 K	10 K	25 K
			Mean			7.7	0.6 K	32	51	49	0.19 K	24	163	38	12 K	11 K	31 K

(sedchm94.wk1)

Section 4. Benthic Macroinvertebrate Community

Philosophical Approach/Background

Benthic macroinvertebrates are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have limited capability of movement thereby preventing them from avoiding undesirable conditions. The macroinvertebrate community in a reservoir is expected to be vastly different from that in the river in the preimpoundment state. Also, substantial differences are expected along a longitudinal gradient with a more riverine community expected at the upper end or inflow of a reservoir and a more lake like community expected in the pool near the dam. Other factors to consider in evaluating this community in reservoirs include reservoir operational characteristics (e.g., depth of withdrawal for discharge, water depth, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability) and physical/chemical features owing to geological characteristics of different ecoregions.

All these factors, plus the fact that a reservoir is an artificial system, must be considered in selecting community characteristics or expectations that will be used to represent good, fair, and poor conditions. Given that reservoirs are artificial systems, it not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using references site to determine characteristics or expectations of a reservoir unaffected by human impacts. Other approaches must be used such as: historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. The state of the science of benthic macroinvertebrate communities in reservoirs simply is insufficient for predictive models to be effective. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for this community in reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment is the best approach.. Use of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for

which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 30 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics.

Run-of-the-River Reservoirs	Tributary Reservoirs: Ridge and Valley Ecoregion
Kentucky	Cherokee
Pickwick	Fort Patrick Henry*
Wilson	Boone
Wheeler	South Holston
Guntersville	Norris
Nickajack	Douglas
Chickamauga	Tims Ford**
Watts Bar	
Melton Hill	
Tellico	Tributary Reservoirs: Blue Ridge Ecoregion
Fort Loudon	Fontana
	Hiwassee
Tributary Reservoirs: Interior Plateau Ecoregion	Chatuge
Bear Creek	Nottely
Cedar Creek	Parksville***
Little Bear	Blue Ridge
Normandy	Watauga
Beech	

* Fort Patrick Henry Reservoir was included in this class because it is in the Ridge and Valley Ecoregion, but results were excluded in developing scoring ranges for this class because the shallow drawdown and short retention are uncharacteristic of the other reservoirs in this class.

** Tims Ford is in the Interior Plateau ecoregion but due to operational and morphological characteristics was considered more similar to and classified with Ridge and Valley reservoirs.

***Results for Parksville Reservoir were excluded from developing reference conditions because of known poor sediments conditions (very high metal concentrations), which would be expected to cause a degraded benthic macroinvertebrate community.

Once reservoirs have been appropriately classified, scoring criteria (i.e., those values for each metric which will be considered good, fair, or poor) must be developed. When using best observed conditions, a database must exist and decisions made as to how best separate data for each metric into the three scoring ranges of good, fair, and poor. The approach taken by TVA is, for each metric, first

omit outliners (defined as more than three standard deviations from the mean), then trisect the range of the remaining values. Cutoff points are examined closely and adjusted if appropriate based on professional judgment. These three ranges represent good, fair, and poor conditions and form the reference conditions or expectations for each metric. More details of TVA's approach to developing scoring ranges are provided under the Benthic Community Scoring Scheme below.

Sample Collection Methods

Benthic macroinvertebrate community samples were collected in the spring (March and April) of 1994 at 69 locations on 30 TVA reservoirs (Table 1). At each sample location, a line-of-sight transect was established across the width of the reservoir, and one Ponar grab sample collected at 10 equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Care was taken to collect samples only from the permanently wetted bottom portion of the reservoir (i.e., below the elevation of the minimum winter pool level). Samples were washed in the field, transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution. Samples were sent to the laboratory where they were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request

To assess the reproducibility of benthic macroinvertebrate sampling results, replicate samples were collected at 13 of the 69 sampling locations in 1994, with all types of reservoir locations (i.e., forebay, transition zone, embayment, and inflow) included. At each of the replicate sampling locations, the sampling protocol involved collection of a first set of 10 samples, leaving the sampling location, and then returning as near as possible to the original transect site (on the same day) and repeating the collection of a second (replicate) set of 10 samples. The results from sets of replicate samples were then evaluated for reproducibility.

Note: Beginning in 1995, benthic macroinvertebrate sampling will be conducted in late fall/early winter rather than late winter/early spring as in 1990 -1994. The problem with late winter/early spring time frame is that results are reflective of conditions the previous year. This has the undesirable effect of causing results for benthic macroinvertebrates to be out of synch with the rest of the monitoring data. This period was initially selected because late fall/early winter was thought unfeasible because the required reporting date of mid-January would not allow processing time in the laboratory. Also, there was concern that insect instars would be so small that they could pass through the collection screen and/or be difficult to identify. Thorough evaluation of the 1993 - 1994 results

showed late fall/early winter collection and use of field identification to the family and order levels would negate problems resulting from early spring sampling and would not impact the contribution of this important community to the overall evaluation. Appendix A documents the basis of this change.

Benthic Community Rating Scheme

Eight community characteristics (or metrics), were selected to evaluate the benthic community.

1. **Taxa richness**—The average total number of taxa per sample at each site. An increase taxa richness indicates better conditions than low taxa richness.
2. **EPT**—The average total number of Ephemeroptera, Plecoptera, and Trichoptera per sample at each site. Higher diversity of these taxa indicate good water quality and other habitat conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.
3. **Long-lived species**—The percent of samples with at least one long-lived organism (Corbicula, Hexagenia, mussels, and snails) present. The presence of long-lived taxa is indicative of conditions which allow long-term survival.
4. **Proportion as Chironomidae**—The average proportion of chironomids in each sample at each site. A higher proportion indicates poor water quality.
5. **Proportion as Tubificidae**—The average proportion of tubificids in each sample at each site. A higher proportion indicates poor water quality.
6. **Proportion as dominant taxa**—The average proportion of the two dominant families in each sample even if the dominant taxon differed among the samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples a site. This metric is used as an evenness indicator. Dominance of one or two families indicates poor conditions.
7. **Total abundance excluding Chironomidae and Tubificidae**—The average number of organisms excluding chironomids and tubificids per sample at each site. This metric examines the community excluding families which often dominate under adverse conditions. A higher abundance of non-chironomids and tubificids indicates good water quality conditions.
8. **Percentage of samples with no organisms present**—Percentage of samples with no organisms present. "Zero-samples" indicate living conditions unsuitable to support aquatic life (i.e. toxicity, unsuitable substrate, etc.). Any site having one or more empty samples was assigned a score of one. Sites with no empty samples were assigned a score of five.

Scoring Criteria for each of the eight metrics were developed using the five years of Vital Signs monitoring data (1990 - 1994). Scoring ranges were developed as follows:

- Individual criteria were developed for each type of sampling location (forebay, transition zone/mid-reservoir, embayment and inflow) for each of the four classes of reservoirs.
- Results from the 10 samples along a transect for each sample year were combined (averaged for most metrics) and outliers deleted.
- The range of average values was then trisected with the third of the range representing desirable conditions assigned a value of 5 (good), the middle one-third assigned a 3 (fair), and the third representing undesirable conditions was assigned a 1 (poor).

Professional judgment along with supplementary statistical analyses were used to adjust the cutoffs for each range as appropriate. Scoring Criteria resulting from these efforts are detailed for each metric in Table 2. Separate tables are provided for each class of reservoir.

Sample results at each site were compared with these criteria for each metric and assigned the rating described above--5 (good) 3 (fair), 1(poor) if they fell within the top, middle, or bottom group, respectively. Numerical ratings for the eight metric were then summed. This resulted in a minimum score of 8 if all metrics at a site were poor, and a maximum score of 40 if all metrics were good.

The resulting score has two uses. One is to evaluate the condition of the benthic macroinvertebrate itself. The other is to help establish the overall ecological health of a reservoir. In the latter case, the benthic macroinvertebrate community is one of five equally weighted indicators which are summed to arrive at an overall Ecological Health Index for a reservoir.

To arrive at an evaluation of the condition of the benthic macroinvertebrate community at a sample location, scores were evaluated as follows:

Benthic Community Score	8-15	16-21	22-27	28-33	34-40
Community Condition	Very Poor	Poor	Fair	Good	Excellent

The contribution of the benthic macroinvertebrate results for each sample site to the overall reservoir Ecological Health Index was as follows:

Benthic Community Score	8-15	16-21	22-27	28-33	34-40
Contribution to Reservoir Ecological Health Index	1	2	3	4	5

One further use of these results is for TVA's report to the public on the conditions of Tennessee Valley reservoirs. In this publication, titled *Riverpulse,* results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good),

yellow (fair), or red (poor). This necessitated dividing the benthic macroinvertebrate scores into three ranges as follows:

Benthic Community Score	8-18	19-29	30-40
Color (Rating) in *RiverPulse*	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1994 Monitoring

Results from 1994 monitoring activities are summarized by reservoir class and type of location for each metric in the Table 3. Also included with the 1994 results are results from all previous years. Abbreviations for metrics in the table are those provided above each metric is defined. Appendix B provides mean density for each species at each location in 1994.

Results of Quality Control samples are identified in the table with a "Q". Approximately 20 percent of all the benthic sampling stations were revisited for Quality Control purposes. All together, 13 randomly selected sites were revisited, usually on the same day as the first sample set. The desired maximum difference between the score for the original sample and the QA sample was 6. A difference greater than this would cause the rating to change 2 categories (e.g., very poor to fair, fair to good), which was deemed unacceptable. Results for each set of repeat samples are provided below.

	Original Score	QA/QC Score	Difference
Run-of-the-River Reservoirs			
Forebays			
Chickamauga	28 (Good)	34 (Excellent)	6
Nickajack	34 (Excellent)	30 (Good)	4
Transition Zones			
Chickamauga	38 (Excellent)	38 (Excellent)	0
Kentucky	32 (Good)	34 (Excellent)	2
Inflows			
Nickajack	34 (Excellent)	38 (Excellent)	4
Pickwick	30 (Good)	32 (Good)	2
Embayments			
Hiwassee	24 (Fair)	22 (Fair)	2
Tributary Reservoirs			
Forebays			
Parksville	12 (Very Poor)	8 (Very Poor)	4
Blue Ridge	22 (Fair)	28 (Good)	6
Little Bear	24 (Fair)	28 (Good)	4
Upper			
Watauga	22 (Fair)	16 (Poor)	6
Hiwassee	18 (Poor)	18 (Poor)	0
Nottely	28 (Good)	34 (Excellent)	6

The maximum observed difference was 6 (4 sets of samples) and the minimum was 0 (2 sets of samples). A greater difference generally was found for the tributary reservoirs than for the run-of-the-river reserves. The mean difference for all reservoirs was 3.54. The 95% confidence interval around the mean would be 2.17 to 4.9, well below the desired level of 6.

TABLE 1 (revised 10/31/94)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	FB	M	A	A	A	A
	TRM 85.0	TZ	M	A	A	A	A
	TRM 200-206	I	-	-	-	A	A
	Big Sandy 7.4	E	M	A	A	A	A
Pickwick	TRM 207.3	FB	M	A	A	A	A
	TRM 230.0	TZ	M	A	A	A	A
	TRM 253-259	I	-	-	-	A	A
	Bear Creek 8.4	E	M	A	A	A	A
Wilson	TRM 260.8	FB	M	A	A	A	A
	TRM 273-274	I	-	-	-	A	A
Wheeler	TRM 277.0	FB	M	A	A	A	A
	TRM 295.9	TZ	M	A	A	A	A
	TRM 347-348	I	-	-	-	A	A
	Elk River 6.0	E	M	A	A	A	A
Guntersville	TRM 350.0	FB	M	A	A	A	A
	TRM 375.2	TZ	M	A	A	A	A
	TRM 420-424	I	-	-	-	A	A
Nickajack	TRM 425.5	FB	M	A	A	A	A
	TRM 469-470	I	-	-	-	A	A
Chickamuaga	TRM 472.3	FB	M	A	A	A	A
	TRM 490.5	TZ	M	A	A	A	A
	TRM 518-529	I	-	-	-	A	A
	Hiwassee 8.5	E	M	A	A	A	A

TABLE 1 (Cont'd)

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	FB	M	A	A	A	A
	TRM 560.8	TZ	M	A	A	A	A
	TRM 600-601	I	-	-	-	A	A
	CRM 19-22	I	-	-	-	A	A
Fort Loudoun	TRM 605.5	FB	M	A	A	A	A
	TRM 624.6	TZ	M	A	A	A	A
	TRM 652	I	-	-	-	A	A
Tellico	LTRM 1.0	FB	M	A	A	A	A
	LTRM 15.0	TZ	M	A	A	A	A
Melton Hill	CRM 24.0	FB	M	A	A	A	A
	CRM 45.0	TZ	M	A	A	A	A
	CRM 59-66	I	-	-	-	A	A
		Totals	24	24	24	35	35

TABLE 1 (Cont'd)

RESERVOIR VITAL SIGNS MONITORING ACTIVITIES, 1994

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	FB	M	A	A	A	A
	CRM 125.0	MR	M	A	A	A	A
	PRM 30.0	MR	M	A	A	A	A
Cherokee	HRM 53.0	FB	M	A	A	A	A
	HRM 76.0	MR	M	A	A	-	A
	HRM 91	I	-	-	-	A	-
Douglas	FBRM 33.0	FB	M	A	A	A	A
	FBRM 51.0	MR	M	A	A	A	A
	FBRM 61	I	-	-	-	-	-
Ft.Pat Henry	SFHR 8.7	FB	M	A	A	A	A
Boone	SFHR 19.0	FB	M	A	A	A	A
	SFHR 27.0	MR	M	A	A	A	A
	WRM 6.5	MR	M	A	A	A	A
South Holston	SFHR 51.0	FB	M	A	A	A	A
	SFHR 62.5	MR/I	M	A	A	A	A
Watauga	WRM 37.4	FB	M	A	A	A	A
	WRM 45.5	MR	M	A	A	A	A
Fontana	LTRM 62.0	FB	M	A	A	-	A
	LTRM 81.5	MR	M	A	A	A	A
	TkRM 3.0	MR	M	A	A	A	A

TABLE 1 (Cont'd)

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	FB	M	A	A	A	A
	HiRM 85.0	MR	M	A	A	A	A
	HiRM 90	I	-	-	-	A	-
Chatuge	HiRM 122.0	FB	M	A	A	A	A
	Shooting Cr 1.5	FB	M	A	A	A	A
Nottely	NRM 23.5	FB	M	A	A	A	A
	NRM 31.0	MR	M	A	A	A	A
Blue Ridge	ToRM 54.1	FB	M	A	A	A	A
Ocoee No.1	ORM 12.5	FB	M	A	A	A	A
Tims Ford	ERM 135.0	FB	M	A	A	A	A
	ERM 150.0	MR	M	A	A	A	A
Bear Creek	BCM 75.0	FB	M	A	A	A	A
L. Bear Creek	LBCM 12.5	FB	M	A	A	A	A
Cedar Creek	CCM 25.2	FB	M	A	A	A	A
Normandy	DRM 249.5	FB	M	A	A	A	A
Beech	BRM 36.0	FB	M	A	A	A	A
		Totals	33	33	33	32	33

TABLE 1 (Cont'd)

Footnotes
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a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

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

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

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

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

Table 2. Scoring Criteria for Benthic Macroinvertebrate Community
1994 Reservoir Vital Signs Monitoring

Run-of-the-River Reservoirs

Benthic Community	Forebay			Transition			Inflow		
Metrics	1	3	5	1	3	5	1	3	5
Taxa Richness	≤4.6	4.6-6.9	≥7	≤6	6.1-8.9	≥9	≤5	5.1-7.9	≥8
EPT	≤.5	.6-.9	≥1	≤.5	.6-1.4	≥1.5	≤.8	.9-1.9	≥2
Long-lived	≤.5	.6-.8	≥.9	≤.5	.6-.9	≥1	≤.5	.6-.8	≥.9
Percent Chironomids	≥60.0	45.1-59.9	≤40.0	≥60.0	35.1-59.9	≤35.0	≥40.0	10.1-39.9	≤10.0
Percent Tubificids	≥30.0	15.1-29.9	≤15.0	≥30.0	15.1-29.9	≤15.0	≥30.0	15.1-29.9	≤15.0
Dominance	≥90.0	80.1-89.9	≤80.0	≥85.0	75.1-84.9	≤75.0	≥85.0	70.1-84.9	≤70.0
Non-tolerant Density	≤250	250.1-324.9	≥325	≤300	300.1-699.9	≥700	≤500	500.1-999.9	≥1000
Zero Samples	≥1	-	0	≥1	0	0	≥1	-	0

Blue Ridge Tributary Reservoirs

Benthic Community	Forebay						Upper		
Metrics	1	3	5	1	3	5	1	3	5
Taxa Richness	≤2	2.1-3.9	≥4	-	-	-	≤3	3.1-3.9	≥4
EPT	≤.1	.11-.39	≥.4	-	-	-	≤.1	.11-.59	≥.6
Long-lived	≤.1	.11-.49	≥.5	-	-	-	≤.1	.11-.49	≥.5
Percent Chironomids	≥45.0	30.1-44.9	≤30.0	-	-	-	≥60.0	30.1-59.9	≤30.0
Percent Tubificids	≥65.0	40.1-64.9	≤40.0	-	-	-	≥65.0	35.1-64.9	≤35.0
Dominance	≥95.0	90.1-94.9	≤90.0	-	-	-	≥96.0	92.1-95.9	≤92.0
Non Chi. and Tub. Density	≤100.0	100.1-199.9	≥200.0	-	-	-	≤25.0	25.1-49.9	≥50.0
Zero Samples	1	-	0	-	-	-	1	-	0

Table 2. Cont', Scoring Criteria for Benthic Macroinvertebrate Community
1994 ReservoirVital Signs Monitoring

Interior Plateau Tributary Reservoirs

Benthic Community Metrics	Forebay			Transition			Inflow		
	1	3	5	1	3	5	1	3	5
Taxa Richness	≤2.5	2.6-3.9	≥4	-	-	-	-	-	-
EPT	≤.1	.11-.59	≥.6	-	-	-	-	-	-
Long-lived	≤.1	.11-.49	≥.5	-	-	-	-	-	-
Percent Chironomids	≥60.0	30.1-59.9	≤30.0	-	-	-	-	-	-
Percent Tubificids	≥96.0	92.1-95.9	≤92.0	-	-	-	-	-	-
Dominance	≥95.0	90.1-94.9	≤90.0	-	-	-	-	-	-
Non Chi. and Tub. Density	≤30.0	30.1-59.9	≥60.0	-	-	-	-	-	-
Zero Samples	0	-	1	-	-	-	-	-	-

Ridge and Valley Tributary Reservoirs

Benthic Community Metrics	Forebay			Transition			Upper		
	1	3	5	1	3	5	1	3	5
Taxa Richness	≤1.5	1.6-2.9	≥3	-	-	-	≤3	3.1-4.9	≥5
EPT	0	.1-.19	≥.2	-	-	-	0	.1-.19	≥.2
Long-lived	≤.1	.11-.49	≥.5	-	-	-	≤.2	.21-.69	≥.7
Percent Chironomids	≥50.0	25.1-49.9	≤25.0	-	-	-	≥65.0	35.1-64.9	≤35.0
Percent Tubificids	≥80.0	50.1-79.9	≤50.0	-	-	-	≥60.0	40.1-59.9	≤40.0
Dominance	≥98.0	94.1-97.9	≤94.0	-	-	-	≥98.0	94.1-97.9	≤94.0
Non Chi. and Tub. Density	≤1.5	1.4-2.9	≥3.0	-	-	-	≤25.0	25.1-49.9	≥50.0
Zero Samples	0	-	1	-	-	-	0	-	1

Table 3. Results and Ratings for Individual Metrics and Final Benthos Score. Separated by Reservoir Class and Type of Sample Location

Run-of-River Reservoirs--Forebays

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		472.3	91	30	5.8	3	1.0	5	0.9	3	54.4	3	6.7	5	84.3	3	280.0	3	0.0	5
CHICKAMAUGA		472.3	92	38	5.9	3	1.0	5	1.1	5	38.6	5	9.3	5	74.4	5	501.7	5	0.0	5
CHICKAMAUGA		472.3	93	36	7.2	5	1.0	5	0.9	3	41.6	5	17.8	3	75.1	5	348.3	5	0.0	5
CHICKAMAUGA	Q *	472.3	93	34	6.7	3	1.0	5	1.0	5	43.9	5	19.4	3	73.6	5	308.3	3	0.0	5
CHICKAMAUGA		472.3	94	28	6.5	3	1.0	5	1.3	5	61.8	1	14.2	5	85.4	3	198.3	1	0.0	5
CHICKAMAUGA	Q	472.3	94	34	7.4	5	1.0	5	1.0	5	48.7	3	23.1	3	85.1	3	378.3	5	0.0	5
FORT LOUDOUN		603.2	91	16	3.5	1	0.4	1	0.0	1	36.1	5	44.6	1	99.9	1	33.5	1	0.0	5
FORT LOUDOUN		605.5	92	10	2.1	1	0.4	1	0.2	1	72.5	1	25.3	3	100.0	1	6.8	1	0.1	1
FORT LOUDOUN		603.2	92	14	3.0	1	0.3	1	0.1	1	67.4	1	27.0	3	99.1	1	12.7	1	0.0	5
FORT LOUDOUN		605.5	93	14	5.2	3	0.5	1	0.3	1	63.6	1	33.5	1	97.1	1	22.7	1	0.0	5
FORT LOUDOUN		605.5	94	14	4.5	1	0.4	1	0.2	1	65.1	1	22.8	3	99.3	1	17.4	1	0.0	5
GUNTERSVILLE		350.0	91	36	7.2	5	1.0	5	1.1	5	58.9	3	11.7	5	80.0	5	318.3	3	0.0	5
GUNTERSVILLE		350.0	92	32	5.9	3	1.0	5	0.8	3	43.4	5	15.8	3	77.4	5	313.3	3	0.0	5
GUNTERSVILLE		350.0	93	30	6.8	3	0.9	5	0.8	3	50.8	3	13.9	5	80.2	3	316.7	3	0.0	5
GUNTERSVILLE		350.0	94	28	6.9	3	1.0	5	1.0	5	54.1	3	15.2	3	82.0	3	220.0	1	0.0	5
KENTUCKY		23.0	91	28	5.4	3	1.0	5	0.6	3	52.9	3	11.4	5	84.4	3	221.7	1	0.0	5
KENTUCKY		23.0	92	32	5.4	3	1.0	5	0.4	1	39.2	5	18.6	3	78.3	5	371.7	5	0.0	5
KENTUCKY		7.4#	93	32	8.7	5	1.0	5	0.6	3	71.8	1	3.4	5	87.2	3	360.0	5	0.0	5
KENTUCKY		23.0	93	36	7.5	5	1.0	5	0.6	3	42.2	5	13.0	5	85.2	3	708.3	5	0.0	5
KENTUCKY		7.4#	94	22	8.7	5	0.8	3	0.4	1	77.1	1	10.8	5	90.1	1	138.3	1	0.0	5
KENTUCKY		23.0	94	26	5.9	3	1.0	5	0.4	1	50.0	3	23.3	3	83.6	3	283.3	3	0.0	5
MELTON HILL		24.0	91	16	3.9	1	0.7	3	0.4	1	68.4	1	16.9	3	96.3	1	31.7	1	0.0	5
MELTON HILL		24.0	92	22	6.7	3	0.7	3	0.6	3	54.1	3	30.1	1	87.1	3	143.5	1	0.0	5
MELTON HILL		24.0	93	14	4.1	1	0.3	1	0.1	1	65.9	1	16.2	3	94.4	1	25.0	1	0.0	5
MELTON HILL		24.0	94	16	5.7	3	0.3	1	0.5	1	67.7	1	25.3	3	93.9	1	33.3	1	0.0	5
NICKAJACK		425.5	91	36	6.1	3	1.0	5	1.0	5	25.6	5	3.4	5	84.7	3	543.3	5	0.0	5
NICKAJACK		425.5	92	38	6.8	3	1.0	5	1.0	5	23.7	5	9.4	5	74.0	5	521.7	5	0.0	5
NICKAJACK		425.5	93	36	7.3	5	1.0	5	1.3	5	37.6	5	11.4	5	81.6	3	270.0	3	0.0	5
NICKAJACK	Q	425.5	93	40	7.2	5	1.0	5	1.0	5	37.4	5	7.1	5	77.8	5	358.3	5	0.0	5
NICKAJACK		425.5	94	34	8.2	5	1.0	5	1.9	5	51.7	3	10.1	5	78.0	5	235.0	1	0.0	5
NICKAJACK	Q	425.5	94	30	6.0	3	0.9	5	1.4	5	49.2	3	12.8	5	81.2	3	170.0	1	0.0	5
PICKWICK		207.3	91	18	4.8	3	0.8	3	0.8	3	63.2	1	16.1	3	88.8	3	208.3	1	0.1	1
PICKWICK		207.3	92	34	6.1	3	0.9	5	0.8	3	39.2	5	9.5	5	76.8	5	290.0	3	0.0	5
PICKWICK		8.4#	93	16	6.5	3	0.7	3	0.4	1	62.8	1	33.4	1	96.6	1	40.0	1	0.0	5
PICKWICK		207.3	93	32	6.3	3	1.0	5	0.9	3	30.7	5	16.9	3	75.8	5	290.0	3	0.0	5
PICKWICK		8.4#	94	16	6.5	3	0.2	1	0.0	1	71.5	1	26.9	3	98.4	1	20.0	1	0.0	5
PICKWICK		207.3	94	38	8.0	5	0.9	5	1.2	5	41.2	5	19.6	3	77.1	5	625.0	5	0.0	5
TELLICO		1.0	91	12	1.7	1	0.1	1	0.0	1	38.5	5	73.5	1	100.0	1	6.7	1	0.2	1
TELLICO		1.0	92	16	2.7	1	0.3	1	0.1	1	17.2	5	59.8	1	99.2	1	8.9	1	0.0	5
TELLICO		1.0	93	16	3.6	1	0.5	1	0.2	1	20.3	5	67.9	1	92.0	1	25.0	1	0.0	5
TELLICO	Q	1.0	93	12	2.7	1	0.1	1	0.1	1	30.5	5	78.7	1	99.2	1	5.0	1	0.1	1
TELLICO		1.0	94	16	2.8	1	0.5	1	0.1	1	18.8	5	61.2	1	95.7	1	28.3	1	0.0	5
WATTS BAR		531.0	91	22	3.8	1	0.9	5	0.4	1	58.0	3	2.1	5	96.0	1	98.3	1	0.0	5
WATTS BAR		531.0	92	22	5.8	3	0.9	5	0.6	3	49.8	3	36.7	1	95.9	1	67.6	1	0.0	5
WATTS BAR		531.0	93	26	6.4	3	1.0	5	0.9	3	68.0	1	4.2	5	87.5	3	170.0	1	0.0	5
WATTS BAR		531.0	94	22	4.9	3	0.8	3	0.6	3	56.1	3	18.9	3	90.2	1	53.3	1	0.0	5
WHEELER		277.0	91	20	5.4	3	0.8	3	0.3	1	77.9	1	9.2	5	95.1	1	50.0	1	0.0	5
WHEELER		277.0	92	16	4.4	1	0.7	3	0.3	1	64.2	1	20.2	3	93.9	1	61.7	1	0.0	5
WHEELER		277.0	93	22	4.9	3	0.9	5	0.3	1	83.4	1	2.8	5	94.8	1	100.0	1	0.0	5
WHEELER		277.0	94	20	6.1	3	0.8	3	0.1	1	65.0	1	18.8	3	87.9	3	101.7	1	0.0	5
WILSON		260.8	91	18	5.2	3	0.7	3	0.0	1	66.7	1	25.4	3	93.3	1	73.3	1	0.0	5
WILSON		260.8	92	14	4.2	1	0.6	3	0.1	1	61.7	1	33.7	1	95.3	1	41.7	1	0.0	5
WILSON		260.8	93	22	6.5	3	0.8	3	0.4	1	74.0	1	13.6	5	89.4	3	131.7	1	0.0	5
WILSON		260.8	94	16	4.1	1	0.3	1	0.0	1	75.4	1	12.2	5	93.8	1	91.7	1	0.0	5

*Q = Identifies results from a replicate set of samples for QA purposes

= Identifies an embayment sample location; included with forebays because habitat (sediment substrate and reservoir flow) in these embayments was similar to forebay habitat

Table 3 (Cont'd)

Run-of-River Reservoirs--Transition Zones

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		490.5	91	34	5.9	1	1.0	5	1.1	3	21.6	5	7.9	5	74.9	5	913.3	5	0.0	5
CHICKAMAUGA		490.5	92	36	6.4	3	1.0	5	1.0	3	23.4	5	9.2	5	74.7	5	908.3	5	0.0	5
CHICKAMAUGA		8.5 #	93	32	12.2	5	1.0	5	1.3	3	19.3	5	40.7	1	76.4	3	825.0	5	0.0	5
CHICKAMAUGA		490.5	93	34	8.4	3	1.0	5	1.1	3	29.2	5	14.9	5	75.0	5	466.7	3	0.0	5
CHICKAMAUGA	Q*	490.5	93	32	7.8	3	1.0	5	1.0	3	28.3	5	15.4	3	70.3	5	490.0	3	0.0	5
CHICKAMAUGA		8.5 #	94	24	6.0	1	0.8	3	1.2	3	17.2	5	33.6	1	75.3	3	380.0	3	0.0	5
CHICKAMAUGA		490.5	94	38	8.9	3	1.0	5	2.1	5	28.5	5	14.6	5	67.3	5	735.0	5	0.0	5
CHICKAMAUGA	Q	8.5 #	94	22	4.9	1	0.9	3	0.9	3	8.1	5	38.6	1	83.7	3	211.7	1	0.0	5
CHICKAMAUGA	Q	490.5	94	38	8.3	3	1.0	5	2.0	5	33.2	5	11.8	5	70.7	5	715.0	5	0.0	5
FORT LOUDOUN		624.6	91	14	4.7	1	0.4	1	0.4	1	49.3	3	42.5	1	97.0	1	51.7	1	0.0	5
FORT LOUDOUN		624.6	92	18	5.9	1	0.7	3	0.5	1	55.7	3	26.7	3	90.4	1	90.0	1	0.0	5
FORT LOUDOUN		624.6	93	20	7.7	3	0.8	3	0.7	3	53.0	3	31.2	1	85.2	1	140.0	1	0.0	5
FORT LOUDOUN		624.6	94	16	5.9	1	0.6	3	0.4	1	70.2	1	18.7	3	94.3	1	80.0	1	0.0	5
GUNTERSVILLE		375.2	92	34	6.5	3	1.0	5	0.8	3	22.1	5	6.4	5	83.3	3	906.7	5	0.0	5
GUNTERSVILLE		375.2	93	40	10.8	5	1.0	5	1.5	5	27.6	5	11.2	5	65.0	5	775.0	5	0.0	5
GUNTERSVILLE		375.2	94	38	9.8	5	1.0	5	1.3	3	22.7	5	5.6	5	73.7	5	915.0	5	0.0	5
KENTUCKY		85.0	92	34	7.8	3	1.0	5	0.8	3	16.6	5	12.0	5	79.2	3	871.7	5	0.0	5
KENTUCKY		85.0	93	34	9.1	5	1.0	5	1.1	3	23.6	5	23.8	3	72.6	5	606.7	3	0.0	5
KENTUCKY		85.0	94	32	7.8	3	1.0	5	1.6	5	23.2	5	16.6	3	76.1	3	606.7	3	0.0	5
KENTUCKY	Q	85.0	94	34	8.1	3	1.0	5	1.7	5	27.4	5	19.7	3	71.0	5	426.7	3	0.0	5
MELTON HILL		45.0	91	18	5.6	1	0.8	3	0.8	3	62.1	1	24.8	3	91.0	1	45.0	1	0.0	5
MELTON HILL		45.0	92	16	5.5	1	0.9	3	0.4	1	43.3	3	42.8	1	87.1	1	35.2	1	0.0	5
MELTON HILL		45.0	93	18	4.9	1	0.7	3	0.2	1	51.0	3	29.5	3	91.8	1	35.0	1	0.0	5
MELTON HILL		45.0	94	14	7.1	3	0.5	1	0.4	1	60.4	1	31.8	1	92.1	1	36.7	1	0.0	5
NICKAJACK		433.0	91	24	5.5	1	0.9	3	1.1	3	19.2	5	25.3	3	79.4	3	300.0	1	0.0	5
PICKWICK		230.0	91	28	4.6	1	1.0	5	0.7	3	31.0	5	4.6	5	82.2	3	263.3	1	0.0	5
PICKWICK		230.0	92	34	7.2	3	1.0	5	1.0	3	24.7	5	12.2	5	69.6	5	417.3	3	0.0	5
PICKWICK		230.0	93	32	7.0	3	0.9	3	1.0	3	27.7	5	14.9	5	72.8	5	511.7	3	0.0	5
PICKWICK		230.0	94	34	9.4	5	1.0	5	2.2	5	41.5	3	17.6	3	73.1	5	442.4	3	0.0	5
TELLICO		15.0	93	12	5.0	1	0.3	1	0.1	1	64.1	1	31.9	1	98.8	1	10.0	1	0.0	5
TELLICO		15.0	94	14	4.2	1	0.4	1	0.4	1	76.2	1	16.9	3	98.4	1	13.3	1	0.0	5
WATTS BAR		560.8	91	28	6.7	3	1.0	5	0.9	3	51.4	3	7.5	5	81.3	3	266.7	1	0.0	5
WATTS BAR		560.8	92	30	6.6	3	1.0	5	1.0	3	36.4	3	4.5	5	75.4	3	540.0	3	0.0	5
WATTS BAR		560.8	93	34	7.0	3	1.0	5	1.1	3	33.1	5	1.7	5	80.6	3	786.7	5	0.0	5
WATTS BAR		560.8	94	36	8.9	3	1.0	5	2.0	5	33.8	5	13.2	5	72.4	5	696.7	3	0.0	5
WHEELER		294.1	92	32	6.6	3	1.0	5	0.8	3	30.9	5	12.7	5	78.2	3	416.7	3	0.0	5
WHEELER		6.0 #	93	18	8.4	3	0.9	3	0.3	1	49.6	3	40.5	1	90.1	1	165.0	1	0.0	5
WHEELER		295.9	93	32	7.7	3	1.0	5	1.0	3	18.7	5	9.8	5	78.0	3	643.3	3	0.0	5
WHEELER		6.0 #	94	16	8.4	3	0.5	1	0.3	1	44.1	3	53.6	1	97.6	1	60.0	1	0.0	5
WHEELER		295.9	94	34	8.8	3	1.0	5	1.7	5	35.9	3	12.2	5	74.0	5	395.0	3	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

= Identifies an embay sample location; included with transition zone results because habitat in these embayments was similar to transition zone habitat (sediment substrate and reservoir flow)

Table 3 (Cont'd)

Run-of-River Reservoirs--Inflows

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
CHICKAMAUGA		518.0	91	24	3.2	1	1.0	5	0.5	1	0.7	5	9.1	5	91.4	1	460.6	1	0.0	5
CHICKAMAUGA		518.0	92	26	3.8	1	1.0	5	0.2	1	4.5	5	11.8	5	92.0	1	884.6	3	0.0	5
CHICKAMAUGA		518.0	93	30	6.6	3	0.9	5	0.7	1	5.4	5	9.5	5	77.4	3	690.9	3	0.0	5
CHICKAMAUGA	Q*	518.0	93	32	6.8	3	1.0	5	0.4	1	3.8	5	8.8	5	82.3	3	1487.3	5	0.0	5
CHICKAMAUGA		518.0	94	22	2.7	1	0.8	3	0.0	1	1.0	5	5.0	5	95.0	1	436.7	1	0.0	5
FORT LOUDOUN		652.0	91	16	1.9	1	0.9	5	0.0	1	14.6	3	28.0	3	95.8	1	381.7	1	0.1	1
FORT LOUDOUN		652.0	92	18	5.0	1	0.9	5	0.1	1	45.7	1	18.2	3	96.0	1	397.4	1	0.0	5
FORT LOUDOUN		652.0	93	14	3.5	1	0.7	3	0.1	1	29.4	3	27.7	3	95.2	1	193.3	1	0.1	1
FORT LOUDOUN		649.5	93	26	5.8	3	1.0	5	0.3	1	17.9	3	7.5	5	93.9	1	572.0	3	0.0	5
FORT LOUDOUN		652.0	94	12	2.9	1	0.8	3	0.3	1	23.8	3	42.0	1	92.9	1	165.5	1	0.2	1
GUNTERSVILLE		420.0	91	26	3.5	1	0.9	5	0.2	1	3.3	5	1.2	5	91.4	1	638.3	3	0.0	5
GUNTERSVILLE		420.0	92	36	9.8	5	1.0	5	1.2	3	4.7	5	14.7	5	79.8	3	1380.5	5	0.0	5
GUNTERSVILLE		420.0	93	30	6.5	3	1.0	5	1.1	3	2.5	5	9.7	5	79.6	3	451.8	1	0.0	5
GUNTERSVILLE	Q	420.0	93	30	7.5	3	0.9	5	1.0	3	4.0	5	13.8	5	71.8	3	463.6	1	0.0	5
GUNTERSVILLE		420.0	94	28	7.0	3	1.0	5	0.5	1	5.3	5	7.4	5	77.7	3	468.2	1	0.0	5
KENTUCKY		200.0	91	14	2.7	1	0.8	3	0.3	1	24.3	3	23.1	3	86.9	1	52.5	1	0.2	1
KENTUCKY		15.0	91	34	9.0	5	1.0	5	1.0	3	7.5	5	7.6	5	84.1	3	659.1	3	0.0	5
KENTUCKY		200.0	92	28	7.6	3	1.0	5	0.7	1	4.5	5	9.5	5	72.8	3	490.0	1	0.0	5
KENTUCKY		15.0	92	36	9.0	5	1.0	5	1.2	3	1.7	5	0.6	5	73.4	3	2732.3	5	0.0	5
KENTUCKY		200.0	93	26	5.4	3	0.9	5	0.8	1	17.0	3	0.0	5	78.2	3	210.9	1	0.0	5
KENTUCKY		15.0	93	36	8.1	5	1.0	5	2.2	5	8.7	5	1.9	5	76.0	3	590.9	3	0.0	5
KENTUCKY		15.0	94	26	5.6	3	1.0	5	0.6	1	10.9	3	5.7	5	82.2	3	301.8	1	0.0	5
KENTUCKY		200.0	94	30	8.3	5	0.9	5	0.4	1	23.7	3	1.3	5	68.3	5	150.9	1	0.0	5
MELTON HILL		58.8	91	8	1.4	1	0.3	1	0.1	1	65.0	1	30.0	1	96.7	1	14.2	1	0.3	1
MELTON HILL		58.8	92	18	8.4	5	0.6	3	0.1	1	44.8	1	46.1	1	91.2	1	71.8	1	0.0	5
MELTON HILL		58.8	93	14	7.4	3	0.4	1	0.3	1	49.3	1	43.8	1	93.1	1	121.1	1	0.0	5
MELTON HILL		58.8	94	12	3.3	1	0.0	1	0.0	1	64.1	1	35.4	1	99.5	1	6.4	1	0.0	5
NICKAJACK		469.0	91	34	6.0	3	1.0	5	2.4	5	9.4	5	0.0	5	68.3	5	284.6	1	0.0	5
NICKAJACK		469.0	92	32	7.4	3	1.0	5	1.6	3	6.1	5	3.7	5	75.0	3	799.1	3	0.0	5
NICKAJACK		469.0	93	40	10.2	5	1.0	5	2.1	5	3.2	5	10.1	5	65.2	5	1061.8	5	0.0	5
NICKAJACK	Q	469.0	93	40	10.7	5	1.0	5	2.3	5	1.6	5	0.4	5	67.2	5	2298.0	5	0.0	5
NICKAJACK		469.0	94	34	6.8	3	1.0	5	1.8	3	0.0	5	0.6	5	73.4	3	1196.4	5	0.0	5
NICKAJACK	Q	469.0	94	38	9.4	5	1.0	5	2.8	5	0.5	5	1.9	5	69.3	5	769.1	3	0.0	5
PICKWICK		253.2	91	14	1.7	1	0.8	3	0.0	1	23.3	3	20.0	3	95.8	1	38.2	1	0.2	1
PICKWICK		253.2	92	26	4.6	1	1.0	5	0.1	1	3.9	5	4.2	5	92.2	1	713.3	3	0.0	5
PICKWICK	Q	253.2	92	26	10.0	5	1.0	5	0.0	1	9.0	5	43.6	1	87.2	1	572.7	3	0.0	5
PICKWICK		253.2	93	36	9.7	5	1.0	5	2.4	5	6.4	5	5.7	5	75.4	3	658.2	3	0.0	5
PICKWICK		253.2	94	30	6.5	3	1.0	5	1.5	3	5.9	5	5.4	5	76.7	3	271.8	1	0.0	5
PICKWICK	Q	253.2	94	32	7.3	3	1.0	5	1.3	3	1.6	5	0.3	5	78.4	3	715.2	3	0.0	5
WATTS BAR		600.0	91	18	3.7	1	0.9	5	0.1	1	34.4	3	10.0	5	97.3	1	369.1	1	0.1	1
WATTS BAR		19.0	91	22	4.4	1	1.0	5	0.8	1	22.4	3	6.1	5	94.2	1	420.2	1	0.0	5
WATTS BAR		19.0	92	20	5.6	3	0.9	3	0.4	1	58.2	1	8.1	5	95.3	1	150.7	1	0.0	5
WATTS BAR		600.0	92	22	5.9	3	0.8	3	0.3	1	23.9	3	4.6	5	91.6	1	390.0	1	0.0	5
WATTS BAR		600.0	93	20	4.4	1	0.7	3	0.3	1	28.7	3	0.2	5	91.3	1	256.4	1	0.0	5
WATTS BAR		19.0	93	22	2.9	1	0.9	5	0.2	1	23.7	3	8.0	5	97.7	1	79.1	1	0.0	5
WATTS BAR	Q	19.0	93	24	5.8	3	0.9	5	0.4	1	28.2	3	13.4	5	89.4	1	196.4	1	0.0	5
WATTS BAR		19.0	94	16	4.0	1	0.7	3	0.7	1	28.2	3	10.0	5	91.2	1	60.0	1	0.1	1
WATTS BAR		600.0	94	28	6.5	3	1.0	5	0.9	3	27.7	3	8.1	5	73.5	3	164.6	1	0.0	5
WHEELER		347.0	91	30	6.7	3	1.0	5	1.0	3	5.6	5	1.5	5	79.6	3	325.5	1	0.0	5
WHEELER		347.0	92	38	9.1	5	1.0	5	2.2	5	6.8	5	0.0	5	68.2	5	593.6	3	0.0	5
WHEELER		347.0	93	38	9.9	5	1.0	5	2.2	5	5.7	5	0.0	5	68.7	5	619.1	3	0.0	5
WHEELER		347.0	94	34	9.9	5	1.0	5	1.9	3	8.6	5	0.0	5	59.8	5	407.3	1	0.0	5
WILSON		273.0	91	30	7.0	3	1.0	5	1.2	3	9.9	5	15.2	3	72.8	3	788.3	3	0.0	5
WILSON		273.0	92	32	9.1	5	1.0	5	1.3	3	7.8	5	24.3	3	74.5	3	780.3	3	0.0	5
WILSON		273.0	93	36	10.6	5	1.0	5	1.7	3	4.5	5	9.7	5	67.2	5	566.8	3	0.0	5
WILSON		273.0	94	34	10.9	5	1.0	5	1.7	3	5.1	5	15.0	3	59.3	5	728.5	3	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

Table 3 (Cont'd)

Blue Ridge Ecoregion Tributary Results--Forebays and Upper Reservoir

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																				
BLUE RIDGE		54.1	93	34	5.1	5	0.9	5	0.4	5	40.6	3	37.3	5	85.1	5	498.3	5	0.1	1
BLUE RIDGE		54.1	94	22	2.3	3	0.5	5	0.2	3	48.7	1	34.9	5	94.7	3	73.3	1	0.2	1
BLUE RIDGE	Q*	54.1	94	28	3.7	3	0.5	5	0.8	5	41.3	3	51.2	3	90.5	3	251.7	5	0.2	1
CHATUGE		1.5	93	28	5.6	5	0.4	3	0.5	5	45.2	1	46.0	3	93.3	3	116.7	3	0.0	5
CHATUGE		122.0	93	32	5.6	5	0.4	3	0.4	5	25.9	5	56.1	3	95.4	1	288.3	5	0.0	5
CHATUGE		1.5	94	24	4.6	5	0.1	1	0.3	3	60.3	1	30.2	5	92.4	3	46.4	1	0.0	5
CHATUGE		122.0	94	20	3.6	3	0.2	3	0.2	3	53.1	1	44.4	3	97.5	1	6.7	1	0.0	5
FONTANA		62.0	93	14	1.2	1	0.2	3	0.0	1	20.0	5	97.6	1	100.0	1	23.3	1	0.2	1
HIWASSEE		77.0	93	12	1.2	1	0.0	1	0.0	1	25.3	5	74.7	1	100.0	1	1.7	1	0.1	1
HIWASSEE		77.0	94	10	1.7	1	0.1	1	0.0	1	37.8	3	74.0	1	96.0	1	15.0	1	0.2	1
NOTTELY		23.5	93	16	3.5	3	0.0	1	0.0	1	46.5	1	52.1	3	98.6	1	10.0	1	0.0	5
NOTTELY		23.5	94	16	3.4	3	0.0	1	0.1	1	49.9	1	48.7	3	98.6	1	5.9	1	0.0	5
OCOEE NO 1		12.5	93	18	2.1	3	0.0	1	0.0	1	9.5	5	81.3	1	96.6	1	18.3	1	0.0	5
OCOEE NO 1		12.5	94	12	1.2	1	0.0	1	0.1	1	21.4	5	80.4	1	96.7	1	8.3	1	0.2	1
OCOEE NO 1	Q	12.5	94	8	0.7	1	0.0	1	0.0	1	50.0	1	79.2	1	100.0	1	5.0	1	0.4	1
WATAUGA		37.4	93	12	1.3	1	0.0	1	0.0	1	25.9	5	87.2	1	99.6	1	11.7	1	0.2	1
WATAUGA		37.4	94	16	1.2	1	0.3	3	0.0	1	26.0	5	55.0	3	100.0	1	4.6	1	0.1	1
UPPER																				
FONTANA		3.0	93	20	3.5	3	0.0	1	0.0	1	4.4	5	94.5	1	98.9	1	26.7	3	0.0	5
FONTANA		81.5	93	26	5.3	5	0.1	1	0.0	1	14.1	5	69.2	1	94.1	3	76.7	5	0.0	5
FONTANA	Q	81.5	93	22	3.8	3	0.0	1	0.1	1	21.0	5	64.6	3	97.6	1	41.2	3	0.0	5
FONTANA		3.0	94	10	2.4	1	0.0	1	0.0	1	47.6	3	72.3	1	99.9	1	3.3	1	0.2	1
FONTANA		81.5	94	14	2.8	1	0.0	1	0.0	1	62.1	1	37.7	3	99.8	1	1.7	1	0.0	5
HIWASSEE		85.0	93	18	3.7	3	0.0	1	0.0	1	12.0	5	86.7	1	98.7	1	13.0	1	0.0	5
HIWASSEE		90.0	93	28	5.0	5	0.4	3	0.4	3	34.9	3	60.4	3	95.4	3	43.3	3	0.0	5
HIWASSEE		85.0	94	18	2.8	1	0.2	3	0.1	1	15.2	5	78.3	1	98.1	1	15.0	1	0.0	5
HIWASSEE		90.0	94	20	3.4	3	0.2	3	0.1	1	69.5	1	29.3	5	98.8	1	6.7	1	0.0	5
HIWASSEE	Q	85.0	94	18	3.0	1	0.3	3	0.1	1	12.1	5	82.1	1	96.5	1	14.4	1	0.0	5
NOTTELY		31.0	93	34	5.2	5	0.6	5	0.6	5	54.9	3	36.5	3	93.4	3	58.3	5	0.0	5
NOTTELY		31.0	94	28	4.7	5	0.4	3	0.5	3	82.4	1	7.1	5	95.2	3	35.5	3	0.0	5
NOTTELY	Q	31.0	94	34	4.3	5	0.5	5	0.8	5	73.8	1	7.2	5	89.0	5	44.6	3	0.0	5
WATAUGA		45.5	93	12	1.7	1	0.0	1	0.0	1	93.8	1	16.2	5	100.0	1	0.0	1	0.1	1
WATAUGA		45.5	94	22	3.3	3	0.1	1	0.1	1	35.1	3	57.0	3	96.0	1	438.3	5	0.0	5
WATAUGA	Q	45.5	94	16	2.2	1	0.1	1	0.0	1	68.2	1	31.1	5	99.3	1	1.7	1	0.0	5

Q* = Identifies results from a replicate set of samples for QA purposes

Table 3 (Cont'd)

Ridge and Valley Ecoregion Tributary Reservoirs--Forebays and Upper Reservoir

RESVORNA	MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																			
BOONE	19.0	93	22	3.0	5	0.1	1	0.0	1	4.5	5	89.8	1	95.6	3	23.3	1	0.0	5
BOONE	19.0	94	18	2.7	3	0.1	1	0.0	1	7.1	5	91.6	1	98.9	1	5.2	1	0.0	5
CHEROKEE	53.0	91	10	1.5	1	0.0	1	0.0	1	54.6	1	75.4	3	100.0	1	0.0	1	0.3	1
CHEROKEE	53.0	92	22	3.7	5	0.0	1	0.1	3	41.1	3	58.0	3	99.2	1	5.0	1	0.0	5
CHEROKEE	53.0	93	28	3.8	5	0.1	3	0.3	5	50.9	1	46.9	5	97.8	3	12.5	1	0.0	5
CHEROKEE	53.0	94	22	3.5	5	0.1	1	0.1	3	52.3	1	46.2	5	98.6	1	5.0	1	0.0	5
DOUGLAS	33.0	91	16	1.9	3	0.0	1	0.0	1	47.0	3	59.9	3	97.3	3	8.3	1	0.1	1
DOUGLAS	33.0	92	20	2.9	3	0.1	1	0.1	3	53.9	1	39.9	5	98.8	1	5.0	1	0.0	5
DOUGLAS	33.0	93	18	2.2	3	0.0	1	0.0	1	61.5	1	38.6	5	100.0	1	0.0	1	0.0	5
DOUGLAS	33.0	94	18	2.8	3	0.0	1	0.0	1	66.5	1	33.0	5	99.5	1	1.7	1	0.0	5
FORT PATRICK HENRY	8.7	93	28	3.1	5	0.3	3	0.0	1	17.5	5	76.8	3	96.2	3	56.7	3	0.0	5
FORT PATRICK HENRY	8.7	94	20	3.1	5	0.1	1	0.0	1	48.0	3	50.5	3	98.5	1	6.7	1	0.0	5
NORRIS	80.4	91	32	2.9	3	0.6	5	0.1	3	3.1	5	57.9	3	96.7	3	209.9	5	0.0	5
NORRIS	80.4	92	40	6.5	5	1.0	5	0.6	5	15.5	5	24.0	5	87.5	5	406.4	5	0.0	5
NORRIS	80.4	93	34	3.2	5	0.6	5	0.1	3	3.1	5	71.0	3	94.5	3	214.1	5	0.0	5
NORRIS	80.4	94	22	2.0	3	0.3	3	0.0	1	6.4	5	77.9	3	98.2	1	50.0	1	0.0	5
SOUTH HOLSTON	51.0	93	8	0.6	1	0.1	1	0.0	1	51.1	1	88.9	1	100.0	1	1.7	1	0.5	1
SOUTH HOLSTON	51.0	94	24	2.5	3	0.2	3	0.2	5	6.9	5	81.2	1	98.1	1	10.9	1	0.0	5
TIMS FORD	135.0	93	10	0.7	1	0.0	1	0.0	1	30.0	3	100.0	1	100.0	1	0.0	1	0.3	1
TIMS FORD	135.0	94	8	0.5	1	0.0	1	0.0	1	71.7	1	88.3	1	100.0	1	0.0	1	0.6	1
UPPER																			
BOONE	27.0	93	16	2.9	1	0.1	1	0.0	1	11.5	5	87.8	1	99.4	1	8.3	1	0.0	5
BOONE	6.5	93	18	2.4	1	0.1	1	0.0	1	21.9	5	71.2	1	96.7	3	16.7	1	0.0	5
BOONE	27.0	94	14	2.9	1	0.0	1	0.0	1	39.5	3	60.6	1	100.0	1	0.0	1	0.0	5
BOONE	6.5	94	20	3.0	1	0.1	1	0.0	1	31.2	5	58.9	3	98.4	1	28.3	3	0.0	5
DOUGLAS	51.0	94	18	3.4	3	0.0	1	0.0	1	70.4	1	29.6	5	100.0	1	0.0	1	0.0	5
NORRIS	30.0	91	38	5.1	5	0.9	5	0.2	5	31.0	5	53.7	3	92.6	5	73.3	5	0.0	5
NORRIS	125.0	91	28	4.1	3	0.5	3	0.1	3	84.4	1	7.2	5	96.6	3	66.7	5	0.0	5
NORRIS	30.0	92	30	6.0	5	0.5	3	0.1	3	34.9	5	60.9	1	95.8	3	57.6	5	0.0	5
NORRIS	125.0	92	32	5.0	5	0.6	3	0.1	3	49.8	3	40.7	3	91.6	5	50.2	5	0.0	5
NORRIS	30.0	93	34	6.9	5	0.8	5	0.1	3	41.6	3	52.0	3	93.5	5	77.8	5	0.0	5
NORRIS	125.0	93	22	4.4	3	0.4	3	0.1	3	52.4	3	46.2	3	98.6	1	16.1	1	0.0	5
NORRIS	30.0	94	30	4.7	3	0.6	3	0.2	5	48.5	3	46.2	3	94.8	3	63.3	5	0.0	5
NORRIS	125.0	94	36	5.8	5	0.8	5	0.5	5	57.1	3	37.4	5	94.8	3	53.3	5	0.0	5
SOUTH HOLSTON	62.5	93	22	3.1	3	0.2	1	0.0	1	24.1	5	66.5	1	95.7	3	34.9	3	0.0	5
SOUTH HOLSTON	62.5	94	14	2.8	1	0.0	1	0.0	1	36.9	3	63.1	1	100.0	1	0.0	1	0.0	5
TIMS FORD	150.0	93	12	2.1	1	0.1	1	0.1	3	69.6	1	44.6	3	99.1	1	11.7	1	0.3	1
TIMS FORD	150.0	94	12	1.1	1	0.1	1	0.1	3	89.0	1	50.0	3	100.0	1	1.7	1	0.4	1

Table 3 (Cont'd)

Interior Plateau Tributary Reservoirs--Forebays

RESVORNA		MILE	YEAR	SCORE	TAXA		LONGL		EPT		PCHIR		PTUBI		DOMN		TOTNONCT		ZEROS	
FOREBAY																				
BEAR CREEK		75.0	91	16	2.4	1	0.2	3	0.2	3	68.0	1	23.8	5	96.4	1	24.1	1	0.1	1
BEAR CREEK		75.0	93	32	4.6	5	0.5	5	0.4	3	70.6	1	12.4	5	91.3	5	45.9	3	0.0	5
BEAR CREEK		75.0	94	24	3.8	3	0.1	1	0.3	3	75.3	1	9.8	5	95.3	3	33.3	3	0.0	5
BEECH LAKE		36.0	93	30	5.2	5	0.3	3	0.3	3	75.9	1	14.4	5	94.8	3	81.7	5	0.0	5
BEECH LAKE		36.0	94	30	5.1	5	0.3	3	0.3	3	81.1	1	9.5	5	93.7	3	93.3	5	0.0	5
CEDAR CREEK		25.0	91	14	2.4	1	0.3	3	0.3	3	33.2	3	83.0	1	96.2	1	11.7	1	0.2	1
CEDAR CREEK		25.2	93	24	3.0	3	0.2	3	0.2	3	41.3	3	51.6	3	94.4	3	28.3	1	0.0	5
CEDAR CREEK		25.2	94	38	5.0	5	0.6	5	0.7	5	50.0	3	29.7	5	87.2	5	128.3	5	0.0	5
LITTLE BEAR CREEK		12.3	91	24	2.7	3	0.3	3	0.4	3	3.4	5	90.8	1	96.2	1	50.0	3	0.0	5
LITTLE BEAR CREEK		12.5	93	22	2.8	3	0.2	3	0.2	3	11.1	5	85.3	1	97.8	1	11.7	1	0.0	5
LITTLE BEAR CREEK		12.5	94	24	3.2	3	0.4	3	0.5	3	13.9	5	82.0	1	97.0	1	31.7	3	0.0	5
LITTLE BEAR CREEK	Q*	12.5	94	28	3.6	3	0.3	3	0.2	3	7.9	5	86.6	1	94.4	3	70.0	5	0.0	5
NORMANDY		249.5	93	10	1.4	1	0.1	1	0.0	1	46.4	3	80.1	1	99.6	1	5.0	1	0.3	1
NORMANDY		249.5	94	16	2.0	1	0.0	1	0.0	1	34.0	3	62.2	3	99.5	1	3.3	1	0.0	5

Q* = Identifies a replicate set of samples for QA purposes

Section 5. Fish Community

Philosophical Approach/Background

Many of the same considerations discussed for the benthic macroinvertebrate community (Section 4) also apply for the fish community. These are repeated here, as appropriate, in case the reader does not have access to that information.

Fish are usually included in aquatic monitoring programs because they are important to the aquatic foodweb and because they have long a life cycle which allows them to integrate conditions over time. In streams fish community monitoring has often been found to reflect environmental degradation when physical and chemical monitoring have failed to do so. Fish are also important to the public for aesthetic, recreational, and commercial reasons.

Reservoir fish communities are be vastly different from that in the river prior to impoundment due to significant habitat alterations. Also, substantial differences are expected along a longitudinal gradient with a more riverine community expected at the upper end or inflow of a reservoir and a more lacustrine community expected in the pool near the dam. Other factors to consider in evaluating biotic communities in reservoirs include reservoir operational characteristics (e.g., depth of withdrawal for discharge, water depth, depth of drawdown for flood control, retention time, stratification, bottom anoxia, substrate type and stability) and physical/chemical features owing to geological characteristics of different ecoregions.

All these factors, plus the fact that a reservoir is an artificial system, must be considered in selecting community characteristics or expectations that will be used to evaluate aquatic resource conditions. Given that reservoirs are artificial systems, it is not possible to use the well accepted Index of Biotic Integrity (IBI) approach of using reference sites to determine characteristics or expectations of a reservoir unaffected by human impacts. By definition, IBI specifies reference conditions should be developed from natural, unaltered habitats (Karr and Dudley, 1981 after Frey 1975). Therefore, other approaches must be used; such as, using historical or preimpoundment conditions, predictive models, best observed conditions, or professional judgment. As stated above, preimpoundment conditions are inappropriate due to significant habitat alterations. Like benthic macroinvertebrates, the state of the understanding of fish communities in reservoirs simply is insufficient for models to effectively predict species composition and relative abundance. This leaves the latter two as the most viable alternatives for establishing appropriate reference conditions or expectations for reservoirs. TVA's experience has found use of best observed conditions adjusted using professional judgment as the best approach. Use

of best observed conditions requires an extensive database to determine metric expectations, and use of professional judgment to adjust scoring ranges requires substantial experience with the group of reservoirs under consideration. To use this concept results in the data base which approach desired conditions for a given community characteristic are considered representative of best observed condition. Monitoring results falling within that range would be considered "good". Details of this approach to developing reference conditions are provided latter in this document.

Another important consideration in developing reference conditions is that care must be taken to compare only those reservoirs for which comparison is appropriate. That is, only reservoirs for which similar communities would be expected should be compared--those in the same ecoregion with comparable physical characteristics. Hence, separation of reservoirs into appropriate classes is a critical step.

TVA's monitoring program includes 30 reservoirs. For classification purposes these have been divided into two major groups : run-of-the-river reservoirs (those with short retention times and winter drawdown of only a few feet) and tributary reservoirs (those with long retention times and substantial winter drawdowns). The tributary reservoirs have been further divided into three groups by ecoregion and reservoir physical characteristics.

Run-of-the-River Reservoirs	Tributary Reservoirs: Ridge and Valley Ecoregion
Kentucky	Cherokee
Pickwick	Fort Patrick Henry
Wilson	Boone
Wheeler	South Holston
Guntersville	Norris
Nickajack	Douglas
Chickamauga	
Watts Bar	
Melton Hill	
Tellico	Tributary Reservoirs: Blue Ridge Ecoregion
Fort Loudon	Fontana
	Hiwassee
Tributary Reservoirs: Interior Plateau Ecoregion	Chatuge
Bear Creek	Nottely
Cedar Creek	Parksville
Little Bear	Blue Ridge
Normandy	Watauga
Beech	
Tims Ford	

Sample Collection Methods

Shoreline electrofishing samples were collected during daylight hours from inflow, transition, and forebay zones of most reservoirs during autumn (September to mid-November 1994). Only one or two zones were sampled on reservoirs where zones were indistinguishable. No inflow zones were sampled in tributary reservoirs during 1994 because environmental quality of major inflow streams was addressed using Index of Biotic Integrity (IBI) techniques in the free flowing portion upstream of the impoundment. Location of collection sites in 1994 are identified in Table 1

A total of 15 electrofishing transects, each covering 300m of shoreline, was collected from each of the sampled zones. All habitats were sampled in proportion to their occurrence in the zone. Twelve experimental gill nets with five 6.1m panels (mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7cm) were set for one overnight period in forebay and transition zones. Excessive current prevented use of gill nets in mainstream inflow areas limiting sampling to only electrofishing in these locations. Nets were set in all habitat types, alternating mesh sizes toward the shoreline between sets.

Total length (mm) and weight (g) were obtained for all sport species and channel catfish. Remaining species captured were enumerated prior to release. During electrofishing, fish observed but not captured were included if positive identification could be made and counts were estimated when high densities of identifiable fish were encountered. Young-of-year fish were counted separately and, as in stream IBI calculations (Karr 1981), were excluded from proportional and abundance metrics due to sampling inefficiencies. Only fish examined closely as a result of obtaining length and weight measurements were inspected externally for signs of disease, parasites, and anomalies. Other species groups often included several individuals which were observed, but not captured, thus the ratio of diseased, etc. was not obtainable for these groups. Natural hybrids (i.e., those known not to be part of a fisheries management program) were included as an anomaly. Data loggers were used to record all sampling results.

Reservoir Fish Assemblage Index

The current RFAI uses 12 fish community metrics from five general categories (Hickman and McDonough, 1995). The 12 metrics include:

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.
2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.
3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and suitable sediment quality in littoral areas.
4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs.
5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.
6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.
7. **Percentage dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.
9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners spawn over rocky substrate and do not provide parental care. This guild is expected to

be sensitive to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

Fish Health

12. **Percentage individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Establishing scoring criteria (reference conditions) by trisecting observed conditions requires a substantial data base for each class of reservoir and assumes the data base contains reservoirs with conditions ranging from poor to good for each metric. The smaller the number of reservoirs within a class, the less likely these assumptions can be met and the greater the need for sound professional judgment based on extensive knowledge of reservoir communities being studied.

Because some reservoir classes contained relatively few reservoirs, the approach used to develop scoring criteria for RFAI was to include all sampling results from Vital Signs monitoring (1990 - 1994). A slightly different approach was used for species richness metrics than for abundance and proportional metrics. For species richness metrics, a list was made of all species collected from comparable locations within a reservoir class from 1990 - 1994. This species list was adjusted using inferences of experienced biologists knowledgeable of the reservoir system, resident fish species, susceptibility of each species to collection methods being used, and effects of human-induced impacts on these species. This effort resulted in a list of the maximum number of species expected to occur at a sampling location and be captured by collection devices in use. Given that only one collection effort is exerted each year, this maximum number of species would not be expected to be represented in that one collection. Therefore, the range from zero to 95% of the maximum was trisected to provide the three scoring ranges (good, fair, and poor). Although even 95% of the maximum number of species at a site would not be expected to be collected in one

sampling event, this "high" expectation was adopted to keep these metrics conservative in light of potential uncertainties introduced by relying heavily on professional judgment.

Scoring criteria for proportional metrics and the abundance metric were determined by trisecting observed ranges after omitting outliers. Next, cutoff points between the three ranges were adjusted based on examination of frequency distributions of observed data for each metric along with professional judgment. In some cases, the narrow range of observed conditions required further adjustment based on knowledge of metric responses to human-induced impacts observed in other reservoir classes. Scoring criteria for the fish health metric are those described by Karr et.al. (1986). Scoring criteria are detailed in Table 2.

To develop metric scores for taxa richness, reproductive composition, and fish health metrics, electrofishing and experimental gill net sampling results were pooled prior to scoring. For abundance and proportional metrics, electrofishing and gill netting results were scored separately, then the two scores averaged to arrive at a final metric value. These scoring criteria separated sites into three categories assumed to represent relative degrees of degradation. Sample results are compared to these reference conditions and assigned a corresponding value: good = 5; fair = 3; and poor = 1.

The sum of the 12 metric ratings constituted the RFAI score. To arrive at an evaluation of the condition of the fish assemblage at a sample location, scores were evaluated as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Community Condition	Very Poor	Poor	Fair	Good	Excellent

The contribution of the fish community results for each sample site to the overall reservoir Ecological Health Index was as follows:

RFAI Score	12-21	22-31	32-40	41-50	51-60
Contribution to Reservoir Ecological Health Index	1	2	3	4	5

One further use of these results is in TVA's annual report to the public on the conditions of Tennessee Valley reservoirs. In this publication, titled *Riverpulse,* results for each of the five environmental indicators at each sample site are presented using one of three colors -- green (good), yellow (fair), or red (poor). This necessitated dividing the RFAI scores into three ranges as follows:

RFAI Score	12-28	29-44	45-60
Color (Rating) in *RiverPulse*	Poor (Red)	Fair (Yellow)	Good (Green)

Results from 1994 Monitoring

RFAI scores for 1990 through 1994 are summarized by reservoir class and type of location in Table 3. (Note that 10 electrofishing runs were used in 1990 - 1992 rather than the 15 used in 1993 and 1994.) Appendix A summarizes results and ratings for individual metrics and final RFAI scores for each sample location based on 1994 data. Appendix B provides mean catch per effort by species for electrofishing and gill netting efforts at each location in 1994.

Approximately 20 percent of all sampling locations were revisited for Quality Control purposes. All together, 12 randomly selected sites were revisited by a second sample crew several days or weeks after the initial sampling to collect a second set of samples. A RFAI score was developed separately for each of the two sample sets. The desired maximum difference between the RFAI score from the original sample and the QA sample set was 10. A difference greater than this would cause the rating to change 2 categories (e.g., very poor to fair, fair to good), which was deemed unacceptable. Results for each set of repeat samples are provided below.

	Original Score	QA/QC Score	Difference
Run-of-the-River Reservoirs			
Forebays			
Chickamauga	36 (Fair)	36 (Fair)	0
Nickajack	40 (Fair)	38 (Fair)	2
Transition Zones			
Chickamauga	36 (Fair)	46 (Good)	10
Kentucky	40 (Fair)	40 (Fair)	0
Inflows			
Pickwick	42 (Good)	44 (Good)	2
Embayments			
Hiwassee (on Chick. Res.)	42 (Good)	39 (Fair)	3
Tributary Reservoirs			
Forebays			
Parksville	37 (Fair)	33 (Fair)	4
Blue Ridge	36 (Fair)	37 (Fair)	1
Little Bear	46 (Good)	49 (Good)	3
Upper			
Watauga	30 (Poor)	32 (Fair)	2
Hiwassee	34 (Fair)	33 (Fair)	1
Nottely	31 (Poor)	34 (Fair)	3

The maximum observed difference was 10 (1 sets of samples) and the minimum was 0 (2 sets of samples). The mean difference for all reservoirs was 2.58. The 95% confidence interval around the mean would be 0.8 to 4.3, well below the desired level of 10.

References

Karr, J.R., 1981. "Assessment of Biotic Integrity Using Fish Communities." Fisheries 6(6), pp. 21-27.

Karr, J.R. and D.R. Ducley. 1981. Ecologocal Perspective on Water Quality Goals. Environ. Manage. 5:55-68

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing Biological Integrity in Running Waters: A Method and Its Rationale. Illinois Natural History Survey, Special Publication 5.

Hickman, G.D. and T.A McDonough. 1995. Assessing the Reservoir Fish Assemblage Index - A Potential Measure of Reservoir Quality. (in preparation). Submitted for publication in Proceeding of Third National Reservoir Symposium, June 1995, American Fisheries Association. D. DeVries, Editor.