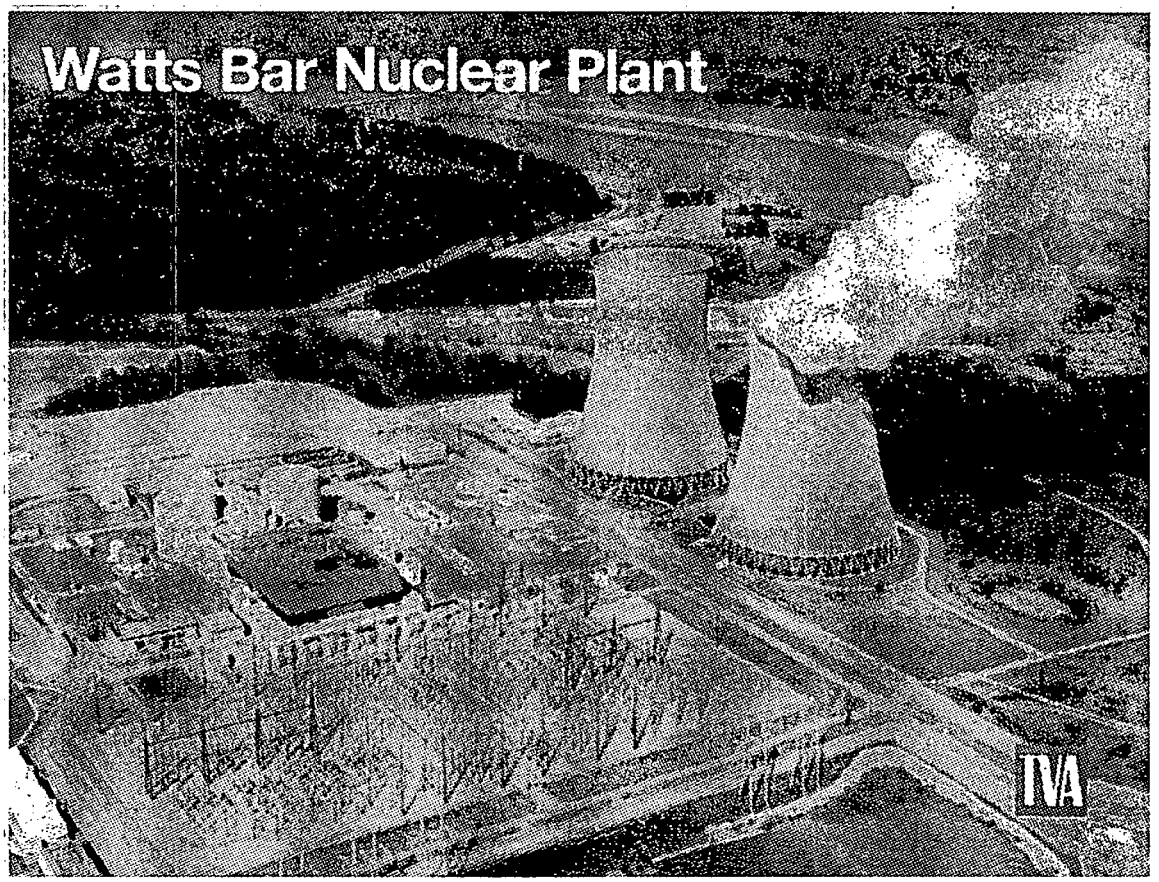
Biological Monitoring of the Tennessee River Near Watts Bar Nuclear Plant Discharge 2006



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Acronyms

BI	Benthic Macroinvertebrate Index
BIP	Balanced Indigenous Population
NPDES	National Pollutant Discharge Elimination System
PSD	Proportional Stock Density
QA	Quality Assurance
RFAI	Reservoir Fish Assemblage Index
RSD	Relative Stock Density
RSDM	Relative Stock Density of Memorable-sized
RSDP	Relative Stock Density of Preferred-sized
RSDT	Relative Stock Density of Trophy-sized
SAHI	Shoreline Assessment Habitat Index
SCCW	Supplemental Condenser Cooling Water
SFI	Sport Fishing Index
SSS	Spring Sport Fish Survey

Acronyms
(continued)

TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
VS	Vital Signs
WBN	Watts Bar Nuclear Plant
Wr	Relative Weight

Introduction

Section 316(a) of the Clean Water Act specifies that industrial, municipal, and other facilities must obtain permits if their thermal discharges go directly to surface waters. Industries responsible for point-source discharges of heated water can obtain a variance from state water quality standards if the industry can demonstrate compliance with thermal criteria by documenting the maintenance of Balanced Indigenous Populations (BIP) of aquatic life in the vicinity of its discharge.

Historically, the Tennessee Valley Authority (TVA) used special studies to evaluate effects on aquatic life in the vicinity of its power plant discharges. In July 1999, a Supplemental Condenser Cooling Water (SCCW) system went on line at TVA's Watts Bar Nuclear Plant (WBN). As required by WBN's National Pollutant Discharge Elimination System (NPDES) permit TN0020168, impacts to aquatic communities in the vicinity of WBN were evaluated. Baxter et al. (2001) recommended components of TVA's Vital Signs (VS) monitoring program (Dycus and Meinert 1993), the Reservoir Fish Assemblage Index (RFAI) and Benthic Macroinvertebrate Index (BI), to WBN management as a means of assessing Chickamauga Reservoir's aquatic community integrity while the SCCW is operational. The purpose of this document is to briefly summarize and provide results of the Calendar Year 2006 monitoring and analyses to the Tennessee Department of Environment and Conservation and compare these results with historical monitoring data.

Prior to 1990, TVA reservoir studies focused on reservoir ecological assessments to meet specific needs as they arose. In 1990, TVA instituted a Valley-wide VS monitoring program which is a broad-based evaluation of the overall ecological conditions in major reservoirs. Data is evaluated with a multi-metric monitoring approach utilizing five environmental indicators: dissolved oxygen, chlorophyll, sediment quality, benthic macroinvertebrate community, and the fish community. When this program was initiated, specific evaluation techniques were developed for each indicator, and these techniques were fine-tuned to better represent ecological conditions. The outcome of this effort was development of multi-metric evaluation techniques for the fish assemblage (i.e., RFAI) and the benthic macroinvertebrate community (i.e., BI), as described below. These multi-metric evaluation techniques have proven successful in TVA's monitoring efforts as well as for other federal and state monitoring programs. For consistency, only RFAI analyses between 1993 and 2006 will be utilized. The BI is used primarily to support the RFAI analysis.

The Sport Fishing Index (SFI) was developed to quantify sport fishing quality for individual sport fish species. The SFI relies on measurements of quantity and quality aspects of angler success and fish population characteristics. This provides biologists with a reference point to measure the quality of a sport fishery. Comparison of the population sampling parameters and creel results for a particular sport fish species with expectations of these parameters from a high quality fishery (reference conditions) allows for the determination of fishing quality. Indices have been developed for black bass (largemouth, smallmouth, and spotted bass), crappie, sauger, striped bass, bluegill, channel catfish, and white bass.

In recent years, SFI information has been used to describe the quality of the resident sport fishery in conjunction with compliance monitoring, thermal variance requests, and other regulatory issues at TVA nuclear plants in Tennessee. Similar NPDES compliance monitoring programs using the methodologies described above are also being performed at Browns Ferry Nuclear Plant and Colbert and Widows Creek Fossil Plants in Alabama.

The TVA Spring Sport Fish Survey (SSS) is conducted to evaluate the sport fish population of TVA Reservoirs. The results of the survey are used by state agencies to protect, improve and assess the quality of sport fisheries. Predominant habitat types in the reservoir are surveyed to determine sport fish abundance. In addition to accommodating TVA and state databases, this surveying method aligns with TVA's Watershed Team and Reservoir Operations Study objectives. Sample sites are selected using the shoreline habitat characteristics employed by the Watershed Teams. The survey targets three species of black bass (largemouth, smallmouth, and spotted bass) and black and white crappie. These species are the predominant sport fish sought by fisherman.

Methods

Fish Community

Reservoirs are typically divided into three zones for VS monitoring – inflow, transition, and forebay. The inflow zone is generally in the upper reaches of the reservoir and is riverine in nature; the transition zone or mid-reservoir is the area where water velocity decreases due to increased cross-sectional area; and the forebay is the lacustrine area near the dam. The Chickamauga Reservoir inflow zone sample site is located at Tennessee River Mile (TRM) 529.0, the transition zone is sampled at TRM 490.5, and the forebay zone sample site is located at TRM 472.3. The VS inflow zone starts below Watts Bar Dam at TRM 529 and extends downstream to TRM 526.3. This station was used to provide downstream data for the 316(a) thermal variance studies performed in 1993 to 1995, 1997, and 1999 to 2006. Since the WBN discharge is located within Chickamauga Reservoir inflow zone, no upstream control site data are available for comparison. Watts Bar Reservoir forebay site (TRM 531) will be used to document any notable changes in Tennessee River ecological conditions above the WBN discharge but will not be used for upstream/downstream comparisons of RFAI scores.

Sampling effort consisted of fifteen 300-meter electrofishing runs (approximately 10 minute duration) and ten experimental gill net sets (five 6.1 meter panels with mesh sizes of 2.5, 5.1, 7.6, 10.2, and 12.7 cm) per site. Attained values for each of the 12 metrics were compared to reference conditions for transition zones of lower mainstream Tennessee River reservoirs and assigned scores based upon three categories hypothesized to represent relative degrees of degradation: least degraded - 5; intermediate - 3; and most degraded - 1. These categories are based on "expected" fish community characteristics in the absence of human-induced impacts other than impoundment. Individual metric scores for a site are summed to obtain the RFAI score.

Comparison of the attained RFAI score from the potential impact zone to a predetermined criterion has been suggested as a method useful in identifying the presence of normal community structure and function and hence existence of a BIP. For multi-metric indices, two criteria have been suggested to ensure a conservative screening for a BIP. First, if an RFAI score reaches 70 percent of the highest attainable score (adjusted upward to include sample variability), and second, if fewer than half of RFAI metrics potentially influenced by thermal discharge receive a low (1) or moderate (3) score, then normal community structure and function would be present indicating that a BIP existed. Under these conditions the heated discharge would meet screening criteria and no further evaluation would be needed.

Potential RFAI scores range from 12 to 60. Ecological health ratings ("Very Poor" 12-21, "Poor" 22-31, "Fair" 32-40, "Good" 41-50, or "Excellent" 51-60) are then applied to scores. As discussed in detail below, the average variance for RFAI scores in TVA reservoirs is 6 ($\pm$ 3).

Therefore, any location that attains an RFAI score of 45 (42 + our sample variance of 3) or higher would be considered to demonstrate a BIP. It must be stressed that scores below this endpoint do not necessarily reflect an adversely impacted fish community. The endpoint is used to serve as a conservative screening level; for example, any fish community that meets these criteria is obviously not adversely impacted. RFAI scores below this level would require a more in-depth look to determine if a BIP exist. If a score below this criterion is obtained, an inspection of individual RFAI metric results would be an initial step to help identify if WBN operation is a contributing factor. This approach is appropriate if a validated multi-metric index is being used and scoring criteria applicable to the zone of study are available.

The Quality Assurance (QA) component of VS monitoring deals with how well the RFAI scores can be repeated and is accomplished by collecting a second set of samples at 15-20 percent of the sites each year. Previous statistical analyses with the QA component of VS has shown that the comparison of RFAI index scores from 54 paired sample sets collected over a seven year period ranged from 0 to 18 points. Based on these findings, the 75th percentile is 6 and the 90th percentile is 12. The mean difference between these 54 paired scores is 4.6 points with 95 percent confidence limits of 3.4 and 5.8. Therefore, a difference of 6 points or less was the value selected for defining "similar" scores between upstream and downstream fish communities. That is, if the downstream RFAI score is within 6 points of the upstream score, the communities will be considered similar. It is important to bear in mind that differences greater than 6 points can be expected simply due to method variation (25 percent of the QA paired sample sets exceeded that value). When this occurs, a metric-by-metric examination will be conducted to determine what caused the difference in scores and the potential for the difference to be thermally related.

Benthic Macroinvertebrate Community

Ten benthic grab samples were collected at equally spaced points along a transect extending from the left descending bank to the right descending bank at each site. A Ponar sampler was used for most samples but a Peterson sampler was used when larger substrate was encountered. Collection and processing techniques followed standard VS procedures. Bottom sediments were washed on a 533μ screen; organisms were then picked from the screen and remaining substrate and identified to Order or Family level in the field using no magnification. Benthic community results were evaluated using seven community characteristics or metrics. Results for each metric were assigned a rating of 1, 3, or 5 depending upon how they compared to reference conditions developed for VS sample sites. The ratings for the seven metrics were summed to produce a total benthic score for each sample site. Each reservoir section (inflow, transition, or forebay) differs in their maximum potential for benthic diversity; thus, the criteria for assigning metric ratings were adjusted accordingly such that the total benthic scores from sites at different reservoir sections are comparable. Potential scores range from 7 to 35. Ecological health ratings ("Very Poor" 7-12, "Poor" 13-18, "Fair" 19-23, "Good" 24-29, or "Excellent" 30-35) are then applied to scores. A similar or higher benthic index score at the downstream site (TRM 518.0) compared to the Watts Bar forebay site (TRM 532.5) is used as basis for determining WBN's absence of impact on the benthic community.

The QA component of VS monitoring shows that the comparison of benthic index scores from 49 paired sample sets collected over a seven year period ranged from 0 to 14 points; the 75th percentile was 4 and the 90th percentile was 6. The mean difference between these 49 paired scores was 3.1 points with 95 percent confidence limits of 2.2 and 4.1. Based on these results, a difference of 4 points or less is the value selected for defining "similar" scores between upstream and downstream benthic communities. That is, if the downstream benthic score is

within 4 points of the upstream score, the communities will be considered similar and it will be concluded that WBN has had no effect. Once again, it is important to bear in mind that differences greater than 4 points can be expected simply due to method variation (25 percent of the QA paired sample sets exceeded that value). When this occurs, a metric-by-metric examination will be conducted to determine what caused the difference in scores and the potential for the difference to be thermally related.

Sport Fishing Index

Calculations described by Hickman (2000) were used to compare SFI values for selected quantity and quality parameters from creel and population samples to expected values that would occur in a good or high quality fishery. Quantity parameters include angler success and catch per unit effort from standard population samples (electrofishing, trap, and experimental gill netting). Population quality is based on measurement of five aspects of each resident sport fish community. Four of these aspects address size structure (proportional number of fish in each length group) of the community, Proportional Stock Density (PSD), Relative Stock Density of Preferred-sized fish (RSDP), Relative Stock Density of Memorable-sized fish (RSDM), and Relative Stock Density of Trophy-sized fish (RSDT) (Figure 1). Relative weight (Wr), a measure of the average condition of individual fish, makes up the fifth population quality aspect.

As described by Hickman (2000), observed values were compared to reference ranges and assigned a corresponding numerical value. The SFI value is calculated by adding the scores for quantity and quality from existing data and multiplying by two when only creel or population data are available. Species received a low score when insufficient numbers of individuals were captured to reliably determine proportional densities or relative weights for particular parameters. SFI scores are typically compared to average Tennessee Valley reservoir scores; however, Valley-wide scores are unavailable from natural resource agencies. Therefore, Chickamauga Reservoir fish species scores will be compared to previous years. The 2006 Tennessee Wildlife Resources Agency gill netting and creel data were not available for analyses before this report was submitted; therefore 2005 SFI data were used. Additionally, 2005 SFI values were only calculated for black bass species in Chickamauga Reservoir and black bass species and crappie in Watts Bar Reservoir due to insufficient data for other sport fish species.

Spring Sport Fish Survey

SSS's were conducted on Chickamauga Reservoir March 21-23, 2006 and on Watts Bar Reservoir April 18-20, 2006. During the sampling periods, water levels on Chickamauga Reservoir were 676.8 to 677.3 msl (summer pool level is 682.5 msl) and were 738.8 to 739.3 msl on Watts Bar Reservoir (summer pool level is 741.0 msl). Sampling was conducted using a boat mounted electrofishing unit at twelve sites on each reservoir. Chickamauga Reservoir sampling sites were located at Harrison Bay, Ware Branch, and Sale Creek, and Watts Bar sampling sites were located at Watts Bar Dam, Blue Springs and Caney Creek. Sampling effort at each site consisted of thirty minutes of continuous electrofishing in the littoral zones of prominent habitat types present. After being stunned, fish were collected with dip nets, counted, weighed, measured, and then released unharmed.

Results of the SSS monitoring were calculated using Shoreline Assessment Habitat Index (SAHI), Relative Stock Density (RSD), Proportional Stock Density (PSD), and Relative Weight (Wr). Habitat type is evaluated using the SAHI metric and is a critical component incorporated into the SSS. The resultant habitat designations ("Good", "Fair", and "Poor") are correlated to black bass abundance (numbers/hour). RSD is the number of fish greater than a minimum

preferred length in a stock divided by the number of fish greater than or equal to a minimum stock size. PSD is the number of fish greater than or equal to a minimum quality length in a sample divided by the number of fish greater than or equal to a minimum stock length. Wr is an index that quantifies fish condition and the preferred range value is 90-105% for moderate density bass populations such as those found in the Tennessee Valley latitudes.

Results and Discussion

Fish Community

RFAI fish data collected during autumn 2006 from the inflow site at TRM 529 downstream from WBN resulted in a RFAI score of 42 ("Good") (Table 1). During the twelve sample years this site has averaged a RFAI score of 46 (Table 2) and the RFAI scores have remained in the "Good" to "Excellent" ecological health range for all sampling seasons (Figure 2). Chickamauga inflow reached 70 percent of its highest potential score in sample year 2006 indicating that a BIP exists downstream of the WBN discharge and that neither the operation of WBN or SCCW are adversely affecting fish communities in the vicinity of the discharge. Electrofishing catch rates for individual species collected at this site are listed in Table 3. Gill net sampling is not conducted at inflow sites because flow inhibits the ability to set and retain nets. Species diversity at this site was similar in 2006 to 2005; 28 species were collected in 2006 (Table 3) compared to 29 species collected in 2005 (Baxter et al. 2006).

RFAI data collected at TRM 531, Watts Bar Reservoir forebay, is used to indicate the health of the fish community upstream from WBN. Watts Bar Reservoir forebay RFAI data collected between 1993 and 2006 reflect little change in the overall ecological health of the fish communities at this site (Figure 3). Nine of the twelve sample seasons scored in the "Good" range. Three sample seasons (1999, 2001, and 2002) were only slightly below the "Good" range illustrating only slight variability in ecological health. During 2006, Watts Bar Reservoir forebay scored 44 ("Good") reaching 73 percent of its highest potential RFAI score (Tables 2 and 4). Electrofishing and gill netting catch rates for this site are listed in Table 3.

RFAI scores (Table 1, Figure 2) and electrofishing and gill netting catch rates (Tables 3 and 5) are presented for the Chickamauga Reservoir transition site (TRM 490.5) and the forebay sites (TRM 482 and TRM 472.3) to provide an overview of ecological health throughout the reservoir; however, aquatic communities at these sites are not affected by WBN temperature effects and are not used to determine BIP in relation to WBN.

Benthic Macroinvertebrate Community

Benthic macroinvertebrate data collected during autumn 2006 from the inflow site downstream from WBN (TRM 518) resulted in a BI score of 33 ("Excellent") (Table 6). This was five points higher than the average of the eleven sample years (Table 8). With the exception of the 1994 sample, the BI scores have remained in the "Good" to "Excellent" ecological health range for all sampling seasons at this site. Table 7 summarizes density by taxon from the 2006 sample at this site. These data indicate that a healthy benthic macroinvertebrate community exists in the downstream vicinity of WBN and that the plant is not adversely impacting this fauna.
The Chickamauga Reservoir transition zone sample site (TRM 490.5) is located 37 river miles downstream of WBN and sampling results should not reflect temperature effects from the plant. This site is included to provide additional data on the downstream integrity of the benthic macroinvertebrate community (Tables 6 and 8).

BI data collected at TRM 532.5, Watts Bar Reservoir forebay, is used to indicate the health of the benthic macroinvertebrate community upstream from WBN. During 2006, Watts Bar Reservoir forebay scored 13 ("Poor") (Table 6). Watts Bar Reservoir forebay BI data collected between 1994 and 2006 reflect little change in the overall ecological health of the benthic macroinvertebrate community at this site. Nine of the ten sample seasons scored in the "Poor" range, while the 1996 sample scored "Very Poor" (Table 8).

To ensure data integrity, samples collected and identified in the field at the inflow sites downstream from WBN were also identified in the laboratory by an independent consultant. The average Benthic Index scores during years when a sample was both field and lab processed were identical at both inflow sites (Table 9). These results indicate that scores based on field-processed samples provide an acceptable representation of scores based on lab-processed samples. Therefore, during future monitoring, samples will be lab processed one out of every five years in a permit cycle instead of every year.

Sport Fishing Index

SFI scores for Chickamauga Reservoir during 2005 were only calculated for black bass species (largemouth, smallmouth, and spotted) due to insufficient data to accurately calculate SFI scores for other sport fish species. Largemouth and spotted bass scored higher than the nine year average during 2005, while smallmouth bass scored 2 points lower than the nine year average (Table 10, Figure 4). Overall, the nine year average score for black bass was the same as the 2005 score (Table 10).

SFI scores for Watts Bar Reservoir during 2005 were calculated for crappie and black bass species (largemouth, smallmouth, and spotted). Scores for other sport fish species were not calculated due to insufficient data. SFI scores for largemouth bass, smallmouth bass, spotted bass, and crappie were all higher than both the average over all sampling years and the previous year (Table 11, Figure 5)

Tables 12 and 13 illustrate SFI scoring criteria for population metrics and creel quantity and quality.

Spring Sport Fish Survey

Chickamauga Reservoir

A total of 18 hours of electrofishing resulted in collection of 608 largemouth bass, 78 spotted bass, and 22 smallmouth bass; of these, 72 percent were harvestable size (≥ 10 inches). Overall catch rate (39.4 fish/hour) was substantially less than the 2005 survey (72.6 fish/hour), but was similar to the average catch rate from all twelve sample years (Table 14). The largest black bass collected was a 7.1 pound largemouth bass taken from Sale Creek. Large bass were well represented with 39 bass greater than three pounds, 14 greater than four pounds, and 7 over five pounds. The three-pound category showed an increase of 50 percent over 2005 results, while the four and five-pound categories remained constant. Almost half of the largemouth bass collected were in the 10-13 inch size class (Figure 6). Fish >14 inches comprised 19 percent of the overall sample. All size classes up to 21 inches were represented in the population.

Habitat type is derived from the Shoreline Assessment Habitat Index (SAHI) which was developed by TVA's Resource Stewardship Program. The resultant habitat designations (good, fair, and poor) are correlated to black bass abundance (numbers/hour). Among the three areas

sampled during 2006, the correlations of habitat type to black bass abundance at Harrison Bay were positive while bass collected at Sale Creek and Skull Island showed some variability among habitat types, *i.e.*, the catch rates (abundance) did not align with the habitat designation types (Table 16). Overall catch rates for the reservoir were 50, 41, and 26 at the good, fair, and poor habitats, respectively (Table 17).

The following results describe the quality and condition of black bass collected in Chickamauga Reservoir during spring 2006: The RSD value (22) fell within the desirable range (10-25) (Figure 8). The PSD value (57) was also within the preferred range (40-70) (Figure 9). Relative weight values shown in Figure 10 are designated by inch groups which reflect the classical categories, *i.e.*, 0-7 = substock, 8-11 = stock, 12-14 = quality, 15-19 = preferred, 20-24 = memorable and 25+ = trophy. All categories fell within the desired range, which reflects excellent condition of black bass in all size groups of the population.

Only 32 crappie (29 black crappie and 3 white crappie) were collected during the survey. Crappie were collected predominantly from tree tops, stumps, and other physical structures in shallow water. Optimum water temperatures for crappie spawning occurred earlier in the spring of 2006 which may have been a factor affecting the catch rate.

Watts Bar Reservoir

A total of 18 hours of electrofishing resulted in collection of 820 largemouth bass, 23 spotted bass, and 84 smallmouth bass; of these 64.4 percent were harvestable size (≥ 10 inches). Overall catch rate (51.1 fish/hour) was similar to the average of the twelve sampling years (52.3 fish/hour) (Table 15). The average weight of harvestable sized black bass was 1.8 pounds which was higher than the twelve year average. The largest black bass was a 6.5 pound largemouth bass taken from Caney Creek. Numbers of bass > four pounds were much higher than the twelve year average (Table 15). Largemouth bass 6-8 inches, 11-12 inches, and 15-17 inches were the dominant size classes which could be seen from the three distinct modes in the length frequency histogram (Figure 7). All size classes up to 21 inches were represented in the population.

The Shoreline Assessment Habitat Index (SAHI) resulted in a positive correlation at only one Watts Bar site (Watts Bar Dam) (Table 16). However, the overall reservoir catch rates were positively correlated (54, 51, and 48 fish/hour at the good, fair, and poor habitat types, respectively) (Table 17).

The following results describe the quality and condition of black bass collected in Watts Bar Reservoir during spring 2006: The RSD value (38) fell outside the desirable range (10-25) (Figure 8) while the PSD value (66) fell within the preferred range (40-70) (Figure 9). Relative weight data for Watts Bar fell within the desirable range of 90-105% indicating that a balanced population of healthy, robust fish were present (Figure 11).

A total of 609 crappie (329 black and 280 white crappie) were collected during the survey.

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Table 1. Scoring Results for the Twelve Metrics and Overall Scores for RFAI Samples Collected in Chickamauga Reservoir, 2006.

Metric		Forebay TRM 472.3		Forebay TRM 482.0		Transition TRM 490.5		Inflow TRM 529.0	
		Obs	Score	Obs	Score	Obs	Score	Obs	Score
A. Species richness and composition									
1. Number of species		25	3	27	3	31	5	27	3
2. Number of centrarchid species		8	5	6	5	7	5	6	5
3. Number of benthic invertivores		2	1	3	1	4	3	5	3
4. Number of intolerant species		5	5	3	3	5	5	6	5
5. Percent tolerant individuals	electrofishing	74.6	0.5	72.4	0.5	70.1	0.5	65.3	1
	gill netting	28.6	0.5	29.6	0.5	30	1.5	-	-
6. Percent dominance by one species	electrofishing	37.4	1.5	33.6	1.5	35.3	1.5	29.1	3
	gill netting	24.4	1.5	22.5	1.5	25.2	1.5	-	-
7. Number non-native species	electrofishing	0.5	2.5	0	2.5	0	2.5	0.1	5
	gill netting	0.4	2.5	0	2.5	0	2.5	-	-
8. Number of top carnivore species		8	5	8	5	10	5	9	5
B. Trophic composition									
9. Percent top carnivores	electrofishing	5.9	1.5	6.5	1.5	8.3	1.5	9	1
	gill netting	62.8	2.5	40.8	1.5	51.2	1.5	-	-
10. Percent omnivores	electrofishing	8.3	2.5	24.6	1.5	37.2	1.5	31.5	3
	gill netting	30.8	1.5	47.9	0.5	27.2	1.5	-	-

Table 1. (continued)

Metric		Forebay TRM 472.3		Forebay TRM 482.0		Transition TRM 490.5		Inflow TRM 529.0	
		Obs	Score	Obs	Score	Obs	Score	Obs	Score
C. Fish abundance and health									
11. Average number per run	electrofishing	55.1	0.5	60.9	0.5	49.1	0.5	61.7	3
	gill netting	26.6	2.5	14.2	1.5	25	2.5	-	-
12. Percent anomalies	electrofishing	0.7	2.5	0.4	2.5	0.3	2.5	1.5	5
	gill netting	1.9	2.5	3.5	1.5	0.4	2.5	-	-
RFAI		44		37		47		42	
		Good		Fair		Good		Good	

*TRM 472.3 and 482 scored with forebay criteria, TRM 490.5 scored with transition criteria, and TRM 529 scored with inflow criteria. RFAI Scores: Very Poor 12-21, Poor 22-31, Fair 32-40, Good 41-50, Excellent 51-60.

Table 2. RFAI Scores Developed Using the RFAI Metrics from Samples Collected during 1993 to 2006 Upstream and Downstream of Watts Bar Nuclear Plant.

Station	Reservoir	Location	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	1993-2006 Average
Downstream	Chickamauga	TRM 529	52	52	46	-	44	-	42	44*	46	48*	48	42*	42	42*	46
Upstream	Watts Bar	TRM 531	43	48	-	44	-	41	36*	44	39*	39	45*	43	47*	44	43

*Sample years were not part of the VS monitoring program, however the same methodology was applied.

Table 3. Species Listing and Catch Per Unit Effort for the Transition and Inflow Transects on Chickamauga Reservoir, and the Forebay Transect on Watts Bar Reservoir during Fall Electrofishing and Gill Netting, 2006. (Electrofishing Effort = 300 Meters of Shoreline, Gill Netting Effort = 10 Net-Nights)

	Transition TRM 490.5			Inflow TRM 529.0		Forebay TRM 531.0		
Common Name	Electrofishing Catch Rate Per Run	Electrofishing Catch Rate Per Hour	Gill Netting Catch Rate Per Net Night	Electrofishing Catch Rate Per Run	Electrofishing Catch Rate Per Hour	Electrofishing Catch Rate Per Run	Electrofishing Catch Rate Per Hour	Gill Netting Catch Rate Per Net Night
Longnose gar	-	-	-	0.13	0.58	-	-	-
Spotted gar	0.07	0.32	-	0.13	0.58	0.13	0.53	-
Skipjack herring	-	-	3.10	-	-	-	-	0.20
Gizzard shad	17.33	84.14	6.30	17.93	77.52	23.53	94.39	4.20
Threadfin shad	3.87	18.77	0.10	0.07	0.29	0.07	0.27	0.50
Common carp	-	-	-	0.07	0.29	0.60	2.41	0.40
Golden shiner	0.60	2.91	-	-	-	-	-	-
Emerald shiner	1.53	7.44	-	1.27	5.48	-	-	-
Spotfin shiner	0.40	1.94	-	2.93	12.68	5.73	22.99	-
Bluntnose minnow	0.07	0.32	-	-	-	1.40	5.61	-
Bullhead minnow	0.07	0.32	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	0.20	0.80	0.40
Black buffalo	-	-	-	-	-	0.07	0.27	-
Northern hog sucker	0.07	0.32	-	-	-	-	-	-
Spotted sucker	0.33	1.62	0.10	0.20	0.86	0.53	2.14	0.80
Black redhorse	-	-	-	0.40	1.73	-	-	-
Golden redhorse	-	-	-	0.80	3.46	-	-	-
Blue catfish	-	-	0.10	0.07	0.29	-	-	0.20
Channel catfish	0.27	1.29	0.40	1.33	5.76	0.27	1.07	0.10
Flathead catfish	0.20	0.97	-	0.47	2.02	0.33	1.34	1.00
White bass	-	-	0.80	-	-	1.40	5.61	1.10
Yellow bass	-	-	5.50	0.53	2.31	-	-	2.60

Table 3. (continued)

	Transition TRM 490.5			Inflow TRM 529.0		Forebay TRM 531.0		
Common Name	**Electrofishing Catch Rate Per Run**	**Electrofishing Catch Rate Per Hour**	**Gill Netting Catch Rate Per Net Night**	**Electrofishing Catch Rate Per Run**	**Electrofishing Catch Rate Per Hour**	**Electrofishing Catch Rate Per Run**	**Electrofishing Catch Rate Per Hour**	**Gill Netting Catch Rate Per Net Night**
Striped bass	-	-	-	-	-	0.13	0.53	-
Rock bass	-	-	-	0.07	0.29	-	-	-
Warmouth	0.07	0.32	-	-	-	0.13	0.53	0.10
Redbreast sunfish	4.33	21.04	-	1.27	5.48	5.53	22.19	-
Green sunfish	0.07	0.32	-	0.20	0.86	1.60	6.42	-
Bluegill	11.40	55.34	-	16.67	72.05	32.33	129.68	0.10
Longear sunfish	1.00	4.85	-	1.67	7.20	0.40	1.60	-
Redear sunfish	2.80	13.59	-	5.53	23.92	3.67	14.71	-
Smallmouth bass	1.13	5.50	0.10	0.67	2.88	0.73	2.94	-
Spotted bass	1.60	7.77	1.00	2.13	9.22	0.20	0.80	-
Largemouth bass	0.27	1.29	0.40	1.07	4.61	2.00	8.02	0.40
White crappie	-	-	-	-	-	-	-	0.50
Black crappie	0.80	3.88	1.80	0.33	1.44	0.20	0.80	2.90
Yellow perch	-	-	-	-	-	0.20	0.80	-
Logperch	0.27	1.29	-	1.47	6.34	0.47	1.87	-
Sauger	-	-	0.10	-	-	-	-	-
Freshwater drum	0.20	0.97	0.60	1.27	5.48	0.07	0.27	0.60
Brook silverside	-	-	-	1.00	4.32	0.20	0.80	-
Inland silverside	0.40	1.94	-	2.00	8.65	3.20	12.83	-
Chestnut lamprey	-	-	0.10	-	-	-	-	-
Total	**49.15**	**238.46**	**25**	**61.68**	**266.59**	**85.32**	**342.22**	**16.10**
Number Samples	**15**		**10**	**15**		**15**		**10**
Number Collected	**737**		**250**	**925**		**1280**		**161**
Species Collected	**25**		**17**	**28**		**28**		**17**

Table 4. Scoring Results for the Twelve Metrics and Overall RFAI for Watts Bar Reservoir Forebay, 2006.

Metric		Forebay TRM 531.0 Obs.	Forebay TRM 531.0 Score
A. Species richness and composition			
1. Number of species		29	5
2. Number of centrarchid species		8	5
3. Number of benthic invertivores		3	1
4. Number of intolerant species		5	5
5. Percent tolerant individuals	electrofishing	85.2	0.5
	gill netting	34.8	0.5
6. Percent dominance by one species	electrofishing	37.9	1.5
	gill netting	26.1	1.5
7. Number non-native species	electrofishing	1.1	2.5
	gill netting	2.5	2.5
8. Number of top carnivore species		10	5
B. Trophic composition			
9. Percent top carnivores	electrofishing	6	1.5
	gill netting	54	2.5
10. Percent omnivores	electrofishing	30.5	1.5
	gill netting	32.9	1.5
C. Fish abundance and health			
11. Average number per run	electrofishing	85.3	0.5
	gill netting	16.1	1.5
12. Percent anomalies	electrofishing	0.2	2.5
	gill netting	0	2.5
RFAI			44
			Good

Table 5. Species Listing and Catch Per Unit Effort for Forebay Transects on Chickamauga Reservoir during Fall Electrofishing and Gill Netting, 2006. (Electrofishing Effort = 300 Meters of Shoreline, Gill Netting Effort = 10 Net-Nights)

	Forebay TRM 472.3			Forebay TRM 482.0		
Common Name	**Electrofishing Catch Rate Per Run**	**Electrofishing Catch Rate Per Hour**	**Gill Netting Catch Rate Per Net Night**	**Electrofishing Catch Rate Per Run**	**Electrofishing Catch Rate Per Hour**	**Gill Netting Catch Rate Per Net Night**
Spotted gar	-	-	-	0.13	0.58	-
Longnose gar	-	-	-	-	-	0.20
Skipjack herring	-	-	3.90	-	-	2.10
Gizzard shad	3.47	14.53	6.50	12.53	54.65	3.20
Threadfin shad	5.53	23.18	-	0.33	1.45	-
Hybrid shad	-	-	0.40	-	-	0.50
Common carp	0.27	1.12	0.10	-	-	-
Golden shiner	0.53	2.23	0.50	0.27	1.16	0.20
Emerald shiner	0.67	2.79	-	1.73	7.56	-
Spotfin shiner	0.47	1.96	-	2.53	11.05	-
Bluntnose minnow	-	-	-	2.00	8.72	-
Bullhead minnow	-	-	-	0.13	0.58	-
Spotted sucker	0.20	0.84	0.20	0.13	0.58	0.10
Blue catfish	-	-	0.50	-	-	1.50
Channel catfish	0.33	1.40	0.20	0.20	0.87	1.40
Flathead catfish	0.07	0.28	0.40	0.13	0.58	0.30
Western mosquitofish	-	-	-	0.07	0.29	-
Yellow bass	-	-	3.20	-	-	0.90
Warmouth	0.27	1.12	-	-	-	-
Redbreast sunfish	14.33	60.06	-	4.67	20.35	-
Green sunfish	0.47	1.96	-	0.07	0.29	-
Bluegill	20.60	86.31	0.10	20.47	89.24	0.50
Longear sunfish	0.67	2.79	-	0.73	3.20	-
Redear sunfish	2.20	9.22	0.90	7.47	32.56	0.70
Hybrid sunfish	0.07	0.28	-	-	-	-
Smallmouth bass	1.00	4.19	-	-	-	-
Spotted bass	1.13	4.75	4.10	2.00	8.72	0.90
Largemouth bass	1.00	4.19	0.30	1.53	6.69	0.10
White crappie	-	-	0.10	-	-	-
Black crappie	-	-	-	0.13	0.58	1.30
Logperch	-	-	-	1.00	4.36	-
Freshwater drum	0.40	1.68	0.50	0.13	0.58	0.30
Brook silverside	0.20	0.84	-	-	-	-
Inland silverside	1.20	5.03	-	2.53	11.05	-
Total	55.15	231.03	26.60	60.91	265.69	14.20
Number Samples	15		10	15		10
Number Collected	827		266	914.00		142
Species Collected	23		17	23		16

Table 6. Individual Metric Ratings and the Overall Benthic Index Field Scores for Watts Bar Reservoir Forebay (TRM 532.5), and Chickamauga Reservoir Inflow (TRM 518) and Transition (TRM 490.5) Downstream of Watts Bar Nuclear Plant, 2006.

	TRM 532.5		TRM 518		TRM 490.5	
Metric	**Obs**	**Rating**	**Obs**	**Rating**	**Obs**	**Rating**
1. Average number of taxa	3.3	3	9.1	5	5.4	5
2. Proportion of samples with long-lived organisms	0.1	1	0.8	5	0.8	5
3. Average number of EPT taxa	0	1	1.5	5	.05	3
4. Average proportion of oligochaete individuals	28.5	3	2.7	5	2.5	5
5. Average proportion of total abundance comprised by the two most abundant taxa	97.4	1	65.3	5	83.1	3
6. Average density excluding chironomids and oligochaetes	16.7	1	1016.7	3	223.3	1
7. Zero-samples - proportion of samples containing no organisms	0.1	3	0	5	0	5
Benthic Index Score		**13 Poor**		**33 Excellent**		**27 Good**

TRM 532.5 scored with forebay criteria, TRM 518 scored with inflow criteria, TRM 490.5 scored with transition criteria.
Benthic Index Scores: Very Poor 7-12, Poor 13-18, Fair 19-23, Good 24-29, Excellent 30-35

Table 7. Average Mean Density Per Square Meter of Benthic Taxa Collected at the Closest Site Downstream of Watts Bar Nuclear Plant, Chickamauga Reservoir, October 2006.

Chickamauga Reservoir Species	TRM 518 Downstream Mean Density
Tubellaria	
Tricladida	
Planariidae	62
Oligocheata	
Oligochaetes	28
Hirudinea	65
Crustacea	
Amphipoda	385
Isopoda	
Insecta	
Ephemeroptera	
Mayflies	5
Ephemeridae	
Hexagenia (<=10 mm)	
Hexagenia (>10 mm)	
Megaloptera	
Sialidae	
Sialis sp.	
Odonata	
Anisoptera	
Zygoptera	
Trichoptera	
Caddisflies	97
Plecotera	
Stoneflies	
Coeleoptera	
Diptera	
Ceratopogonidae	
Chironomidae	
Chironomids	62
Gastropoda	
Snails	21.7
Basommatophora	
Ancylidae	
Ferrissia sp.	
Bivalvia	
Unionidae	
Mussels	20

Table 7. (continued)

Chickamauga Reservoir Species	TRM 518 Downstream Mean Density
Veneroida	
Corbiculidae	
Corbicula (≤10mm)	147
Corbicula (>10mm)	122
Sphaeriidae	
Fingernail clams	90
Dreissenidae	
Dreissena polymorpha	
Number of samples	**10**
Total Mean Density/SQMeter	**1104.7**
Total area sampled (SQ Meters)	**0.6**

Table 8. Benthic Index Field Scores from Data Collected during 1994-2006 at Watts Bar Reservoir Forebay (TRM 532.5) Upstream from Watts Bar Nuclear Plant, and Chickamauga Reservoir Inflow (TRM 527.4, TRM 518) and Transition (TRM 490.5) Downstream from Watts Bar Nuclear Plant.

Site	Reservoir	Location	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Upstream	Watts Bar	TRM 532.5	13	-	11	-	13	-	15	13	13	15	17	15	13	14
Downstream	Chickamauga	TRM 527.4	-	-	-	-	-	-	-	29	27	33	35	31	-	31
Downstream	Chickamauga	TRM 518.0	19	31	-	25	-	21	23	29	23	27	35	29	33	27
Downstream	Chickamauga	TRM 490.5	33	29	-	31	-	31	23	25	25	31	31	31	27	29

Benthic Index Scores: Very Poor 7-12, Poor 13-18, Fair 19-23, Good 24-29, Excellent 30-35

Table 9. A Comparison of Benthic Index Scores from Field and Lab Processed Samples at the Closest Two Downstream Sites from Watts Bar Nuclear Plant. (Scores are only presented for years when field samples were lab processed.)

Site	TRM	Score	2000	2002	2004	2005	2006	Average
Chickamauga Inflow	527.4	Field	-	27	35	31	-	31
		Lab	-	27	33	33	-	31
Chickamauga Inflow	518.0	Field	23	23	35	29	33	29
		Lab	21	25	33	31	33	29

Table 10. Sport Fishing Index Scores for Chickamauga Reservoir, 1997-2005.

Species	1997	1998	1999	2000	2001	2002	2003	2004	2005	1997-2005 Average SFI Score
Black bass	35	41	25	35	31	34	34	31	33	33
Smallmouth bass	20	20	24	22	40	32	32	32	26	28
Spotted bass	20	37	24	40	26	32	32	32	36	31
Largemouth bass	34	37	34	32	28	36	36	38	36	35
Bluegill	30	-	32	33	32	32	31	34	-	32
Channel catfish	-	-	32	29	30	25	33	38	-	31
Crappie	32	-	31	31	32	38	42	40	-	35
Sauger	27	36	32	39	30	31	27	26	-	31
Striped bass	35	-	30	30	40	34	31	-	-	33
White bass	-	-	31	30	30	30	40	-	-	32

Table 11. Sport Fishing Index Scores for Watts Bar Reservoir, 1997-2005.

Species	1997	1998	1999	2000	2001	2002	2003	2004	2005	1997-2005 Average SFI Score
Black bass	42	39	25	41	37	36	31	38	31	36
Smallmouth bass	22	39	32	38	30	38	24	31	35	32
Spotted bass	-	31	-	38	30	28	30	29	38	32
Largemouth bass	44	26	36	43	39	36	34	40	42	38
Bluegill	35	30	31	27	36	26	36	42	-	33
Channel catfish	30	25	25	22	26	21	30	24	-	25
Crappie	20	44	35	37	31	30	31	34	47	34
Sauger	32	30	30	34	29	20	30	26	-	29
Striped bass	25	25	36	39	36	40	43	32	-	35
White bass	-	25	30	25	30	30	30	54	-	32

Table 12. Sport Fishing Index Population Quantity, Creel Quantity, Quality Metrics, and Scoring Criteria.

Metrics	Scores 5	10	15
Black bass			
Population (quantity)			
TVA electrofishing catch/hour	< 15	15-31	> 31
State electrofishing (catch/hour)	< 62	62-124	> 124
Creel (quantity)[a]			
Anglers (catch/hour)	< 0.3	0.3-0.6	> 0.6
BAIT and BITE data	< 1.1	1.1-2.3	> 2.3
Creel (quality)			
Pressure (hours/acre)	< 8	8-16	> 16
Largemouth bass			
Population (quantity)[b]			
TVA electrofishing catch/hour	< 13	13-25	> 25
State electrofishing (catch/hour)	< 53	53-106	> 106
Creel (quantity)			
Anglers (catch/hour)	< 0.29	0.29-0.58	> 0.58
Creel (quality)			
Pressure (hours/acre)	< 8	8-16	> 16
Smallmouth bass			
Population (quantity)			
TVA electrofishing catch/hour	< 4	4-8	> 8
State electrofishing (catch/hour)	< 8	8-15	> 15
Creel (quantity)			
Anglers (catch/hour)	< 0.1	0.1-0.3	> 0.3
Creel (quality)			
Pressure (hours/acre)	< 8	8-16	> 16
Spotted bass			
Population (quantity)			
TVA electrofishing catch/hour	< 5	5-11	> 11
State electrofishing (catch/hour)	< 14	14-27	> 27
Creel (quantity)			
Anglers (catch/hour)	< 0.07	0.07-0.13	> 0.13
Creel (quality)			
Pressure (hours/acre)	< 8	8-16	> 16

Table 12. (continued)

Metrics	Scores 5	10	15
Sauger			
Population (quantity)			
Experimental gill net (catch/net night)	< 9	9-17	> 17
Creel (quantity)			
Anglers (catch/hour)	< 0.5	0.5-1	> 1
Creel (quality)			
Pressure (hours/acre)	< 5	5-10	> 10
Channel catfish			
Population (quantity)			
Experimental gill net (catch/net night)	< 2	2-4	> 4
Creel (quantity)			
Anglers (catch/hour)	< 0.3	0.3-0.7	> 0.7
Creel (quality)			
Pressure (hours/acre)	< 9	9-19	> 19

[a]Each worth 2.5, 5.0, and 7.5 points if both data sets are available.
[b]TVA electrofishing only used when state agency electrofishing data are unavailable.

Table 13. Sport Fishing Index Population Quality Metrics and Scoring Criteria.

Metrics	Scores 5	10	15
Population (quality)	1	2	3
PSD	< 20 or > 80	20-39 or 61-80	40-60
RSDP (preferred)	0 or > 60	1-9 or 41-60	10-40
RSDM (memorable)	0 or > 25	1-4 or 11-25	5-10
RSDT (trophy)	0	< 1	≥ 1
W_r (Stock-preferred size fish)	< 90	> 110	90-110

Table 14. Electrofishing Catch Rates and Population Characteristics of Black Bass Collected during Spring Sport Fish Surveys on Chickamauga Reservoir, 1995-2006.

Year	EF Catch Rate (no./hr.)	Mean Weight (lbs.)	% Harvestable	Bass >4 lbs.	Bass >5 lbs.	Largest bass (lbs.)
2006	39.4	1.3	71.7	14	7	7.1
2005	72.6	1.3	36.9	15	9	6.2
2004	40.9	1.3	60.2	13	6	6.6
2003	62.0	1.3	65.8	23	8	6.4
2002	57.4	1.1	59.4	9	4	6.6
2001	34.5	0.8	45.2	0	0	2.8
2000	34.4	1	51.2	3	0	4.8
1999	10.6	1.3	60.7	3	1	6.1
1998	37.2	1.1	44.5	9	2	6.6
1997	40.2	1	70.1	8	4	8.7
1996	51	1.2	42.6	13	9	7.9
1995	62	1.2	61.8	28	12	8.3
Average	**45.2**	**1.2**	**55.8**	**11.5**	**5.2**	**6.5**

Table 15. Electrofishing Catch Rates and Population Characteristics of Black Bass Collected during Spring Sport Fish Surveys on Watts Bar Reservoir, 1995-2006.

Year	EF Catch Rate (no./hr.)	Mean Weight (lbs.)	% Harvestable	Bass >4 lbs.	Bass >5 lbs.	Largest bass (lbs.)
2006	51.1	1.8	64.4	28	10	6.5
2005	47.8	1.8	81.1	25	9	6.9
2004	51.9	1.5	88.2	13	2	5.9
2003	56.6	1.1	81.6	11	2	5.4
2002	57.0	1.2	70.7	28	10	6.4
2001	73.6	1.5	29.3	5	5	6.4
2000	17.0	1.2	56.3	3	1	5.3
1999	19.9	0.9	66.7	11	3	8.1
1998	55.8	1.0	88.6	6	4	7.2
1997	61.8	1.3	47.6	8	8	6.2
1996	34.3	1.6	79.0	9	7	7.7
1995	101.0	1.1	78.6	32	15	6.6
Average	**52.3**	**1.3**	**69.3**	**14.9**	**6.3**	**6.6**

Table 16. Black Bass Catch Per Hour Compared to Habitat Types by Location during Spring Sport Fish Surveys on Chickamauga and Watts Bar Reservoirs, 2006.

	Habitat Designation		
Reservoir and Site	**Good**	**Fair**	**Poor**
Chickamauga			
Harrison Bay	58(4)	36(4)	41(4)
Sale Creek	27(4)	45(4)	15(4)
Skull Island	79(2)	42(8)	17(2)
Watts Bar			
Blue Springs	66(3)	52(4)	62(5)
Caney Creek	36(4)	51(4)	40(4)
Watts Bar Dam	60(3)	52(6)	44(3)

Catch per hour = number of fish collected per hour
( ) = number of transects sampled at each location

Table 17. Black Bass Catch Per Hour Compared to Habitat Types by Reservoir during Spring Sport Fish Surveys on Chickamauga and Watts Bar Reservoirs, 2006.

	Habitat Designation		
Reservoir	**Good**	**Fair**	**Poor**
Chickamauga	50	41	26
Watts Bar	54	51	48

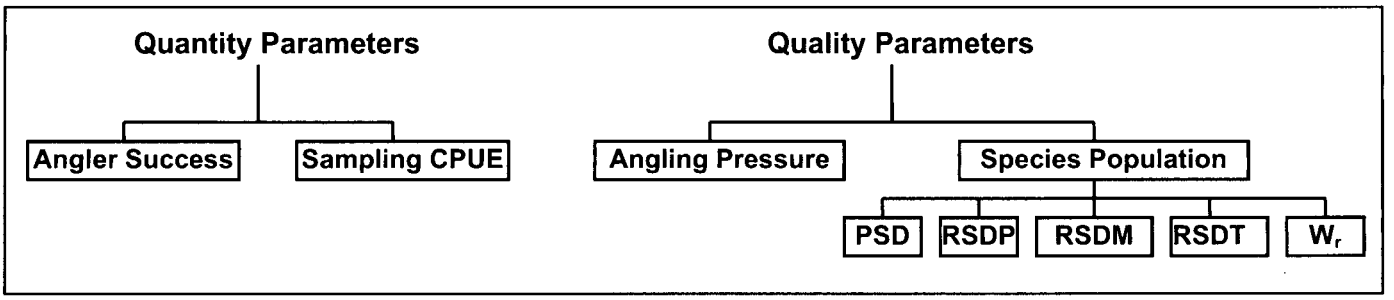

Figure 1. Parameters used to calculate the Sport Fishing Index.

Figure 2. Annual Chickamauga Reservoir RFAI scores for sample years between 1993 and 2006.

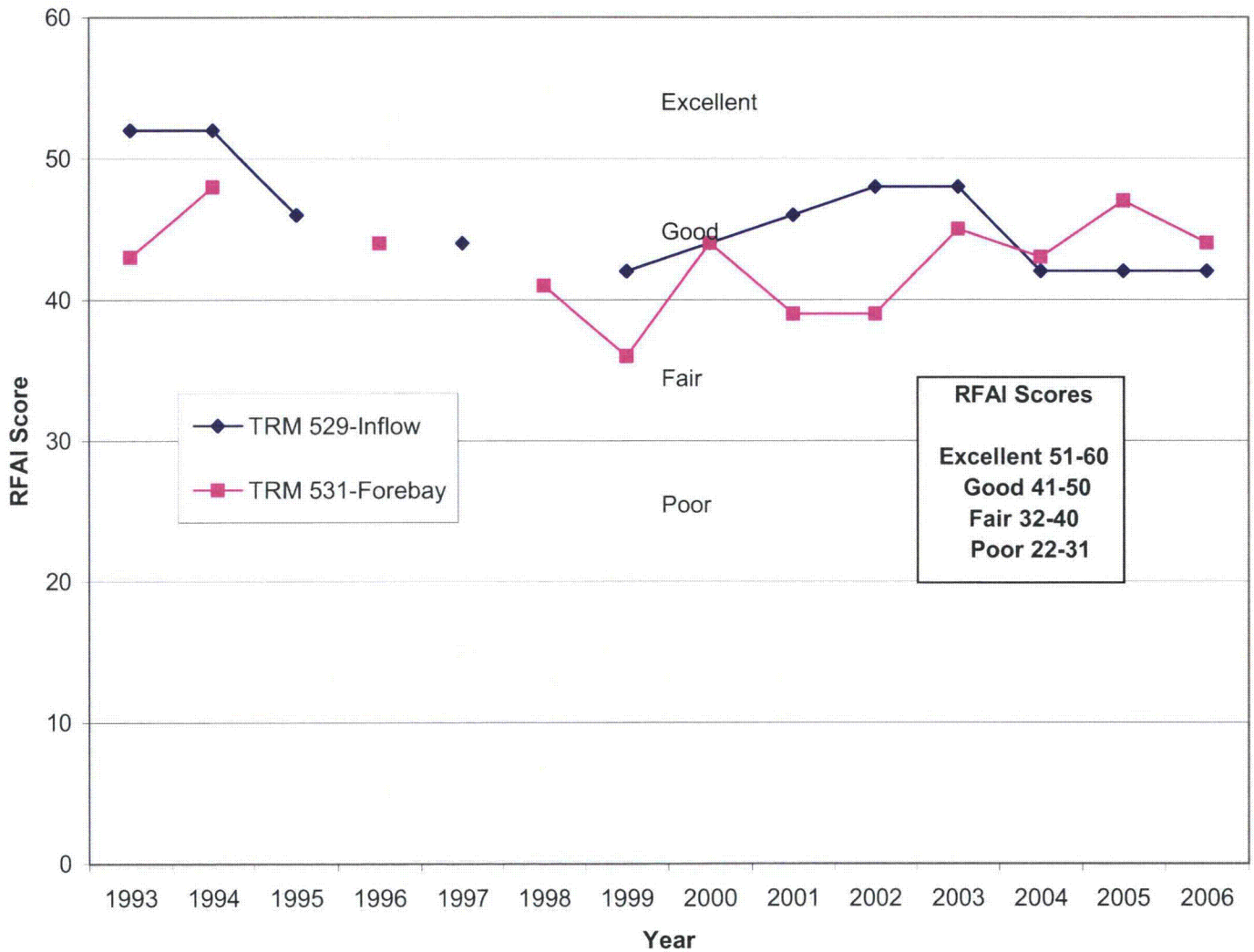

Figure 3. Annual Watts Bar Reservoir RFAI scores for sample years between 1993 and 2006.

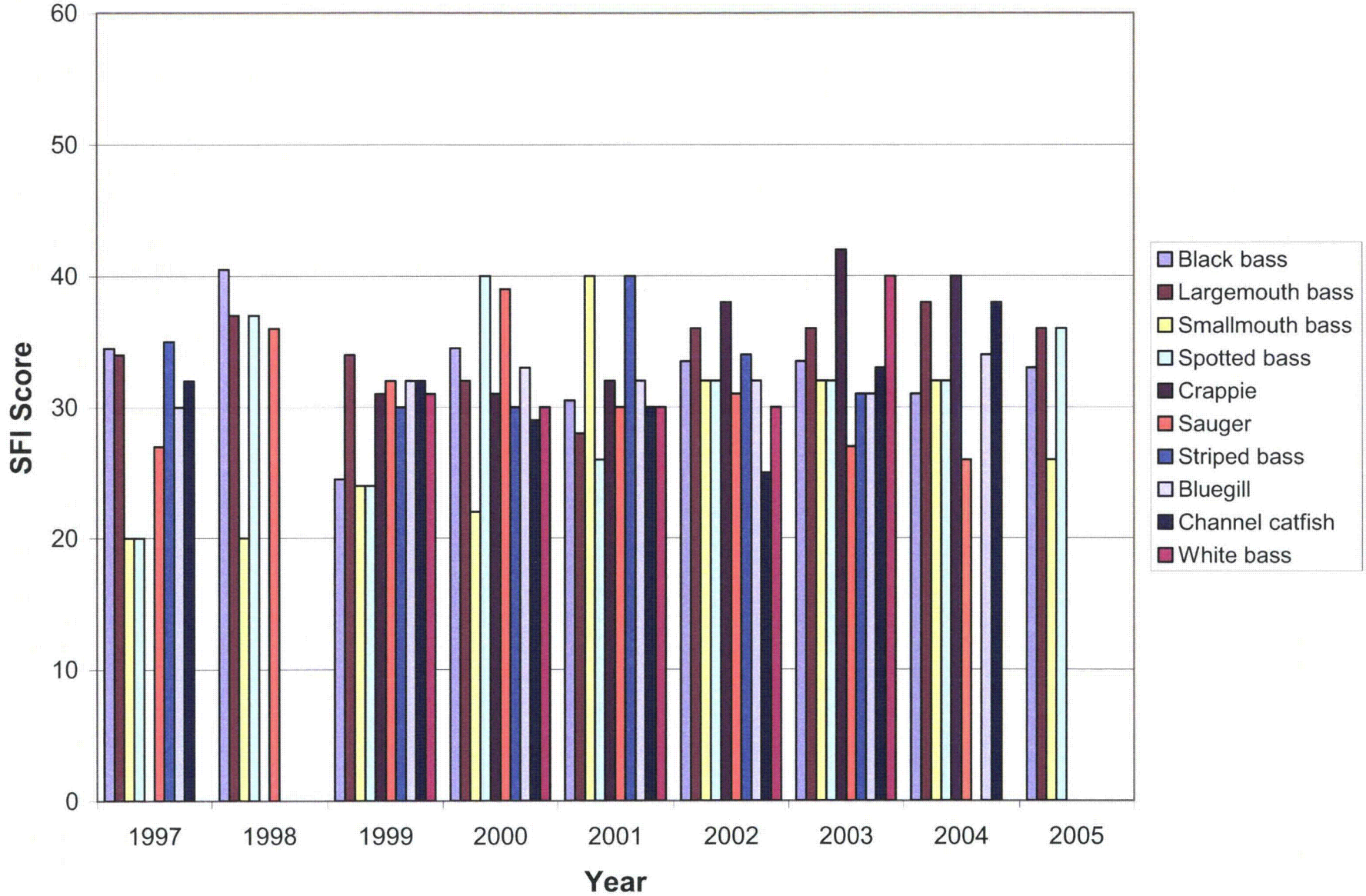

Figure 4. Sport Fishing Index results for Chickamauga Reservoir between 1997 and 2005.

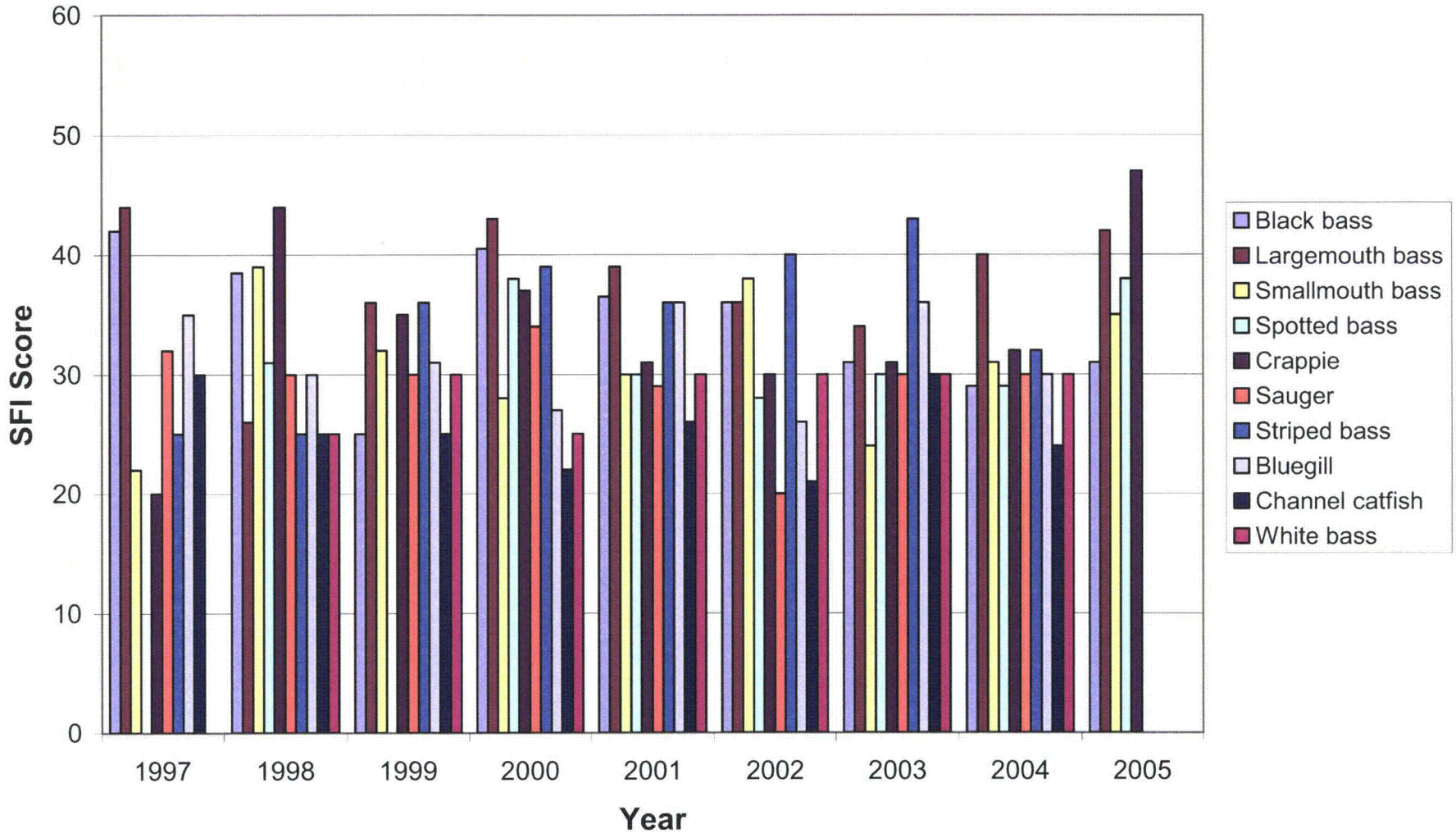

Figure 5. Sport Fishing Index results for Watts Bar Reservoir between 1997 and 2005.

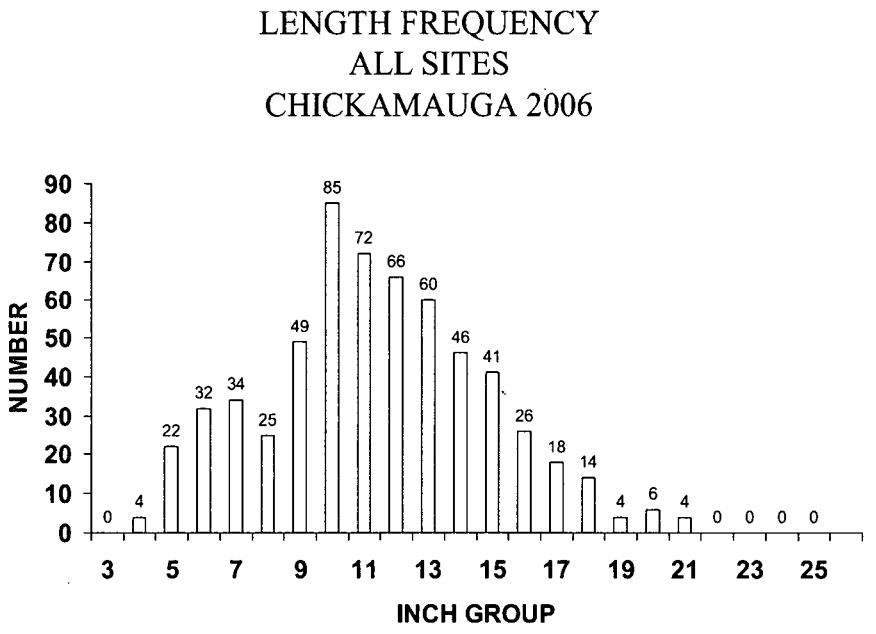

Figure 6. Length frequency distribution for largemouth bass collected from Chickamauga Reservoir (all sites) during the Spring Sport Fish Survey, 2006.

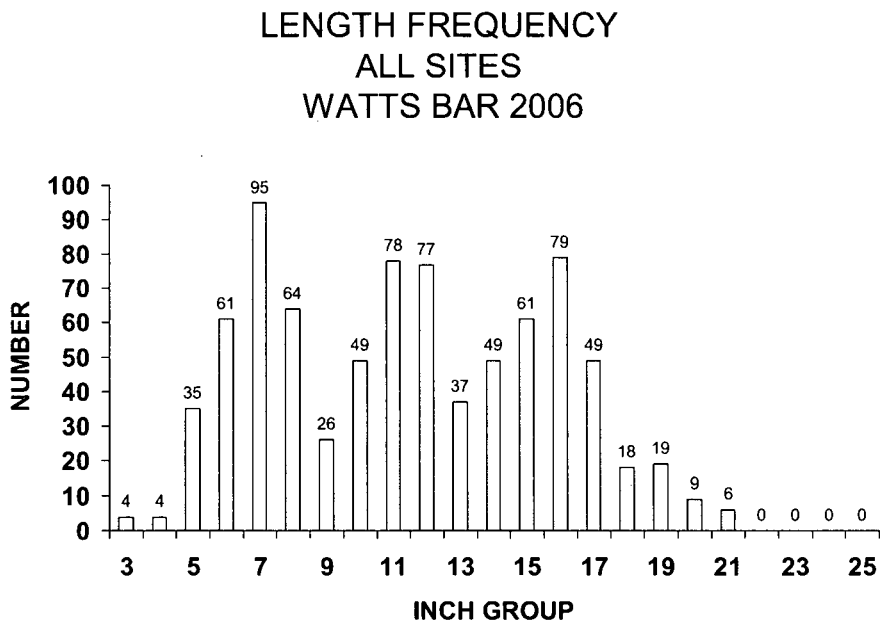

Figure 7. Length frequency distribution for largemouth bass collected from Watts Bar Reservoir (all sites) during the Spring Sport Fish Survey, 2006

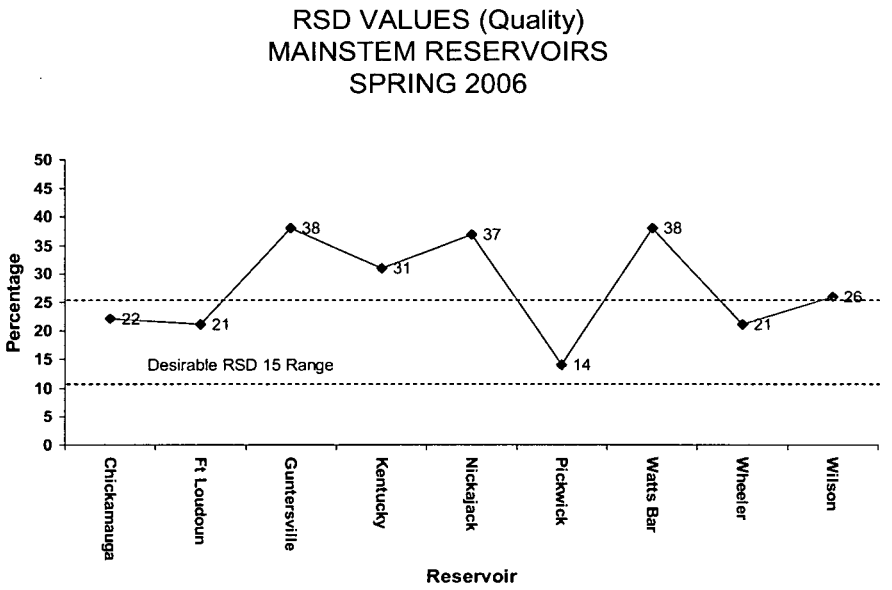

Figure 8. Relative stock density values for Tennessee River reservoirs calculated from 2006 Spring Sport Fish Survey samples.

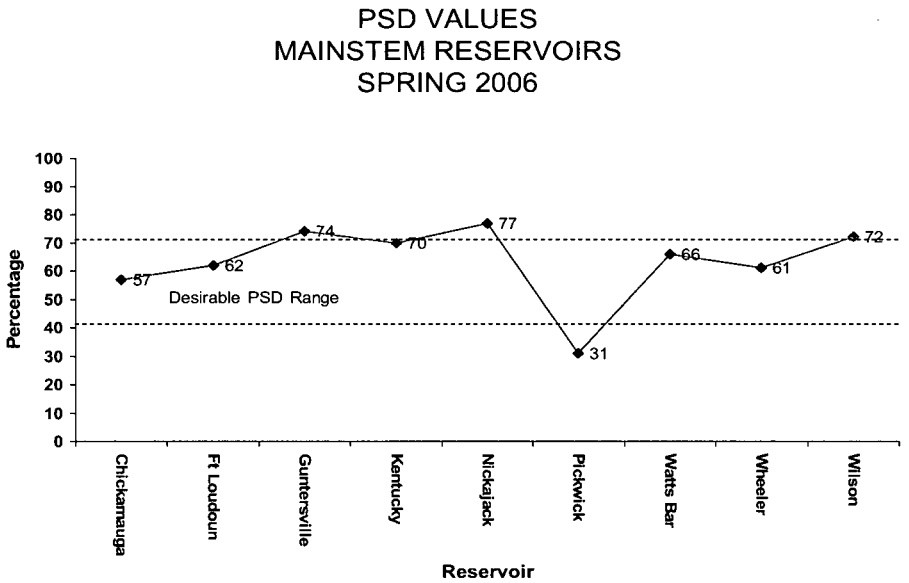

Figure 9. Proportional stock density values for Tennessee River reservoirs calculated from 2006 Spring Sport Fish Survey samples.

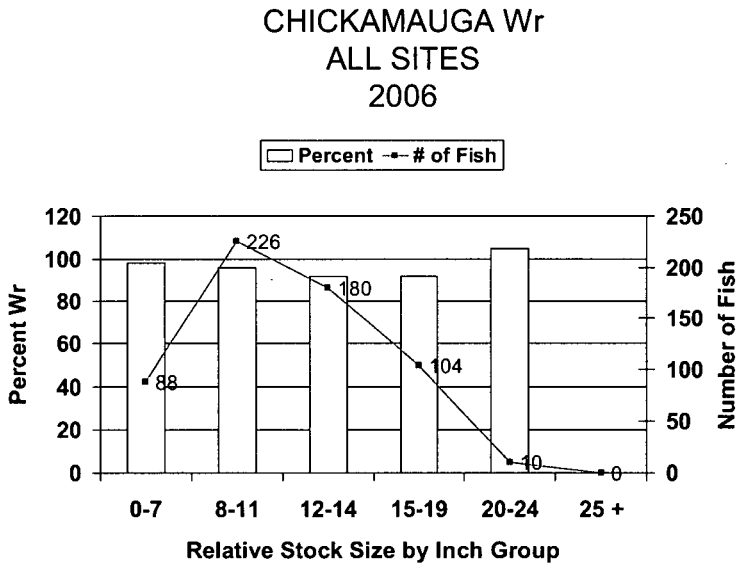

Figure 10. Chickamauga Reservoir mean relative weights (Wr) for largemouth bass by RSD category and number of fish during 2006.

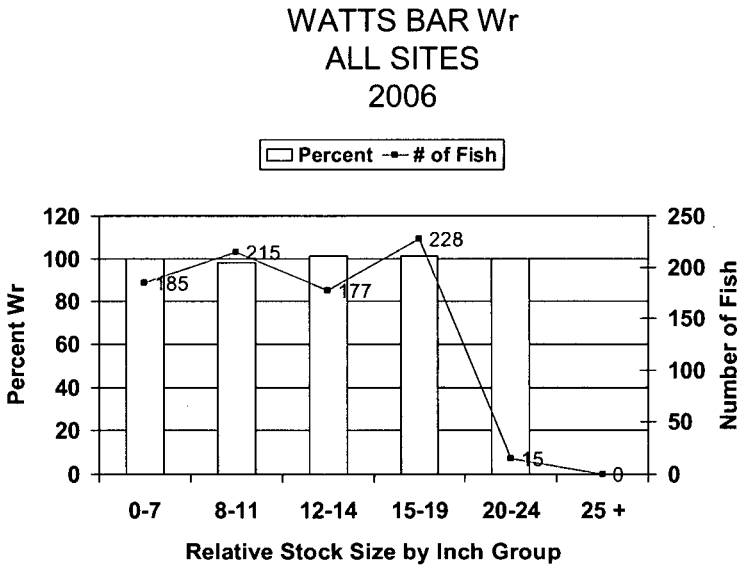

Figure 11. Watts Bar Reservoir mean relative weights (Wr) for largemouth bass by RSD category and number of fish during 2006.

TENNESSEE VALLEY AUTHORITY

ENVIRONMENTAL INFORMATION

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2

Index No: 86
Title: Watts Bar Nuclear Plant Units 1 & 2

TENNESSEE VALLEY AUTHORITY

ENVIRONMENTAL INFORMATION
WATTS BAR NUCLEAR PLANT
UNITS 1 AND 2

NOV 18 1976

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SECTION A

This section identifies and discusses environmental aspects of those features relating to the design, construction, and operation of the Watts Bar Nuclear Plant which have been revised since the FES was published on November 9, 1972. There are nine general items discussed in this section. These are: (1) Watts Bar/Volunteer 500kV Transmission Line, (2) Location of blowdown diffusers, (3) Tritium disposal method, (4) water chemistry changes, (5) minor changes in construction practices, (6) visitor facilities, (7) addition of condensate demineralizers, (8) addition of radwaste evaporator and (9) other changes, miscellaneous items.

RELOCATION OF WATTS BAR/VOLUNTEER
500-kV TRANSMISSION LINE

A relocation of the Watts Bar/Volunteer 500-kV transmission line became necessary because of the selection of a more desirable substation location for the tie-in of this line. An assessment of the transmission line along this relocated route has been conducted by TVA. This assessment has been included in the Volunteer, Tennessee, 500-kV Substation And Transmission Connections Final Environmental Statsment that was sent to the Council on Environmental Quality and made available to the public on July 6, 1976. This statement concluded that the environmental impacts due to the transmission line at the new location would be similar in nature to the environmental impacts of the previous location but markedly reduced, especially with regard to acquisition of new acreage of right of way and clearing of woodlands, due to use of existing right of way.

During development of the proposed transmission line route, preplanning discussions were held with the following Federal, state, and local commissions, departments and planning agencies:

Knoxville-Knox County Metropolitan Planning Commission, Knoxville
East Tennessee Development District, Knoxville
Southeast Development District, Chattanooga
Tennessee State Planning Office, East Tennessee Section, Knoxville
Meigs County Planning Commission, Decatur
Loudon County Regional Planning Commission, Loudon
McMinn County Planning Commission, Athens
Roane County Planning Commission, Rockwood
Anderson County Planning Commission, Clinton
State of Tennessee Wildlife Resources Agency, Nashville
Tennessee Department of Transportation, Nashville
U.S. Department of Agriculture, Soil Conservation Service, Nashville
Tennessee Department of Conservation, Nashville

Through the early disclosure of TVA's plans, potential conflicts with other agency programs or interests have been factored into the decision-making process. No major conflicts or environmental impacts were identified which may accrue to this action that cannot be reasonably controlled or avoided.

RELOCATION OF BLOWDOWN DIFFUSERS

The TVA Watts Bar Nuclear Plant FES stated that blowdown from the cooling towers would be discharged by means of blowdown diffusers located in the Chickamauga Reservoir. The environmental assessment of this action was based on placement of the blowdown diffuser at about Tennessee River Mile (TRM) 527.6. This location has been determined to be infeasible due to insufficient river depths in that area. As a result, TVA has found it necessary to relocate the blowdown diffusers to an area approximately 1,000 feet upstream of the originally proposed location. Both locations are within an area designated by the State of Tennessee as a mussel sanctuary.

In choosing the location discussed above, TVA has conducted an environmental review of this action. The environmental review considered three reasonable alternatives. These alternatives consisted of (1) relocation of the diffuser system to an area of adequate depth for barge clearance approximately 1,000 feet upstream from the originally proposed area, (2) locating the diffusers as planned and realigning a total of about one mile of the present navigation channel in the Tennessee River (upstream and downstream) approximately 250 feet toward the left bank, away from the diffuser location, and (3) redesign and relocation of the diffusers to an area between the right bank and the navigation channel with the diffusers oriented parallel to the river flow.

Alternative 1 would have essentially the same environmental impact as that outlined for the original diffuser location outlined in the Watts Bar Nuclear Plant FES. TVA estimates that about 1,600 yd^3 of material would

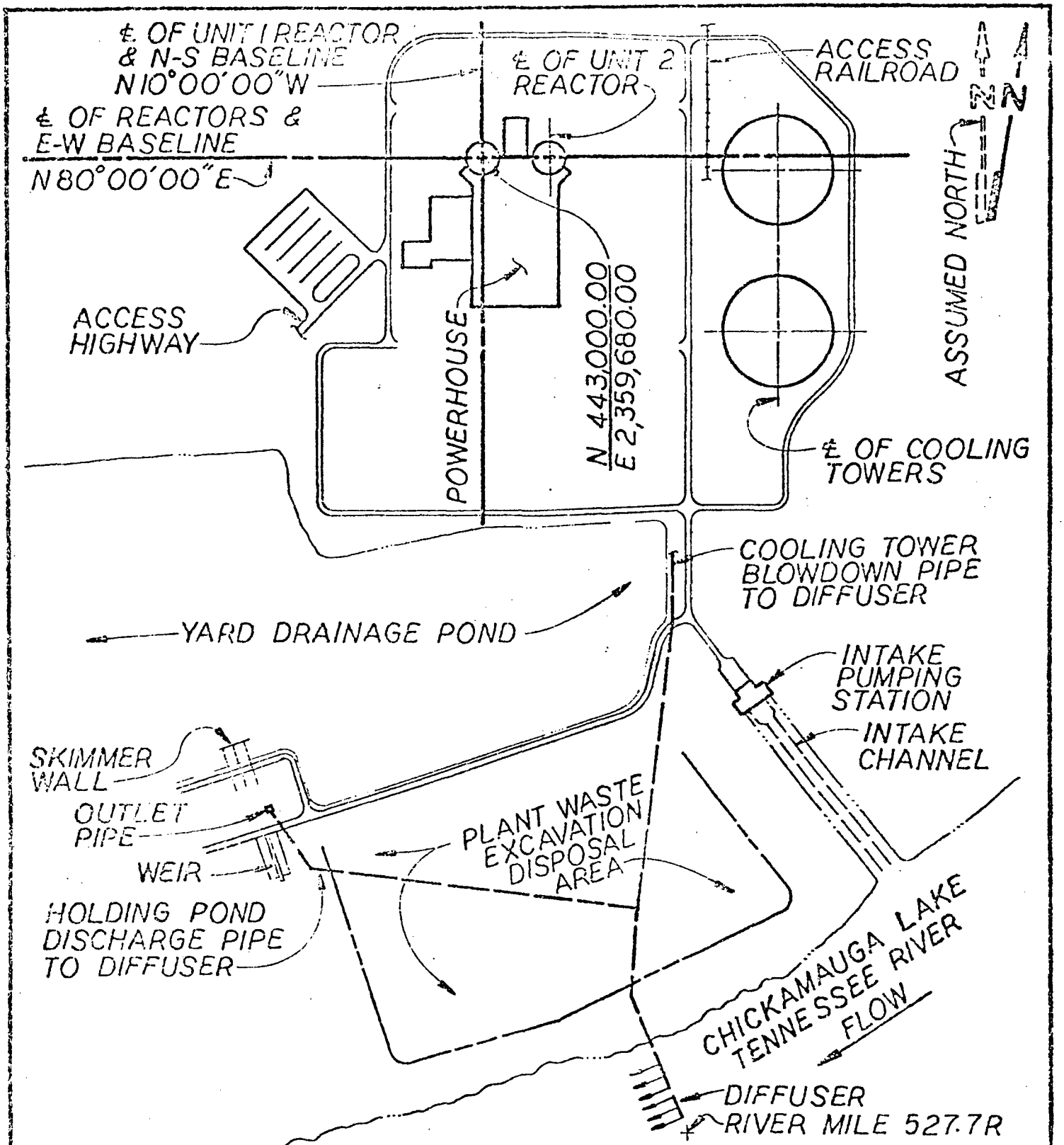
have to be removed, resulting in 0.3 acre of river bottom being disturbed. Owing to the nature of the substrate, the impact of this action on the mussel sanctuary below Watts Bar Dam is expected to be negligible. Alternative 2 is expected to result in the greatest environmental impact of all three alternatives since dredging work would be performed in areas designated as a mussel sanctuary by the State of Tennessee, as well as requiring a 1-mile realignment of the present river navigation channel. Alternative 3 would result in greater potential for environmental impacts on aquatic and terrestrial biota than Alternative 1 due to the requirement of a longer diffuser pipe system and also the effluent plume being closer to the right bank. Construction impacts for alternatives 1 and 3 would be expected to be nearly the same. Although the capital cost estimates favor alternative 3, the fact that the diffuser is oriented perpendicular to the river flow and consequently would provide more rapid dilution of thermal, radioactive and nonradioactive discharges weighs heavily in favor of alternative 1. TVA has conducted a review of these alternatives and determined that alternative 1 is the preferred selection with respect to feasibility, environmental impacts, and associated capital costs. See Figures 1, 2, and 3 for a detailed layout of the blowdown diffuser system chosen under alternative 1. A fourth figure shows bottom contours of the Tennessee River in the vicinity of river mile 527.7R. The streambed between the original diffuser location and the location of alternative 1 is mostly bedrock. Implementation of alternative 1 should result in minimal environment impacts to the overall aquatic ecosystem, and afford the greatest protection to the State of Tennessee mussel sanctuary below Watts Bar Dam.

TVA has notified both the State of Tennessee and the U.S. Army Corps of Engineers (since their comments had expressed concern over the mussel sanctuary described in the Watts Bar Nuclear Plant Draft Environmental Statement) of the plans to relocate the discharge diffuser. Their responses as well as other referenced correspondence are included at the end of this discussion (following the four figures in the order they are cited).

The State of Tennessee indicated that their concurrence with alternative 1 was contingent upon disposal of spoil onshore and not back into the Tennessee River. TVA plans to use dredging equipment to remove the estimated quantity of 1,600 cubic yards of spoil material to an onshore location that will be properly diked to avoid excessive runoff. By letter dated May 14, 1976, TVA responded to the State of Tennessee's request for additional information concerning mussel beds between the original diffuser site and Watts Bar Dam (included at end of this discussion). As stated in this letter, TVA does not consider any of the mussel species found in the area of the Tennessee River below Watts Bar Dam to be endangered or threatened. However, one mussel species (*Lampsilis orbiculata*) found in the mussel bed from Tennessee River miles 527.6 to 528.5 has recently been determined by the U.S. Department of the Interior (Fish and Wildlife Service) to be an endangered species, pursuant to Section 4 of the Endangered Species Act of 1973 (see Federal Register, Vol. 41, No. 115-Monday, June 14, 1976, pages 24062-24067). This mussel bed is situated on the left side of the river navigation channel while the proposed discharge diffuser location at about TRM 527.7 is on the opposite side of the channel, along with the Watts Bar Nuclear Plant.

Since the nearest mussel bed is located across the river and almost entirely upstream of the proposed discharge diffuser location and relatively high river velocities exist in this area, TVA believes that construction of the discharge diffuser as proposed would not result in any adverse impact (e.g., turbidity of the river) on the mussel species Lampsilis orbiculata. In the event of low flow river conditions during construction of the diffuser, the minor sedimentation expected would be even more localized on the right side of the river, downstream and across the river from the nearest mussel concentration. Thermal and chemical discharges through the diffuser during operation of the plant are also not expected to have any adverse impact on this mussel species since the thermal discharge plume and mixing zone (both thermal and chemical) would always be well downstream of the discharge diffuser location except during periods of low flow in the vicinity of Watts Bar Dam. As stated in the discussion on "Cooling Tower Blowdown Holdup Modification," discharges of cooling tower blowdown through the diffuser system will be discontinued during periods that releases from Watts Bar Dam are less than 3,500 cfs. This provides reasonable assurance that no adverse impacts to Lampsilis orbiculata would result from plant operation during low flow conditions. Further protection from plant discharges is afforded to Lampsilis orbiculata (as well as to the overall aquatic ecosystem in the area of the discharge diffusers) since TVA will be required to operate Watts Bar Nuclear Plant in accordance with the terms of both the facility NPDES permit for thermal and nonradioactive chemical discharges, and 10 CFR 50, Appendix I for radioactive materials discharged through the diffusers.

The U.S. Army Corps of Engineers also expressed concern over possible impacts on the mussel populations of the area. They stated that use of silt screens for controlling sedimentation and concomitant high turbidity had proven useful for certain slack water situations. TVA is committed to developing a course of action that will protect the mussel sanctuary located in the area of the diffuser pipes and has considered the use of silt screens for siltation control during dredging of the overburden material. The high velocity of the Tennessee River in this area would offset any advantage regarding siltation control that might be gained by use of silt screens. In discussions on this matter, the U.S. Army Corps of Engineers has agreed with our evaluation. As suggested by the U.S. Army Corps of Engineers, construction activities related to this action will be carried out under TVA's supervision. Dredging activities for the Watts Bar Nuclear Plant discharge diffuser system are now scheduled to begin in early December 1976.

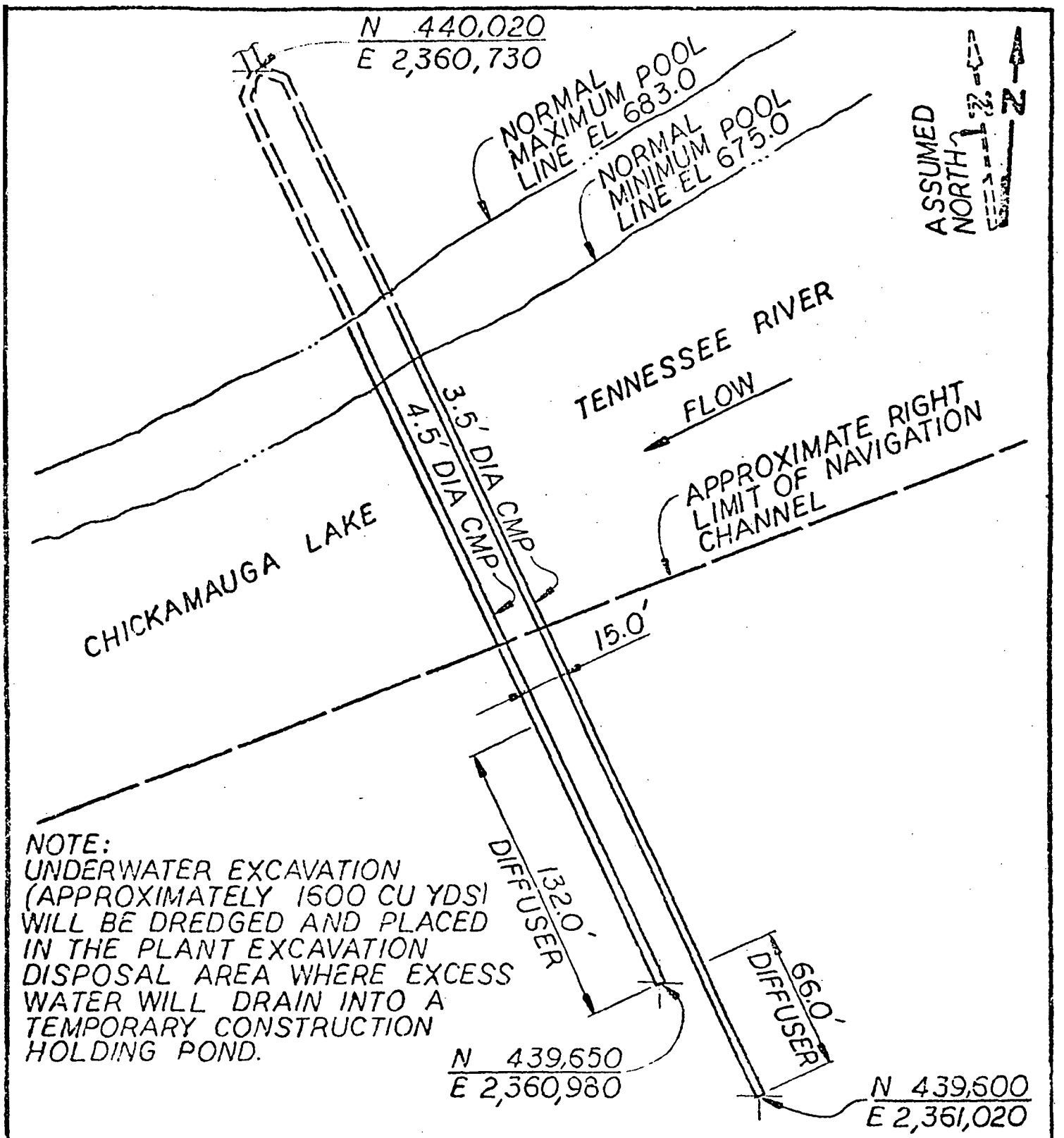


SCALE 1" = 500'

COMPANION DRAWINGS:
FIGURES 2 & 3

CONDENSER WATER SUPPLY

WATTS BAR NUCLEAR PLANT
COOLING TOWER BLOWDOWN
DIFFUSER FACILITY-FIGURE 1

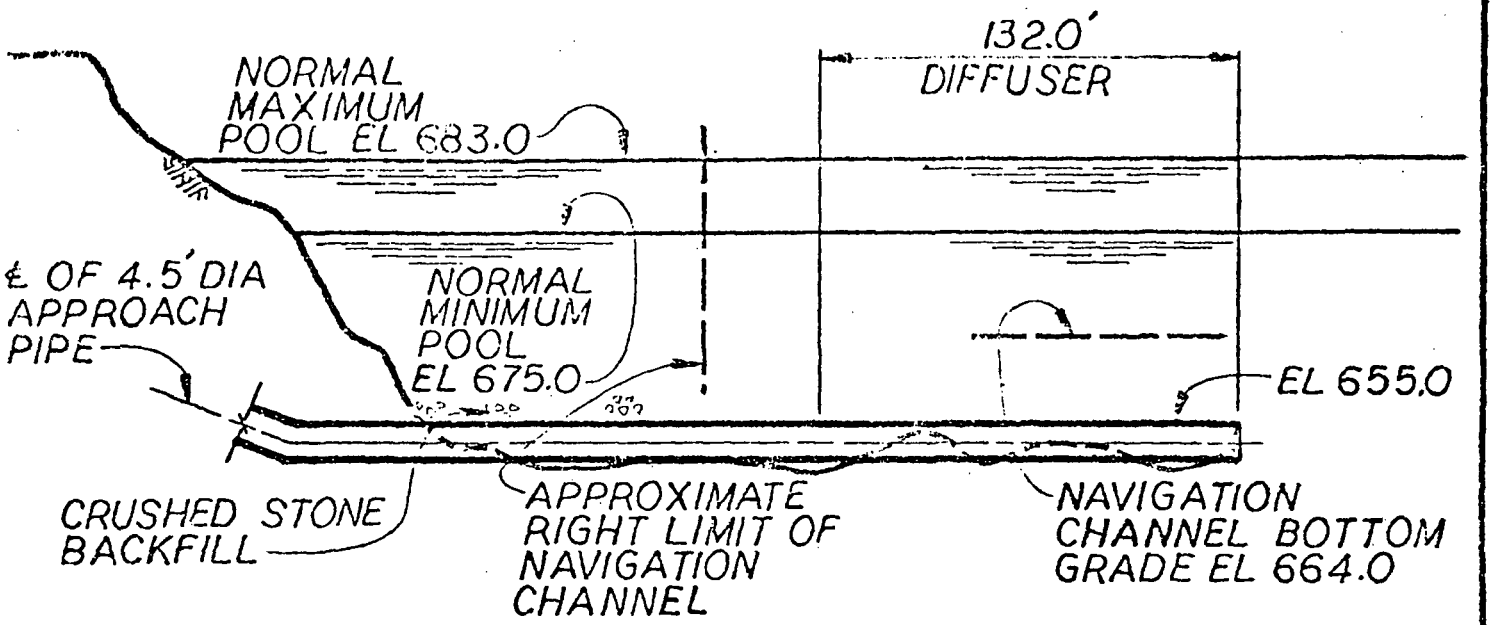


NOTE:
UNDERWATER EXCAVATION (APPROXIMATELY 1600 CU YDS) WILL BE DREDGED AND PLACED IN THE PLANT EXCAVATION DISPOSAL AREA WHERE EXCESS WATER WILL DRAIN INTO A TEMPORARY CONSTRUCTION HOLDING POND.

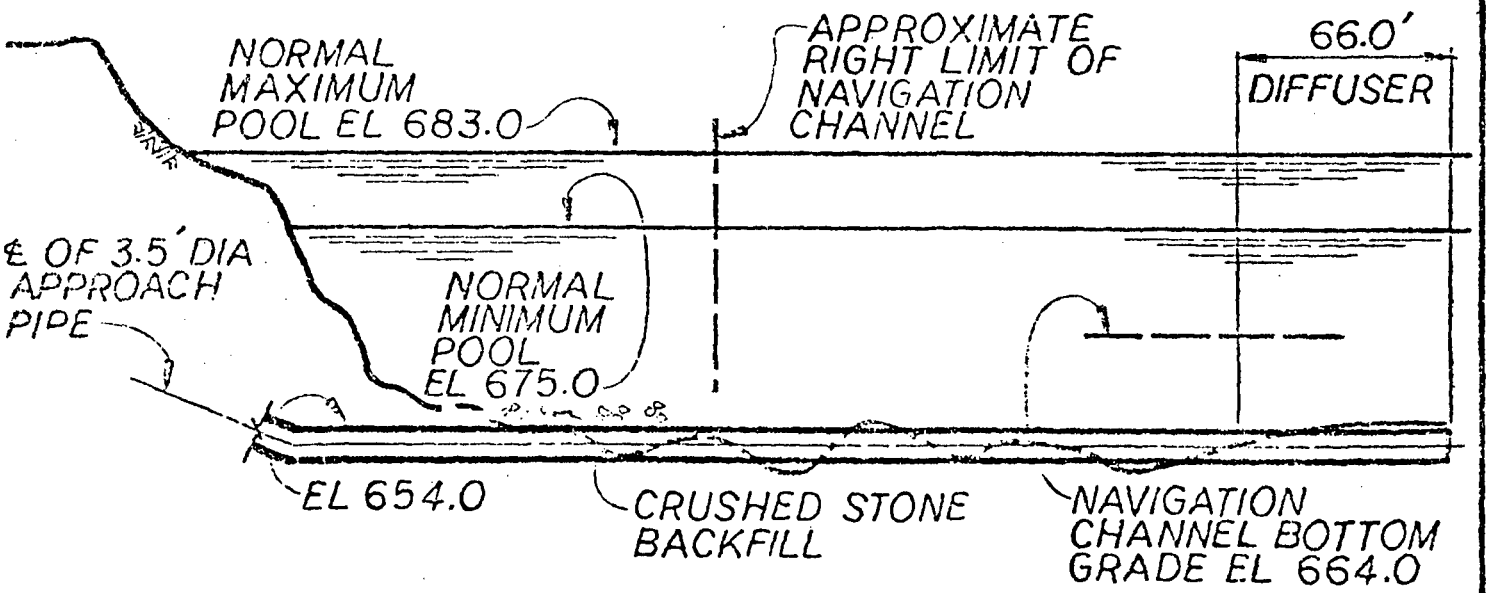
SCALE 1" = 60'
COMPANION DRAWINGS: FIGURES 1 & 3

CONDENSER WATER SUPPLY

WATTS BAR NUCLEAR PLANT
COOLING TOWER BLOWDOWN
DIFFUSER FACILITY—FIGURE 2



SECTION THRU 4.5' DIA CMP PIPE

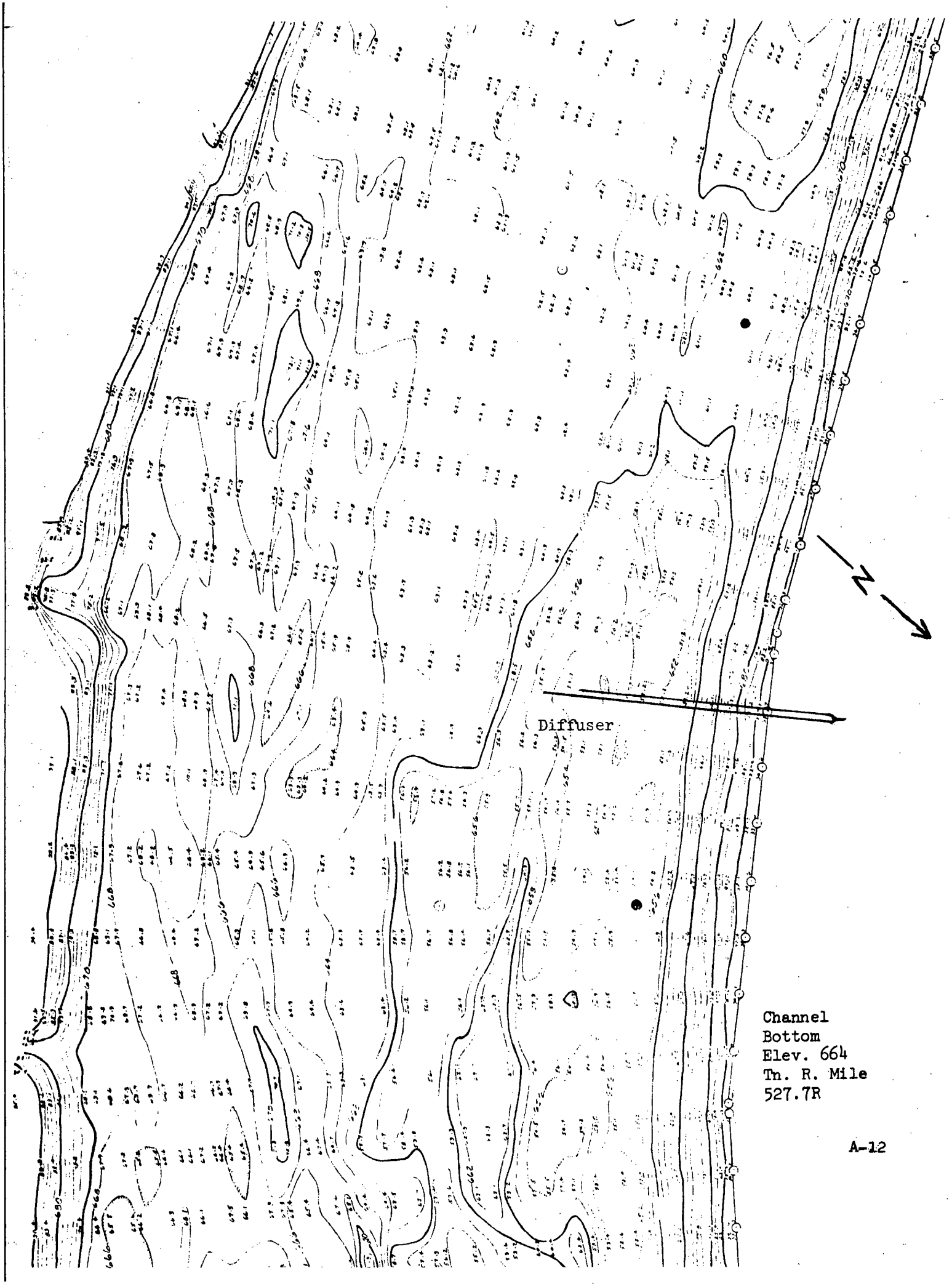


SECTION THRU 3.5' DIA CMP PIPE

SCALE: HORIZONTAL 1" = 60'
VERTICAL 1" = 20'
COMPANION DRAWINGS:
FIGURES 1 & 2

CONDENSER WATER SUPPLY

WATTS BAR NUCLEAR PLANT
COOLING TOWER BLOWDOWN
DIFFUSER FACILITY—FIGURE 3



Channel
Bottom
Elev. 664
Tn. R. Mile
527.7R

Ray Blanton
GOVERNOR

Eugene W. Fowinkle, M.D., M.P.H.
Commissioner

STATE OF TENNESSEE
DEPARTMENT OF PUBLIC HEALTH
NASHVILLE 37219

March 19, 1976

Dr. Peter A. Krenkel
Director of Environmental Planning
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Re: Change of Proposed
Location of Diffuser Pipe
from Watts Bar Nuclear Plant

Dear Dr. Krenkel:

Your letter of February 10, 1976, to Mr. John W. Saucier requested comments on the change in the proposed location of the diffuser pipe at the Watts Bar Nuclear Plant to a site approximately 1000 feet upstream of the site previously chosen. The entire matter is somewhat confused. The final environmental statement does not indicate the location except for a schematic (Figure 2.5-1) which shows the diffuser somewhat downstream of the intake structure. The intake structure is at Tennessee River mile 528.0 as shown by Figure 1.1-2. More exact information on the diffuser has not been transmitted to Water Quality Control Division.

Your letter states that the new location will lessen the impact on the mussel beds in the area. Based on the information in your letter and in the final environmental statement, it is the opinion of the staff of Water Quality Control Division that the change of location will not significantly exacerbate the environmental consequences. The Division, therefore, offers no objection to the change of location.

The third paragraph of your letter discusses disposal of 1600 cubic yards of spoil, but does not explicitly state that the designated spoil area is onshore. The statement that Water Quality Control Division offers no objection to the new location is based on disposal of spoil onshore.

Thank you for the information on the change.

Sincerely,

Wm Harold Martin
William H. Martin, Assistant Director
Division of Water Quality Control

WHM/CAS/grr

cc: Rhea County Health Department
cc: Division of Water Quality Control - Chattanooga

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1070
NASHVILLE, TENNESSEE 37202

IN REPLY REFER TO

ORNED-P

30 April 1976

Dr. Peter A. Krenkel
Director of Environmental Planning
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Krenkel:

We offer the following comments in response to your 10 February 1976 letter about the proposed relocation of Watts Bar Nuclear Plant blowdown diffuser pipes, Chickamauga Reservoir.

As stated in our 26 February 1976 letter, addressed to Mr. M. I. Foster, Division of Navigation Development and Regional Studies, we have no objections to the proposed action. However, because of the economic and ecologic importance of the existing mussel sanctuary, every effort should be made to control sedimentation from construction activity. Silt screens have been effective in controlling sedimentation and concomitant high turbidity in certain slack water situations. If appropriate, we urge you to consider their use. Further, disposal areas should be planned so that sediment from runoff is held to a minimum.

As you are aware, pollution, silting of rivers, and establishment of slack water environments have reduced our American mussel fauna, hence one reason for establishment of the mussel sanctuary by Tennessee Wildlife Resources Agency. If the 1600 cubic yards are to be removed by contract, strict supervision should be made by TVA field personnel to insure that sedimentation is held to a minimum.

We appreciate you advising us of the proposed change and the opportunity to comment.

Sincerely yours,

R. E. McLaughlin
for E. C. MOORE
Chief, Engineering Division

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

May 14, 1976

Mr. Harvey Bray, Executive Director
Tennessee Wildlife Resources Agency
Ellington Agricultural Center
P. O. Box 40747
Nashville, Tennessee 37204

Dear Mr. Bray:

PROPOSED RELOCATION OF DIFFUSERS FROM WATTS BAR NUCLEAR PLANT

This refers to your March 2, 1976, letter in which you requested additional information concerning the status of the mussel beds between the original diffuser site and the Watts Bar Dam. The original diffuser location was along the right side of the channel at approximately TRM 527.6. The present planned diffuser location is still along the right side of the channel but relocated approximately 1000 feet upstream at about TRM 527.8.

Enclosed is a summary of the results of mussel surveys conducted by TVA during the summer of 1975 in the reach of the Tennessee River downstream from the Watts Bar Dam. As indicated in the summary, no mussel concentrations were found along the right river bank in the area where the diffuser is to be located. However, mussel concentrations were found along the left river bank in the reach between TRM 527.6 and TRM 528.5. No data concerning mussel populations in the 1.4 mile reach between TRM 528.5 and Watts Bar Dam (TRM 529.9) is included in the survey since the swift river currents in that area precluded collection activities by our scuba divers.

Based on the results of these surveys, and the proposed method of operation, it is our conclusion that relocation of the diffuser would not have a significant impact on the mussel population in this reach of the Tennessee River.

Please let me know if you have any further questions.

Sincerely,

J. Clement Bandich

Peter A. Krenkel, Ph.D., P.E.
Director of Environmental Planning

SUMMARY STATUS OF MUSSEL POPULATION BELOW WATTS BAR DAM

The mussel fauna below Watts Bar Dam is represented by at least 13 species (table 1). Virtually, all of these species prefer a substrate of firm, porous gravel or sand and gravel with a moderate to swift current. Based on findings of recent surveys, July and August 1975, in the area below Watts Bar Dam, the most suitable mussel habitat is in the vicinity of TRM 520.5 to 521.3 (tables II, III, and IV). Species variability, however, was not as great in the TRM 520.5 to 521.3 area as it was in the TRM 527.6 to 528.5 area. The numbers found (table I) and the concentrations (table III), based on numbers collected per minute indicate the 520.5 to 521.3 area to have the greatest population. Table III also indicates the presence of a good localized population in the immediate tailwater area at TRM 527.7. Differences in shell condition from these two areas were pronounced. Those from the TRM 527.6 to 528.5 area were eroded and abraded while those from the TRM 520.8 vicinity were in excellent condition--especially the commercially valuable Pleurobema cordatum. The bedrock substrate and swifter currents in the upstream area account for this difference in shell quality.

The mussel population from TRM 520.0 to 528.5 is apparently a viable one as animals as young as five years were found. Mussels younger than this are not often collected by divers in areas with large populations of Corbicula due to similarity in size.

We do not consider any species found below Watts Bar Dam endangered or threatened. However, Lampsilis orbiculata was tentatively given such status (**Federal Register**, Volume 39, Number 202, Thursday, October 17, 1974, page 37078). TVA consultants have recommended that "this species should not be listed as either endangered or threatened. L. orbiculata

is more widespread than the list indicates, but even locations noted are widespread, indicating probable lack of being endangered." The preceding is quoted from the consultants' report attached to a letter from TVA General Manager, Lynn Seeber, to the Director of the Fish and Wildlife Service dated January 8, 1975, with regard to fish and wildlife service notice entitled "Snails, Mussels and Crustaceans, Endangered Species" (Federal Register, Volume 39, Number 202, Thursday, October 17, 1974). No final ruling regarding threatened or endangered mussels has been made by the Department of Interior.

No mussel concentrations were located on the right side of the river in the general vicinity of the old or proposed diffuser pipe location. Therefore, relocation of the diffuser pipe 1,000 feet upstream from the original site should have no significant impact on the mussel population.

Table I

COMPOSITION OF MUSSEL POPULATION BELOW WATTS BAR DAM COLLECTED (ALL METHODS)

JULY AND AUGUST 1975

Name	Number from TRM 527.6 to 528.5	Number from TRM 520.5 to 521.3	Total	% of Total
Amblema plicata	6	2	8	5%
Quadrula pustulosa	9	20	29	19%
Quadrula metanevra	1	3	4	3%
Tritogonia verrucosa	2	1	3	2%
Cyclonaias tuberculata	5	15	20	13%
Pleurobema cordatum	12	21	33	22%
Elliptio crassidens	16	14	30	20%
Obliquaria reflexa	1	1	2	1%
Actinonaias carinata	1	0	1	<1%
Plagiola lineolata	2	7	9	6%
Proptera alata	6	3	9	6%
Ligumia recta	3	0	3	2%
Lampsilis orbiculata *	2	0	2	1%
Total	66	87	153	100%

* On Department of Interior list of proposed endangered species.

Table II

Square Meter Samples (By SCUBA)

TRM	Number of Replicate Sq. Meters	Total Number of Mussels
528.5 - 20 yards left bank	3	0
528.4 - 40 yards right bank	4	0
528.1 - 40 yards left bank	3	3
527.7 - 50 yards left bank	6	0
527.7 - 10 yards left bank	3	11
527.6 - 30 yards left bank	3	2

Average - .73 mussels per m^2

Of the twenty-two square meter samples taken, only five produced living mussels. Listed below are the square meter samples by location and the species they produced.

TRM	Number of Replicate Sq. Meters	Number and Species
527.6 - 30 yards left bank	1	1 - *Amblema plicata* 1 - *Lampsilis orbiculata*
527.7 - 10 yards left bank	1	1 - *Pleurobema cordatum* 1 - *Elliptio crassidens*
527.7 - 10 yards left bank	2	1 - *Amblema plicata* 1 - *Pleurobema cordatum* 1 - *Elliptio crassidens* 6 - *Quadrula pustulosa*
528.1 - 40 yards left bank	2	1 - *Elliptio crassidens*
528.1 - 40 yards left bank	3	1 - *Plagiola lineolata* 1 - *Ligumia recta*

Table III

Random Sampling (Two Divers)

TRM	Time in Minutes	Number of Mussels	Number of Mussels/Minute
528.5 - 25 yards left bank	20 min.	4	.2
528.4 - 40 yards right bank	5 min.	1	.2
528.2 - 30 yards left bank	20 min.	7	.35
528.1 - 40 yards left bank	20 min.	0	.0
528.0 - 40 yards left bank	10 min.	7	.7
527.7 - 40 yards left bank	5 min.	10	2.0
527.7 - 10 yards left bank	10 min.	16	1.6
520.8 - 30 yards left bank	27 min.	63	2.33
520.8 - 40 yards left bank	10 min.	15	1.5
Total	127 min.	123	Average .97/minute

Table IV

Brail Samples

TRM	Time in Minutes	Number of Mussels	Number of Mussels/Minute
528.1 to 528.0	20 min.	1	.05
528.0 to 527.3	210 min.	3	.014
521.0 to 520.9	14 min.	1	.07
520.8 to 520.7	16 min.	3	.18
520.8 to 520.7	20 min.	1	.05
520.6 to 520.5	20 min.	3	.15
520.6 to 520.5	20 min.	2	.1
Total	320 min.	14	Average .044/minute

TRITIUM DISPOSAL METHOD

The Watts Bar Nuclear Plant FES stated that tritium would be recycled to the maximum extent feasible and that beginning some 7 to 12 years after initial plant startup, aqueous solutions containing tritium wastes would be shipped offsite using tank trucks licensed for low specific activity liquids (see FES page 2.1-14). These shipments were to be sent to an AEC-licensed disposal site in accordance with applicable AEC and DOT regulations.

Operating data at a Westinghouse-designed reactor has shown that tritium buildup in the reactor coolant system may be excessive if total recycle is used and that undesirably high doses to inplant radiation workers might consequently result. Therefore TVA is reevaluating methods of tritium disposal. TVA is conducting a detailed study of PWR tritium disposal alternatives, which is expected to be completed in early 1977. Any planned release of radioactive materials would be performed in accordance with 10 CFR Part 50, Appendix I which ensures that radioactive materials in plant effluent releases to unrestricted areas are kept as low as is reasonably achievable. Concentrations of tritium in the environment resulting from this practice would be within a few percent of the limits as specified in 10 CFR Part 20 "Standards for Protection Against Radiation."

Such low concentrations of tritium in the environment are generally recognized to have a minimal effect on public health. By meeting the requirements of 10 CFR Part 50, Appendix I, it is believed that TVA would be assured of protecting the environment from unnecessary degradation and also that the routine release of small amounts of tritium to the environment would eliminate any hazards, however slight, from offsite shipment of these tritium wastes to an NRC-licensed disposal site. Thus, implementation of this practice would not be expected to result in a significant environmental impact.

WATER CHEMISTRY CHANGES

A. Steam Generator Water Chemistry

In the original plant design, feedwater entering the steam generators was to be treated by a coordinated phosphate treatment method. This method would have utilized sodium phosphate and hydrazine as additives to the feedwater. Some PWR plants using this type of treatment have experienced steam generator tube failures, while those employing all volatile treatment (ammonia and hydrazine additives) have had fewer tube failures. After analyzing operating results and laboratory studies, Westinghouse recommended that all volatile treatment be employed for Watts Bar Nuclear Plant. This change took place after TVA had decided to install reverse osmosis units and an evaporator unit (see discussions in this section on ADDITION OF CONDENSATE DEMINERALIZERS and ADDITION OF RADWASTE EVAPORATOR for additional information regarding these treatment systems). By not using sodium phosphate additions, there would be a slight reduction in the overall environmental impact; however, no significant impact is expected in either case.

B. Sodium Hypochlorination System

The Watts Bar Nuclear Plant FES stated that Asiatic clam populations in the Raw Cooling Water (RCW), Raw Service Water (RSW) and Essential Raw Cooling Water (ERCW) systems would be controlled by treatment with acrolein. Acrolein has not yet been approved by EPA as a chemical clamicide. In order to maintain the capability for controlling Asiatic clams at Watts Bar Nuclear Plant, TVA has decided to treat the RCW, RSW, and ERCW systems with sodium hypochlorite. Slime and algae control is

planned to be maintained by adding sodium hypochlorite to the Condenser Cooling Water (CCW) system and the Makeup Water Treatment Plant.

TVA plans to inject sodium hypochlorite as near to points of need as practical. Feed rates will be controlled using equipment for which flows are known or otherwise calibrated. It is anticipated that sodium hypochlorite injections will be made according to the following schedule:

I. Slime Control

Condenser Cooling Water (CCW) system - shock treatment, chlorinate 1 hr/day with total free chlorine residual of 0.2 mg/l at condenser outlet.

II. Asiatic Clam Control

Essential Raw Cooling Water (ERCW) systems - 32,000 gpm system flow, low-level continuous chlorination (May-October) with total free chlorine residual of 0.6 - 0.8 mg/l.

Raw Cooling Water (RCW) systems - 31,000 gpm system flow, two three-week periods of continuous treatment annually (beginning and end of Asiatic clam spawning season).

Raw Service Water (RSW) systems - 1000 gpm system flow, low-level continuous chlorination (May-October) with total free chlorine residual of 0.6 - 0.8 mg/l.

The principal constituents present in the above systems as a result of sodium hypochlorite addition will be sodium, chlorides, and a negligible amount of inert impurities found in the salt used for producing the sodium hypochlorite. Quantities of these constituents are presented in a revised version of Table 2.5-1 from the Watts Bar Nuclear Plant FES. The revised

Table 2.5-1 appears at the end of this discussion. During chlorination periods no discharges of residual chlorine in excess of the NPDES permit limitations will be allowed through the discharge diffusers. Findings of TVA's environmental review of the overall impact of nonradioactive chemical discharges are presented in Section B of this transmittal.

To accommodate anticipated plant use of sodium hypochlorite, TVA has determined that the capacity of onsite sodium hypochlorite generation facilities must be expanded. This will be accomplished by increasing the sodium hypochlorite generation capacity from 1000 lb/day to 2500 lb/day available chlorine.

C. Change in Chemical Usage for the Component Cooling Water System

The Watts Bar Nuclear Plant FES stated that sodium chromate would be used as a corrosion inhibitor in the component cooling water system (see page 2.5-11). Instead of using sodium chromate, TVA now plans to use sodium nitrite. The operating procedure will not change; hence, as the FES stated, there will be no discharges to the river. Therefore, no significant environmental impacts would be expected to accrue from this change.

(Revised) Table 2.5-1

SUMMARY OF ADDED CHEMICALS AND RESULTING END PRODUCT CHEMICALS

Watts Bar Nuclear Plant

Item No.	System	Chemical Treatment Source Chemical And Waste Products	Estimated Maximum Annual Use Lbs.	Waste End Product Chemical	Resulting End Product[a] Average Annual Lbs.	Resulting End Product[a] Mean Daily Lbs.
1	Makeup Water Filter Plant	Alum $Al_2(SO_4)_3 \cdot 18\ H_2O$	78,800	$Al(OH)_3$[b]	16,510	45
		Soda Ash Na_2CO_3	23,685	Na^+	10,300	28
				SO_4^{--}	30,600	84
				Settled Solids[b,c]	70,800	194
		Sodium Hypochlorite				
		NaOCl	770	Na^+	480[e]	<5.0
		NaCl	600	Cl^-	722[e]	<5.0
	Makeup Water Demineralizer	Sulfuric Acid H_2SO_4 (93% Solution)	231,000	SO_4^{--} (Neutral pH)	217,000	595
		Sodium Hydroxide NaOH (50% Solution)	431,000	Na^+ (Neutral pH)	124,000	340
	Natural Minerals Removed by Demineralizers					
		Sodium Na^+	10,120	Na^+	10,120	28
		Chloride Cl^-	19,700	Cl^-	19,700	54
		Sulfate SO_4^{--}	21,750	SO_4^{--}	21,750	60
		Total Dissolved Solids	117,500	Dissolved Solids	117,500	322
3	Secondary Steam System Condensate Polishing Demineralizers h	Sulfuric Acid	590,100	SO_4^{--} (Neutral pH)	578,000	1580
		Sodium Hydroxide NaOH	353,500	Na^+ (Neutral pH)	203,260	560
	Ionized Soluble Species Removed by Demineralizers	-Carbonates (CO_3^{--})	25,400	CO_3^{--}	25,400	70
		-Ammonia (NH_4^+)	15,050	NH_4^+	15,050	41
		-Metallic Salts	d	d	d	d

(Revised) Table 2.5-1 (Cont)

SUMMARY OF ADDED CHEMICALS AND RESULTING END PRODUCT CHEMICALS

Watts Bar Nuclear Plant

Item No.	System	Chemical Added Source Chemical	Maximum Annual Use Lbs.	Waste End Product Chemical	Resulting End Product[a] Average Annual Lbs.	Resulting End Product[a] Mean Daily Lbs.
4	Auxiliary Steam Generator Blowdown	Ammonia NH_3	3[f]	NH_3	3	<0.1
		Hydrazine $H_2N_2H_2$	10[g]	NH_3	10	<0.1
5	Condenser Cooling Water System[i]	Sodium Hypochlorite				
		NaOCl	157,130	Na^+	97,050	265
		NaCl[i]	123,370	Cl^-	147,880	405
		<<Copper (corrosion product only)[k]		Cu	6,200	17
		<<Nickel (corrosion product only)[k]		Ni	690	1.9
6	Raw Cooling Water[i]	Sodium Hypochlorite				
		NaOCl	24,610	Na^+	15,575	43
		NaCl[j]	20,285	Cl^-	23,740	65
7	Raw Service Water[i] System	Sodium Hypochlorite				
		NaOCl	3,420	Na^+	2,165	6
		NaCl[j]	2,820	Cl^-	3,300	9
8	Essential Raw[i] Cooling Water	Sodium Hypochlorite				
		NaOCl	108,870	Na^+	67,280	185
		NaCL[j]	85,500	Cl^-	102,470	280

a. Items 1, 2, 4, 5, 6, 7, and 8 are based on 365 days/year operation at rated capacity. Item 3 based on 292 days/year operation at rated capacity.
b. Precipitated material that will make up the water treatment sludge on a day weight basis. Ultimately put in landfill. No discharge.
c. Estimates based on maximum suspended solids data observed at TRM 529.9.
d. The quantities of ionized soluble species continuously removed by the condensate demineralizers are predicated upon a primary to secondary leak rate or a condenser tube leak. These constituents will be discharged in the form of neutral salts of sodium, oxides of iron, or suspended solids. High crud filters will treat the backwash waste prior to discharge.
e. The residual chlorine and sodium consumed by the makeup demineralizers and ultimately discharged.
f. Ammonia will be added as needed to maintain pH of 9.0 in the system.
g. Hydrazine will be added as needed as a DO scavenger. Hydrazine conservatively assumed to decompose to ammonia.
h. Under radioactive conditions, this waste will be treated in the plants radwaste system.
i. Basis for calculated valves are shown elsewhere.
j. For each pound of equivalent chlorine as sodium hypochlorite produced, 0.785 pounds of sodium chloride are in the product solution.
k. Although copper and nickel will not be added to the systems, the values shown represent high estimates of corrosion losses. Actual losses are expected to be immeasurable.

MINOR CHANGES IN CONSTRUCTION PRACTICES

A. Chemical Cleaning Ponds

Two temporary chemical cleaning holdup ponds (cells) have been constructed within the main yard holding pond area. These temporary ponds are to be used for the containment and treatment of chemicals and waste water that will be used during preoperational cleaning and testing. The small pond has a volume of approximately 699,380 gallons and the larger pond has a volume of approximately 6,919,000 gallons. The ponds are located about 1,100 feet west of the unit 1 N-S centerline and 1,200 feet south of the E-W baseline. The embankments of the ponds are built-up dikes that will be leveled and graded to blend with the surrounding terrain upon retirement of the ponds. The small pond will have a polyvinyl liner to prevent seepage loss of the chemicals. The small pond, which will handle the more concentrated chemicals, is not expected to have significant quantities of any chemicals other than trisodium phosphate, hydrazine, ammonia, and detergents (e.g., triton X-100 and QS 30). The large pond will hold the diluted chemical waste flushing water and will have a 2-foot freeboard above the operating level to provide protection against overflow. Prior to discharge to the Tennessee River, the chemical cleaning wastes will be treated within the ponds so as to meet the applicable effluent limitations for this point source discharge. Treatment and subsequent discharge in this manner will not result in any significant adverse impacts to the aquatic environment. Findings of TVA's environmental review of the overall impact of nonradioactive chemical discharges are presented in Section B of this transmittal.

B. Changes in Grading Quantities

The table on page 2.8-4 of the Watts Bar Nuclear Plant FES (under "2.8(2) General grading and Excavation") does not include entries of 135,740 cubic

yards for "Grading and Excavation Earth" and 123,000 cubic yards for "Backfill or Embankment" that reflect a relocation of the essential raw cooling water pipes around the east side of the cooling towers. Inclusion of these entries raises the totals, respectively, by the above-stated quantities. The above action is in no way expected to result in a significant environmental impact at the Watts Bar Nuclear Plant.

C. Addition of Settling Pond for Siltation Control

The Watts Bar Nuclear Plant FES stated that the Twin Fork Slough would be given consideration for a possible natural sedimentation pond. Actual field conditions rendered it economically more feasible to develop another settling pond area nearby since greater quantities of excavation and piping would have been required to use the Twin Fork Slough. The pond to be used is located approximately 1,800 feet west of the N-S baseline and along the E-W baseline. This temporary pond will hold rainfall runoff from the construction site, thus allowing some of the suspended solids from the runoff to settle out prior to release to the reservoir. The volume of this pond is about 1 million cubic feet. There are four 20-inch diameter pipes for releasing effluent from the ponds. In cases of extremely high runoff (i.e., during a period of Probable Maximum Precipitation), runoff flow will be handled by a weir with its invert 2 feet above the invert of the pipes. After the pond is no longer needed, the earthen embankment will be leveled and graded to blend with the surrounding terrain.

The action described above satisfies the intent of the Watts Bar Nuclear Plant FES and also reduces the commitment of resources (excavation, piping, and monetary costs) in doing so. For this reason, we feel there is a reduction in environmental impact resulting from this change to the settling pond.

D. Use of Steam Plant Docking Facility

The Watts Bar Nuclear Plant FES indicated that TVA was considering the construction of a small docking facility on the Tennessee River for handling barge traffic in and out of the plant (see page 2.8-12 of the FES). Although only minor and infrequent interference with recreation and navigation would result from operation of such a facility, TVA has opted to use the existing coal-handling dock associated with the Watts Bar Fossil Plant. There would be no significant environmental impacts resulting from this change.

VISITOR FACILITIES

The Watts Bar Nuclear Plant FES stated that provisions would be made for picnic and recreational facilities and a visitors' information lobby at the Watts Bar site. TVA now plans to provide for an overlook on a ridge above the installation with picnic tables, sanitary facilities, and a display to provide information on the role of this plant in the production of electrical power. The overlook area will afford a panoramic view of the nuclear plant and associated support facilities as well as of the other two types of electrical generation facilities present at the Watts Bar site (fossil-fueled steam electric and hydroelectric). No new impacts significantly affecting the quality of human environment would ensue from these actions.

ADDITION OF CONDENSATE DEMINERALIZERS

The original plant design allowed no provisions for treatment of steam generator blowdown when the steam generators were operated with primary-to-secondary leakage. The design was modified so that potentially radioactive steam generator blowdown could be treated by reverse osmosis units and an auxiliary waste evaporator. The radioactive wastes recovered from treatment in the reverse osmosis system could then be concentrated during auxiliary waste evaporator processing and packaged for shipment to an NRC-approved offsite burial facility. After this design modification was made, generic problems with steam generator water chemistry were identified. Upon the recommendation of Westinghouse, TVA subsequently decided to employ all-volatile treatment for Watts Bar Nuclear Plant.

TVA has recently determined that with all-volatile treatment of the steam generators, condensate demineralizers should be added to protect the system against intrusion of impurities due to condenser leakage. As the condensate demineralizers would also have the capability for treating steam generator blowdown, the reverse osmosis-evaporator system discussed above would no longer be needed. It is expected that the condensate demineralizers will operate normally in a partial bypass mode, with approximately one-third of the flow from the condenser hotwell being passed through the demineralizers. The demineralizers will be switched to full flow operation upon detection of condenser leakage or primary-to-secondary leakage. This practice would ensure that radioactive materials released in steam generator blowdown to the reservoir are minimized and should result in lower quantities of radioactive materials in liquid effluents, thus providing a consequent reduction in radiological doses to downstream reservoir users.

Figure 2.4-1a (included at the end of this discussion) shows the routing of steam generator blowdown. The blowdown first enters a flash tank, where it is cooled as about one-half of the liquid entering the tank is converted to vapor. The vapor is recovered by sending it to a heater in the secondary system. The liquid is normally routed to the inlet header of the condensate demineralizers, so that liquid is processed whether the demineralizer is in bypass or full-flow operation. The liquid may also be routed to the condenser hotwell, from which it is pumped to the condensate demineralizers. This route is employed only when the demineralizers are in full-flow operation. The liquid may also be sent to discharge via the cooling tower blowdown line. This route will normally be used only during startups. Flow to discharge will be terminated manually when radioactivity is detected, and a radiation monitor will terminate the discharge automatically at a radioactivity concentration of 1×10^{-4} uCi/gm if it has not been terminated earlier by operator action. Upon termination of discharge, the blowdown flow is diverted, to the condensate demineralizers.

When a unit is operated with primary-to-secondary leakage, the demineralizers remove not only the radioactive materials in the steam generator blowdown, but also those materials that are carried over with the steam and are dissolved in the condensed steam. When the demineralizers are regenerated (with sulfuric acid and sodium hydroxide), the radioactive materials are removed into the spent regenerant liquid. If primary-to-secondary leakage is low enough that the spent regenerants contain less gross radioactivity than 10^{-4} uCi/gm, the spent regenerants are discharged to the cooling tower blowdown line. If the gross radioactivity content is greater than 10^{-4} uCi/gm, the regenerants are transferred to the floor drain collector tank for processing in the auxiliary waste evaporator. Most of the radioactive material is retained in the evaporator concentrates. The distillate, which is to be discharged to the cooling tower blowdown line, would contain less than 1/1000

of the radioiodines and less than 1/10,000 of the isotopes other than radioiodines that leaked from the primary system into the secondary system.

The condensate demineralizer system can handle any blowdown flow rate up to 120 gpm. This limit is imposed by the design of the blowdown piping. During periods of operation with condenser leakage or primary-to-secondary leakage, the blowdown rate will be maintained at or near the maximum. At other times, lower rates will be employed.

Condensate demineralizers are employed to treat all or part of the condensate pumped from the condenser hotwells. As described above, most of the steam generator blowdown is treated by the condensate demineralizers also. The principal constituent of both these streams is ammonia, used in treatment of secondary system water. Both streams also contain corrosion products from the condenser, steam generators, and system piping. During operation with condenser leakage, impurities contained in the condenser cooling water will be present in the condensate. During operation with primary-to-secondary leakage, the steam generator blowdown and, to a lesser extent, the condensate contain fission and corrision products and boric acic from the primary system.

Impurities in the influent to the condensate demineralizers will be in the forms of suspended particles and dissolved materials. The demineralizers will act as filters in removing suspended particles and dissolved ionic impurities will be removed by ion exchange. The demineralizers are regenerated periodically with sulfuric acid and sodium hydroxide. The process to be employed at Watts Bar Nuclear Plant will reduce, by about one-half, the amounts of these chemicals employed in conventional condensate demineralizer regeneration systems.

The regeneration process removes the impurities that have been accumulated in the demineralizers. Regenerant waste solutions will be discharged to the cooling tower blowdown line when they contain less than 10^{-4} uCi/gm of gross radioactivity. It is expected that in normal operation, radioactivity will be much lower than 10^{-4} uCi/gm. Revised Table 2.5-1 (included in the discussion in this section on WATER CHEMISTRY CHANGES) shows expected quantities of ammonia and other constituents discharged annually as condensate demineralizer regeneration wastes. The data in this portion of the table are based on the assumptions that the demineralizers are operated on a full-flow basis. A description of the condensate cleanup system is given in Section 10.4.6 of the Watts Bar Nuclear Plant Final Safety Analysis Report. Findings of TVA's environmental review of the overall impact of nonradioactive chemical discharges are presented in Section B of this transmittal.

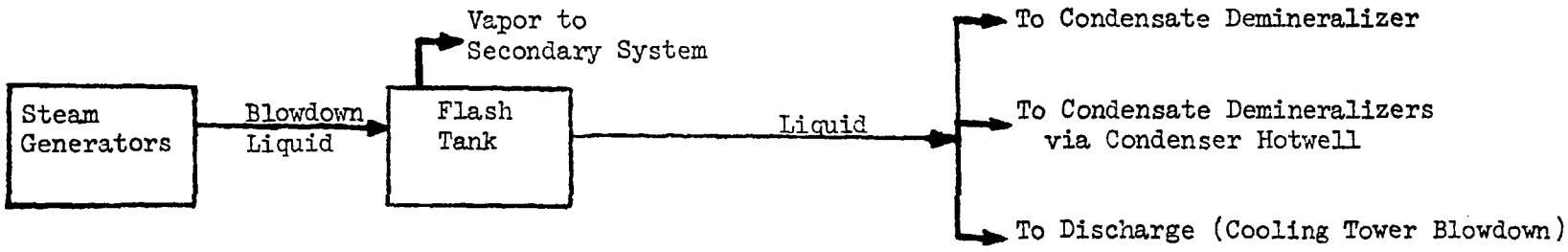


Figure 2.4-1a
Steam Generator
Blowdown Treatment

ADDITION OF RADWASTE EVAPORATOR

In order to have capability for processing condensate demineralizer wastes when both units are operating with primary-to-secondary leakage, TVA has decided to install an additional evaporator in the liquid radwaste system at Watts Bar Nuclear Plant. This forced circulation evaporator, termed the Condensate Demineralizer Waste Evaporator, will be rated at 30 gpm. When simultaneous primary-to-secondary leakage occurs in both units of the plant, having this additional evaporator capacity would allow operation of both units instead of only one, thereby indirectly increasing the potential radwaste output. The incremental amount of radwaste produced annually as a result of using the additional evaporator capacity (as necessary) during simultaneous primary-to-secondary leakage events in both units is, however, not expected to exceed a small fraction of the total annual quantity of radwaste produced at the plant. This additional evaporator may also serve as a backup to the Auxiliary Waste Evaporator.

Of course, procedures for the release of radioactive materials to the environment will be established and controlled by the technical specifications issued for Watts Bar Nuclear Plant and, additionally, all applicable regulations (e.g., 10 CFR Part 20, 10 CFR Part 50, and 10 CFR Part 50, Appendix I) must be met. Appendix I calculations for Watts Bar Nuclear Plant used source terms that included the operation of this evaporator. The results of the Appendix I calculations showed no significant environmental impact.

OTHER CHANGES, MISCELLANEOUS ITEMS

A. Dewatering of Radioactive Demineralizer Wastes

The Watts Bar Nuclear Plant FES stated that demineralizer resin wastes would be solidified and that no significant environmental impacts were expected to result from this action since the specific radioactivity levels involved would be so low (see page 2.1-18). Instead, TVA plans to dewater the demineralizer resins prior to shipment in containers qualified for low specific radioactivity wastes. On an annual basis the volumes and weights of shipments involving demineralizer resins would be slightly less for dewatering than for solidification; hence, no significant impact is expected to result.

B. Cooling Tower Blowdown Holdup Modification

The Watts Bar Nuclear Plant FES stated that under certain low flow conditions in the vicinity of the Watts Bar Dam, cooling tower blowdown discharge from the nuclear plant to Chickamauga Reservoir would be discontinued (see FES pages 2.6-8 through 2.6-13). The capability for withholding blowdown during low flow conditions (as described in the FES) was based on the assumption that evaporation plus drift losses from the cooling towers would be greater than the inflow from the essential raw cooling water system (ERCW).

TVA has determined that under certain environmental conditions evaporation and drift losses from the cooling towers may be less than the inflow from the ERCW system, resulting in buildup of water in the cooling tower basins. In order to avoid this situation during periods of low flow (i.e., less than 3,500 cfs), valves located at the discharge diffusers, the steam

generator blowdown outlet, and radioactive waste system outlet would automatically be closed and the flow control valves (inlet to the yard holding pond) would be opened. This valving system, which will be interlocked with the hydroelectric units at Watts Bar Dam, will be automatically activated whenever releases from Watts Bar Dam are less than 3,500 cfs. However, it should be emphasized that this level of streamflow (3,500 cfs) is an operational limitation of the hydroelectric units at Watts Bar Dam and should not be considered as the minimum streamflow required for assimilation of waste discharges from the Watts Bar Nuclear Plant. This would divert cooling tower blowdown to the holding pond (see revised Figure 2.5-1 and Figure 2.5-1a included at the end of this discussion). Upon attaining sufficient river flow, discharges to the reservoir of blowdown stored in the yard holding pond along with that coming directly from the cooling towers would commence.

The temperature of combined yard holding pond drawdown and direct cooling tower blowdown would be approximately the same as normal cooling tower blowdown for a given set of environmental conditions, neglecting possible mixing in the yard holding pond due to effects of precipitation cooling and solar heating of the yard holding pond contents (both of which would be minimal). The discharge diffusers were designed to provide mixing sufficient to meet the State of Tennessee stream thermal standards assuming the yard holding pond discharge temperature equalled direct cooling tower blowdown (which is a maximum of 95° F.).

The environmental impact of this alternative procedure should be more favorable than with the original procedure. By maintaining continuous

blowdown from the cooling towers, no increase of dissolved solids concentrations above the normal operating levels (approximately a factor of 2) should occur within the heat rejection system. No significant new impact on the environment is expected to ensue from this action. Findings of TVA's environmental review of the overall impact of nonradioactive chemical discharges are presented in Section B of this transmittal.

C. Modifications to Makeup Water Treatment Plant

On page 2.5-8 of the Watts Bar Nuclear Plant FES, it was stated that wastes from the Makeup Water Filter Plant would be routed to a lagoon area and, as necessary, the sludge would be disposed of by burial on TVA property. It is now planned to dewater flocculator sludge and filter backwash to a product containing about 50 percent solids and bury this solid waste in an offsite approved sanitary landfill. The system has been designed to treat approximately 20,000 gallons of liquid.

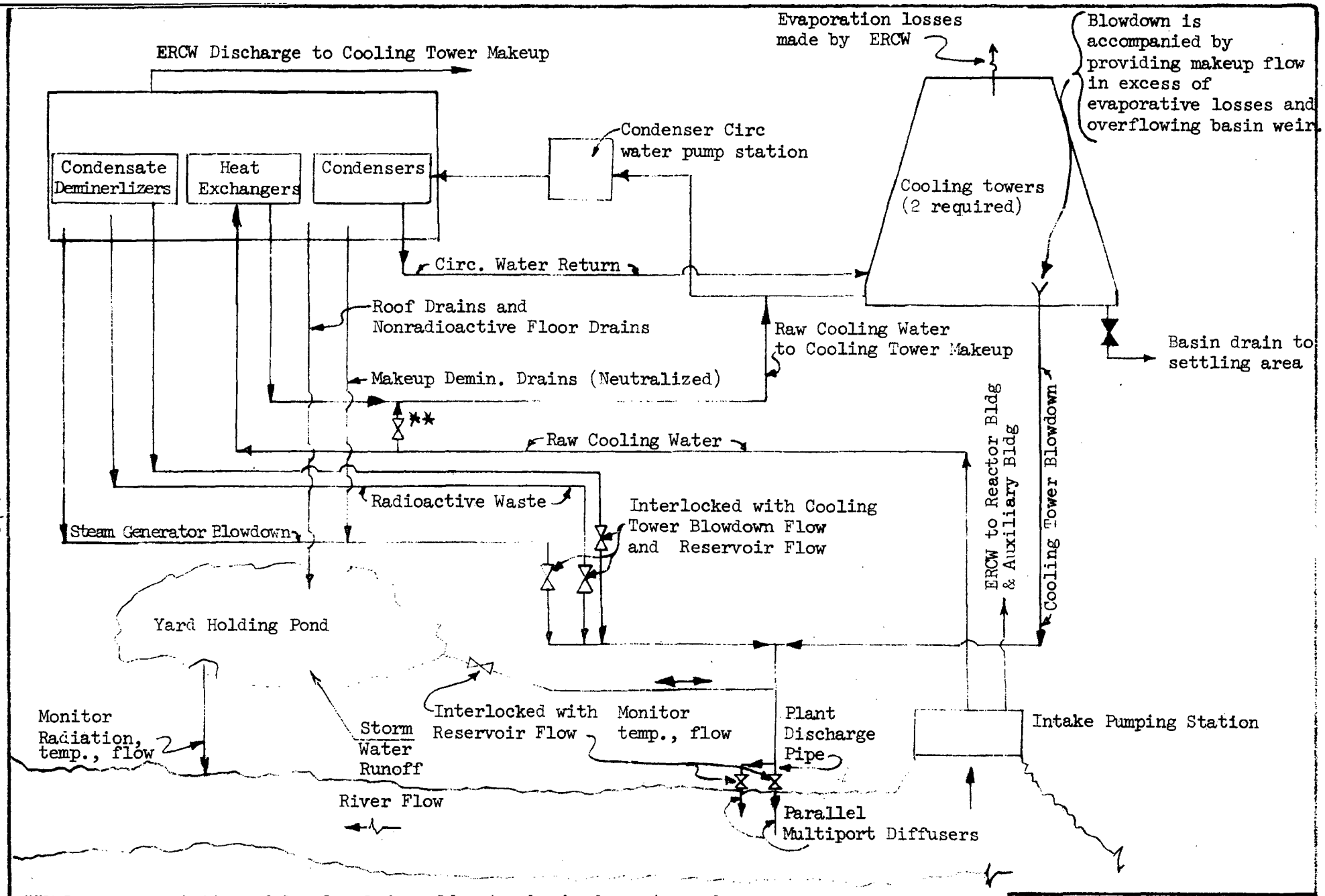
Treatment of demineralizer wastes will no longer employ a weak cation resin neutralizer. A batch neutralization process that monitors and adjusts the pH to meet applicable discharge requirements will be used instead. The estimated quantities of chemicals to be discharged to the environment from the makeup demineralizer system have not changed from those previously listed in Table 2.5-1 of the Watts Bar Nuclear Plant FES. (A revised version of this table is included at the end of the discussion in this section on WATER CHEMISTRY CHANGES.) Findings of TVA's environmental review of the overall impact of nonradioactive chemical discharges are presented in Section B of this transmittal. Additionally, the reference to possible use of coagulation aids in the filter plant (see page 2.5-8 of the FES) cites an EPA approved list which may be out of date when

the plant becomes operational. EPA has revised this list once and may revise it again in the future. TVA's intent is to use coagulation aids, when necessary, in such a manner as to meet applicable requirements and to ensure that the environment will be protected.

No environmental impact significantly different from that discussed in the Watts Bar Nuclear Plant FES would be likely to result from the action described above. Due to the minor nature of these changes, no further considerations with regard to resulting environmental impacts are warranted.

D. Modification to Liquid Radwaste System Procedures

The Watts Bar Nuclear Plant FES stated that releases from the Liquid Radwaste System tanks through the discharge pipe to the reservoir would be controlled by a 2-valve system that would be locked closed when not in service. One valve would be controlled by a radiation monitor and the other would be interlocked with a flow meter such that no radioactive liquid discharges would be permitted unless a dilution flow of at least 28,000 gpm existed. The purpose of this system was to provide assurance that radioactive liquid discharges would be diluted so as not to exceed applicable concentration limits. TVA now plans to employ this valve system with the dilution flow requirement of 20,000 gpm instead of 28,000 gpm. Since liquid radioactive effluent discharges would not be permitted to exceed the limits of 10 CFR Part 50, Appendix I for either flow requirement, no significant environmental impact should ensue from this change.



**Valve opens at time of low level in cold water basin for extra makeup.

FIGURE 2.5-1
FLOW DIAGRAM - DISCHARGE OF PLANT LIQUIDS
(REVISED)

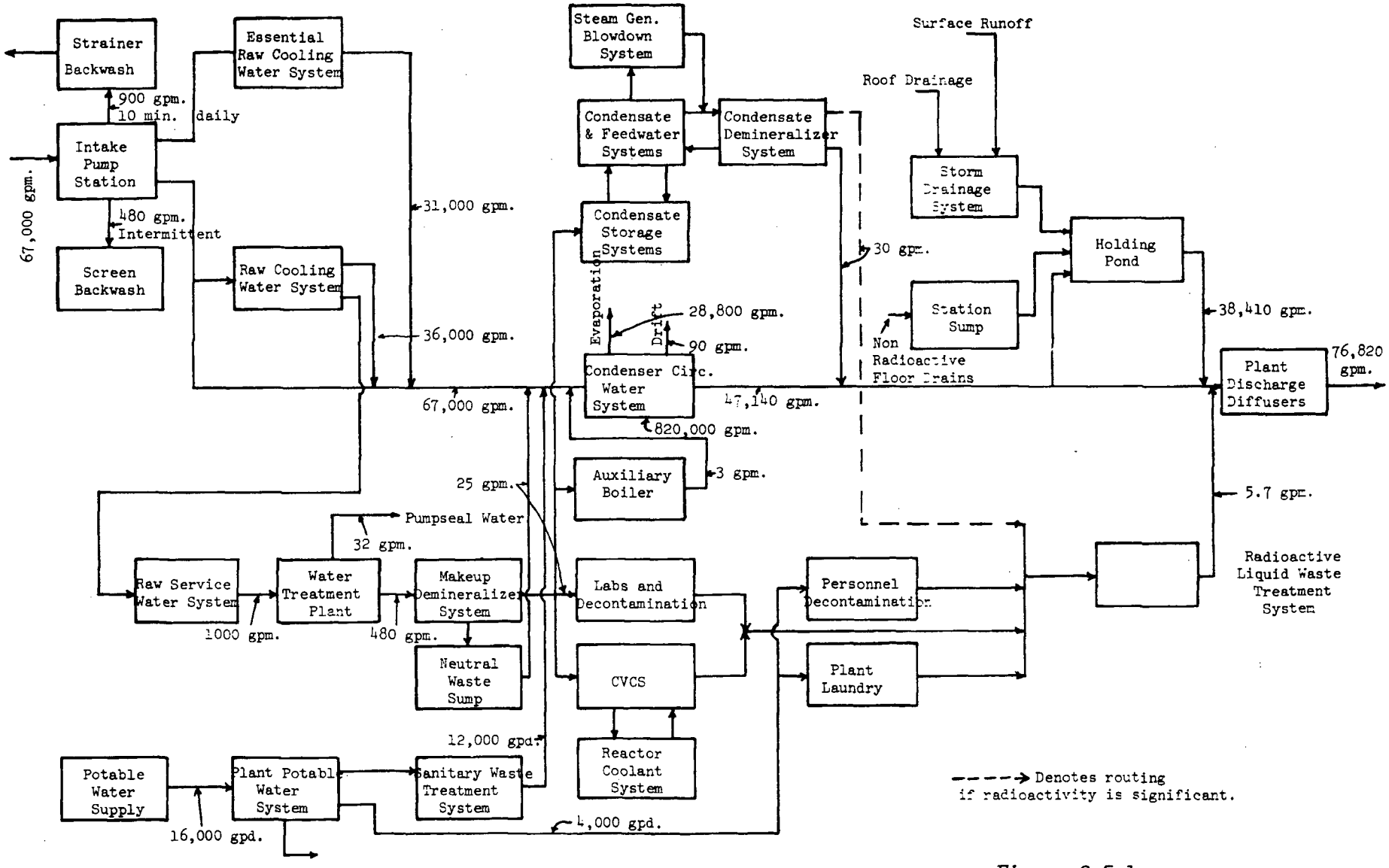


Figure 2.5-1a

PLANT WATER USE DIAGRAM

SECTION B

Included in this section are updated versions to parts of two subsections of the Watts Bar Nuclear Plant FES. These two subsections are "1.1 General Information," and "2.5 Nonradioactive Discharges." To facilitate your staff's review of these updated subsections, they have been presented in exactly the same format as the FES. All changes made to the text of these subsections are clearly denoted by vertical lines in the right-hand margin.

Subsection 1.1 of the FES has been revised to reflect results of the nonradiological water quality preoperational monitoring program and the current status of municipal and industrial water supplies in the Watts Bar Nuclear Plant area. The information as identified in this subsection is consistent with the water use information that has already been provided for the 10CFR 50 Appendix I evaluation of this project.

Subsection 2.5 of the FES has been specifically revised to incorporate: (1) acknowledgement of the need to obtain NPDES permits, (2) the assessment of corrosion losses within the cooling systems, (3) the changes in plant operation to provide for continued blowdown from the Condenser Cooling Water (CCW) System, (4) the use of chlorine (in the hypochlorite form) as a molluscicide rather than acrolein, (5) the change in waste treatment methods for the makeup water filter plant and the makeup demineralizer wastes, (6) the addition of condensate demineralizers, and (7) a revised description of the proposed method of treating chemical cleaning wastes. This revision to subsection 2.5 of the FES incorporates the related changes enumerated above (most of which are discussed individually in Section A of

this transmittal) and addresses the response of the aquatic environment in terms of impacts due to the overall differences from the FES in the quantity and/or quality of the combined discharge through the diffuser system.

Based on the results of this evaluation, it is TVA's conclusion that the resulting impacts upon the aquatic environment associated with the implementation of the changes identified in this section would be less than those previously identified in the FES.

Pages 1.1-1 through 1.1-9 have not been revised.

distinct aquifer in the Conasauga Formation at the Watts Bar site. The shales and limestones are essentially impervious, and the majority of the ground water flows through the terrace deposits overlying bedrock. Water level readings made in the exploration holes show that the water table stands approximately 20 feet above rock in the terrace material.

Preliminary ground water investigations made by measuring ground water levels in exploratory holes in the proposed plant area indicate a ground water gradient sloping toward Chickamauga Lake through the terrace deposits overlying bedrock. Migration of ground water through bedrock is insignificant as shown by the refusal of the rock to accept water at pressures of 50 lb/in^2 by water testing the exploratory holes. TVA will install a series of monitor wells to determine the seasonal ground water fluctuations and to provide baseline data.

(b) Surface water - Surface water is derived from precipitation remaining after losses due to evaporation and transpiration. It can be generally classified as local surface runoff or streamflow.

(c) Water use - The Tennessee River from its head near Knoxville to its mouth near Kentucky Dam is a series of highly controlled multiple-use reservoirs. The primary uses for which this chain of reservoirs was built are flood control, navigation, and the generation of electric power. In addition to these, other industrial and public uses have developed, such as sport and commercial fishing, industrial and public water supply, recreation, and waste disposal.

There are four public water supplies taken from Watts Bar and Chickamauga Reservoirs within the reach from Lenoir City, Tennessee, 73 miles upstream of the site, to

the Daisy-Soddy-Falling Water Utility District 45 miles downstream of the site in the Soddy Creek embayment of Chickamauga Reservoir. The intake for Lenoir City, Tennessee, is located on Watts Bar Reservoir some 73 miles upstream from the Watts Bar Nuclear Plant site. There are no public water supplies taken from the Tennessee River between the Watts Bar Dam and plant site. The closest downstream surface water supply is Dayton, Tennessee, at TRM 503.8 (25 miles downstream), which serves 6,150 people. The Daisy-Soddy-Falling Water Utility District, which serves about 8,500 people, has a water intake on Soddy Creek embayment of Chickamauga Reservoir about 45 miles below the plant site.

The present water supply intake for the Tennessee-American Water Company, which serves a population of about 270,000 in the metropolitan Chattanooga area, is located in the headwaters of Nickajack Reservoir at TRM 465.3 approximately 63 miles downstream from the site and 6 miles downstream from Chickamauga Dam. Studies are being made by a task force organized by the Tennessee Department of Public Health to evaluate the present water supply source and intake location for the City of Chattanooga and recommend any needed action to the State Health Department.

The East Side Utility District had developed plans to locate a surface water supply intake on the Wolftever Creek embayment of Chickamauga Reservoir about 52 miles downstream from the site. However, the district has subsequently decided to continue using its present ground water supply (wells) and has abandoned any definite plans to develop a surface water supply in the foreseeable future.

There are 18 public water systems within a 20-mile radius of the proposed site that depend either totally or in part on ground water as a source of supply. The City of Decatur now obtains its supply from Breedenton Spring, located near the left bank of the Tennessee River about 5 miles downstream from the site. Engineering studies have been made to evaluate the feasibility of a proposed regional water system that would serve both the cities of Decatur and Spring City, as well as numerous small communities and outlying areas. The engineer's report recommends that the intake for such a regional system be located on Watts Bar Reservoir (TRM 532L) about 4 miles upstream from the site. Watts Bar Dam, located between the proposed intake location and the plant site, would preclude any adverse impact resulting from the discharge of liquid effluents from the plant. The ground water supply and the distribution system which was developed for the nuclear plant and the Watts Bar Reservation have been designed so as to be readily incorporated within the regional system whenever it is developed. Public water supply information is included in Table 1.1-13 and the locations are shown on figure 1.1-5.

There are six industrial water supplies taken from Watts Bar and Chickamauga Reservoirs between Tennessee River mile 592 and mile 473. This includes the supply for TVA's Watts Bar Steam Plant which is taken from the Tennessee River at mile 529.9 through an intake constructed as part of Watts Bar Dam, and the supply for Watts Bar Nuclear Plant itself. The industrial water supplies located within a 20-mile radius of the plant and those industrial supplies obtained from the Tennessee River between miles 592 and

473 are summarized in Table 1.1-14. Those industrial supplies in the table also using the supplies for potable water within the plant are so indicated. All other industrial users purchase potable water.

The major industrial water users are downstream from the plant site. These industries withdraw a total of about 164 million gallons of process water from Chickamauga Reservoir each day. Seven industrial water supplies are taken from wells and springs within a 20-mile radius of the plant site. Olin Mathieson Chemical Corporation and Bowaters Southern Paper Corporation obtain water from the Hiwassee River, 22 and 23 miles upstream from its mouth, respectively. The Watts Bar Nuclear Plant will use a maximum of about 111 million gallons of water each day.

(8) Land use - The existing land use around the Watts Bar Nuclear Plant site reflects the trends of development taking place within the larger Great Valley of east Tennessee. This pattern is essentially the development of small satellite cities focusing on the major metropolitan centers of Knoxville and Chattanooga.

Pages 1.1-14 through 1.1-21 have not been revised.

cannot be made, the data indicate that the upper end of Chickamauga Reservoir plays a significant role in production of the fisheries resource of the reservoir, especially in terms of the reproduction and early growth of game and forage species.

Data for 1971-72 indicate an annual commercial fish harvest of approximately 307,000 pounds in Chickamauga Reservoir and the principal commercial species were catfish, buffalo, and carp.[3]

(10) Chemical and physical characteristics of air and water -

(a) Air - The general physical characteristics were described previously under Climatology and Meterology. The only air quality data collected from the vicinity of the plant are from two settled particulate samplers that were placed in operation in April 1969. The location of these samplers is shown in figure 1.1-10. The data collected to date are summarized in Table 1.1-18 and represent measurement of settled particulate from all sources. The highest monthly reading registered was 21 tons per square mile and occurred in June 1971.

Additional baseline data on the chemical and physical characteristics of the air in the vicinity of the plant will be gathered as monitoring programs are instituted prior to plant operation.

(b) Water - The Watts Bar Nuclear Plant will be located on Chickamauga Reservoir approximately 2 miles below Watts Bar Dam. The drainage area of the Tennessee River

at the site amounts to 17,320 square miles. At the plant site Chickamauga Reservoir is about 1,100 feet wide with the depths ranging up to 25 feet at normal pool, elevation 682.5. A 9-foot navigation channel is maintained past the site. The reservoir lies generally in a northeast-southwest direction with flow toward the southwest.

The Watts Bar Dam discharge records, maintained since its closure on January 1, 1942, indicate that the average discharge at the dam has been 26,480 ft^3/s. The maximum discharge occurred on December 30, 1942, and was 187,000 ft^3/s. Flow data for water years 1951-65 indicate an average flow of about 21,500 ft^3/s during the summer months and about 35,500 ft^3/s during the winter months. These data reflect for all practical purposes the volume of water that passes the plant site since there is less than 1 percent difference between the drainage areas at the plant site and the Watts Bar Dam.

Channel velocities at the plant site average 2.3 feet per second under average winter flow conditions and 1.0 foot per second under average summer conditions.

The most comprehensive source of water quality information available at the beginning of the Watts Bar project was a year-long water quality survey of Chickamauga Reservoir made by TVA beginning in May 1960.[4] This survey included some special sampling which continued into January 1962 and bacteriological determinations made at 6-day intervals during July, August, and September 1960, and May and June 1961, at 22 locations along the main stem and principal tributaries of the reservoir.

The results of this survey showed the overall reservoir water quality to be good. The overall bacteriological quality was good, and the water in the main stem of the reservoir was relatively low in organic content. Color and odor concentrations were low. The main stem waters were slightly hard (up to 80 mg/l), but satisfactory for practically all industrial uses.

Water temperature observations at selected Tennessee River stations were included in the data collected during the 1960-61 survey. These observations indicate that Chickamauga Reservoir is stratified during summer months, although stratification does not occur in the 20 miles immediately downstream from Watts Bar Dam. Bottom temperatures observed at TRM 487.7 (table 1.1-21) ranged from 41.5°F in January (1961) to 77.9°F in August (1960); surface temperatures ranged from 41.7°F in January (1961) to 81.9°F in July (1960). Temperature data at TRM 487.5 (table 1.1-22) collected over a 5-year period (1943-48) by TVA indicated little variation in these temperature patterns. It was concluded that water in Chickamauga Reservoir is well mixed except during the summer period when stratification occurs in the downstream one-half of the reservoir.

The survey also showed that dissolved oxygen (DO) concentrations in Chickamauga Reservoir were quite high during the winter and spring months. During the summer and fall months, however, the dissolved oxygen concentrations in the upper 20 miles of the reservoir were depressed because of low DO concentrations occurring in the Watts Bar Dam releases.

More recent data confirms that water passing into Chickamauga Reservoir through Watts Bar Dam continues

to be of overall good quality. A monthly sampling program, encompassing over 50 water quality parameters, has been in effect at Watts Bar Dam tailrace from January 1973 through September 1976.[5] The water quality data observed during most of this period is summarized in Table 1.1-19.

The dissolved oxygen concentrations of the Watts Bar Dam releases for the years 1960-75 are summarized in Table 1.1-20. Significantly increased DO levels are apparent, beginning in 1972. This improvement is primarily due to the installation of secondary wastewater treatment facilities at Knoxville, Tennessee. The release of water low in DO through low level intakes from deep headwater reservoirs located upstream is the remaining reason for low DO releases from Watts Bar Dam. TVA is investigating methods of increasing the DO levels in the releases from its headwater reservoirs.

Water temperature records for releases from Watts Bar Hydro Plant for 1965-75 are shown in Table 2.6-1 and show a maximum natural water temperature of 80.6°F.

More recent bacteriological studies[6] show that water continues to be of good quality at swimming and recreation areas on Chickamauga Reservoir.

(c) Temperature - Water temperature observations at selected Tennessee River stations were included in the data collected during the 1960-61 survey. These observations indicate that Chickamauga Reservoir is stratified during summer months,

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5. Tennessee Valley Authority, Division of Environmental Planning. TVA Water Quality Monitoring Network, August 1974.

6. Tennessee Valley Authority, Division of Environmental Planning, The Bacteriological Quality of Water at Selected Recreation Areas in the Tennessee Valley, May 1975.

although stratification does not occur in the 20 miles immediately downstream from Watts Bar Dam. Bottom temperature observed at TRM 487.7 (Table 1.1-21) ranged from 41.5°F in January (1961) to 77.9°F in August (1960); surface temperatures ranged from 41.7°F in January (1961) to 81.9°F in July (1960). Temperature data at TRM 487.5 (Table 1.1-22) collected over a 5-year period (1943-48) by TVA indicate little variation in these temperature patterns. It may be concluded that water in Chickamauga Reservoir is well mixed except during the summer period when stratification occurs in the downstream one-half of the reservoir.

Water temperature records for releases from Watts Bar Hydro Plant for 1965-75 are shown in Table 2.6-1 and show a maximum natural water temperature of 27°C (80.6°F).

(11) Historical and archaeological significance of the Watts Bar site - No sites listed in the National Register of Historic Places, or known to be under consideration for such listing, are located at or near the proposed Watts Bar Nuclear Plant.

The project has been reviewed by the Tennessee Historical Commission and other appropriate agencies, and no specific items of particular historical significance have been identified.

An archaeological survey of the site was made in December 1970 by the University of Tennessee, Department of Anthropology. Investigations to determine archaeological significance of the site are discussed in Section 2.10, Other impacts.

Pages 1.1-27 through 1 1-38 have not been revised.

Table 1.1-13

WATER SUPPLIES WITHIN 20-MILE RADIUS OF SITE INCLUDING SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN FORT LOUDOUN AND CHICKAMAUGA DAMS

Public Supplies

Water Supply	Distance From Site[a]	Estimated Population Served	Average Daily Use	Source
	Miles		Gallons	
1. Athens	13.7	15,000	1,852,000	Surface (Oostanaula Cr. 50%) and Ground, spring 50%
2. Cedar Valley Elementary School	12.5	187	4,700	Ground, well
3. Dayton	24.2	6,150	1,366,000	Surface (TRM 503.8)
4. Decatur	3.3	1,500	117,000	Ground, spring
5. Eastview Elementary School	19.7	130	3,200	Ground, well
6. E. K. Baker School	9.2	340	8,500	Ground, well
7. Englewood	19.2	1,810	253,000	Surface (Middle Creek 1.8)
8. Evensville Elementary School	12.3	125	3,100	Ground, well
9. Fairview Elementary School	3.0	180	4,600	Ground, well
10. Frazier Elementary School	11.7	153	3,800	Ground, well
11. Idlewild Elementary School	8.6	173	4,300	Ground, well
12. Midway High School	19.2	290	7,200	Ground, spring
13. Niota	17.1	2,500	290,000	Ground, spring
14. Paint Rock Elementary School	18.9	196	4,900	Ground, well

a. Radial distance to all supplies except those that take water directly from the Tennessee River which are shown as river mile distance from TRM 528.0.

Table 1.1-13
(Continued)

WATER SUPPLIES WITHIN 20-MILE RADIUS OF SITE INCLUDING
SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN FORT LOUDOUN AND CHICKAMAUGA DAMS

Public Supplies

Water Supply	Distance From site[a]	Estimated Population Served	Average Daily Use	Source
	Miles		Gallons	
15. Riceville Utility District	17.0	581	18,000	Ground, spring 99%[b]
16. Rockwood	17.6	10,000	1,420,000	Ground, spring
17. Spring City	7.6	2,300	300,000	Surface (Piney River mile 5.7 - 33%) and Ground, spring 67%
18. Sweetwater	17.5	5,000	700,000	Ground, spring 90% and Surface (Sweetwater Cr. mile 21.6 - 10%)
19. Ten Mile Elementary School	7.9	170	4,200	Ground, well
20. Watts Bar Reservation[c]	1.9	480	44,980	Ground, well
21. Daisy-Soddy-Falling Water Utility District	44.7	8,500	400,000	Surface (Soddy Creek 4.2 - 67%) and Ground, well 33%
22. Lenoir City	73.3	6,600	950,000	Surface (TRM 601.3)
23. Savannah Valley Utility District	44.4	1,610	122,000	Ground, well

a. Radial distance to all supplies except those that take water directly from impounded waters of the Tennessee River, which are shown as river mile distance from TRM 528.0.

b. Has auxiliary water intake at King Creek embayment mile 1.3.

c. Supplies potable water to nuclear plant, steam plant, hydro plant, and resort area.

Table 1.1-14

INDUSTRIAL WATER SUPPLIES

	Water Supply	Distance From Site[a]	Number of Employees	Average Daily Use	Source
		Miles		Gallons	
1-I	Athens Hosiery Mill, Inc.	13.0	170	239,000	Ground, well
2-I	Athens Stove Works	13.8	400	160,400	Ground, well
3-I	Carolyn Products, Inc.	19.2	150	655,000	Surface (Sweetwater Creek)
4-I	Cherokee Photo Finishers	12.7	52	59,000	Ground, well
5-I	Crescent Hosiery Mills	15.6	125	25,000	Ground, well
6-I	Mayfield Dairy Farms, Inc.	15.0	345	290,000	Ground, well
7-I	Plastic Industries, Inc.	13.4	210	10,000	Ground, well
8-I	Southern Silk Mills	9.2[b]	850	300,000	Surface (Piney Creek)
9-I	Sweetwater Hosiery Mills	16.6[b]	90	24,000	Ground, well
10-I	Watts Bar Steam Plant	1.9	100	449,726,000[c]	Surface (TRM 529.9)
11-I	Watts Bar Nuclear Plant	-0-	300	111,166,500[d]	Surface (TRM 528.0)
12-I	ICI America, Inc. (Volunteer Army Ammunition Plant)	55.0	2,000	50,000,000	Surface (TRM 473.0)
13-I	Charles H. Bacon Company	63.5[b]	600	350,000	Surface (TRM 591.5 and spring)
14-I	C. F. Industries, Inc.	55.0[b]	210	3,140,000[e]	Surface (TRM 473.0)
15-I	Union Carbide Corporation	64.0	430	3,272,000	Surface (TRM 592.0)

a. Radial distance to all supplies except those that take water directly from impounded waters of the Tennessee River which are shown as river mile distance from TRM 528.0.

b. Water supply is also used for potable water within the plant.

c. Primarily cooling water.

d. Cooling water and cooling tower makeup.

e. Does not include approximately 81.0 MGD recirculation.

Pages 1.1-42 through 1.1-45 have not been revised. Table 1.1-20 (page 1.1-47) has been deleted while tables 1.1-19 and 1.1-21 have been placed in reverse order. All tables have been properly renumbered.

Table 1.1-19
SUMMARY OF WATER QUALITY DATA
TENNESSEE RIVER MILE 529.9

Parameter	Number of Observations	Observed Concentrations[a] Maximum	Minimum	Mean[c]	Number of Observations	Observed Concentrations[b] Maximum	Minimum	Mean[c]
Alkalinity (total, as $CaCO_3$), mg/l	38	82	36	54	8	59	57	57
Aluminum, µg/l	23	1800	<200	705	-	-	-	-
Arsenic, µg/l	24	5	<5	5	1	0	0	0
Barium, µg/l	23	<100	<100	<100	-	-	-	-
Beryllium, µg/l	22	<10	<10	<10	-	-	-	-
BOD (5-day, 20°C), mg/l	22	3.7	<1.0	1.4	-	-	-	-
Boron, µg/l	20	<1000	<100	<386	-	-	-	-
Cadmium, µg/l	23	13	<1	2	1	0	0	0
Calcium, mg/l[d]	39	23	8	19.2	10	23	19	21
Chloride, mg/l[d]	40	35	4	6.8	7	7.9	3.4	5.7
Chromium, µg/l	23	5	<5	5	1	<10	<10	<10
Cobalt, µg/l	4	<5	<5	<5	1	1	1	1
COD, mg/l	40	11	3	5.9	-	-	-	-
Color, PCU	40	30	5	12.2	-	-	-	-
Copper, µg/l	23	90	<10	20.5	1	11	11	11
Fecal Coliforms, no. per 100 ml	16	20	<10	11	6	82	3	29
Fluoride, mg/l[d]	38	0.1	0.04	0.08	10	0.3	0.0	0.14
Hardness (Ca + Mg), mg/l	39	79	31	67	10	77	66	71
Iron (total), µg/l	39	1300	190	498	1	670	670	670
Iron (dissolved), µg/l	24	200	<50	75	1	30	30	30
Lead, µg/l	23	130	<10	15.5	1	26	26	26
Lithium, µg/l	17	<10	<10	<10	-	-	-	-
Magnesium, mg/l[d]	39	5.6	2.7	4.6	10	5.0	4.4	4.6
Manganese (total), µg/l	39	120	40	64	-	-	-	-
Manganese (dissolved), µg/l	24	40	<10	20	1	23	23	23
Mercury, µg/l	24	1.0	<0.2	0.3	1	0	0	0
Nickel, µg/l	23	290	<50	67	-	-	-	-
Nitrogen (ammonia), mg/l	40	0.18	<0.01	0.06	-	-	-	-
Nitrogen (Kjeldahl), mg/l	-	-	-	-	7	0.33	0.16	0.25
Nitrogen (nitrate plus nitrite), mg/l	38	0.79	0.11	0.39	7	0.53	0.18	0.41
Nitrogen (organic), mg/l	38	0.45	<0.03	0.17	-	-	-	-
pH, units	36	8.5	6.8	7.4	11	7.7	6.7	7.3
Phosphorus (total), mg/l	38	0.05	<0.01	0.03	8	0.05	0.02	0.04
Phosphorus (dissolved), mg/l	24	0.040	<0.010	0.017	-	-	-	-
Potassium, mg/l[d]	39	2.4	0.9	1.5	10	1.6	1.2	1.4
Selenium, µg/l	24	<2	<1	<2	-	-	-	-
Silica (total), mg/l	27	7.2	4.1	5.2	-	-	-	-
Silica (dissolved), mg/l	13	5.6	3.1	4.7	7	6.0	4.0	5.3
Silver, µg/l	23	<10	<10	<10	-	-	-	-
Sodium, mg/l[d]	39	50.0	2.3	6.4	10	7.3	2.9	4.6
Solids (dissolved), mg/l	36	180	60	94	7	116	79	92
Solids (suspended), mg/l	36	14.0	<1.0	7.5	11	43	4	11.9
Specific Conductance, µmhos	36	320	97	161	11	180	140	160
Sulfate, mg/l[d]	40	18.0	9.0	12.4	8	15.0	9.9	12.5
Titanium, µg/l	15	<1000	<1000	<1000	-	-	-	-
Total Organic Carbon, mg/l	19	4.7	1.6	2.4	1	3.1	3.1	3.1
Turbidity, JTU	92	60	<1	12.5	7	20	3	8.5
Zinc, µg/l	23	70	<10	20.5	-	-	-	-

a. Samples collected and analyzed by the Tennessee Valley Authority, January 1973-December 1975.
b. Samples collected and analyzed by the U.S. Geological Survey October 1974-September 1975.
c. Arithmetic mean, detection limit values averaged as real numbers.
d. TVA data represents analyses performed on an unfiltered sample; USGS data represents analyses performed on a filtered (0.45 µ filter) sample.

Table 1.1-20

SUMMARY OF WEEKLY OBSERVED DISSOLVED OXYGEN

CONCENTRATIONS IN THE TAILRACE OF WATTS BAR DAM

1960-75

Year	Observed Dissolved Oxygen Concentrations mg/l		Number of Days Dissolved Oxygen Less than Stated Concentration			
	Minimum	Maximum	3.0 mg/l Days	4.0 mg/l Days	5.0 mg/l Days	6.0 mg/l Days
1960	3.3	10.5	0	6	47	101
1961	4.7	11.8	0	0	3	73
1962	2.9	11.6	4	30	77	144
1963	2.3	11.5	11	50	98	121
1964	3.2	11.4	0	25	39	116
1965	2.7	10.7	6	46	95	131
1966	2.1	12.6	32	43	82	120
1967	3.9	13.5	0	2	23	71
1968	3.3	12.4	0	25	78	133
1969	2.2	11.0	10	66	96	122
1970	2.9	11.6	2	66	116	148
1971	3.0	10.8	0	36	86	146
1972	4.1	11.3	0	0	34	87
1973	4.2	11.5	0	0	26	56
1974	5.2	10.7	0	0	0	50
1975	3.9	13.3	0	2	21	47

This page is now blank due to deletion of Table 1.1-20 as per comments on page B-18.

Table 1.1-21

OBSERVED WATER TEMPERATURES - CHICKAMAUGA RESERVOIR *

Tennessee River Mile 487.7

July 1960 - June 1961

Date	Distance From Right Bank (% of Width)	Surface - depth 1 ft. Temperature	Bottom Temperature	Bottom depth, ft
July 12, 1960	50	81.9	75.6	38
August 5, 1960	50	81.7	77.9	35
August 23, 1960	50	79.0	76.5	37
September 22, 1960	50	76.9	74.1	40
October 18, 1960	50	73.6	72.1	36
November 22, 1960	50	55.6	55.0	36
January 18, 1961	50	41.7	41.5	35
February 21, 1961	50	46.6	46.6	40
March 21, 1961	50	52.5	52.5	40
April 18, 1961	50	57.9	56.5	44
May 16, 1961	50	65.8	63.9	42
June 14, 1961	50	78.3	72.0	48

*Data from Quality of Water in Chickamauga Reservoir, 1960-1961, Division of Health and Safety, TVA

Table 1.1-22

OBSERVED MAXIMUM AND MINIMUM TEMPERATURES

Chickamauga Reservoir - Tennessee River Mile 487.5

Calendar Year	Surface Temperatures, °F. *	
	Maximum	Minimum
1943	84.2	44.6
1944	82.4	41.0
1945	84.2	41.0
1946	84.2	42.8
1947	82.4	39.2
1948	82.4	42.8

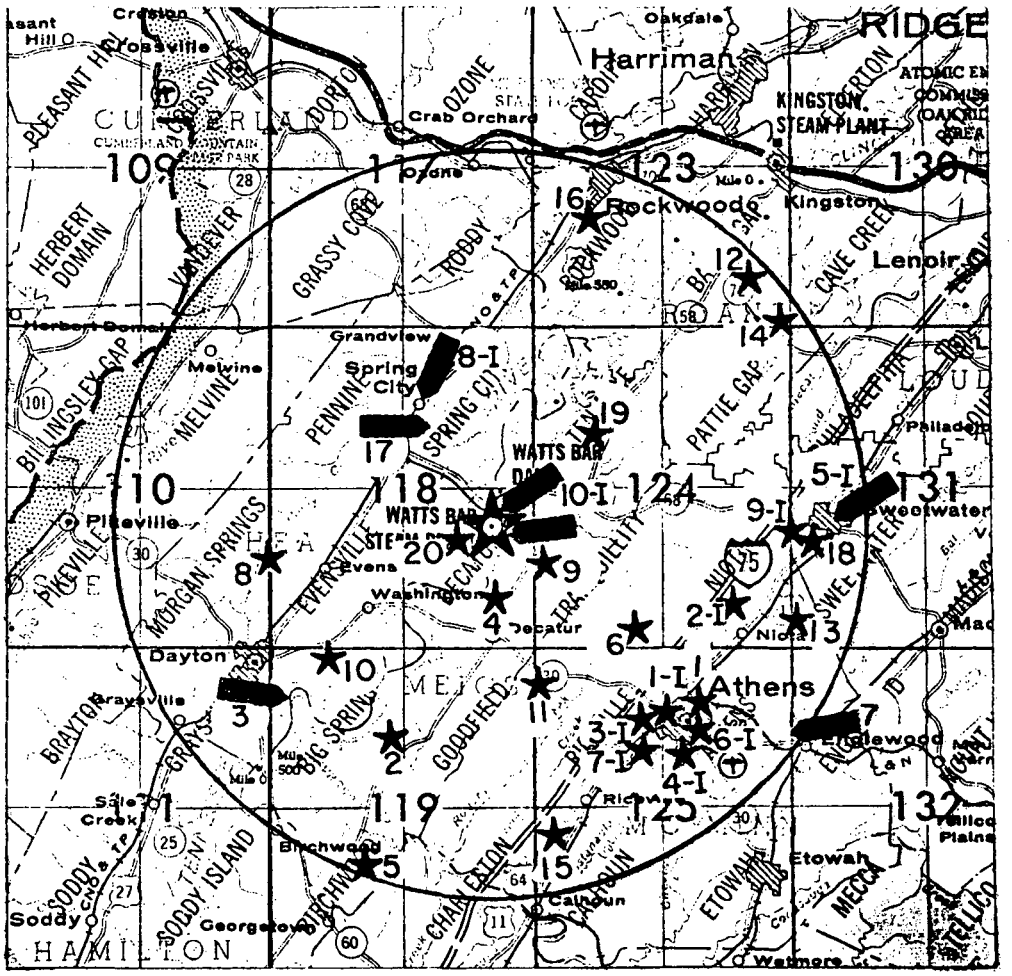
* Data from Water Temperature of Streams and Reservoirs in the Tennessee River Basin, Hydraulic Data Branch, TVA

Table 2.6-1*
Observed Watts Bar Dam Tailrace
Water Temperature Data
(Weekly Observations)

Week Number	1965-1975 Average Temperature °C	1965-1975 Maximum Temperature °C
1	8.8	10.0
2	7.9	11.0
3	6.4	7.5
4	7.4	11.0
5	6.8	10.0
6	6.8	8.0
7	7.0	9.5
8	7.4	10.0
9	7.8	11.0
10	9.0	13.0
11	9.8	13.0
12	10.0	11.0
13	11.3	13.0
14	12.7	15.0
15	13.6	16.0
16	14.4	18.0
17	16.2	18.5
18	17.1	18.5
19	18.0	19.5
20	18.9	20.0
21	19.9	22.0
22	21.1	23.0
23	21.6	23.0
24	22.6	24.0
25	22.8	23.5
26	23.5	24.5
27	23.7	26.0
28	24.4	25.5
29	24.3	26.0
30	24.6	26.0
31	25.0	26.0
32	25.1	27.0
33	25.3	26.0
34	24.8	26.0
35	25.3	27.0
36	25.3	27.0
37	24.9	26.0
38	24.4	26.0
39	23.4	26.0
40	22.2	26.0
41	21.8	26.0
42	20.9	24.0
43	19.2	22.0
44	18.4	22.0
45	16.6	19.0
46	15.1	16.0
47	13.2	15.0
48	12.1	16.0
49	10.8	15.0
50	10.2	11.5
51	9.4	12.0
52	9.0	11.5

*This table has been included here in a revised form since the information it now contains is referenced from the revised text of subsection 1.1.

The figures of pages 1.1-51 through 1.1-54 have not been revised.



WATTS BAR NUCLEAR PLANT

Plant Site

Surface Water Supply

Ground Water Supply

NOTE: The number associated with the symbol corresponds to the numbering in tables

FIGURE 1.1-5

Public Water Supplies Within a 20-Mile Radius of the plant site

Scale of Miles

10 0 10 20

The figures of pages 1.1-56 through 1.1-60 have not been revised.

2.5 Nonradioactive Discharges - It is TVA's policy to keep the discharge of all wastes from its facilities at the lowest practicable level by using the best and highest degree of waste treatment available under existing technology, within reasonable economic limits.

A description of the potential sources and amounts of non-radioactive discharges which have been identified is given in this section, along with a description of the specific treatment of these potential sources.

An NPDES permit application for the sanitary waste discharges from the construction facilities was filed with EPA on April 13, 1973. The NPDES sewage treatment plant permit No. TN0020168 was issued by EPA for these discharges on December 10, 1973. An NPDES permit application for other construction discharges was filed with EPA on July 21, 1975. The application for an NPDES operating permit is being finalized at the present time. The NPDES permit when issued by EPA will include specific effluent limitations for each regulated point source discharge along with appropriate monitoring and reporting requirements necessary to determine compliance with the effluent limitations.

1. Chemical discharges - TVA has altered the originally proposed design for handling plant effluents including the chemical discharges at the Watts Bar Nuclear Plant. These alterations in handling the plant chemical discharges are included in the present plant design for handling the plant effluents as shown schematically in Figure 2.5-1. This section describes the modified design and discusses the control and treatment of chemical wastes and the probable environmental impact of chemical releases.

The sources of these chemicals and the maximum expected quantity of chemical end products that could be discharged are summarized in Table 2.5-1. The average and the maximum expected total chemical concentrations in the discharge pipe and in the reservoir after initial jet mixing are shown in Table 2.5-2. The tables were generated using conservative assumptions for chemical usage and solids concentrations in the cooling towers. These computations show that even under adverse conditions and using conservative assumptions, impacts to the environment due to chemical discharges from the Watts Bar Nuclear Plant will be very small.

(1) Cooling tower blowdown and drift - Operation of the two natural draft cooling towers for the condenser circulating water system will evaporate approximately 64 ft^3/s of the flow to the towers during periods of high evaporation. Drift will also be carried from the towers but is not expected to exceed about 0.1 ft^3/s per tower. To control the dissolved solids concentrations in the condenser cooling water, a certain amount of blowdown from the towers and makeup to the towers must be provided.

Normal blowdown rate will be approximately 85 ft^3/s during periods of high evaporation. This will maintain a condenser cooling system solids concentration about twice the reservoir solids concentration. Blowdown will be returned to the river through a diffuser system designed to provide the best diffusion possible with the streamflow available and minimize environmental impacts due to disturbances of aquatic life during construction and operation of the plant.

Chemical additives other than intermittent chlorination for biological control should not be required for cooling water concentration factors normally held to about 2. The water in Chickamauga Reservoir at the Watts Bar site normally shows a scaling rather than a corrosive nature and use of corrosion inhibitors is not necessary.

Heat exchangers that could contribute to added corrosion products in the plant effluent include the main condensers, main feed pump turbine condensers, and raw cooling water system tubing material (90:10 copper-nickel). However, a closed-cycle cooling water system concentrates the scaling constituents in the recirculated water such that general corrosion of heat exchanger tube material is virtually nonexistent. Recent measurements of a 90:10 copper-nickel tube at Bull Run Steam Plant (after 10 years of service with once-through fresh-water cooling) revealed no measurable metal loss due to general corrosion.

As a worst case example, it can be assumed that the Bull Run measurement amounted to 1 percent tube loss (within the accuracy of the analysis), or as much as 0.1 percent tube loss per year as the average. Taking no credit for a reduction in corrosivity of the circulating water due to the concentrating effect of the cooling tower, the concentration of corrosion products added to the Watts Bar blowdown could be 35 ppb copper and 3.8 ppb nickel based on this assumption. Considering the reduced corrosivity during tower operation, the actual quantities of corrosion products are expected to be less than these values. There are no planned uses of corrosion inhibitors in the condenser cooling system.

As described in Section 2.6, Heat Dissipation, cooling tower blowdown will be retained in the holding pond when the releases from the Watts Bar Dam are less than 3,500 ft^3/s. During normal

operation of Watts Bar Dam these periods seldom exceed 12 hours in duration on any given day. During such periods, valves located at the cooling tower blowdown diffusers, in the steam generator blowdown outlet, and radioactive waste system outlet would automatically be closed and the flow control valves (inlet to the yard holding pond) would be opened. This valving system, which will be interlocked with the hydroelectric units at Watts Bar Dam, will be automatically activated whenever releases from Watts Bar Dam are less than 3,500 cfs. However, it should be emphasized that this level of streamflow (3,500 cfs) is an operational limitation of the hydroelectric units at Watts Bar Dam and should not be considered as the minimum streamflow required for assimilation of waste discharges from the Watts Bar Nuclear Plant. This would divert cooling tower blowdown to the holding pond (see Figure 2.5-1). Upon attaining sufficient river flow, discharges to the reservoir of blowdown stored in the yard holding pond along with that coming directly from the cooling towers would commence.

A water level indicator will be installed to alarm in the main control room of Watts Bar Nuclear Plant whenever the yard holding pond nears the overflow level. Upon alarm, a plant operator could notify Watts Bar hydroelectric plant personnel that streamflow is needed to allow discharge of yard holding pond contents to begin.

The temperature of combined yard holding pond drawdown and direct cooling tower blowdown would be approximately the same as normal cooling tower blowdown for a given set of environmental conditions, neglecting possible mixing in the yard holding pond due to precipitation cooling and solar heating of the yard holding pond contents (both of which are expected to be minimal). The blowdown diffusers were designed to meet the

State of Tennessee stream thermal standards assuming the yard holding pond discharge temperature equalled direct cooling tower blowdown (which is a maximum of 95° F.). This procedure should result in parameter concentrations that would not be expected to have a significant environmental impact. By maintaining continuous blowdown from the cooling towers, no increase of dissolved solids concentrations above the normal operating levels (approximately a factor of 2) should occur within the heat rejection system. The mean and maximum concentrations of trace metals expected to occur in the effluent and at the edge of the jet mixing zone (dilution of 9:1) are shown in Table 2.5-3.

Addition of sodium hypochlorite to the condenser circulating water may be necessary for biological control and, if used, will be fed at a rate to achieve a chlorine residual of 1 mg/l for 30 minutes per day per unit. Data collected at Paradise Steam Plant, where the chlorinated condenser circulating water discharges to a natural draft tower, indicated about 0.1 mg/l residual chlorine at the inlet to the tower and zero to a trace of chlorine in the tower basin during the injection period, when the chlorine residual was 0.7 mg/l in the condenser inlet and 0.4 mg/l at the condenser outlet.

It is anticipated that the Watts Bar cooling water will have a similar chlorine demand and that only trace amounts of residual chlorine would be discharged in the cooling tower blowdown.

Cooling tower drift is not expected to exceed 0.2 ft^3/s. This amount of drift would result in an average discharge of solids of less than 300 lb/d. The drift is expected to fall out in the immediate vicinity of the tower. No significant environmental impacts will occur since no area outside the immediate vicinity of the towers will receive significant concentrations of solids.

(2) Raw cooling water and essential raw cooling water systems - In order to have the capability for controlling Asiatic clam populations at Watts Bar Nuclear Plant, TVA has decided to treat the Raw Cooling Water (RCW), Raw Service Water (RSW) and Essential Raw Cooling Water (ERCW) systems with sodium hypochlorite. Slime and algae control is planned to be maintained by adding sodium hypochlorite to the Condenser Cooling Water (CCW) system and the Makeup Water Treatment Plant. TVA plans to inject sodium hypochlorite as near to points of need as practical. Feed rates will be controlled using equipment for which flows are known or otherwise calibrated. It is anticipated that sodium hypochlorite injections will be made according to the following schedule:

I. Slime Control

Condenser Cooling Water (CCW) system - shock treatment, chlorinate 1 hr/day with total free chlorine residual of 0.2 mg/l at condenser outlet.

II. Asiatic Clam Control

Essential Raw Cooling Water (ERCW) systems - 32,000 gpm system flow, low-level continuous chlorination (May-October) with total free chlorine residual of 0.6 - 0.8 mg/l.

Raw Cooling Water (RCW) systems - 31,000 gpm system flow, two three-week periods of continuous treatment annually (beginning and end of Asiatic clam spawning season).

Raw Service Water (RSW) systems - 1000 gpm system flow, low-level continuous chlorination (May-October) with total free chlorine residual of 0.6 - 0.8 mg/l.

The principal constituents present in the above systems as a result of sodium hypochlorite addition will be sodium, chlorides, and a negligible amount of inert impurities found in the salt used for producing the sodium hypochlorite. Quantities of these constituents are presented in a revised version of Table 2.5-1 from the Watts Bar Nuclear Plant FES. During chlorination periods no discharges of residual chlorine in excess of the NPDES permit limitations will be allowed from the condenser cooling system.

(3) Makeup water filter plant - Operation of the makeup water filter plant will require the use of lime, alum, and chlorine. Residual chlorine in the treated water will be removed by the makeup water treatment demineralizers and will be released as combined chlorides in the demineralizer regenerant solutions. Filter backwash water and clarifier sludge will contain aluminum hydroxide floc and settled solids. These wastes will be dewatered to a product containing about 50 percent solids and buried in an approved offsite sanitary landfill. The system has been designed to treat about 20,000 gallons of liquid.

The addition of a coagulation aid may be necessary for proper operation of the filter plant. Coagulation aids will be used, when necessary, in such a manner as to meet applicable requirements and to ensure that the environment will be protected.

(4) Makeup demineralizer wastes - Normal procedure for treatment of makeup demineralizer wastes is to hold the acid and caustic wastes in a tank, monitor pH, and adjust pH by addition of acid or caustic as required, and when pH is neutralized the waste is discharged from the plant. At Watts Bar Nuclear Plant makeup demineralizer regeneration wastes will be treated by a batch neutralization process that monitors and

adjusts the pH to meet applicable discharge requirements, and will then be pumped to the cooling tower blowdown stream. The estimated quantities of chemicals to be discharged to the environment from the makeup demineralizer system are listed in Table 2.5-1.

(5) Condensate demineralizer wastes - Condensate demineralizers are employed to treat all or part of the condensate pumped from the condenser hotwells. As discussed under ADDITION OF CONDENSATE DEMINERALIZERS (see Section A of this transmittal) most of the steam generator blowdown is also treated by the condensate demineralizers. The principal constituent of both these streams is ammonia, used in treatment of secondary system water. Both streams also contain corrosion products from the condenser, steam generators, and system piping. During operation with condenser leakage, impurities contained in the condenser cooling water will be present in the condensate. During operation with primary-to-secondary leakage, the steam generator blowdown and, to a lesser extent, the condensate contain fission and corrosion products and boric acid from the primary system.

Impurities in the influent to the condensate demineralizers are in the forms of suspended particles and dissolved materials. The demineralizers act as filters in removing suspended particles. Dissolved ionic impurities are removed by ion exchange. The demineralizers are regenerated periodically with sulfuric acid and sodium hydroxide. The process employed at the Watts Bar plant reduces by about one-half the amounts of these chemicals employed in conventional condensate demineralizer regeneration systems.

The regeneration process removes the impurities that have been accumulated in the demineralizers. The regenerant waste solutions are discharged to the cooling tower blowdown line when they

contain less than 10^{-4} uCi/gm of gross radioactivity (see discussion on ADDITION OF CONDENSATE DEMINERALIZERS located in Section A of this transmittal). It is expected that in normal operation, radioactivity will be much lower than 10^{-4} uCi/gm. Table 2.5-1 shows the quantities of ammonia and other constituents discharged annually as condensate demineralizer regeneration wastes. The data in this portion of the table are based on the assumptions that the demineralizers are operated on a full-flow basis.

(6) Component cooling water system - Sodium nitrite will be used as a corrosion inhibitor in the closed component cooling water system. When necessary for maintenance purposes, the nitrite-containing water will be drained from portions of the closed system. Whenever possible, the water will be returned to the system. If not, it will be routed to the radwaste system and processed by evaporation.

(7) Reactor coolant system - Boric acid, lithium hydroxide, and hydrazine will be used in the reactor coolant system. Hydrazine will be used only during startup. Letdown from this system will be processed as tritium-containing waste and recycled for reuse in the plant.

(8) Auxiliary steam generator blowdown - Two 40,000-pound-per-hour oil-fired steam generators will be supplied. One steam generator will operate continuously and one will operate during the heating season and intermittently during the remainder of the year. Hydrazine will be added continuously to the feedwater as a dissolved oxygen scavenger. The hydrazine concentration in the feedwater will be about 10-15 ug/l and within the system is expected to be at less than detectable concentrations. Ammonia will be intermittently added to the feedwater for pH control. Blowdown rate will vary from 2,000 to 4,400 gallons per day total for both steam generators and will result in an annual discharge of ammonia

of only about 13 pounds. The blowdown, which will have a residual ammonia concentration of about 0.3 mg/l, will be discharged to the condenser circulating water system. As shown in Table 2.5-2, contribution to the increases in the cooling water blowdown stream will not cause ammonia discharge concentrations to be significant.

(9) Chemical cleaning wastes - Two temporary chemical cleaning holdup ponds (cells) have been constructed within the main yard holding pond area. These temporary ponds are to be used for the containment and treatment of chemicals and waste water that will be used during preoperational cleaning and testing. The small pond has a volume of approximately 699,380 gallons and the larger pond has a volume of approximately 6,919,000 gallons. The ponds are located about 1,100 feet west of the unit 1 N-S centerline and 1,200 feet south of the E-W baseline. The embankments of the ponds are built-up dikes that will be leveled and graded to blend with the surrounding terrain upon retirement of the ponds. The small pond will have a polyvinyl liner to prevent seepage loss of the chemicals. The small pond, which will handle the more concentrated chemicals, is not expected to have significant quantities of any chemicals other than trisodium phosphate, hydrazine, ammonia, and detergents (e.g., triton X-100 and QS 30). The large pond will hold the diluted chemical waste flushing water and will have a 2-foot freeboard above the operating level to provide protection against overflow. Prior to discharge to the Tennessee River, the chemical cleaning wastes will be treated within these ponds so as to meet the applicable effluent limitation for this point source discharge. Treatment and subsequent discharge in this manner will not result in any significant adverse impacts to the aquatic environment.

(10) Miscellaneous - Most equipment cleaning and decontamination operations will be performed with high-pressure water and with detergent solutions. These liquids will be treated in the radwaste system by filtration and will be released to the cooling tower blowdown discharge line.

Some decontamination operations will involve the use of chemicals such as sodium phosphate, sodium permanganate, ammonium citrate, alkaline potassium permanganate, and nitric, citric, oxalic, acetic, and hydrofluoric acids. Although the amounts of such chemicals have not been determined at this time, they will not be discharged to the reservoir but will be drained to the chemical tank in the radwaste system. The solutions will be neutralized and either drummed directly or processed by evaporation and the concentrates drummed.

Inputs to the chemical drain tank in the radwaste system consist of laboratory drains and decontamination wastes. The principal chemical reagents used in the laboratory include sodium and ammonium hydroxides; hydrochloric, nitric, and sulfuric acids; ammonium acetate; and sodium carbonate.

Before the chemical drain tank is emptied, its contents are analyzed. If the liquid does not contain chemicals that would be harmful to the evaporator (principally, chlorides and sulfides) it will be processed in the auxiliary evaporator. The concentrates are drummed and the distillate is released to the reservoir in the usual manner. If the chemical drain tank contains chemicals that would be harmful to the evaporator, the contents are drummed without further processing. The contents of the tank are released to the reservoir only when analysis shows that no environmentally harmful concentrations of chemicals are present and the radioactivity level is within acceptable limits. It is expected that release would be an infrequent event.

Usage of detergents will be minimized for laundry and similar uses. Benefits gained by treatment of the small amount of detergent wastes are not great enough to justify radioactively contaminating a normally uncontaminated system such as the sewage treatment system. The detergent solutions will be filtered and discharged. Treatment and discharge of these detergent solutions in this manner are not anticipated to result in any significant environmental impacts.

It is anticipated that the cooling tower basins will be drained infrequently for maintenance purposes. When this operation is necessary, the contents of the tower basin will be routed to a settling area. Sludge removed from the tower basins will be buried onsite or on other TVA grounds. No significant environmental impacts are expected to occur from this operation.

The building drainage system (roof and high floor drains) drains into the storm drainage system and thence to the holding pool. These drains will handle only innocuous materials and present no hazard to the environment.

The station sump also discharges to the holding pool and would not normally handle any substances potentially detrimental to the environment. It may occasionally contain some oil which has leaked from some indoor machinery. Oil reaching the holding pool via this route will be reclaimed for disposal as described below for the yard drainage system.

2. Yard drainage system - An area of approximately 30 acres will be diked to provide a yard drainage holding pool. Any debris or oil which may be spilled and enter the yard drainage system will flow to

this pool. A skimming type outflow will be provided so that floating debris and oil cannot escape from the pool. This material will be periodically removed from the pool for disposal. It will be disposed of in a manner to minimize environmental impact, dependent on the character of the wastes, such as burial, landfill, or burning. Oil will be reclaimed for reuse when practicable. If not suitable for reuse it will be drummed and held onsite for disposal by the most environmentally suitable method.

3. Transformers and electrical machinery - Some oil leakage may occur from bearings and other parts of certain machinery inside buildings. The oil will be drained to an oil sump that will have adequate capacity to contain all spillage which will be drummed for ultimate disposal.

In the event of an outside oil spill from the main stepup transformer or insulating oil storage tank, the oil spillage will be routed to the storm drains and then to the holding pool. At the holding pool the oil will be reclaimed for reuse or disposal.

Diesel fuel oil for auxiliary boilers and lube oil will be stored in tanks in an area which will be depressed below the surrounding ground to form a basin of sufficient capacity to retain the contents of the enclosed tanks. During periods of rainfall, some runoff water may accumulate in the basin. A valved low-level discharge pipe will be provided for periodic removal of precipitation collected within this area and basin contents will be inspected prior to discharge to assure that oil will not be released by this mechanism. The valve will be maintained in a closed position at all other times to provide for retention of oil should the tanks rupture.

In the interest of fire prevention for indoor installations, either Askarel-filled or dry-type transformers will be used. When the former

is used, the transformer will be located within a concrete curb to prevent the possibility of spillage of this liquid, which contains polychlorinated biphenyls, from entering the common floor drainage system. A floor drain in the confined area will carry any spillage to a separate storage sump or else the curb will be made high enough to hold the entire liquid content of the transformer. In either case, the liquid will be drummed for proper disposal if not suitable for reuse.

4. Sanitary wastes - Extended aeration sewage treatment facilities will be provided during the construction period to treat the domestic wastes from a peak construction force of approximately 2,000 persons. Effluent from the plant will be chlorinated before entering the river. These treatment facilities will be complemented during construction by portable-type chemical toilets for use in isolated or remote areas of the project site. At the end of construction, these initially installed facilities will be removed to storage, surplus, or new construction.

Secondary treatment facilities with provision for chlorination will be provided for the permanent plant. It is estimated that the ultimate operating force will number 170 permanent employees. The treatment facility will be designed to handle approximately 300 persons including permanent and temporary employees and visitors. During periods when a large temporary maintenance force is working at the plant, the permanent waste treatment will be supplemented by portable-type chemical toilets.

Both construction and permanent systems will be operated to prevent untreated effluents from entering the river. The design will be in accordance with approved sanitation standards applicable to TVA facilities and will meet Tennessee Pollution Control Board requirements.

TVA routinely sends plans of its sanitary waste treatment facilities to the appropriate state pollution control organization for their information and files.

5. Gaseous emissions - Each oil-fired auxiliary steam generator is expected to operate at an average of about 75 percent capacity, which will result in both units burning a total of about 4.8×10^6 gallons per year of No. 2 fuel oil, having a maximum sulfur content of 0.5 percent.

The boilers are each rated at 40,000 lb/h steamflow with an input rating of about 55×10^6 Btu/h.

Emissions resulting from this operation were used to calculate the annual average ambient pollutant concentrations. For shorter averaging times (24 hours and less) both units were assumed to operate at full capacity, which results in burning 727 gallons/h of fuel.

The following emissions rates were used to calculate ambient pollutant concentrations:

Particulates	5.84 lb/h
Sulfur Oxides	5.74 lb/h
Carbon Monoxide	0.029 lb/h
Hydrocarbons	1.47 lb/h
Nitrogen Oxides	251.98 ton/yr

The emissions will be released through a stack which is approximately 127 feet above ground level.

Calculated maximum ambient pollutant concentrations resulting from these emissions, together with the applicable ambient standards, are given below.

Pollutant	Averaging Time	Calculated Concentrations	Secondary Ambient Standards
Particulates	24-hour	0.23 ug/m^3	150 ug/m^3
Sulfur Oxides	24-hour	8.78×10^{-5} ppm	0.14 ppm
Carbon Monoxide	1-hour	5.08×10^{-6} ppm	35 ppm
Hydrocarbons	3-hour	2.93×10^{-4} ppm	0.24 ppm
Nitrogen Oxides	1-year	7.07×10^{-5} ppm	0.05 ppm

For this evaluation of the emissions from the auxiliary boilers, it can be seen that the emissions will have a negligible environmental impact.

6. Normal solid waste disposal - Normal solid waste disposal during plant operations will be accomplished by contract collection and disposal in a State-approved sanitary landfill.

(Revised) Table 2.5-1

SUMMARY OF ADDED CHEMICALS AND RESULTING END PRODUCT CHEMICALS

Watts Bar Nuclear Plant

Item No.	System	Chemical Treatment Source Chemical And Waste Products	Estimated Maximum Annual Use Lbs.	Waste End Product Chemical	Resulting End Product[a] Average Annual Lbs.	Resulting End Product[a] Mean Daily Lbs.
1	Makeup Water Filter Plant	Alum $Al_2(SO_4)_3 \cdot 18\ H_2O$	78,800	$Al(OH)_3$[b]	16,510	45
		Soda Ash Na_2CO_3	23,685	Na^+	10,300	28
				SO_4^{--}	30,600	84
				Settled Solids[b,c]	70,800	194
		Sodium Hypochlorite				
		NaOCl	770	Na^+	480[e]	<5.0
		NaCl	600	Cl^-	722[e]	<5.0
2	Makeup Water Demineralizer	Sulfuric Acid H_2SO_4 (93% Solution)	231,000	SO_4^{--} (Neutral pH)	217,000	595
		Sodium Hydroxide NaOH (50% Solution)	431,000	Na^+ (Neutral pH)	124,000	340
	Natural Minerals Removed by Demineralizers					
		Sodium Na^+	10,120	Na^+	10,120	28
		Chloride Cl^-	19,700	Cl^-	19,700	54
		Sulfate SO_4^{--}	21,750	SO_4^{--}	21,750	60
		Total Dissolved Solids	117,500	Dissolved Solids	117,500	322
3	Secondary Steam System Condensate Polishing Demineralizers[h]	Sulfuric Acid	590,100	SO_4^{--} (Neutral pH)	578,000	1580
		Sodium Hydroxide NaOH	353,500	Na^+ (Neutral pH)	203,260	560
	Ionized Soluble Species Removed by Demineralizers	-Carbonates (CO_3^{--})	25,400	CO_3^{--}	25,400	70
		-Ammonia (NH_4^+)	15,050	NH_4^+	15,050	41
		-Metallic Salts	d	d	d	d

(Revised) Table 2.5-1 (Cont)

SUMMARY OF ADDED CHEMICALS AND RESULTING END PRODUCT CHEMICALS

Watts Bar Nuclear Plant

Item No.	System	Chemical Added Source Chemical	Maximum Annual Use Lbs.	Waste End Product Chemical	Resulting End Product[a] Average Annual Lbs.	Resulting End Product[a] Mean Daily Lbs.
4	Auxiliary Steam Generator Blowdown	Ammonia NH_3	3[f]	NH_3	3	<0.1
		Hydrazine $H_2N_2H_2$	10[g]	NH_3	10	<0.1
5	Condenser Cooling[i] Water System	Sodium Hypochlorite				
		NaOCl	157,130	Na^+	97,050	265
		NaCl[i]	123,370	Cl^-	147,880	405
		<<Copper (corrosion product only)[k]		Cu	6,200	17
		<<Nickel (corrosion product only)[k]		Ni	690	1.9
6	Raw Cooling Water[i]	Sodium Hypochlorite				
		NaOCl	24,610	Na^+	15,575	43
		NaCl[j]	20,285	Cl^-	23,740	65
7	Raw Service Water[i] System	Sodium Hypochlorite				
		NaOCl	3,420	Na^+	2,165	6
		NaCl[j]	2,820	Cl^-	3,300	9
8	Essential Raw[i] Cooling Water	Sodium Hypochlorite				
		NaOCl	108,870	Na^+	67,280	185
		NaCL[j]	85,500	Cl^-	102,470	280

a. Items 1, 2, 4, 5, 6, 7, and 8 are based on 365 days/year operation at rated capacity. Item 3 based on 292 days/year operation at rated capacity.
b. Precipitated material that will make up the water treatment sludge on a day weight basis. Ultimately put in landfill. No discharge.
c. Estimates based on maximum suspended solids data observed at TRM 529.9.
d. The quantities of ionized soluble species continuously removed by the condensate demineralizers are predicated upon a primary to secondary leak rate or a condenser tube leak. These constituents will be discharged in the form of neutral salts of sodium, oxides of iron, or suspended solids. High crud filters will treat the backwash waste prior to discharge.
e. The residual chlorine and sodium consumed by the makeup demineralizers and ultimately discharged.
f. Ammonia will be added as needed to maintain pH of 9.0 in the system.
g. Hydrazine will be added as needed as a DO scavenger. Hydrazine conservatively assumed to decompose to ammonia.
h. Under radioactive conditions, this waste will be treated in the plants radwaste system.
i. Basis for calculated valves are shown elsewhere.
j. For each pound of equivalent chlorine as sodium hypochlorite produced, 0.785 pounds of sodium chloride are in the product solution.
k. Although copper and nickel will not be added to the systems, the values shown represent high estimates of corrosion losses. Actual losses are expected to be immeasurable.

Table 2.5-2

SUMMARY OF CHEMICAL DISCHARGES
Watts Bar Nuclear Plant

Waste Product Chemical	Mean[a] Annual Discharge of Product Chemical lbs.	Waste Product[b] Chemical Contribution to Discharge Concentration mg/l	Observed[c] Concentrations in River at TRM 529.9 mg/l		Concentrations[d] in Effluent CF = 2 mg/l		Concentrations in[e] River at Edge of Jet Mixing Zone mg/l	
			Mean	Maximum	Mean	Maximum	Mean	Maximum
Sulfates SO_4^{--}	847,350	6.960	12.4	18	31.76	42.96	14.34	20.50
Sodium Na^+	530,230	4.355	6.4	50	17.16	104.36	7.48	55.44
Chlorides Cl^-[f]	297,812	2.437	6.8	35	16.04	72.44	7.72	38.74
Ammonia NH_3	14,227	0.117	0.06	0.18	0.237	0.477	0.078	0.210
Copper Cu[g]	<<6,200	<<0.051	<0.020	0.09	<0.091	0.231	<0.271	1.041
Nickel Ni[g]	<<690	<<0.006	<0.067	0.29	<0.140	0.586	<0.743	3.196
Dissolved Solids	1,762,439	14.422	94	180	202.42	374.42	104.84	199.44

a. Based on 365 days/year operation at rated capacity.
b. Equivalent concentration of added chemical end products in blowdown.
c. TVA data January 1973 - December 1975.
d. Concentration factor of blowdown = 2.
e. Based on jet diffuser designed to mix nine volumes of river water with one volume of plant discharge.
f. Computation is for chlorides since the chlorine demand of the cooling water is such that no residual chlorine will be discharged.
g. Although no copper or nickel will be "added" in plant operation, the values cited represent high estimates of corrosion losses. Actual losses are expected to be immeasurable.

(Revised Sept. 1976)

TABLE 2.5-3

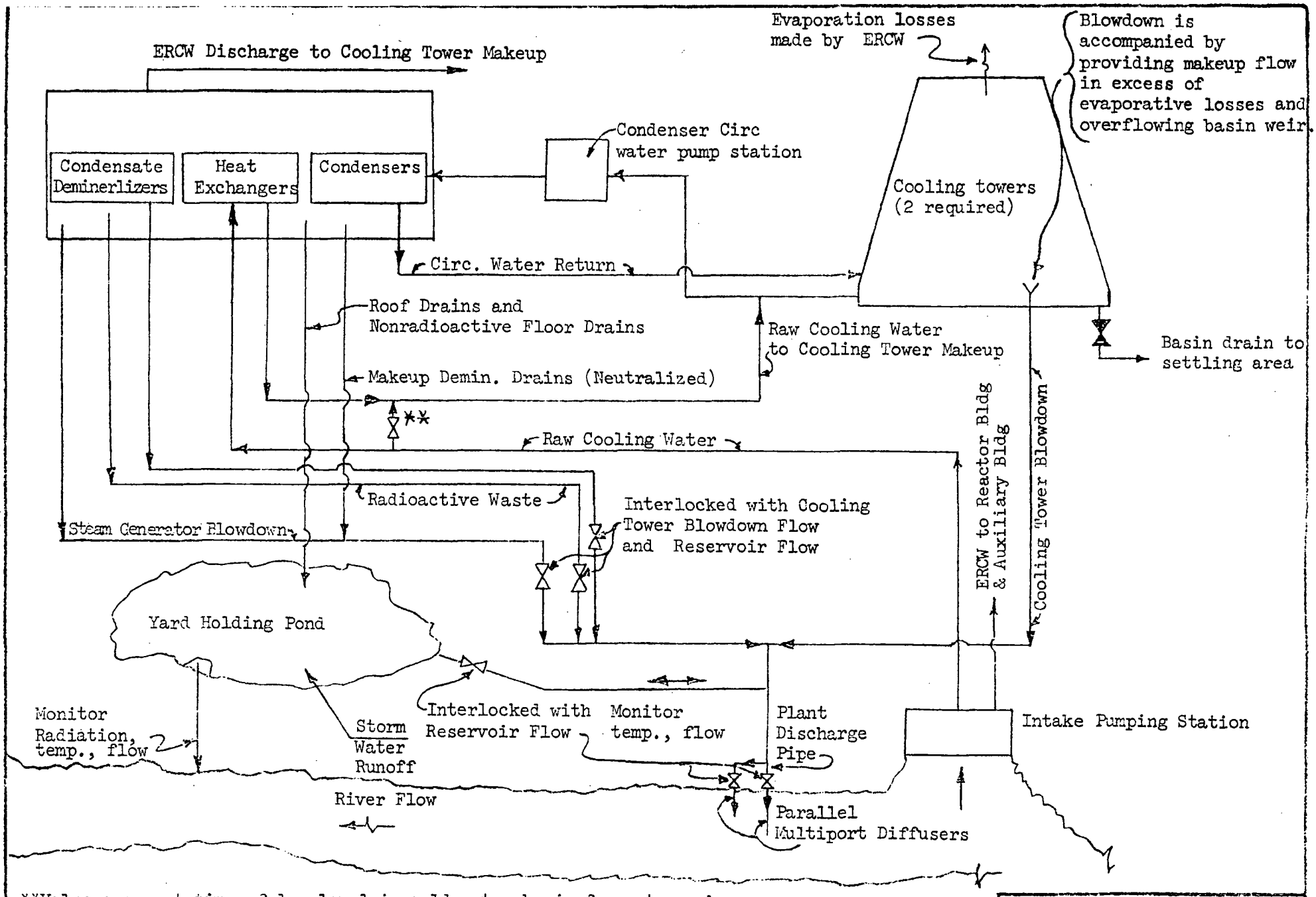
SUMMARY OF OBSERVED TRACE METAL CONCENTRATIONS AND EXPECTED TRACE METAL CONCENTRATIONS IN THE EFFLUENT AND AT THE EDGE OF THE JET MIXING ZONE

Parameter Total	Observed Concentrations at TRM 529.9 Jan 1973 - Dec 1975 µg/l			Expected Trace Metal Concentrations - µg/l			
				In Effluent: CF=2[a]		at Edge of jet Mixing[b] zone: CF=2	
	Maximum	Minimum	Mean	Mean	Maximum	Mean	Maximum
Iron	1,300	190	498	996	2,600	547.8	1,430
Zinc	70	<10	<20.5	<41	140	<22.6	77
Barium	<100	<100	<100	<200	<200	<110	<110
Beryllium	<10	<10	<10	<20	<20	<11	<11
Silver	<10	<10	<10	<20	<20	<11	<11
Aluminum	1,800	<200	705	1410	3,600	775.5	1,980
Selenium	<2	<1	<2	<4	<4	<2.2	<2.2
Arsenic	<10	<5	<5	<10	<20	<5.5	<11
Manganese	120	30	64	128	240	70.4	132
Lead	130	<10	15	30	260	16.5	143
Chromium	5	<5	<5	<10	10	<5.5	5.5
Cadmium	13	<1	<2	<4	26	<2.2	14.3
Mercury	1.0	<0.2	<0.3	<0.6	2	<0.33	1.1

a. Concentration factor of blowdown = 2

b. Based on jet diffuser designed to mix 9 volumes of river water with one volume of plant discharge

Revised September 1976



**Valve opens at time of low level in cold water basin for extra makeup.

FIGURE 2.5-1
FLOW DIAGRAM - DISCHARGE OF PLANT LIQUIDS
(REVISED)

SECTION C

AQUATIC BIOTA (NONFISH) DATA SUMMARY

WATTS BAR NUCLEAR PLANT

The preoperational aquatic biology (nonfish) monitoring program in the vicinity of Watts Bar Nuclear Plant was implemented in February 1973. The results of this monitoring program which are available as of September 1976 are summarized in this section. This summary contains additional information on the subject of subsection 1.1.3(9)(b) in TVA's "Final Environmental Statement - Watts Bar Nuclear Plant Units 1 and 2" dated November 9, 1972. The specific results included in this summary are as follows:

Phytoplankton	1973, 1974
Chlorophyll	1973, 1974, and 1975
Productivity	1973, 1974, and 1975
Benthos	1975
Mussels	1975 and 1976
Zooplankton	1973 and 1974
Periphyton (summer only)	1975

Additional samples have been collected, preserved, and are currently in various stages of processing in the laboratory including the following:

Plankton	1975 and 1976
Chlorophyll	1976
Productivity	1976
Benthos	1973, 1974, and 1975
Mussels	Current
Zooplankton	1975 and 1976
Periphyton (summer only)	1974

The results of the samples now in process along with those collected within the near future will be included in the preoperational monitoring report.

Also included at the end of this section is a summary of preoperational water quality and aquatic (nonfish) monitoring programs which have been implemented at Watts Bar Nuclear Plant. This program description incorporates the non-radiological portions of the monitoring program described in subsection 2.4

and the construction effects monitoring described in subsection 2.8 of the Watts Bar Nuclear Plant FES as well as those monitoring programs implemented for point-source discharges regulated under the FWPCA. In addition, the program description identifies the basis upon which the operational water quality and aquatic biology monitoring programs will be developed.

BIOLOGICAL ENVIRONMENTAL REVIEW

WATTS BAR NUCLEAR PLANT

I. Aquatic (Other Than Fish)

Biological samples for preoperational baseline data have been taken at seven locations on the Tennessee River since February 1973. These samples are taken quarterly each year (winter, spring, summer, and fall) at the following locations--TRM 496.5, 506.6, 518.0, 527.4, 528.0, 529.9 (Watts Bar Dam tailrace), and 532.1 (Watts Bar Reservoir forebay). Biological samples include phytoplankton, periphyton, zooplankton, and benthos. Sampling will continue as preoperational baseline monitoring and change to operational monitoring after initial criticality of the first unit.

The following baseline information has been compiled from biological data that have been analyzed.

A. Phytoplankton

1. Genera Diversity

a. Chrysophyta

The maximum number of Chrysophyta genera found were 13 different genera at TRM 528.0 during the winter of 1973 (table 1E). There were a minimum of three different genera at TRM 506.6 and 518.0 (tables 1B and 1C) during the fall of 1974. The diatom genera diversity was generally larger during the winter and spring of both years at all

stations (tables 1A-1E). More diatom genera were found upstream from TRM 496.5, reaching a maximum at TRM 529.9, but still high at TRM 532.1. Melosira, Navicula, Stephanodiscus, and Synedra were generally found at all stations during all seasons. Asterionella was found more frequently from TRM 527.4 to TRM 532.1 than below 527.4. Certain other genera were found more often at certain river miles as shown in tables 1A-1E.

b. Chlorophyta

There were a maximum of 21 different Chlorophyta genera found at TRM 528.0 during the summer of 1973 (table 2E). The minimum number of genera found was one genera at TRM 496.5 and TRM 532.1 during the winter of 1973 (tables 2A and 2G) and at TRM 506.6 during the fall of 1974 (table 2B). The green algae genera diversity was larger during the summer than other seasons, but spring and fall seasons showed a high diversity on occasion and at certain locations (tables 2A-2G). TRM 528.0 and TRM 532.1 are generally the dominant Chlorophyta stations according to genera diversity, with minimum genera found at TRM 506.6, and the other stations are similar. Chlamydomonas and Scenedesmus were generally found at all stations during all seasons.

c. Cyanophyta

A maximum of four different genera were found at TRM 527.4, 528.0, 529.9, and 532.1 during the summer of 1973 (tables 3D-3G). Each of the seven stations had only one genera present during at least three or more of the eight sampling trips during 1973 and 1974. The blue-green algae genera was more prevalent during the summer months than any other season, and genera numbers during the fall were more than winter and spring. *Dactylacoccopsis* was found at every station during every season during 1973 and 1974.

2. Group Composition and Enumeration

Table 4 shows the percent composition of Chrysophyta, Chlorophyta, and Cyanophyta cells. Chrysophyta cells were dominant at all stations in 1973 during winter, spring, and fall and at all stations during all seasons in 1974. Chlorophyta cells were dominant during the summer of 1973 at all stations except TRM 529.9 where Cyanophyta cells were dominant.

Table 4 also shows the numerical evaluation of each group. Over 1 million Chrysophyta cells/l were found on two occasions. During the spring of 1973 1,019,000 cells/l were found at TRM 532.1 and 1,126,000 cells/l were found at the same location during the spring of 1974. The minimum number of Chrysophyta cells found were 67,000/l and occurred at TRM 496.5 during the

winter of 1974. Over 1 million Chlorophyta cells/1 were also found on two occasions. At TRM 528.0 1,094,000 cells/1 were found, and 1,211,000 cells/1 were found at TRM 532.1 during the summer of 1973. The minimum number of Chlorophyta cells found were 2,000/1, and this occurred at TRM 532.1 during the winter of 1973. Over 1 million Cyanophyta cells/1 were found on only one occasion and this was during the summer of 1973 when 1,033,000 cells/1 were found at TRM 532.1. The minimum number of Cyanophyta cells/1 found were 1,000 cells/1 and this occurred at TRM 496.5 during the winter of 1974.

Generally, larger phytoplankton populations progressed upstream from TRM 496.5 with the largest population occurring in the forebay area at TRM 532.1. All numerical evaluations are rounded to the nearest 1,000/1. Some Englenophyta and Pyrophyta genera were found, but always less than 5 percent of the total algal composition and are not included in this report.

3. Chlorophyll a

Table 5 shows the concentrations of chlorophyll a extracted from the phytoplankton during the winter, spring, summer, and fall seasons of 1973, 1974, and 1975 at each station and are expressed as mg chl. a/m^2. This plant pigment content

measurement is used as a measure of phytoplankton standing stock to compliment the phytoplankton enumeration and productivity measurements.

Plant pigment biomass of the phytoplankton increased upstream from TRM 496.5 to TRM 532.1. During the fall of 1974 the concentrations of chlorophyll a were generally higher than any other season during 1973, 1974, and 1975. Minimum values were found during the spring of 1975. The lowest value of chlorophyll a was 2.62 mg chl. a/m^2 found at TRM 506.6 during the spring of 1975. The highest chlorophyll a concentration was 37.87 mg chl.a/m^2 and was found at TRM 532.1 during the fall of 1974.

4. Phytoplankton Productivity

Carbon-14 was used for measuring phytoplankton productivity. Productivity during the incubation period was extrapolated to the total per day based on a ratio of total incident light during the incubation period. Table 6 shows the phytoplankton productivity expressed as mg C/m^2/day at each station during 1973, 1974, and 1975. Physical factors such as solar radiation, secchi disc visibility depth, and water temperature are shown on this table.

Phytoplankton productivity generally increases upstream from TRM 496.5 with maximum productivity values occurring in the forebay area at TRM 532.1. Higher productivity values usually

occur during the summer months with the highest average value for all stations occurring during the summer of 1973 (1009 mg C/m^2/day). Lowest average value was 58 mg C/m^2/day and occurred during the winter of 1975. The lowest single value was 9 mg C/m^2/day at TRM 496.5 during the winter of 1975 and the highest single value was 1,590 mg C/m^2/day at TRM 532.1 during the summer of 1973.

5. Phytoplankton Summary

All phytoplankton parameters (enumeration, composition, chlorophyll a, and productivity) exhibit a similar normal and healthy pattern for the mainstream Tennessee River. Seasonal variations of turbidity, temperature, and flow tend to vary these patterns depending on the severity and duration of these physical factors. The forebay area at TRM 532.1 is the most active for phytoplankton due to water retention time and clarity of the water. All phytoplankton activity increases progressively from TRM 496.5 to TRM 532.1. Minimal values are shown during the winter months, increasing in the spring, to a maximum in the summer, and usually tapering off in the fall season.

B. Periphyton

Periphyton organisms are communities of organisms which grow upon but do not penetrate into a submerged substrate. This includes but is not limited to bacteria, fungi, algae, protozoans, rotifers, and other small organisms.

1. Autotrophic Index

The biomass-chlorophyll a relationship, the autotrophic index, is used to evaluate various effects on the periphyton communities. Two quantities are necessary for the calculation of the autotrophic index (1) the ash free organic weight and (2) the concentration of chlorophyll a, thus using the following formula:

$$\frac{\text{Ash-free organic weight } (mg/m^2)}{\text{Chlorophyll } a \ (mg/m^2)} = \text{Autotrophic Index}$$

Smaller values of the index indicate that the periphyton community is having optimal growth. Larger numbers indicate that the community is experiencing some type of stress (turbidity, season, toxicity, etc.).

Artificial substrates (Plexiglas plates) are exposed during two periods each summer with each period having a 2-week colonization time. These periods are selected during the summer months which is the maximum periphyton growth period. Tables 7A and 7B show the autotrophic index average for each station and an analysis of variance of these means. During June of 1975 TRM 529.9 shows optimal autotrophic growth which was significantly different from only the growth at TRM 496.5. During August of 1975 the autotrophic growth is greatest at TRM 527.4 followed by good growth at TRM 529.9. TRM 527.4, 529.9, 528.0

and 506.6 are not significantly different during August. Healthy autotrophic growth of the periphyton community is shown during the summer of 1975 through the studied reach of the river.

C. Zooplankton

Zooplankton enumeration data for 1973 and 1974 are shown in tables 8-14, indicating species numbers for each station during the 2-year period. Also shown are percentage composition values for the three zooplankton groups (Rotatoria, Cladocera, and Copepoda) as they occurred in each season and year. In table 15, zooplankton enumerations are summarized by showing group totals and total numbers for each station and season. A yearly summary of zooplankton enumeration by groups is shown in table 16, supplying mean population numbers for 1973, 1974, and combined years. In tables 17-23 zooplankton taxa identified at each station are shown as they occurred throughout the sampling period.

The pattern of dominance for the zooplankton group Rotatoria was varied as numerous species of the genera Asplanchna, Brachionus, Conochiloides, Conochilus, Keratella, Ploesoma, Polyarthra, and Synchaeta comprised a major part of the rotifer population. The highest concentration of any one species occurred in the summer of 1973 at Tennessee River mile (TRM) 529.9 and 532.1 when Brachionus angularis reached densities of 110,309 organisms per cubic meter and 92,296 organisms per cubic meter, accounting for 45 percent and 35 percent of their respective rotifer populations. The highest single species concentration in 1974 occurred in the fall at TRM 532.1 when Keratella earlinae reached a density of 24,281 organisms per cubic meter (43

percent of the rotifer population). A high variability occurred between the 1973 and 1974 zooplankton standing crops and is best illustrated by noting that Brachionus angularis, which reached a 110,309 organism per cubic meter concentration in 1973, only appeared in concentrations reaching a maximum of 334 organisms per cubic meter in 1974 (99.7% reduction). Reductions occurred in the 1974 rotifer standing crop numbers for most species and are reflected in the total zooplankton enumerations (combined group numbers) at every sampling station.

The zooplankton group Cladocera was dominated by a single species, Bosmina longirostris, which reached a standing crop maximum of 74,732 organisms per cubic meter (96 percent of the Cladoceran standing crop) in the spring of 1973 at TRM 528.0. 1974 population numbers for the Cladocera were lower than those of 1973 for the winter, spring, and summer seasons, but higher in the fall.

Copepoda population numbers were dominated by the immature forms; i.e., Calanoid and Cyclopoid Copepodids and Nauplii. The total Copepod standing crop numbers for 1973 and 1974 were similar.

Total zooplankton numbers for the 2-year period ranged from a summer high of 344,437 organisms per cubic meter at TRM 532.1 (1973) to a fall low of 1,925 organisms per cubic meter at TRM 496.5 (1973). Tennessee River mile 532.1, Watts Bar Dam Reservoir forebay, produced the highest standing crop numbers for every season of 1973 and 1974 with the exceptions of the winter sampling period for both years at TRM 528.0 where population numbers were only slightly elevated above those of the forebay station.

Zooplankton standing crop numbers were larger in the spring and summer of 1973 and in the spring and fall of 1974. Population numbers for 1974 showed a combined station reduction of 60 percent below the 1973 population estimates. A similar reduction occurred at every station during 1974 and ranged from 23 percent at TRM 496.5 to 76 percent at TRM 518.0.

The largest number of taxa identified for Rotatoria, Cladocera, Copepoda, and combined groups occurred in the spring of 1974 at TRM 496.5 with 22, 11, 12, and 45 respectively. Eleven taxa of Cladocera were also identified in the spring of 1973 at TRM 506.6 and TRM 532.1. The smallest number of taxa identified for Rotatoria was 5 at TRM 506.6 and TRM 518.0 in fall of 1973. The smallest number of taxa identified for the Cladocera occurred at TRM 506.6 (winter 1973) when only Bosmina longirostris was encountered. The smallest number of taxa for combined groups was 19 and occurred at TRM 506.6 in the summer of 1974.

D. Benthos

1. Other Than Mussels

During the 1975 study period, benthic samples were collected from Chickamauga Reservoir in the vicinity of the Watts Bar Nuclear Plant. Artificial substrates were selected as the method for sampling the benthic fauna because of physical difficulties associated with the quantitative sampling of the natural substrate. Each artificial substrate was a cylinder-shaped barbeque basket filled with rocks and had a volume of 7,675.2 cm^3. Substrates were allowed to colonize for a period of 30 days. Tennessee River Mile (TRM) 518.0 and 527.4 were the only stations from which one or more substrate collections were made in every quarter

during 1975. Station TRM 528.0 was also included in this report since artificial substrates were recovered in every quarter with the exception of the fall quarter.

From these samples, 14 benthic macroinvertebrate taxa were identified (table 24). Insects were the most diverse group with seven taxa (three chironomid midges, one mayfly, and three caddisflies). Following the insects were aquatic worms (two taxa), crustaceans (two taxa), bryozoa, flatworms, and leaches (each with one taxon).

Macrobenthic species diversity data are shown in table 25. The greatest number (12) of taxa were collected at TRM 518.0 during 1975, while eight taxa were collected from both TRM 527.4 and 528.0. Species collected during the summer quarter at each river mile were the crayfish Orconectes sp., the midge Chironomus sp., the mayfly Stenonema sp., and the caddisfly Cyrnellus marginalis (BANKS). The caddisfly Cheumatopsyche sp. was found at each of the three stations during the spring quarter.

Macrobenthic enumeration data are shown in tables 26-28. The most organisms collected during 1975 were 42 organisms/substrate during the spring quarter from TRM 527.4. This station also yielded the greatest average number (33) of organisms per substrate.

The average number of organisms per substrate (seasons combined) were 15.3 and 16.1 for TRM 518.0 and 527.4, respectively. Station 528.0 was not included because data were not available for the fall quarter.

D. Benthos

2. Other Aquatic Forms

Freshwater Mussels--Historically there has been a large and diverse mussel fauna below Watts Bar Dam in the Tennessee River. Scruggs (1960) reported results of an extensive mussel study in the Tennessee River mile (TRM) area 498-519 below the Watts Bar Nuclear Plant site. Table 29 provides some population data from Scruggs' findings. Basically, his other data showed that mussels were being depleted by commercial harvest at a rate significantly higher than natural recruitment to the population. Isom (1969) found that mussel population around and downstream of the site area had declined significantly during the interim between Scruggs' studies (1956-1957) and the period of his study (1964), table 30. Isom (1969) showed the relationship between declining mussel harvest and increase in price given per ton of shells (figure 1). The graph illustrates a classic example of over exploitation. His data (table 31) showed that price paid for shells was essentially doubled for post 1960 years, while catch per boat declined as compared with earlier harvest during the period 1945-1959.

As a result of the latter study and recommendations, the Tennessee Game and Fish Commission issued proclamation no. 153 (1967) declaring "that area of the Tennessee River (Chickamauga

Reservoir) between the Rhea navigation light (River mile 526.3) and Watts Bar Dam" as sanctuaries, and musseling is prohibited.

Commercial harvesting in the area, immediately downstream of the sanctuary, has essentially ceased since the late 1960's, with the last official tonnage harvested reported in 1970. Reference was made to minor harvests in 1973 and 1974.

Presently, the mussel fauna below Watts Bar Dam is represented by at least 13 species (table 32). Virtually all of these species "prefer" a substrate of firm porous gravel or sand and gravel with a moderate to swift current. Based on findings of surveys, July and August 1975 and May and August 1976, the most suitable mussel habitat is on the left bank in the vicinity of TRM 520.5 to 521.3 and 527.6 to 528.5, variability was greater in the TRM 527.6 to 528.5 area. The numbers found per unit effort by SCUBA diving indicate the 520.5 to 521.5 has the greater population density. SCUBA efforts also revealed a good localized population in the TRM 527.7 area. Many mussels collected from the latter area were eroded and abraded while those from the TRM 520.8 vicinity were in excellent condition, especially the commercially valuable Pleurobema cordatum (pigtoe). The swift current in the upstream area may account for this difference in shell quality.

The mussel population at TRM 520.5 to 528.5 is apparently reproducing since animals as young as 5 years old were found.

While TVA does not consider any species found below Watts Bar Dam to be endangered or threatened, the U.S. Fish and Wildlife

Service declared *Lampsilis orbiculata* to be endangered in Federal Register, vol. 41, No. 115, June 14, 1976. The notice in the Federal Register indicates that this specie's known distribution range includes Green R., Kentucky; Kanawha River in West Virginia; Tennessee River (Tennessee and Alabama); Muskingum River, Ohio. Isom (1969) reported finding *L. orbiculata* from the Kentucky Dam tailwater all the way upstream to Watts Bar Dam tailwater.

The Asiatic clam (Corbicula manilensis) has become prominent in the benthos of the Tennessee River in the vicinity of the Watts Bar site during the past decade. Densities vary from a few individuals to hundreds per square meter, depending on type of substrate and water currents. Representative data taken in 1976 are shown in table 33.

Scruggs, G. D. Jr., 1960. Status of Freshwater Mussel Stocks in the Tennessee River. U.S. Fish and Wildlife Ser., Spec. Rpt., Fisheries No. 370:1-41.

Isom, Billy G. The Mussel Resource of the Tennessee River. Malocologia, 7(2-3):397-425.

Table 1A

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 496.5

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Asterionella	x			x		x		
Cocconeis							x	x
Cyclotella	x			x		x		
Cymbella		x						
Diatoma					x			
Dinobryon		x	x			x	x	
Fragilaria		x						
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x	x	x	x	x	x
Nitzschia				x				
Rhizosolenia		x	x				x	
Stephanodiscus		x		x	x			
Surirella					x			
Synedra	x	x	x	x	x	x	x	x
Tabellaria								x
Eunotia			x					
Mallomonas		x						
Total Genera	5	9	6	7	6	6	6	5

Table 1B

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 506.6

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Achnanthes							x	
Asterionella	x	x			x	x		
Cyclotella	x							
Cymbella	x	x			x		x	
Dinobryon	x	x						
Fragilaria						x		
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x	x		x	x	
Pinnularia	x							
Rhizosolenia			x					
Stephanodiscus	x	x		x	x	x	x	x
Surirella	x							
Synedra	x	x	x	x	x	x	x	x
Eunotia	x	x	x			x		
Mallomonas	x	x						
Chaetoceros				x	x			
Attheya							x	
Total Genera	12	9	5	5	6	7	7	3

Table 1C

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 518.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Asterionella	x	x				x		
Cyclotella	x	x	x	x	x	x		
Cymbella	x	x				x		
Dinobryon	x		x				x	
Fragilaria						x	x	
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x		x	x	x	x
Pleurosigma		x						
Rhizosolenia			x					
Stephanodiscus		x		x	x	x	x	
Surirella	x							
Synedra	x	x	x	x	x	x	x	x
Tabellaria					x			
Eunotia			x					
Mallomonas	x							
Chaetoceros			x					
Total Genera	9	8	8	4	6	8	6	3

Table 1D

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 527.4

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Achnanthes								x
Asterionella	x	x			x	x	x	x
Cyclotella	x	x		x				x
Cymbella	x				x	x		
Diatoma		x			x			
Dinobryon	x	x				x		
Fragilaria						x		
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x			x	x	
Pinnularia	x							
Rhizosolenia			x					
Stephanodiscus		x		x	x	x		
Surirella						x		
Synedra	x	x	x	x	x	x	x	x
Eunotia			x			x		
Meridion								
Rhiocosphenia								
Mallomonas	x	x				x		
Chaetoceros			x		x			
Total Genera	9	9	6	4	7	11	4	5

Table 1E

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 528.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Achnanthes								x
Asterionella	x	x		x	x	x		x
Cyclotella	x			x	x	x		
Dinobryon	x	x				x		
Fragilaria	x	x				x		x
Gomphonema	x							
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x	x	x	x	x	x
Pleurosigma	x							
Rhizosolenia			x					
Stephanodiscus	x	x				x	x	
Surirella	x							
Synedra	x	x	x		x	x	x	x
Tabellaria						x	x	
Eunotia	x		x					
Mallomonas	x	x						
Chaetoceros				x	x			
Total Genera	13	8	5	5	6	9	5	6

Table 1F

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 529.9

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Asterionella	x	x		x		x	x	x
Cocconeis							x	x
Cyclotella	x	x		x		x		
Cymbella	x	x		x				
Diatoma								x
Dinobryon	x	x						
Fragilaria	x	x			x	x	x	
Gomphonema				x				
Gyrosigma		x						
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x	x	x	x		x
Rhizosolenia		x	x					
Stephanodiscus	x	x	x	x	x	x		
Synedra	x	x	x	x	x	x	x	x
Eunotia			x					
Mallomonas	x							
Chaetoceros			x	x	x			
Total Genera	10	11	7	9	6	7	5	6

Table 1G

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 532.1

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chrysophyta								
Achnanthes								x
Asterionella	x	x			x	x	x	x
Cocconeis						x		
Cyclotella	x	x	x	x				
Cymbella							x	
Diatoma		x						
Dinobryon	x					x	x	
Fragilaria		x	x			x	x	
Melosira	x	x	x	x	x	x	x	x
Navicula	x	x	x		x			x
Pleurosigma		x						
Rhizosolenia			x				x	
Stephanodiscus	x	x			x	x		x
Synedra	x	x	x	x	x	x	x	x
Tabellaria						x		
Eunotia			x					
Mallomonas	x	x						
Chaetoceros			x	x	x			x
Total Genera	8	10	8	4	6	8	7	7

Table 2A

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 496.5

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum		x				x	x	
Ankistrodesmus		x	x					
Chodatella						x	x	
Chlamydomonas		x	x	x	x	x	x	x
Chlorella			x			x	x	x
Coelastrum			x			x		
Crucigenia				x				
Dactylococcus					x			
Dictyosphaerium			x	x	x	x		
Eudorina							x	
Micractinium		x	x	x		x	x	
Pandorina		x	x					
Pediastrum			x	x		x	x	
Scenedesmus	x	x	x	x	x	x	x	x
Staurastrum			x					
Tetraspora			x			x		
Golenkinia			x			x		
Kirchneriella				x				
Ulothrix						x		
Oocystis						x	x	
Treubaria			x					
Planktosphaeria			x	x	x	x		
Schroederia							x	
Total Genera	1	6	14	8	5	14	10	3

Table 2B

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 506.6

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum		x	x					
Ankistrodesmus			x					
Chodatella							x	
Chlamydomonas	x	x	x	x	x	x	x	
Chlorella			x			x	x	x
Coelastrum			x				x	
Crucigenia			x					
Dictyosphaerium	x		x				x	
Micractinium			x	x				
Pandorina		x	x					
Pediastrum			x					
Scenedesmus	x	x	x	x	x	x	x	
Staurastrum			x					
Tetraspora	x	x						
Kirchneriella			x	x				
Ulothrix	x							
Oocystis	x					x		
Treubaria			x					
Planktosphaeria	x		x	x	x	x		
Total Genera	7	5	16	5	4	6	6	1

Table 2C

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 518.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum		x	x					
Ankistrodesmus			x	x				
Arthrodesmus								x
Chodatella								x
Chlamydomonas	x	x	x	x	x	x	x	
Chlorella			x			x	x	x
Coelastrum		x	x				x	
Crucigenia			x				x	
Dictyosphaerium	x		x	x				
Micractinium			x				x	
Pandorina		x	x			x		
Pediastrum			x					
Scenedesmus	x	x	x	x	x	x	x	x
Staurastrum			x					
Tetraspora	x		x	x				
Sphaerocystis						x		
Golenkinia			x	x		x		
Kirchneriella			x					
Ulothrix	x							
Oocystis	x							
Treubaria			x	x		x	x	
Planktosphaeria			x	x	x	x		
Pleodorina			x					
Schroederia							x	
Total Genera	6	5	18	8	3	8	8	4

Table 2D

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 527.4

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum		x	x	x				x
Ankistrodesmus			x					
Chodatella						x		x
Chlamydomonas	x		x	x	x	x	x	x
Chlorella			x			x	x	x
Coelastrum			x	x		x	x	
Crucigenia			x	x			x	
Dictyosphaerium	x		x	x			x	
Eudorina							x	
Micractinium			x					
Pandorina		x	x					
Pediastrum			x					x
Scenedesmus	x	x	x	x		x	x	x
Staurastrum			x					
Tetraspora						x		
Tetraedron							x	
Golenkinia			x	x	x			
Kirchneriella			x					
Ulothrix	x							
Oocystis	x						x	x
Treubaria			x					
Planktosphaeria			x	x	x	x		
Botryoccus			x					
Schroederia							x	
Total Genera	5	3	17	8	3	7	10	6

Table 2E

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 528.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum			x	x				
Ankistrodesmus		x	x					
Chodatella						x		x
Chlamydomonas	x	x	x	x	x		x	x
Chlorella			x			x	x	x
Coelastrum			x	x		x	x	x
Cosmarium		x						
Crucigenia			x				x	
Dictyosphaerium			x	x			x	
Eudorina			x				x	
Micractinium			x				x	
Pandorina		x	x			x	x	x
Pediastrum			x	x			x	
Scenedesmus	x	x	x	x		x	x	x
Staurastrum			x				x	
Tetraspora	x		x			x		
Sphaerocystis						x		
Golenkinia			x	x	x			
Kirchneriella			x					
Ulothrix	x							
Oocystis			x			x	x	x
Treubaria			x	x		x		
Planktosphaeria			x	x	x	x		
Pleodorina			x					
Botryococcus			x					
Platydorina							x	
Schroederia							x	
Total Genera	4	5	21	9	3	10	14	7

Table 2F

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 529.9

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum			x					
Ankistrodesmus			x	x				
Chodatella								x
Chlamydomonas	x	x	x	x	x	x	x	x
Chlorella			x			x	x	x
Coelastrum		x	x			x	x	
Crucigenia			x		x		x	
Dictyosphaerium	x				x			
Micractinium			x	x				
Pandorina		x	x			x	x	
Pediastrum			x	x				
Scenedesmus	x	x	x	x	x	x	x	x
Staurastrum			x				x	
Tetraspora	x	x	x	x		x		
Sphaerocystis							x	
Golenkinia			x	x	x			
Kirchneriella			x					
Ulothrix	x							
Oocystis						x	x	x
Treubaria			x					
Planktosphaeria			x	x	x			
Pleodorina			x					
Total Genera	5	5	17	8	6	7	9	5

Table 2G

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 532.1

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Chlorophyta								
Actinastrum			x	x				x
Ankistrodesmus			x					
Chodatella						x		x
Chlamydomonas	x	x	x	x	x	x	x	x
Chlorella			x			x	x	x
Coelastrum		x	x			x	x	
Crucigenia			x	x			x	
Dactylococcus					x	x		
Closteriopsis							x	
Dictyosphaerium			x	x			x	
Eudorina							x	
Micractinium			x				x	
Pandorina		x	x	x	x	x	x	
Pediastrum			x				x	
Scenedesmus		x	x	x	x	x	x	x
Staurastrum			x					
Tetraspora		x	x	x				
Sphaerocystis						x	x	
Gonium							x	
Golenkinia			x	x	x	x		
Kirchneriella			x	x				
Oocystis		x	x				x	
Treubaria			x	x				
Planktosphaeria			x	x	x	x		
Closterium						x		
Pleodorina			x					
Schroedoria							x	
Total Genera	1	6	19	11	6	11	15	5

Table 3A

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 496.5

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x				x	
Oscillatoria							x	x
Phormidium			x					
Total Genera	1	1	3	1	1	1	3	2

Table 3B

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 506.6

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x					
Oscillatoria							x	x
Phormidium			x					
Total Genera	1	1	3	1	1	1	2	2

Table 3C

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 518.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Anabaena	x							
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x			x		
Oscillatoria							x	x
Phormidium			x					
Total Genera	2	1	3	1	1	2	2	2

Table 3D

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 527.4

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x					
Microcystis			x					
Oscillatoria							x	x
Phormidium			x					
Total Genera	1	1	4	1	1	1	2	2

Table 3E

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 528.0

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x			x		
Microcystis			x					
Oscillatoria							x	x
Phormidium			x					
Total Genera	1	1	4	1	1	2	2	2

Table 3F

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 529.9

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x					
Microcystis			x					
Oscillatoria							x	x
Phormidium			x					
Total Genera	1	1	4	1	1	1	2	2

Table 3G

Watts Bar Nuclear Plant - Phytoplankton Occurrence
TRM 532.1

	1973				1974			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Cyanophyta								
Dactylococcopsis	x	x	x	x	x	x	x	x
Merismopedia			x				x	
Microcystis			x					
Oscillatoria								x
Phormidium			x					
Total Genera	1	1	4	1	1	1	2	2

Table 4

WATTS BAR NUCLEAR PLANT

PHYTOPLANKTON ENUMERATION AND PERCENTAGES

	1973								1974							
	Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
TRM	Avg. No./l	%	Avg. No./l	%	Avg. No./l	%	Avg. No./l	%	Avg. No./l	%	Avg. No./l	%	Avg. No./l	%	Avg. No/l	%
496.5																
Chrysophyta	560,000	(96)	410,000	(80)	207,000	(39)	119,000	(64)	67,000	(70)	348,000	(55)	130,000	(50)	85,000	(70)
Chlorophyta	5,000	(1)	77,000	(15)	252,000	(47)	61,000	(33)	28,000	(29)	247,000	(39)	101,000	(39)	32,000	(26)
Cyanophyta	18,000	(3)	27,000	(5)	76,000	(14)	7,000	(3)	1,000	(1)	35,000	(6)	29,000	(11)	4,000	(4)
Total	583,000		514,000		535,000		187,000		96,000		630,000		260,000		121,000	
506.6																
Chrysophyta	731,000	(71)	282,000	(84)	204,000	(23)	76,000	(60)	69,000	(70)	368,000	(78)	79,000	(54)	105,000	(81)
Chlorophyta	242,000	(24)	44,000	(13)	439,000	(51)	42,000	(33)	25,000	(25)	91,000	(19)	60,000	(41)	23,000	(18)
Cyanophyta	44,000	(5)	8,000	(3)	224,000	(26)	8,000	(7)	5,000	(5)	14,000	(3)	7,000	(5)	2,000	(1)
Total	1,022,000		334,000		867,000		126,000		99,000		473,000		146,000		130,000	
518.0																
Chrysophyta	749,000	(77)	426,000	(81)	523,000	(29)	135,000	(63)	90,000	(78)	466,000	(79)	108,000	(55)	224,000	(74)
Chlorophyta	177,000	(18)	74,000	(14)	781,000	(44)	65,000	(31)	23,000	(20)	76,000	(13)	85,000	(44)	65,000	(21)
Cyanophyta	43,000	(5)	25,000	(5)	483,000	(27)	13,000	(6)	2,000	(2)	48,000	(8)	2,000	(1)	14,000	(5)
Total	973,000		525,000		1,787,000		213,000		115,000		590,000		195,000		303,000	
527.4																
Chrysophyta	517,000	(84)	777,000	(93)	677,000	(31)	206,000	(60)	142,000	(84)	712,000	(83)	266,000	(56)	373,000	(73)
Chlorophyta	58,000	(10)	44,000	(6)	854,000	(39)	125,000	(36)	20,000	(12)	118,000	(14)	205,000	(43)	115,000	(23)
Cyanophyta	38,000	(6)	12,000	(2)	650,000	(30)	12,000	(4)	7,000	(4)	30,000	(3)	4,000	(1)	21,000	(4)
Total	613,000		833,000		2,181,000		343,000		169,000		860,000		475,000		509,000	
528.0																
Chrysophyta	624,000	(90)	613,000	(88)	823,000	(28)	277,000	(63)	219,000	(85)	778,000	(81)	394,000	(61)	407,000	(76)
Chlorophyta	47,000	(7)	70,000	(10)	1,094,000	(38)	151,000	(34)	26,000	(10)	145,000	(15)	251,000	(38)	111,000	(21)
Cyanophyta	20,000	(3)	14,000	(2)	998,000	(34)	13,000	(3)	12,000	(5)	41,000	(4)	2,000	(1)	14,000	(3)
Total	691,000		697,000		2,915,000		441,000		257,000		964,000		647,000		532,000	
529.9																
Chrysophyta	680,000	(83)	643,000	(89)	701,000	(28)	273,000	(61)	129,000	(75)	901,000	(81)	245,000	(70)	350,000	(79)
Chlorophyta	96,000	(12)	68,000	(9)	874,000	(35)	138,000	(31)	35,000	(20)	168,000	(15)	102,000	(29)	72,000	(16)
Cyanophyta	44,000	(5)	12,000	(2)	929,000	(37)	34,000	(8)	9,000	(5)	38,000	(4)	2,000	(1)	23,000	(5)
Total	820,000		723,000		2,504,000		445,000		173,000		1,107,000		349,000		445,000	
532.1																
Chrysophyta	423,000	(94)	1,019,000	(77)	941,000	(30)	328,000	(62)	133,000	(71)	1,126,000	(82)	712,000	(64)	400,000	(77)
Chlorophyta	2,000	(1)	279,000	(21)	1,211,000	(38)	168,000	(32)	44,000	(24)	233,000	(17)	389,000	(35)	92,000	(18)
Cyanophyta	24,000	(5)	33,000	(2)	1,033,000	(32)	29,000	(6)	9,000	(5)	21,000	(1)	16,000	(1)	25,000	(5)
Total	449,000		1,331,000		3,185,000		525,000		186,000		1,380,000		1,117,000		517,000	

Table 5

WATTS BAR NUCLEAR PLANT

CHLOROPHYLL A EXPRESSED IN mg Chl. A/m^2

TRM	1973 Winter	1973 Spring	1973 Summer	1973 Fall	1974 Winter	1974 Spring	1974 Summer	1974 Fall	1975 Winter	1975 Spring	1975 Summer	1975 Fall	Station $\bar{x}$
496.5	-	4.06	3.04	6.76	1.69	14.02	5.80	7.86	9.06	4.27	-	8.57	6.51
506.6	13.69	2.30	19.01	10.05	10.16	6.00	3.28	15.60	11.13	2.62	9.19	3.33	8.86
518.0	16.63	6.39	19.92	7.02	10.95	9.93	9.80	27.02	15.04	4.26	9.22	4.89	11.76
527.4	18.85	9.58	20.97	11.57	16.08	13.65	15.39	35.24	14.38	6.19	11.15	10.46	15.29
528.0	16.46	11.10	18.01	18.72	12.68	19.36	17.63	36.79	10.90	5.25	10.22	11.34	15.70
524.9	16.52	10.18	31.45	15.59	9.89	17.90	14.27	34.05	16.05	2.80	10.37	12.89	16.00
532.1	15.91	26.87	-	17.82	12.10	32.26	37.00	37.87	12.24	7.68	26.03	23.64	22.67
Season $\bar{x}$	16.34	10.07	18.73	12.49	12.20	16.20	14.74	27.78	12.68	4.72	12.70	10.73	

Table 6

WATTS BAR NUCLEAR PLANT

PHYTOPLANKTON PRODUCTIVITY EXPRESSED IN mg C/day/m^2

TRM	1973 Winter	1973 Spring	1973 Summer	1973 Fall	1974 Winter	1974 Spring	1974 Summer	1974 Fall	1975 Winter	1975 Spring	1975 Summer	1975 Fall	Season $\bar{x}$
496.5	130	157	400	33	45	328	140	48	9	311	220	127	162
506.6	258	75	313	47	21	115	182	50	58	733	240	123	185
518.0	329	157	842	98	33	176	380	151	67	502	246	100	229
527.4	359	210	1488	159	36	313	575	242	73	588	290	361	391
528.0	322	214	1359	243	36	298	728	267	72	553	327	349	397
529.9	255	181	1074	241	28	229	498	261	59	253	268	391	311
532.1	375	558	1590	419	40	468	1356	322	71	211	1294	387	591
Season $\bar{x}$	290	222	1009	177	34	275	551	192	58	448	412	263	
Langleys/Day on Incubation Date	336	345	499	232	226	98	185	271	62	421	295	254	
Secchi Disc Visibility	1.10M	1.50M	1.50M	1.25M	0.80M	125M	2.40M	1.15M	0.55M	1.80M	1.75M	1.15M	
Water Temp. @ 1 Meter (^{o}F)	44.3	67.7	77.7	58.2	46.8	66.3	78.1	59.6	47.3	65.0	81.2	63.8	

Table 7A

Watts Bar Periphyton Autotrophic Index
June 1975

Analysis of Variance

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value
Among Locations	5	28,808.76	5,761.75	F = 4.08**
Within Locations	30	42,356.56	1,411.89	F_{95} = 2.53 F_{99} = 3.70

** Highly Significant

The F-Value for testing the null hypothesis of station differences is highly significant (1% level). This is evidence that there are real differences among station means.

RANKING THE MEANS

TRM	529.9	527.4	528.0	506.6	518.0	496.5
Autotrophic Index	147.39	159.07	166.84	190.94	195.18	225.18

Any two means underscored by the same line are not significantly different. Any two means not underscored by the same line are significantly different by using Duncan's Multiple Range Test.

Table 7B

Watts Bar Periphyton Autotrophic Index
August 1975

Analysis of Variance

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value
Among Locations	5	155,301.88	31,060.38	F = 8.62**
Within Locations	38	136,857.97	3,601.53	F_{95} = 2.47 F_{99} = 3.55

** Highly Significant

The F-Value for testing the null hypothesis of station differences is highly significant (1% level). This is evidence that there are real differences among station means.

RANKING THE MEANS

TRM	527.4	529.9	528.0	506.6	496.5	518.0
Autotrophic Index	163.54	167.38	194.22	204.15	278.10	316.52

Any two means underscored by the same line are not significantly different. Any two means not underscored by the same line are significantly different by using Duncan's Multiple Range Test.

Table 8

Zooplankton Enumeration at Tennessee River Mile 496.5
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.		5,781	336	38	37	5,804	399	585
Brachionus angularis		264	2,957	11		263	185	55
Brachionus bidentata			17			178		
Brachionus budapestinensis			956			12	496	
Brachionus calyciflorus		991			6	2,037	65	33
Brachionus caudatus		26	16				43	
Brachionus quadridentatus		49				1,022	11	
Cephalodella sp.			17	6	9	24		
Collotheca pelagica		241		28	265	72		343
Conochiloides sp.			829	146	9	83	99	
Conochilus hippocrepis						36		
Conochilus unicornis		8,081	812	38	17	16,355	295	329
Euchlanis sp.	NO SAMPLE TAKEN	30				24		7
Filinia spp.		49			29			
Hexarthra spp.						12		
Hexarthra mira							66	
Kellicottia bostoniensis		26		6	14			
Keratella cochlearis		361	17	27	11	96		199
Keratella crassa		507	82	135	894	833	34	2,288
Keratella earlinae		2,056	65		6	381	197	274
Keratella valga				6				
Lecane spp.						12		
Lecane luna						12		
Ploesoma truncatum		72	274	6		1,096		118
Polyarthra spp.		1,366	32	22	309	345	217	286
Rotaria sp.				22	14			
Rotaria neptunia								7
Synchaeta stylata		1,537	49	141	1,940	618	154	167
Trichocerca spp.		98	17			154	22	13
Total Rotatoria		21,535	6,476	632	3,560	29,469	2,383	4,704
Percent Composition		44.3%	37.8%	32.8%	70.4%	65.9%	25.3%	48.0%
Cladocera								
Alona				1				
Bosmina longirostris		24,307	6,614	826	267	13,303	2,972	2,799
Ceriodaphnia (instar)			129					
Ceriodaphnia lacustris			33					
Ceriodaphnia quadrangula						1		
Chydorus spp.						13		
Daphnia (instar)		53	907	6	12	107		6
Daphnia galeata mendotae							3	
Daphnia parvula		2	33	1	10	2	23	58

Table 8 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Daphnia pulex		1				2		
Daphnia retrocurva		2	162	11			466	6
Diaphanosoma leuchtenbergianum		27	356			119		7
Ilyocryptus spinifer				1				
Leptodora kindtii		2	32	2		15	17	1
Leydigia quadrangularis						1		
Moina micrura			17			1		
Sida crystallinia		1				2		
Simocephalus (instar)		1			1			
Total Cladocera		24,396	8,285	848	290	13,566	3,481	2,877
Percent Composition	NO SAMPLE TAKEN	50.2%	48.3%	44.1%	5.7%	30.3%	36.9%	29.3%
Copepoda								
Calanoida (copepodid)		5	97	1	60	29	185	20
Cyclopoida (copepodid)		312	856	114	188	321	152	428
Harpacticoida (copepodid)					1			
Nauplii		2,229	1,067	287	894	1,237	2,388	1,649
Cyclops bicuspidatus thomasi		49			57	60		
Cyclops varicans rubellus				2		1		
Cyclops vernalis		49	130	12		24	152	40
Diaptomus pallidus		3	97	11	6	24	274	32
Diaptomus reighardi		2					232	7
Diaptomus sanguineus		1				5		
Ergasilus spp.				6				
Eucyclops agilis						1		
Mesocyclops edax		1	113	11	1	1	173	48
Nitocra lacustris			16					
Paracyclops fimbriatus poppei						1		
Tropocyclops prasinus				1	2	1	1	
Total Copepoda		2,651	2,376	445	1,209	1,705	3,557	2,224
Percent Composition		5.5%	13.9%	23.1%	23.9%	3.8%	37.8%	22.7%
Total Zooplankton		48,582	17,137	1,925	5,059	44,740	9,421	9,805

[a] Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 um) bolting cloth.

Table 9

Zooplankton Enumeration at Tennessee River Mile 506.6
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	35	333	1,169	6	73	26		34
Brachionus angularis		30	5,923	12				34
Brachionus bidentata		30	33			16		
Brachionus budapestinensis			656					33
Brachionus calyciflorus	138				7			
Brachionus caudatus			59	6				
Brachionus havanaensis							34	
Brachionus quadridentatus		30	52					17
Cephalodella sp.					3	26		
Collotheca pelagica	155	98	155	29	175	16		16
Conochiloides sp.			2,074					17
Conochilus unicornis		1,539	1,066	6	3	384		16
Euchlanis sp.			2		6			16
Filinia spp.	69				9			
Hexarthra spp.			33					
Kellicottia bostoniensis	190	30		6	28			
Keratella cochlearis	625	68	241	63	26		69	147
Keratella crassa	740	351	117	98	1,077		171	1,295
Keratella earlinae		1,781		139		2,158	17	1,603
Keratella quadrata	128				7			
Keratella valga				110				16
Notholca limnetica	18							
Ploesoma hudsoni								200
Ploesoma truncatum		68	1,116			206		
Polyarthra spp.	3,710	901	305	47	260	84	17	330
Rotaria sp.		30			3			
Synchaeta stylata	17,214	219	124	122	1,475	158		66
Testudinella sp.			33					
Trichocerca spp.		30	162	6				
Total Rotatoria	23,022	5,538	13,320	650	3,152	3,074	308	3,840
Percent Composition	90.9%	11.3%	42.5%	33.4%	64.5%	13.7%	4.2%	49.3%
Cladocera								
Bosmina longirostris	155	41,843	13,335	926	342	16,927	2,222	3,496
Ceriodaphnia (instar)			59					
Ceriodaphnia lacustris		1	91					
Ceriodaphnia quadrangula				1				
Chydorus spp.					1			
Daphnia (instar)		128	837	17	49	33	188	
Daphnia galeata mendotae							3	
Daphnia parvula		35	91	2	13	8	4	
Daphnia retrocurva		35	305	2		3	1,400	2

Table 9 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Diaphanosoma leuchtenbergianum		31	416	6		1	119	
Ilyocryptus spinifer			1					
Leptodora kindtii		32	65	2		8	154	2
Moina (instar)			52					
Sida crystallina		2	4					
Simocephalus (instar)		1						
Total Cladocera	155	42,108	15,256	956	405	16,980	4,090	3,500
Percent Composition	0.6%	85.7%	48.7%	49.2%	8.3%	75.5%	55.2%	44.9%
Copepoda								
Calanoida (copepodid)	18	34	4	2	46	412		
Cyclopoida (copepodid)	206	155	723	87	221	58	137	17
Harpacticoida (copepodid)			26		1			
Nauplii	1,794	386	1,603	212	1,014	1,086	905	232
Argulus stizostethi			2					
Cyclops bicuspidatus thomasi	69	330		1	32	816		
Cyclops varicans rubellus					4			
Cyclops vernalis	17	484	202	24		14	273	168
Diaptomus pallidus	18	72	59	1	6	8	683	16
Diaptomus reighardi		1				7	291	
Diaptomus sanguineus	17	1			1			
Eucyclops agilis	18				1			
Mesocyclops edax			157	12	1	27	718	18
Tropocyclops prasinus			2		2		2	
Total Copepoda	2,157	1,463	2,778	339	1,329	2,428	3,009	451
Percentage Composition	8.5%	3.0%	8.9%	17.4%	27.2%	10.8%	40.6%	5.8%
Total Zooplankton	25,334	49,109	31,354	1,945	4,886	22,482	7,407	7,791

a. Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 10

Zooplankton Enumeration at Tennessee River Mile 518.0
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
otatoria								
Asplanchna spp.	52	233	11,726	15	70		24	147
Brachionus angularis		182	24,014	7		16		26
Brachionus budapestinensis			2,290					38
Brachionus calyciflorus	181		973		5			13
Brachionus caudatus							24	
Brachionus quadridentatus		51						
Brachionus urceolaris	48							
Cephalodella sp.			38		5			13
Collotheca pelagica	100	182	653	7	144			77
Conochiloides sp.			5,275		25			
Conochilus unicornis		8,359	2,387	14		421		79
Filinia spp.	85				3	127		
Kellicottia bostoniensis	191		19	7	14			
Keratella cochlearis	961	1,029	117	91	11		24	696
Keratella crassa	1,156	1,543	425	233	542		148	1,239
Keratella earlinae		6,396	19	125		2,821	48	4,942
Keratella quadrata	185				5			
Keratella valga				186				
Notholca spp.	15							
Ploesoma hudsoni								16
Ploesoma truncatum		27	7,576	22		142	41	102
Polyarthra spp.	5,300	6,666	992	155	104	299	81	1,340
Rotaria sp.					6			
Synchaeta stylata	16,895	927	1,093	276	1,188	49	17	595
Trichocerca spp.		282	196				50	
Total Rotifera	25,169	25,877	57,793	1,138	2,122	3,881	457	9,323
Percent Composition	92.7%	35.1%	82.6%	40.7%	63.8%	46.4%	2.6%	72.8%
Cladocera								
Alonella sp.					3			
Bosmina longirostris	195	43,893	6,599	1,127	202	3,864	6,339	3,077
Ceriodaphnia (instar)			20	7				
Ceriodaphnia lacustris			19					
Ceriodaphnia quadrangula				7				
Chydorus spp.	19				3			
Daphnia (instar)	19	1,187	632	14	19		145	
Daphnia galeata mendotae							124	
Daphnia parvula		155	39	1	6	3	130	1
Daphnia retrocurva		465	174	20		1	2,099	2
Diaphanosoma leuchtenbergianum		4	1,061	1		1	722	
Ilyocryptus spinifer			1					

Table 10 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Leptodora kindtii		35		1		6	169	3
Moina (instar)			230					
Sida crystallina		53						
Total Cladocera	233	45,792	8,775	1,178	233	3,875	9,728	3,083
Percent Composition	0.9%	62.1%	12.5%	42.1%	7.0%	46.3%	54.7%	24.1%
Copepoda								
Calanoida (copepodid)	33	129	59	3	44	3	678	16
Cyclopoida (copepodid)	191	157	1,005	155	190	33	366	
Harpacticoida (copepodid)					3			
Nauplii	1,428	721	1,935	233	666	442	3,114	289
Canthocamptus robertcokeri					3			
Cyclops bicuspidatus thomasi	33	155		7	54	112		
Cyclops varicans rubellus				7				
Cyclops vernalis		700	213	48		10	1,123	82
Diaptomus pallidus	15	97	21	3	6	4	1,035	2
Diaptomus reighardi	19	44	1	1		1	130	
Diaptomus sanguineus	15	12				3		
Ergasilus spp.			3					
Eucyclops agilis				7				
Mesocyclops edax	15	5	155	17	3	3	1,123	6
Paracyclops fimbriatus poppei							24	
Tropocyclops prasinus				1	2		4	
Total Copepoda	1,749	2,020	3,392	482	971	611	7,597	395
Percent Composition	6.4%	2.7%	4.8%	17.2%	29.2%	7.3%	42.7%	3.1%
Total Zooplankton	27,151	73,689	69,960	2,798	3,326	8,367	17,782	12,801

a. Values represent themean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 11

Zooplankton Enumeration at Tennessee River Mile 527.4
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	122	346	12,383	19	190	135	157	290
Brachionus angularis		141	32,430			74		
Brachionus budapestinensis			4,021	4				40
Brachionus calyciflorus	291		30					105
Brachionus caudatus			8					
Brachionus quadridentatus			22					
Brachionus urceolaris	34							
Cephalodella sp.			25		7	11		
Collotheca pelagica		133	242	47	278	32		264
Conochiloides sp.			5,200		49			27
Conochilus hippocrepis								330
Conochilus unicornis		24,996	2,113	5		7,081		
Epiphanes macroura								53
Filinia spp.	157		43		14			
Hexarthra mira								13
Kellicottia bostoniensis	212		17	33	34	166		27
Keratella cochlearis	1,138	339	832	347	26			1,714
Keratella crassa	1,718	714	1,082	319	1,069	82	444	2,993
Keratella earlinae		6,752		375		3,670	59	11,129
Keratella quadrata	278				7			
Keratella valga				406				
Monostyla quadridentata			8					
Ploesoma hudsoni								145
Ploesoma truncatum		44	9,250	14		396		
Polyarthra spp.	9,879	18,012	877	108	401	1,434	862	1,780
Rotaria sp.					4			
Synchaeta stylata	17,863	1,986	303	145	1,862	205		79
Trichocerca spp.	34	44	169				79	
Trichotria pocillum	22							
Total Rotatoria	31,748	53,507	69,055	1,823	3,941	13,286	1,601	18,989
Percent Composition	88.2%	54.3%	79.5%	27.5%	64.4%	31.3%	7.5%	69.2%
Cladocera								
Alonella sp.					3			
Bosmina longirostris	379	39,626	6,502	2,827	345	26,071	2,438	6,237
Ceriodaphnia (instar)			178	5				
Ceriodaphnia lacustris			23				72	
Ceriodaphnia quadrangula				10				
Daphnia (instar)	90	1,066	1,134	207	43	32	118	
Daphnia ambigua						11		
Daphnia galeata mendotae							101	
Daphnia parvula		228	38	50	11	103	196	81
Daphnia pulex		52						

Table 11 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Daphnia retrocurva		192	275	83		72	3,478	241
Diaphanosoma leuchtenbergianum		10	2,185	10	4	8	2,064	2
Ilyocryptus spinifer			1					
Leptodora kindtii		54	30	5		332	98	10
Moina micrura			84				20	
Total Cladocera	469	41,228	10,450	3,197	406	26,629	8,585	6,571
Percent Composition	1.3%	41.8%	12.0%	48.2%	6.6%	62.6%	40.0%	23.9%
Copepoda								
Calanoid (copepodid)	22	147	16k	67	40	46	1,353	79
Cyclopoid (copepodid)	579	787	1,697	590	285	260	340	145
Harpacticoid (copepodid)			22					
Nauplii	2,924	2,332	5,123	608	1,359	1,903	7,520	1,095
Canthocamptus staphylinoides				5	11			
Cyclops bicuspidatus thomasi	100	141		29	64	270		1
Cyclops vernalis	56	339	122	125		66	412	317
Diaptomus pallidus	56	49	4	68	7	6	843	94
Diaptomus reighardi	34	9	9			36	39	1
Diaptomus sanguineus		11				5		
Ergasilus sp.			22	5				
Eucyclops prionophorus								14
Mesocyclops edax		7	176	115		3	752	132
Nitocra lacustris							20	
Tropocyclops prasinus					5			
Total Copepoda	3,771	3,822	7,336	1,612	1,771	2,595	11,279	1,878
Percent Composition	10.5%	3.9%	8.4%	24.3%	28.9%	6.1%	52.5%	6.8%
Total Zooplankton	33,988	98,557	86,841	6,632	6,118	42,510	21,465	27,438

a. Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 12

Zooplankton Enumeration at Tennessee River Mile 528.0
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	91	1,405	19,526	57	81	341	202	273
Brachionus angularis		156	56,908				22	73
Brachionus budapestinensis			5,383	12				89
Brachionus calyciflorus	64	44	111	9	4	17		
Brachionus caudatus			34					
Brachionus urceolaris	64							
Cephalodella sp.					3			
Collotheca pelagica	64	741	289	203	181			376
Conochiloides sp.			9,823	37	18			78
Conochilus hippocrepis								292
Conochilus unicornis		28,849	3,846	9	4	8,999		
Filinia spp.	123	44	34		6			
Kellicottia bostoniensis	558	88	60	44	9	62		37
Keratella cochlearis	782	2,261	1,127	631	22			1,787
Keratella crassa	791	1,879	1,960	623	1,038	1,077	164	2,187
Keratella earlinae		14,952	26	661		8,842	197	16,207
Keratella quadrata	155				7			
Keratella valga				722				
Monostyla spp.							22	
Notholca sp.	32							
Ploesoma hudsoni								188
Ploesoma truncatum		44	15,950	77	4	876	44	
Polyarthra spp.	7,889	50,710	2,264	373	164	2,585	1,062	371
Synchaeta stylata	11,834	3,913	1,340	350	1,235	325	88	162
Trichocerca spp.		204	365			23	159	
Total Rotatoria	22,447	105,290	119,346	3,808	2,776	23,147	1,960	22,120
Percent Composition	81.7%	54.7%	78.2%	32.0%	62.8%	26.0%	6.3%	63.3%
Cladocera								
Alona quadrangularis		68			4			
Bosmina longirostris	400	74,732	11,215	4,575	313	55,848	2,001	8,062
Ceriodaphnia (instar)			179					
Ceriodaphnia lacustris			187				19	1
Ceriodaphnia quadrangula				9				
Chydorus spp.					6			
Daphnia (instar)	32	2,663	2,922	451	35	47	495	
Daphnia ambigua		1						
Daphnia galeata mendotae							545	
Daphnia parvula	91	179	153	48	9	440	241	40
Daphnia retrocurva		112	1,104	110	1	33	8,652	125
Diaphanosoma leuchtenbergianum		74	4,472	10		11	2,269	38

Table 12 (Cont.)

Organism	No. Organisms Per m^e [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Leptodora kindtii		77	61	20			214	75
Moina (instar)			646			1,206		
Sida crystallina						1		
Simocephalus (instar)				1				
Simocephalus vetulus		1						
Total Cladocera	523	77,907	20,939	5,224	368	57,586	14,436	8,341
Percent Composition	1.9%	40.5%	13.7%	43.9%	8.3%	64.6%	46.0%	23.9%
Copepoda								
Calanoida (copepodid)	32	112	222	87	18	493	1,411	198
Cyclopoida (copepodid)	795	1,899	3,418	1,022	185	809	545	99
Harpacticoida (copepodid)			34					
Nauplii	3,370	5,836	7,713	1,290	1,016	5,564	7,387	3,100
Cantrocamptus staphylinoides					1			
Canthocamptus robertcokeri								3
Cyclops bicuspidatus thomasi	123	494		92	29	852		54
Cyclops varicans rubellus					1			
Cyclops vernalis		712	349	150		214	1,340	480
Diaptomus pallidus		73	41	65	12	21	2,523	324
Diaptomus reighardi	32	49		2		210	423	38
Diaptomus sanguineus		5			1	113		
Ergasilus spp.			28	1		132		
Eucyclops agilis					4			
Eucyclops prionophorus	59							1
Mesocyclops edax	91	44	433	147	3	13	1,329	209
Tropocyclops prasinus					3			
Total Copepoda	4,502	9,224	12,238	2,856	1,273	8,421	14,958	4,506
Percent Composition	16.4%	4.8%	8.0%	24.0%	28.8%	9.4%	47.7%	12.9%
Total Zooplankton	27,472	192,421	152,523	11,888	4,417	89,154	31,354	34,967

a. Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 13

Zooplankton Enumeration at Tennessee River Mile 529.9
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	67	1,078	30,538	126	80	271	76	827
Brachionus angularis		201	110,309			18		39
Brachionus budapestinensis			16,030			18		151
Brachionus calyciflorus	130		413		4			114
Cephalodella sp.					5			
Collotheca pelagica		986	2,162	255	170	41		811
Conochiloides sp.			13,049		12			
Conochilus unicornis		14,853	12,157	32	5	3,834		1,155
Filinia spp.	84	60			8			
Kellicottia bostoniensis	104	201	234	79	12	71		112
Keratella cochlearis	837	1,671	2,682	975	19			5,040
Keratella crassa	577	1,671	3,809	879	862	171	94	4,869
Keratella earlinae		11,307		1,211		5,758	187	22,790
Keratella quadrata	42				5			
Keratella valga	21			1,292				78
Platyias patulus			56					
Ploesoma hudsoni								110
Ploesoma truncatum		60	43,430	78			95	350
Polyarthra spp.	2,747	35,668	6,130	492	152	2,122	939	7,651
Rotaria sp.					5			
Synchaeta stylata	6,634	3,282	2,076	748	1,260	206	57	621
Trichocerca spp.		191	1,571	16			207	39
Total Rotatoria	11,243	71,229	244,646	6,183	2,599	12,510	1,655	45,747
Percent Composition	85.1%	47.8%	78.1%	33.7%	68.5%	22.1%	6.2%	63.4%
Cladocera								
Alona (instar)				16				
Alona quadrangularis					1			
Bosmina longirostris	181	58,510	21,020	4,146	156	37,208	1,901	14,765
Ceriodaphnia (instar)			468					
Ceriodaphnia lacustris			179					37
Ceriodaphnia quadrangula				48				
Ceriodaphnia reticulata								1
Daphnia (instar)		4,772	4,506	332	28	41	130	
Daphnia galeata mendatae							6	
Daphnia parvula	21	201	181	32	5	77	94	925
Daphnia retrocurva		594	1,671	111		41	3,829	485
Diaphanosoma leuchtenbergianum		8	10,858	32		4	2,731	3
Leptodora kindtii		15	91	32		106	206	25
Moina (instar)			1,424					
Moina micrura							1	
Sida crystallina		3						
Total Cladocera	202	64,103	40,398	4,749	190	37,477	8,898	16,241
Percent Composition	1.5%	43.1%	12.9%	25.9%	5.0%	66.3%	33.5%	22.5%

Table 13 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Copepoda								
Calanoida (copepodid)		523	224	78	14	214	1,214	420
Cyclopoida (copepodid)	234	3,470	5,836	2,770	125	649	543	1,334
Nauplii	1,338	8,093	21,103	3,873	849	5,042	10,191	6,882
Argulus stizostethi								1
Canthocamptus staphylinoides				1	1			
Canthocamptus robertcokeri								2
Cyclops bicuspidatus thomasi	67	473		221	6	378		270
Cyclops varicans rubellus					2			
Cyclops vernalis	26	887	413	335		106	563	770
Diaptomus pallidus	21	14	45	47	4	1	1,579	260
Diaptomus reighardi	21	5		2		53	281	41
Diaptomus sanguineus		13				38		
Ergasilus spp.			1					1
Eucyclops agilis	26							
Eucyclops prionophorus								1
Mesocyclops edax	26	74	734	110		73	1,671	226
Tropocyclops prasinus					2		4	
Total Copepoda	1,759	13,552	28,356	7,437	1,003	6,554	16,046	10,208
Percent Composition	13.3%	9.1%	9.0%	40.5%	26.5%	11.6%	60.3%	14.1%

a. Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 14

Zooplankton Enumeration at Tennessee River Mile 532.1
(Watts Bar Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

	No. Organisms Per m^3 [a]							
	1973				1974			
Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	35	23,949	56,865	1,045	104	1,368	1,433	2,818
Brachionus angularis		103	92,296				334	81
Brachionus budapestinensis			9,705	18			79	
Brachionus calyciflorus	133		156		11			271
Brachionus caudatus			57					
Brachionus quadridentatus		38	50					27
Brachionus urceolaris	35							
Cephalodella sp.					2			
Collotheca pelagica		542	1,056	261	227	92		1,571
Conochiloides sp.		27	19,101	129	33			
Conochilus unicornis		19,594	19,923	121	11	22,965	355	1,139
Epiphanes macroura					2			
Euchlanis sp.					4			
Filinia spp.	126	27			2			
Hexarthra spp.			453	45				
Hexarthra mira							1,731	
Kellicottia bostoniensis	126	27	57	95	26	17		135
Kellicottia longispina						17		
Keratella cochlearis	1,101	1,247	5,355	2,803	89		198	8,694
Keratella crassa	1,513	1,042	3,401	1,029	964	384	450	5,590
Keratella earlinae		11,528		2,797		12,505	2,089	24,281
Keratella quadrata	85				2			
Keratella valga				1,154				108
Lecane stokesii					2			
Monostyla spp.					2			
Notholca sp.	29							
Platyias patulus			100					
Ploesoma hudsoni							60	
Ploesoma truncatum		193	41,335	315		1,898	98	136
Polyarthra sp.	4,476	72,925	4,974	3,144	118	6,688	12,274	9,295
Rotaria sp.					6			
Synchaeta stylata	18,041	8,304	9,283	6,127	2,135	374	1,629	2,197
Trichocerca spp.		103	978	22	2	38	255	27
Total Rotatoria	25,700	139,649	265,145	19,105	3,742	46,346	20,985	56,370
Percent Composition	82.1%	77.6%	77.0%	47.1%	71.3%	38.1%	35.7%	57.1%
Cladocera								
Bosmina longirostris	623	68,285	25,278	7,647	294	54,666	533	21,216
Ceriodaphnia (instar)			100					
Ceriodaphnia lacustris			8				20	54
Ceriodaphnia quadrangula				40				
Daphnia (instar)		12,565	3,713	744	40		512	
Daphnia ambigua		54				87		
Daphnia galeata mendatae							454	
Daphnia parvula	63	425	3	40	8	1,917	380	1,543

Table 14 (Cont.)

Organism	No. Organisms Per m^3 [a]							
	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Daphnia retrocurva		1,349	1,792	121		377	8,157	569
Diaphanosoma leuchtenbergianum		205	18,937	121	2	496	8,890	162
Ilyocryptus spinifer			106	22				
Latona setifera			1					
Leptora kindtii		103	270	40			356	32
Moina (instar)			1,651					
Moina micrura							20	
Scapholebris kingi				22		342		
Sida crystallina		8						
Simocephalus (instar)								27
Total Cladocera	686	14,709	51,859	8,797	344	57,385	19,322	23,603
Percent Composition	2.2%	8.2%	15.1%	21.7%	6.6%	47.2%	32.9%	23.9%
Copepoda								
Calanoida (copepodid)	91	697	383	210	43	294	592	541
Cyclopoid (copepodid)	1,077	9,733	7,679	3,794	167	4,461	1,001	3,957
Nauplii	3,533	13,126	18,202	8,278	921	11,679	15,158	12,382
Argulus stizostethi			1					
Canthocamptus staphylinoides					1			
Cyclops bicuspidatus thomasi	91	383		40	10	514		54
Cyclops vernalis		1,357	161	192		113	337	1,329
Diaptomus mississippiensis				1				
Diaptomus pallidus	63	103	17	40	15	50	474	216
Diaptomus reighardi	29	103		1		575	98	54
Diaptomus sanguineus	35	21			1	34		
Ergasilus spp.			57	1				
Eucyclops agilis					1			
Mesocyclops edax		65	858	63	2	88	829	189
Tropocyclops prasinus		38	57		3		2	
Total Copepoda	4,919	25,626	27,433	12,620	1,164	17,808	18,491	18,722
Percent Composition	15.7%	14.2%	8.0%	31.1%	22.2%	14.7%	31.4%	19.0%
Total Zooplankton	31,305	179,984	344,437	40,522	5,250	121,539	58,798	98,695

a. Values represent the mean of duplicate tows made from bottom to surface with a 1/2-meter net fitted with No. 20-mesh (80 μm) bolting cloth.

Table 15

Zooplankton Enumeration by Groups for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

		No Organisms Per m^3							
		1973				1974			
Station	Group	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
TRM 496.5	Rotatoria		21,535	6,476	632	3,560	29,469	2,383	4,704
	Cladocera	*[a]	24,396	8,285	848	290	13,566	3,481	2,877
	Copepoda		2,651	2,376	445	1,209	1,705	3,557	2,224
	Total		48,582	17,137	1,925	5,059	44,740	9,421	9,805
TRM 506.6	Rotatoria	23,022	5,538	13,320	650	3,152	3,074	308	3,840
	Cladocera	155	42,108	15,256	956	405	16,980	4,090	3,500
	Copepoda	2,157	1,463	2,778	339	1,329	2,428	3,009	451
	Total	25,334	49,109	31,354	1,945	4,886	22,482	7,407	7,791
TRM 518.0	Rotatoria	25,169	25,877	57,793	1,138	2,122	3,881	457	9,323
	Cladocera	233	45,792	8,775	1,178	233	3,875	9,728	3,083
	Copepoda	1,749	2,020	3,392	482	971	611	7,597	395
	Total	27,151	73,689	69,960	2,798	3,326	8,367	17,782	12,801
TRM 527.4	Rotatoria	31,748	53,507	69,055	1,823	3,941	13,286	1,601	18,989
	Cladocera	469	41,228	10,450	3,197	406	26,629	8,585	6,571
	Copepoda	3,771	3,822	7,336	1,612	1,771	2,595	11,279	1,878
	Total	35,988	98,557	86,841	6,632	6,118	42,510	21,465	27,438
TRM 528.0	Rotatoria	22,447	105,290	119,346	3,808	2,776	23,147	1,960	22,120
	Cladocera	523	77,907	20,939	5,224	368	57,586	14,436	8,341
	Copepoda	4,502	9,224	12,238	2,856	1,273	8,421	14,958	4,506
	Total	27,472	192,421	152,523	11,888	4,417	89,154	31,354	34,967
TRM 529.9	Rotatoria	11,243	71,229	244,646	6,183	2,599	12,510	1,655	45,747
	Cladocera	202	64,103	40,398	4,749	190	37,477	8,898	16,241
	Copepoda	1,759	13,552	28,356	7,437	1,003	6,554	16,046	10,208
	Total	13,204	148,884	313,400	18,369	3,792	56,541	26,599	72,196
TRM 532.1	Rotatoria	25,700	139,649	265,145	19,105	3,742	46,346	20,985	56,370
	Cladocera	686	14,709	51,859	8,797	344	57,385	19,322	23,603
	Copepoda	4,919	25,626	27,433	12,620	1,164	17,808	18,491	18,722
	Total	31,305	179,984	344,437	40,522	5,250	121,539	58,798	98,695
Combined Stations	Rotatoria	23,222	60,375	110,826	4,763	3,127	18,816	4,193	23,013
	Cladocera	378	44,320	22,280	3,564	319	30,500	9.791	9,174
	Copepoda	3,143	8,337	11,987	3,684	1,246	5,732	10,705	5,483
	Total	26,743	113,032	145,093	12,011	4,692	55,048	24,689	37,670

a. No samples collected.

Table 16

Yearly Summary of Zooplankton by Groups for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Station	Group	No. Organisms Per m^3, 1973	1974	Combined Years
TRM 496.5	Rotatoria	9,548[a]	10,029	9,823[a]
	Cladocera	11,176[a]	5,054	7,678[a]
	Copepoda	1,824[a]	2,174	2,024[a]
	Total	22,548[a]	17,257	19,525[a]
TRM 506.6	Rotatoria	10,633	2,594	6,613
	Cladocera	14,619	6,244	10,431
	Copepoda	1,684	1,804	1,744
	Total	26,936	10,642	18,788
TRM 518.0	Rotatoria	27,494	3,946	15,720
	Cladocera	13,995	4,230	9,112
	Copepoda	1,911	2,394	2,152
	Total	43,400	10,570	26,984
TRM 577.4	Rotatoria	39,033	9,454	24,244
	Cladocera	13,836	10,548	12,192
	Copepoda	4,135	4,381	4,258
	Total	57,004	24,383	40,694
TRM 528.0	Rotatoria	62,723	12,501	37,612
	Cladocera	26,148	20,183	23,166
	Copepoda	7,205	7,290	7,247
	Total	96,076	39,974	68,025
TRM 529.9	Rotatoria	83,325	15,628	49,477
	Cladocera	27,363	15,702	21,532
	Copepoda	12,776	8,453	10,614
	Total	123,464	39,783	81,623
TRM 531.2	Rotatoria	112,400	31,861	72,130
	Cladocera	19,013	25,164	22,088
	Copepoda	17,650	14,046	15,848
	Total	149,063	71,071	110,066
Combined Stations	Rotatoria	50,781[a]	12,288	31,187[a]
	Cladocera	18,386[a]	12,446	15,362[a]
	Copepoda	6,923[a]	5,792	6,347[a]
	Total	76,090[a]	30,526	52,896[a]

a. Winter 1973 values unavailable and not included where indicated.

Table 17

Zooplankton Taxa Identified at Tennessee River Mile 496.5
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.		x	x	x	x	x	x	x
Brachionus angularis		x	x	x		x	x	x
Brachionus bidentata			x			x		
Brachionus budapestinensis			x			x	x	
Brachionus calyciflorus		x			x	x	x	x
Brachionus candatus		x					x	
Brachionus quadridentatus		x				x	x	
Cephalodella sp.			x	x	x	x		
Collotheca pelagica		x		x	x	x		x
Conochiloides sp.			x	x	x	x	x	
Conochilus hippocrepis						x		
Conochilus unicornis		x	x	x	x	x	x	x
Euchlanis sp.		x				x		
Filinia spp.		x			x			
Hexarthra spp.						x		
Hexarthra mira							x	
Kellicottia bostoniensis		x		x	x			
Keratella cochlearis		x	x	x	x	x		x
Keratella crassa		x	x	x	x	x	x	x
Keratella earlinae		x	x		x	x	x	x
Keratella valga				x				
Lecane luna						x		
Ploesoma truncatum		x	x	x		x		x
Polyarthra spp.		x	x	x	x	x	x	x
Rotaria sp.				x	x			
Rotaria neptunia								x
Synchaeta stylata		x	x	x	x	x	x	x
Trichocerca spp.		x	x			x	x	x
Total Rotatoria		17	15	14	14	22	14	14
Cladocera								
Alona				x				
Bosmina longirostris		x	x	x	x	x	x	x
Ceriodaphnia (instar)			x					
Ceriodaphnia lacustris			x					
Ceriodaphnia quadrangula						x		
Chydorus spp.						x		
Daphnia (instar)		x	x	x	x	x		x
Daphnia galeata mendotae							x	
Daphnia parvula		x	x	x	x	x	x	x
Daphnia pulex		x				x		
Daphnia retrocurva		x	x	x			x	x

Table 17 (Cont.)

Organism	1973 Wi	1973 Sp	1973 Su	1973 Fa	1974 Wi	1974 Sp	1974 Su	1974 Fa
Cladocera (cont.)								
Diaphanosoma leuchtenbergianum		x	x			x		x
Ilyocryptus spinifer				x				
Leptodora kindtii		x	x	x		x	x	x
Leydigia quadrangularis			x			x		
Moina micrura			x			x		
Sida crystallinia		x				x		
Simocephalus (instar)		x			x			
Total Cladocera		9	9	7	4	11	5	6
Copepoda								
Calanoida (copepodid)		x	x	x	x	x	x	x
Cyclopoida (copepodid)		x	x	x	x	x	x	x
Harpacticoida (copepodid)					x			
Nauplii		x	x	x	x	x	x	x
Cyclops bicuspidatus thomasi		x			x	x		
Cyclops varicans rubellus								
Cyclops vernalis		x	x	x		x	x	x
Diaptomus pallidus		x	x	x	x	x	x	x
Diaptomus reighardi		x					x	x
Diaptomus sanguineus		x				x		
Ergasilus spp.				x				
Eucyclops agilis						x		
Mesocyclops edax		x	x	x	x	x	x	x
Nitocra lacustris			x					
Paracyclops fimbriatus poppei						x		
Tropocyclops prasinus				x	x	x	x	
Total Copepoda		9	7	9	8	12	8	7
Total Zooplankton		35	31	30	26	45	27	27

Table 18

Zooplankton Taxa Idntified at Tennessee River Mile 506.6
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x	x		x
Brachionus anguiaris		x	x	x				x
Brachionus bidentata		x	x			x		
Brachionus budapestinensis			x					x
Brachionus calyciflorus	x				x			
Brachionus caudatus			x	x				
Brachionus havanaensis							x	
Brachionus quadridentatus		x	x					x
Cephalodella sp.					x	x		
Collotheca pelagica	x	x	x	x	x	x		x
Conochiloides sp.			x					x
Conochilus unicornis		x	x	x	x	x		x
Euchlanis sp.			x		x			x
Filinia spp.	x				x			
Hexarthra spp.			x					
Kellicottia bostoniensis	x	x		x	x			
Keratella cochlearis	x	x	x	x	x		x	x
Keratella crassa	x	x	x	x	x		x	x
Keratella earlinae		x		x		x	x	x
Keratella quadrata	x				x			
Keratella valga				x				x
Notholca limnetica	x							
Ploesoma hudsoni								x
Ploesoma truncatum		x	x			x		
Polyarthra spp.	x	x	x	x	x	x	x	x
Rotaria sp.		x			x			
Synchaeta stylata	x	x	x	x	x	x		x
Testudinella sp.			x					
Trichocerca spp.		x	x	x				
Total Rotatoria	11	15	18	13	14	9	5	15
Cladocera								
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnia (instar)			x					
Ceriodaphnia lacustris		x	x					
Ceriodaphnia quadrangula				x				
Chydorus spp.					x			
Daphnia (instar)		x	x	x	x	x	x	
Daphnia galeata mendotae							x	
Daphnia parvula		x	x	x	x	x	x	
Daphnia retrocurva		x	x	x		x	x	x
Diaphanosoma leuchtenbergianum		x	x	x		x	x	
Ilyocryptus spinifer			x					

Table 18 (Cont.)

Organism	1973 Wi	1973 Sp	1973 Su	1973 Fa	1974 Wi	1974 Sp	1974 Su	1974 Fa
Leptodora kindtii		x	x	x		x	x	x
Moina (instar)			x					
Sida crystallina		x	x					
Simocephalus (instar)		x						
Total Cladocera	1	9	11	7	4	6	7	3
Copepoda								
Calanoida (copepodid)	x	x	x	x	x	x		
Cyclopoida (copepodid)	x	x	x	x	x	x	x	x
Harpacticoida (copepodid)			x		x			
Nauplii	x	x	x	x	x	x	x	x
Argulus stizostethi			x					
Cyclops bicuspidatus thomasi	x	x		x	x	x		
Cyclops varicans rubellus					x			
Cyclops vernalis	x	x	x	x		x	x	x
Diaptomus pallidus	x	x	x	x	x	x	x	x
Diaptomus reighardi		x				x	x	
Diaptomus sanguineus	x	x			x			
Eucyclops agilis	x				x			
Mesocyclops edax			x	x	x	x	x	x
Tropocyclops prasinus			x		x		x	
Total Copepoda	8	8	9	7	11	8	7	5
Total Zooplankton	20	32	38	27	29	23	19	23

Table 19

Zooplankton Taxa Identified at Tennessee River Mile 518.0
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x		x	x
Brachionus angularis		x	x	x		x		x
Brachionus budapestinensis			x					x
Brachionus calyciflorus	x		x		x			x
Brachionus caudatus							x	
Brachionus quadridentatus		x						
Brachionus urceolaris	x							
Cephalodella sp.			x		x			x
Collotheca pelagica	x	x	x	x	x			x
Conochiloides sp.			x		x			
Conochilus unicornis		x	x	x		x		x
Filinia spp.	x				x	x		
Kellicottia Bostoniensis	x		x	x	x			
Keratella cochlearis	x	x	x	x	x		x	x
Keratella earlinae		x	x	x		x	x	x
Keratella quadrata	x				x			
Keratella valga				x				
Notholca sp.	x							
Ploesoma hudsoni								x
Ploesoma truncatum		x	x	x		x	x	x
Polyarthra spp.	x	x	x	x	x	x	x	x
Rotaria sp.					x			
Synchaeta stylata	x	x	x	x	x	x	x	x
Trichocerca spp.		x	x				x	
Total Rotifera	12	12	16	12	13	7	9	14
Cladocera								
Alonella sp.					x			
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnia (instar)			x	x				
Ceriodaphnia lacustris			x					
Ceriodaphnia quadrangula				x				
Chydorus spp.					x			
Daphnia (instar)	x	x	x	x	x		x	
Daphnia galeata mendotae							x	
Daphnia parvula		x	x	x	x	x	x	x
Daphnia retrocurva		x	x	x		x	x	x
Diaphanosoma leuchtenbergianum		x	x	x		x	x	
Ilyocryptus spinifer			x					
Leptodora kindtii		x		x		x	x	x
Moina (instar)			x					
Sida crystallina		x						
Total Cladocera	3	7	9	8	5	5	7	4

Table 19 (Cont.)

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Copepoda								
Calanoida (copepodid	x	x	x	x	x	x	x	x
Cyclopoida (copepodid)	x	x	x	x	x	x	x	
Harpacticoida (copepodid)					x			
Nauplii	x	x	x	x	x	x	x	x
Cantrocamptus robertcokeri					x			
Cyclops bicuspidatus thomasi	x	x		x	x	x		
Cyclops varicans rubellus				x				
Cyclops vernalis		x	x	x		x	x	x
Diaptomus pallidus	x	x	x	x	x	x	x	x
Diaptomus reighardi	x	x	x	x		x	x	
Diaptomus sanguineus	x	x				x		
Ergasilus spp.			x					
Eucyclops agilis				x				
Mesocyclops edax	x	x	x	x	x	x	x	x
Paracyclops fimbriatus poppei							x	
Tropocyclops prasinus				x	x		x	
Total Copepoda	8	9	8	11	9	9	9	5
Total Zooplankton	23	28	33	31	27	21	25	23

Table 20

Zooplankton Taxa Identified at Tennessee River Mile 527.4
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x	x	x	x
Brachionus angularis		x	x			x		
Brachionus budapestinensis			x	x				
Brachionus calyciflorus	x		x					
Brachionus caudatus			x					
Brachionus quadridentatus			x					
Brachionus urceolaris	x							
Cephalodella sp.			x		x	x		
Collotheca pelagica		x	x	x	x	x		x
Conochiloides sp.			x		x			x
Conochilus hippocrepis								x
Conochilus unicornis		x	x	x		x		
Epiphanes macroura								x
Filinia spp.	x		x		x			
Hexarthra mira								x
Kellicottia bostoniensis	x		x	x	x	x		x
Keratella cochlearis	x	x	x	x	x			x
Keratella crassa	x	x	x	x	x	x	x	x
Keratella earlinae		x		x		x	x	x
Keratella quadrata	x				x			
Keratella valga				x				
Monostyla quadridentata			x					
Ploesoma hudsoni								x
Ploesoma truncatum		x	x	x		x		
Polyarthra spp.	x	x	x	x	x	x	x	x
Rotaria Sp.					x			
Synchaeta stylata	x	x	x	x	x	x		x
Trichocerca spp.	x	x	x				x	
Trichotria pocillum	x							
Total Rotatoria	12	11	19	12	12	11	5	13
Cladocera								
Alonella sp.					x			
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnis (instar			x	x				
Ceriodaphnia lacustris			x				x	
Ceriodaphnia quadrangula				x				
Daphnia (instar)	x	x	x	x	x	x	x	
Daphnia ambigua						x		
Daphnia galeata mendotae							x	
Daphnia parvula		x	x	x	x	x	x	x
Daphnia pulex		x						

Table 20 (Cont.)

Organism	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Cladocera (cont.)								
Daphnia retrocurva		x	x	x		x	x	x
Diaphanosoma leuchtenbergianum		x	x	x	x	x	x	x
Ilyocryptus spinifer			x					
Leptodora kindtii		x	x	x		x	x	x
Moina micrura			x				x	
Total Cladocera	2	7	10	8	5	7	9	5
Copepoda								
Calanoida (copepodid)	x	x	x	x	x	x	x	x
Cyclopoida (copepodid)	x	x	x	x	x	x	x	x
Harpacticoida (copepodid)			x					
Nauplii	x	x	x	x	x	x	x	x
Cantrocamptus staphylinoides				x	x			
Cyclops bicuspidatus thomasi	x	x		x	x	x		x
Cyclops vernalis	x	x	x	x		x	x	x
Diaptomus pallidus	x	x	x	x	x	x	x	x
Diaptomus reighardi	x	x	x			x	x	x
Diaptomus sanguineus		x				x		
Ergasilus spp.			x	x				
Eucyclops prionophorus								x
Mesocyclops edax		x	x	x		x	x	x
Nitocra lacustris							x	
Tropocyclops prasinus					x			
Total Copepoda	7	9	9	9	7	9	8	9
Total Zooplankton	21	27	38	29	24	27	22	27

Table 21

Zooplankton Taxa Identified at Tennessee River Mile 528.0
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x	x	x	x
Brachionus angularis		x	x				x	x
Brachionus budapestinensis			x	x				x
Brachionus calyciflorus	x	x	x	x	x	x		
Brachionus caudatus			x					
Brachionus urceolaris	x							
Cephalodella sp.					x			
Collotheca pelagica	x	x	x	x	x			x
Conochiloides sp.			x	x	x			x
Conochilus hippocrepis								x
Conochilus unicornis		x	x	x	x	x		
Filinia spp.	x	x	x		x			
Kellicottia bostoniensis	x	x	x	x	x	x		x
Keratella cochlearis	x	x	x	x	x			x
Keratella crassa	x	x	x	x	x	x	x	x
Keratella earlinae		x	x	x		x	x	x
Keratella quadrata	x				x			
Keratella valga				x				
Monostyla spp.							x	
Notholca sp.	x							
Ploesoma hudsoni								x
Ploesoma truncatum		x	x	x	x	x	x	
Polyarthra spp.	x	x	x	x	x	x	x	x
Synchaeta stylata	x	x	x	x	x	x	x	x
Trichocerca spp.		x	x			x	x	
Total Rotatoria	12	14	17	14	14	10	9	13
Cladocera								
Alona quadrangularis		x			x			
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnia (instar)			x					
Ceriodaphnia lacustris			x				x	x
Ceriodaphnia quadrangula				x				
Chydorus spp.					x			
Daphnia (instar)	x	x	x	x	x	x	x	
Daphnia ambigua		x						
Daphnia galeata mendotae							x	
Daphnia parvula	x	x	x	x	x	x	x	x
Daphnia retrocurva		x	x	x	x	x	x	x
Diaphanosoma leuchtenbergianum		x	x	x		x	x	x
Leptodora kindtii		x	x	x			x	x
Moina (instar)			x			x		

Table 21 (Cont.)

Organism	1973 Wi	1973 Sp	1973 Su	1973 Fa	1974 Wi	1974 Sp	1974 Su	1974 Fa
Cladocera (cont.)								
Sida crystallina						x		
Simocephalus (instar)				x				
Simocephalus vetulus		x						
Total Cladocera	3	9	9	8	6	7	8	6
Copepoda								
Calanoida (copepodid)	x	x	x	x	x	x	x	x
Cyclopoida (copepodid)	x	x	x	x	x	x	x	x
Harpacticoida (copepodid)			x					
Nauplii	x	x	x	x	x	x	x	x
Cantrocamptus staphylinoides					x			
Canthocamptus robertcokeri								x
Cyclops bicuspidatus thomasi	x	x		x	x	x		x
Cyclops varicans rubellus					x			
Cyclops vernalis		x	x	x		x	x	x
Diaptomus pallidus		x	x	x	x	x	x	x
Diaptomus reighardi	x	x		x		x	x	x
Diaptomus sanguineus		x			x	x		
Ergasilus spp.			x	x		x		
Eucyclops agilis					x			
Eucyclops prionophorus	x							x
Mesocyclops edax	x	x	x	x	x	x	x	x
Tropocyclops prasinus					x			
Total Copepoda	7	9	8	9	11	10	7	10
Total Zooplankton	22	32	34	31	31	27	24	29

Table 22

Zooplankton Taxa Identified at Tennessee River Mile 529.9
(Chickamauga Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x	x	x	x
Brachionus angularis		x	x			x		x
Brachionus budapestinensis			x			x		x
Brachionus calyciflorus	x		x		x			x
Cephalodella sp.					x			
Collotheca pelagica		x	x	x	x	x		x
Conochiloides sp.			x		x			
Conochilus unicornis		x	x	x	x	x		x
Filinia spp.	x	x			x			
Kellicottia bostoniensis	x	x	x	x	x	x		x
Keratella cochlearis	x	x	x	x	x			x
Keratella crassa	x	x	x	x	x	x	x	x
Kerotella earlinae		x		x		x	x	x
Keratella quadrata	x				x			
Keratella valga	x			x				x
Platyias patulus			x					
Ploesoma hudsoni								x
Ploesoma truncatum		x	x	x			x	x
Polyarthra spp.	x	x	x	x	x	x	x	x
Rotaria sp.					x			
Synchaeta stylata	x	x	x	x	x	x	x	x
Trichoerca spp.		x	x	x			x	x
Total Rotatoria	10	13	15	12	14	10	7	16
Cladocera								
Alona (instar)				x				
Alona quadrangularis					x			
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnia (instar)			x					
Ceriodaphnia lacustris			x					x
Ceriodaphnia quadrangula				x				
Ceriodaphnia reticulata								x
Daphnia (instar)		x	x	x	x	x	x	
Daphnia galeata mendatae							x	
Daphnia parvula	x	x	x	x	x	x	x	x
Daphnia retrocurva		x	x	x		x	x	x
Diaphanosoma leuchtenbergianum		x	x	x		x	x	x
Leptodora kindtii		x	x	x		x	x	x
Moina (instar)			x					

Table 22 (Cont.)

Organism	1973 Wi	1973 Sp	1973 Su	1973 Fa	1974 Wi	1974 Sp	1974 Su	1974 Fa
Cladocera (cont.)								
Moina micrura							x	
Sida crystallina		x						
Total Cladocera	2	7	9	8	4	6	8	7
Copepoda								
Calanoida (copepodid)		x	x	x	x	x	x	x
Cyclopoida (copepodid)	x	x	x	x	x	x	x	x
Nauplii	x	x	x	x	x	x	x	x
Argulus stizostethi								x
Canthocamptus staphylinoides				x	x			
Canthocamptus robertcokeri								
Cyclops bicuspidatus thomasi	x	x		x	x	x		x
Cyclops varicans rubellus					x			
Cyclops vernalis	x	x	x	x		x	x	x
Diaptomus pallidus	x	x	x	x	x	x	x	x
Diaptomus reighardi	x	x		x		x	x	x
Diaptomus sanguineus		x				x		
Ergasilus spp.			x					x
Eucyclops agilis	x							
Eucyclops prionophorus								x
Mesocyclops edax	x	x	x	x		x	x	x
Tropocyclops prasinus					x		x	
Total Copepoda	8	9	7	9	8	9	8	12
Total Zooplankton	20	29	31	29	26	25	23	35

Table 23

Zooplankton Taxa Identified at Tennessee River Mile 532.1
(Watts Bar Reservoir) for the Sampling Period
Winter 1973 - Fall 1974 - Watts Bar Nuclear Plant

Organism	1973				1974			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Rotatoria								
Asplanchna spp.	x	x	x	x	x	x	x	x
Brachionus angularis		x	x				x	x
Brachionus budapestinensis			x	x			x	
Brachionus calyciflorus	x		x		x			x
Brachionus caudatus			x					
Brachionus quadridentatus		x	x					x
Brachionus urceolaris	x							
Cephalodella sp.					x			
Collotheca pelagica		x	x	x	x	x		x
Conochiloides sp.		x	x	x	x			
Conochilus unicornis		x	x	x	x	x	x	x
Epiphanes macroura					x			
Euchlanis sp.					x			
Filinia spp.	x	x			x			
Hexarthra spp.			x	x				
Hexarthra mira							x	
Kellicottia bostoniensis	x	x	x	x	x	x		x
Kellicottia longispina						x		
Keratella cochlearis	x	x	x	x	x		x	x
Keratella crassa	x	x	x	x	x	x	x	x
Keratella earlinae		x		x		x	x	x
Keratella quadrata	x				x			
Keratella valga				x				x
Lecane stokesii					x			
Monostyla spp.					x			
Notholca sp.	x							
Platyias patulus			x					
Ploesoma hudsoni							x	
Ploesoma truncatum		x	x	x		x	x	x
Polyarthra sp.	x	x	x	x	x	x	x	x
Rotaria sp.					x			
Synchaeta stylata	x	x	x	x	x	x	x	x
Trichocerca spp.		x	x	x	x	x	x	x
Total Rotatoria	11	15	18	15	19	11	13	15
Cladocera								
Bosmina longirostris	x	x	x	x	x	x	x	x
Ceriodaphnia (instar)			x					
Ceriodaphnia laucustris			x				x	x
Ceriodaphnia quadrangula				x				
Daphnia (instar)		x	x	x	x		x	
Daphnia ambigua		x				x		
Daphnia galeata mendatae							x	
Daphnia parvula	x	x	x	x	x	x	x	x

Table 23 (Cont.)

Organism	1973 Wi	1973 Sp	1973 Su	1973 Fa	1974 Wi	1974 Sp	1974 Su	1974 Fa
Cladocera (cont.)								
Daphnia retrocurva		x	x	x		x	x	x
Diaphanosoma leuchtenbergianum		x	x	x	x	x	x	x
Ilyocryptus spinifer			x	x				
Latora setifera			x					
Leptodora kindtii		x	x	x			x	x
Moina (instar)			x					
Moina micrura							x	
Scapholebris kingi				x		x		
Sida crystallina		x						
Simocephalus (instar)								x
Total Cladocera	2	8	11	9	4	6	9	7
Copepoda								
Calanoida (copepodid)	x	x	x	x	x	x	x	x
Cyclopoid (copepodid)	x	x	x	x	x	x	x	x
Nauplii	x	x	x	x	x	x	x	x
Arguius stizostethi			x					
Canthocamptus staphylinoides					x			
Cyclops bicuspidatus thomasi	x	x		x	x	x		x
Cyclops vernalis		x	x	x		x	x	x
Diaptomus mississippiensis				x				
Diaptomus pallidus	x	x	x	x	x	x	x	x
Diaptomus reighardi	x	x		x		x	x	x
Diaptomus sanguineus	x	x			x	x		
Ergasilus spp.			x	x				
Eucyclops agilis					x			
Mesocyclops edax		x	x	x	x	x	x	x
Tropocyclops prasinus		x	x		x		x	
Total Copepoda	7	10	9	10	10	9	8	8
Total Zooplankton	20	33	38	34	33	26	30	30

Table 24

Benthic Macroinvertebrate Fauna
Watts Bar Nuclear Plant - 1975

Annelida
- Clitellata (oligochaetes)
  - Tubificidae
    - *Branchiura sowerbyi* Beddard (1)
    - *Limnodrilus claparedeianus* Ratzel (2)
- Hirudinea (leeches) (3)

Arthropoda
- Crustacea
  - Amphipoda (scuds)
    - Gammaridae
      - *Gammarus* sp. (4)
  - Decapoda (crayfish)
    - Astacidae
      - *Orconectes* sp. (5)
- Insecta
  - Diptera
    - Chironomidae (midges)
      - *Chironomus* sp. (6)
      - *Orthocladius* sp. (7)
      - *Parachironomus* sp. (8)
  - Ephemeroptera (mayflies)
    - Heptageniidae
      - *Stenonema* sp. (9)
  - Trichoptera (caddisflies)
    - Hydropsychidae
      - *Cheumatopsyche* sp. (10)
    - Psychomyiidae
      - *Cyrnellus marginalis* (Banks) (11)
      - *Psychomyiidae* (Genus A) (12)

Bryozoa (freshwater bryozoans) (13)

Platyhelminthes
- Turbellaria (flatworms)
  - Tricladida
    - Planariidae
      - *Cura foremanii* (Girard) (14)

1-14. Identifies number of taxa.

Table 25

Macrobenthic Species, Watts Bar Nuclear Plant, 1975

	TRM 518.0				TRM 527.4				TRM 528.0			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Annelida												
Clitellata (Oligachaetes)												
Tubificidae												
Branchiura sowerbyi Beddard				x								
Limnodrilus claparedeianus Ratzel				x								
Hirudinea (leeches)				x								
Arthropoda												
Crustacea												
Amphipoda (scuds)												
Gammaridae												
Gammarus sp.								x				
Decapoda (crayfish												
Astacidae												
Orconectes sp.			x				x				x	
Insecta												
Diptera												
Chironomidae (midges)												
Chironomus sp.			x	x			x	x			x	
Orthocladius sp.	x								x			
Parachironomus sp.		x				x				x		
Ephemeroptera (mayflies)												
Heptageniidae												
Stenonema sp.		x	x	x			x				x	
Trichoptera (caddisflies)												
Hydropsychidae												
Cheumatopsyche sp.	x	x		x		x			x			
Psychomyiidae												
Cyrnellus marginalis (Banks)		x	x	x			x				x	
Psychomyiidae (Genus A)					x							

Table 25 (Cont.)

	TRM 518.0				TRM 527.4				TRM 528.0			
	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa	Wi	Sp	Su	Fa
Bryozoa (Freshwater Bryozoans)	x								x			
Platyhelminthes												
Turbellaria (flatworms)												
Tricladida												
Planariidae												
Cura foremanii (Girard)				x								
Total	3	4	4	8	1	2	4	8	3	1	4	-
Total No. of Taxa		12				8				8		

Table 26

Macrobenthos Per Artificial Substrate[a], Watts Bar Nuclear Plant, 1975
(30-Day Colonization)

Organisms	Winter			Spring			Summer			Fall		
	A	B	C	A	B	C	A	B	C	A	B	C
	TRM 518.0											
Annelida												
Clitellata (oligochaetes)												
Tubificidae												
Brachiura sowerbyi Beddard										8	15	5
Limnodrilus claparedeianus Ratzel										10	13	6
Hirudinea (leeches)										1		
Arthropoda	NO ORGANISMS FOUND		NO ORGANISMS FOUND									
Crustacea												
Decapoda (crayfish)												
Astacidae												
Orconectes sp.								1				
Insecta												
Diptera												
Chironomidae (midges)												
Chironomus sp.									1	5	6	5
Orthocladius sp.	3											
Parachironomus sp.				13	5	33						
Ephemeroptera (mayflies)												
Heptageniidae												
Stenonema sp.						1	1	1	2	3	2	1
Trichoptera (caddisflies)												
Hydropsychidae												
Cheumatopsyche sp.	1			5		2				1	2	4
Psychomyiidae												
Cyrnellus marginalis (Banks)						1	8	7	7	1	2	

Table 26 (Cont.)

Organism	Winter			Spring			Summer			Fall		
	A	B	C	A	B	C	A	B	C	A	B	C
	TRM 518.0											
Bryozoa (Freshwater Bryozoans)	1	NO ORGANISMS FOUND	NO ORGANISMS FOUND									
Platyhelminthes Turbellaria (flatworms) Tricladida Planariidae *Cura foremanii* (Girard)											1	
Total Organisms	5			18	5	37	9	9	10	29	41	21
Near Organisms/Station		2			20			9			30	

a. Each artificial substrate was a cylinder-shaped barbeque basket filled with rocks and had a volume of 7675.2 cm^3.

Table 27

Macrobenthos Per Artificial Substrate[a], Watts Bar Nuclear Plant, 1975
(30-Day Colonization)

Organisms	Winter			Spring			Summer			Fall		
	A	B	C	A	B	C	A	B	C	A	B	C
	TRM 527.4											
Arthropoda												
Crustacea												
Amphipoda (scuds)												
Gammaridae											1	
Gammarus sp.												
Decapoda (crayfish)												
Astacidae												
Orconectes sp.							1					
Insecta		NO ORGANISMS FOUND	NO ORGANISMS FOUND	SUBSTRATE MISSING								
Diptera												
Chironomidae (midges)												
Chironomus sp.								2		8	5	3
Parachironomus sp.					23	27						
Ephemeroptera (mayflies)												
Heptageniidae												
Stenonema sp.							1		1			
Trichoptera (caddisflies)												
Hydropsychidae												
Cheumatopsyche sp.						15						
Psychomyiidae												
Cyrnellus marginalis (BANKS)							31	27	28			
Psychomyiidae (Genusa)	4											
Total Organisms	4				23	42	33	29	29	8	6	3
Mean Organisms/Station		1			33			30			6	

a. Each artificial substrate was a cylinder-shaped barbeque basket filled with rocks and had a volume of 7675.2 cm^3.

Table 28

Macrobenthos Per Artificial Substrate[a], Watts Bar Nuclear Plant, 1975
(30-Day Colonization)

Organisms	Winter A	Winter B	Winter C	Spring A	Spring B	Spring C	Summer A	Summer B	Summer C	Fall A	Fall B	Fall C
	TRM 528.0											
Arthropoda												
Crustacea												
Decapoda (crayfish)												
Astacidae												
Orconectes sp.								1				
Insecta												
Diptera												
Chironomidae (midges)												
Chironomus sp.								1				
Orthocladius sp.	3											
Parachironomus sp.						14						
Ephemeroptera (mayflies)												
Heptageniidae												
Stenonema sp.								1				
Trichoptera (caddisflies)												
Hydropsychidae												
Cheumatopsyche sp.	13											
Psychomyiidae												
Cyrnellus marginalis (BANKS)							3	10	6			
Bryozoa (Freshwater Bryozoans)	1											
Total Organisms	17					14	3	13	6			
Mean Organisms/Station		6			5			7				

NO ORGANISMS FOUND (Winter B, Winter C, Spring B, Spring C)

SUBSTRATES MISSING (Fall A, Fall B, Fall C)

a. Each artificial substrate was a cylinder-shaped barbeque basket filled with rocks and had a volume of 7675.2 cm^3.

Table 29

Comparison of Species Composition, Population Densities and Catch Per Drag in Two 5,000 Square Yard Test Areas Located in Wheeler and Chickamauga Reservoirs During August and September 1957.

Species Name	Wheeler 1/		Chickamauga 2/	
	Population Per Sq. Yd.	Catch Per Sq. Yd. Per Drag	Population Per Sq. Yd.	Catch Per Sq. Yd. Per Drag
Butterfly	0.25	0.0010	0.20	0.0003
Bullhead	----	------	0.05	0.0008
Elephant ear	0.30	0.0004	1.10	0.0070
Eggshell	0.10	0.0003	0.05	0.0005
Heelsplitter	0.05	------	0.05	------
Ladyfinger	0.05	0.0002	0.15	0.0007
Monkeyface	0.10	0.0001	1.90	0.0009
Mucket	----	------	0.10	0.0001
Pigtoe	2.50	0.0110	10.70	0.0389
Pimpleback	0.15	------	0.05	0.0001
Pistolgrip	----	------	0.05	0.0001
Pocketbook	----	------	0.10	0.0001
Three-horn	0.85	0.0019	0.35	0.0008
Three-ridge	0.45	0.0050	0.05	0.0008
Sandshell-black	----	------	0.05	0.0001
Maple leaf	0.05	0.0002	----	------
Kidney shell	0.05	------	----	------
Washboard	0.25	------	----	------
Wartyback-pink	0.65	0.0030	0.75	0.0025
Wartyback-white	0.80	0.0013	1.00	0.0024
Deertoe	0.05	------	----	------
Totals	6.70	0.0240	16.70	0.0560

1/ Mile 309.
2/ Mile 515.
* From Scruggs (1960).

Table 30**

Mussels Found in Chickamauga Dam Tailwater,
Chickamauga Reservoir and Watts Bar Dam Tailwater (1964)

Species	Chickamauga Dam Tailwater TRM 468-471	Chickamauga Reservoir and Watts Bar Tailwater
Quadrula pustulosa	0.064	0.034
Quadrula metanevra	0.041	-
Cyclonaias tuberculata granifera	0.043	0.023
Pleurobema cordatum	*	0.057
Elliptio crassidens	0.085	0.034
Elliptio dilatatus	-	0.011
Obliquaria reflexa	0.106	0.011
Plagiola lineolata	0.043	-
Proptera alata	0.027	0.011

* Pleurobema cordatum was the principal commercial shell here in the past; however, no specimens were taken in samples.
** From Isom (1969).

Table 31

Annual Shell Harvest, Tennessee River 1945 -- 1967****

Year	Number of boats (approx.)	Average tons per boat	Average value* per ton $	Total shells (tons)	Total value* $
1945	143	26.01	40	3,720	148,660
1946	149	66.28	38	9,875	373,781
1947	186	57.04	39	10,610	410,540
1948	210	55.54	43	11,663	502,229
1949	200	37.85	35	7,570	265,000
1950	228	32.01	30	10,500	315,000
1951	256	40.00	40	10,241	409,640
1952	256	31.73	45	8,124	365,580
1953	261	41.72	55	10,890	600,518
1954	280	40.07	42	11,220	472,975
1955	298	38.47	44	11,463	504,252
1956	280	23.58	59	6,603	390,583
1957	317	23.27	75	7,376	556,026
1958	294	16.33	60	4,802	288,120
1959	519	10.80	69	5,606	389,616
1960	861	12.06	122	10,380	1,267,875
1961	926	7.60	125	7,039	882,397
1962	802	5.59	141	4,716**	666,548
1963	678	8.10	147	5,800***	852,911
1964	398	5.30	139	2,112	294,385
1965	233	10.37	143	2,418	346,121
1966	268	10.20	211	2,734	577,161
1967	366	6.45	182	2,361	428,561

* Based on river bank prices.
** Divers collected 235 tons.
*** Divers collected 212 tons, dredge boats 97 tons.
**** From Isom (1969).

Table 32

Composition of Mussel Population Below Watts Bar Dam Collected (All Methods)
July and August 1975

Name	Number from TRM 527.6 to 528.5	Number from TRM 520.5 to 521.3	Total	% of Total
Amblema plicata	6	2	8	5%
Quadrula pustulosa	9	20	29	19%
Quadrula metanevra	1	3	4	3%
Tritogonia verrucosa	2	1	3	2%
Cyclonaias tuberculata	5	15	20	13%
Pleurobema cordatum	12	21	33	22%
Elliptio crassidens	16	14	30	20%
Obliquaria reflexa	1	1	2	1%
Actinonaias carinata	1	0	1	<1%
Plagiola lineolata	2	7	9	6%
Proptera alata	6	3	9	6%
Ligumia recta	3	0	3	2%
*Lampsilis orbiculata**	2	0	2	1%
Total	66	87	153	100%

* On Department of Interior list of proposed endangered species.

Table 33

CORBICULA MANILENSIS ENUMERATION AT TWO STATIONS[a]

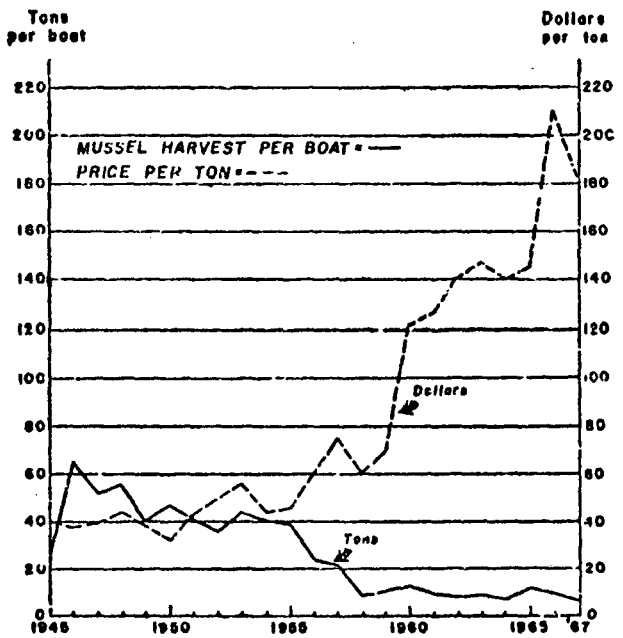
BELOW WATTS BAR DAM (CHICKAMAUGA RESERVOIR)

Date	Area Sampled	No. Samples Collected		Average No. Organisms Sampled		Average No. Organisms m^{2}-1		Mean Lgth. (mm)		Mean Hgt. (mm)		Mean Width (mm)	
		Sta. 1	Sta. 2	Sta. 1	Sta. 2	Sta. 1	Sta. 2	Sta. 1	Sta. 2	Sta. 1	Sta. 2	Sta. 1	Sta. 2
5/5/76	0.5 m^2	5	5	59	48	236	192	38	35	35	32	22	20
8/4/76	1 ft^2	2	2	67	60	268	240	36	32	32	30	20	19

a. Station 1 = TRM 520.5 to TRM 521.3 (10 meters from left shore).
Station 2 = TRM 527.7 to TRM 528.5 (10 meters from left shore).

Figure 1

Annual Mussel Shell Harvest in the Tennessee River, 1945 - 1967*



* From Isom (1969)

Water Quality and Aquatic (Nonfish) Monitoring Program (Nonradiological)

Preoperational Monitoring

The nonradiological water quality and aquatic biology (nonfish) monitoring programs were implemented in the vicinity of the Watts Bar Nuclear Plant in August 1973 and February 1973, respectively. The current monitoring programs are summarized in tables 1 and 2. Although extensive adjustments to improve logistics and coverage were made in the water quality program during the first six months the program was underway, no major revisions have been made in the program since May 1974. With the exception of the addition of mussel surveys by scuba divers in 1975, the aquatic biology program is the same as initially implemented in February 1973.

A construction effects monitoring program to measure the instream impact of construction activities on the suspended solids concentration of the Tennessee River was implemented in January 1973. Based on a review of the results of samples collected during the period from January 1973 to September 1973, it was concluded that the Watts Bar Nuclear Plant construction activities did not have a detectable impact on the turbidity and suspended solids of the Tennessee River. Consequently, the instream water quality construction effects monitoring program was discontinued in September 1973.

Monitoring of the effluents from the sanitary waste treatment plants (construction plants) was initiated on March 1974. The monitoring and reporting of the results of this program are in accordance with the requirements of the NPDES permit for this discharge (TN0020168) which was issued by EPA on December 10, 1973.

Monitoring of the discharge from the construction yard pond for the parameters pH, turbidity, and suspended solids was initiated on a routine basis in March 1975. Although this discharge was identified in the NPDES permit application for construction discharges filed with EPA on July 21, 1975, a discharge permit has not yet been issued by EPA.

Operational Monitoring

In accordance with the requirements of the Federal Water Pollution Control Act Amendments of 1972, TVA plans to file a Section 402 NPDES permit application (standard form C) with the Regional Administrator, EPA Region IV, Atlanta, Georgia, for the operational discharges from the Watts Bar Nuclear Plant. The operational NPDES permit which is expected to be issued by EPA prior to operation of the plant will be the basis for the development of operational aquatic monitoring programs for the Watts Bar Nuclear Plant. The final NPDES permit will specify the specific effluent limitations for thermal, chemical, and sanitary waste discharges originating from the facilities as well as specific effluent and instream (abiotic and biotic) monitoring and reporting requirements necessary to determine compliance with the effluent limitations. The permit will also identify specific monitoring and reporting requirements associated with the assessment of intake technology under Section 316b of the FWPCA. Copies of the NPDES permit and required monitoring reports along with any subsequent revisions in the terms of the NPDES permit will be submitted to USNRC for information.

Table 1

Summary of Quarterly Preoperational Water Quality Monitoring Program (Nonradiological)

Watts Bar Nuclear Plant

Sampling Location (River & Mile)	Horizontal Location (Percent)	Depths for Nonradiological Water Sample Collection (Meters)[a]
Tennessee River Mile 532.1	37	1*, 3*, 5*, 10, 20
	85	1, 10
Tennessee River Mile 529.9	90	(1)*
Tennessee River Mile 529.5	20	1*, 3*, 5*
Tennessee River Mile 528.0	75	1*, 3*, 5*
Tennessee River Mile 527.4	33	(1)*, (5)*
	67	(1)*, 3*, (5)*
Tennessee River Mile 518.0	33	1, 5
	67	1*, 3*, 5*
Tennessee River Mile 506.6	25	1
	70	1*, 3*, 5*, 10
Hiwassee River Mile 2.3	35	1, 10
	80	1
Tennessee River Mile 496.5	57	1*, 3*, 5*, 8

a. Specific Analysis--Temperature and dissolved oxygen concentrations will be determined at each location shown in table 1. Single measurements will be made on samples collected from the Watts Bar Dam tailrace (TRM 529.9). A complete profile of these parameters will be measured at all other locations. Each profile will include measurements at the 1.5-meter depth to correspond to Tennessee water quality standards, measurements at the depths indicated in table 1, and additional measurements at intermediate depths when the difference between successive measurements is greater than 1° C for temperature or 1 mg/l for dissolved oxygen.

Alkalinity and pH will be measured at all depths marked with an asterisk.

Fecal coliform concentrations will be determined at surface (1 meter) depths shown in parentheses.

Laboratory Analyses--At depths marked with an asterisk, appropriate samples are to be collected for laboratory determination of TOC, nitrogens (organic, ammonia, and nitrate plus nitrite), and total phosphorus. At depths shown in parentheses, appropriate samples are to be collected for laboratory determination of conductivity, color (true and apparent), solids (suspended and dissolved), turbidity, BOD (5-day, 20° C), COD, phosphorus (dissolved), calcium, chloride, magnesium, hardness, potassium, silica (dissolved), sodium, sulfate, aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron (filterable and total), lead, lithium, manganese (filterable and total), mercury, nickel, selenium, silver, titanium, and zinc.

NOTE: This program reflects the program underway as of September 1976. However, the complete program is subject to periodic review and revision.

Table 2

Summary of Quarterly Preoperational Aquatic (Nonfish) Monitoring Program (Nonradiological)

Watts Bar Nuclear Plant

Station or TRM	Horizontal Location 1/	Depths Sampled for Chlorophyll, Phytoplankton, & Carbon-14 (meters) 2/	Zooplankton Vertical Tows from Bottom to Surface (duplicate tows)	Artificial Benthos Substrates Colonization Period 3 mths (No. Baskets Set/Sta.)	Periphyton Autotrophic-Heterotrophic Indices and Enumeration Colonization Period 1 mth (No. Racks Set/Sta.) 3/
532.1	R-LM	0,1,3,5	X	3	2
529.9 4/	R-LM	0,1,3,5	X	3	2
528.0 5/	R-LM	0,1,3,5	X	3	2
527.4	R-LM	0,1,3,5	X	3	2
518.0	R-LM	0,1,3,5	X	3	2
506.6	R-LM	0,1,3,5	X	3	2
496.5	R-LM	0,1,3,5	X	3	2
527.7-528.2				X 5/	
520.5-521.3				X 5/	

1/ Horizontal location looking downstream; R-LM = area from right shore to left middle of stream

2/ These depths sampled if applicable; otherwise, surface, middle, and near bottom

3/ Five plexiglas plates per rack - approximate colonization period one month

4/ Tailrace

5/ Mussel bed investigations by SCUBA divers initiated in 1975

NOTE: This program reflects the program underway as of September 1976. However, the complete program is subject to periodic review and revision.

GE Infrastructure
Water & Process Technologies

WATER ANALYSIS REPORT

4000081280
TVA WATTS BAR NUCLEAR
2170 NUCLEAR PLANT ROAD
Spring City, TN
UNITED STATES 37381

Sampled: 30-OCT-2008
Reported: 12-NOV-2008
Field Rep: Overbeck, Susan
WDL0038

	RAW WATER S1031101
Ammonia, Free And Fixed, as N, ppm	F
pH	7.8
Specific Conductance, at 25°C, µmhos	214
Alkalinity, "P" as $CaCO_3$, ppm	0
Alkalinity, "M" as $CaCO_3$, ppm	71
Sulfur, Total, as SO_4, ppm	18.7
Chloride, as Cl, ppm	9.8
Hardness, Total, as $CaCO_3$, ppm	80
Calcium Hardness, Total, as $CaCO_3$, ppm	56
Magnesium Hardness, Total, as $CaCO_3$, ppm	24
Barium, Total, as Ba, ppm	0.03
Strontium, Total, as Sr, ppm	0.09
Copper, Total, as Cu, ppm	< 0.05
Iron, Total, as Fe, ppm	0.06
Sodium, as Na, ppm	9.3
Potassium, as K, ppm	1.9

GE Infrastructure
Water & Process Technologies

WATER ANALYSIS REPORT

4000081280
TVA WATTS BAR NUCLEAR
2170 NUCLEAR PLANT ROAD
Spring City, TN
UNITED STATES 37381

Sampled: 30-OCT-2008
Reported: 12-NOV-2008
Field Rep: Overbeck, Susan
WDL0038

	RAW WATER
	S1031101
Aluminum, Total, as Al, ppm	< 0.1
Manganese, Total, as Mn, ppm	0.03
Nitrate, as NO_3, ppm	< 1
Phosphate, Total, as PO_4, ppm	< 0.4
Silica, Total, as SiO_2, ppm	4.6
Fluoride, as F, ppm	0.1
Lead, Total, as Pb, ppm	< 0.05
Mercury, Total, as Hg, ppb	< 0.2
Carbon, Total Organic, as C, ppm	2.1
Turbidity, NTU	1.8

GE Infrastructure
Water & Process Technologies

WATER ANALYSIS REPORT

4000081280
TVA WATTS BAR NUCLEAR
2170 NUCLEAR PLANT ROAD
Spring City, TN
UNITED STATES 37381

Sampled: 30-OCT-2008
Reported: 12-NOV-2008
Field Rep: Overbeck, Susan
WDL0038

Result Legend

F - A bottle containing the appropriate preservative was not received.

PSO Standard Department Procedure	TITLE **The Vegetation Maintenance Program for 230-kV, 345-kV & 500-kV Transmission Lines**	**SAM-SDP-06.001** **Rev. 0000** **Page 1 of 6** Effective Date 08/04/2006

Prepared by:	Claude Lewis	
Approved by:	Richard Dearman, Manager, System Applied Maintenance	08/04/2006 Date

Current Revision Description

Initial Review

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1.0 PURPOSE

The purpose of this Standard Department Procedure (SDP) is to define the vegetation maintenance program (VMP) on EHV (above 200-kV) transmission lines. The VMP objective is to prevent vegetation related outages on EHV lines.

2.0 SCOPE

This procedure includes all elements required by the NERC standard FAC 003-1. This procedure is applicable to all System Applied Maintenance (SAM) personnel engaged in the VMP for EHV lines.

3.0 INSPECTION PROGRAM

An aerial inspection of each EHV line will be performed annually. The inspection will identify any emergency maintenance needs, and any needs to adjust the cycle of scheduled work due to unforeseen conditions.

Emergency maintenance threats will be documented and removed immediately.

4.0 ANNUAL MAINTENANCE PLAN

The base preventative maintenance program is a three (3) year cycle for undergrowth maintenance and a five (5) year cycle for buffer zone and danger tree maintenance. Maintenance methods will include herbicides, mechanical and hand cutting as appropriate. Work orders will specify the methods to be used based on site specific conditions and easement rights. Work practices for each method will comply with the Line Maintenance Manual, TVA's Environmental Management System, and any specification in the contract for the work including SAM's special requirements.

Due to special conditions some areas may be on shorter or longer cycles than the base program. These exceptions will be documented within the work management system and worked accordingly.

5.0 DOCUMENTATION PROCEDURES

The work management system will be used to schedule, track and document all work orders for inspections, preventative maintenance and corrective maintenance.

6.0 CLEARANCE TO BE ACHIEVED WHEN MAINTENANCE IS PERFORMED

When maintenance is performed on undergrowth or side growth that has the potential to grow within the distance Clearance 2 as shown in Table 1, such vegetation will be maintained in such a manner as to completely eliminate the plant(s) unless easement rights prohibit such work. When easement rights do not allow complete elimination of the plant(s) then they shall be trimmed back to Clearance 1 as shown in Table 1.

Unless limited by easement rights acquired or an agreement with the landowners, danger trees and side growth trees in buffer zones will be maintained if they have grown such that they would come within ten feet of striking the line or structure on falling.

7.0 CLEARANCES TO BE MAINTAINED

Clearance 2 in Table 1 is the minimum approach distance for vegetation to any EHV line conductor. Annual inspections will be used to ensure that either the cyclical maintenance program maintains Clearance 2 or other measures such as emergency maintenance are undertaken to maintain Clearance 2.

8.0 MITIGATION MEASURES FOR RESTRICTED SITES

If a restriction prevents the exercise of the normal preventative maintenance at a site, then a special maintenance cycle will be developed for the site. The work management system will be used to document, schedule and track the special cycle.

9.0 PERSONNEL QUALIFICATION AND TRAINING

Qualifications for TVA employees with duties related to vegetation maintenance activities will be documented in their respective job descriptions in the TVA Human Resources Information System (HRIS). Qualifications for contractors' employees will be specified in each contract. Such qualifications cover, among other things, the necessary requirements to perform the work in a safe, reliable and environmentally acceptable manner

10.0 COMMUNICATION OF IMMINENT VEGETATION THREATS

Any person engaged in vegetation maintenance who identifies an imminent threat of an outage due to vegetation shall contact the TVA Transmission Operator (TO). Pre-job briefs with all contractors will include the telephone numbers for the TO.

11.0 CLEARANCE TABLE 1

Clearance 1 and Clearance 2 distances are from fixed vegetation to conductor after allowing for the effects of ambient temperature on conductor sag under maximum design loading and the effects of wind velocities on conductor sway. Danger tree strike distance is closest approach if tree should fall directly toward the line under maximum design sag.

11.0 CLEARANCE TABLE 1 (continued)

kilovolts	undergrowth and sidegrowth distance clearance 1 - feet	undergrowth and sidegrowth distance clearance 2 - feet	danger tree strike distance - feet
230	21	10	10
345	30	10	10
500	30	10	10

From: Schneider and Tuberville 1981.

Tabla 3.8. Mean annual standing stock estimates (no. /ha and kg/ha) of young and adult threadfin shed collected with rotenone in Watts Bar Reservoir from 1960 to 1980.

Year	Young-of-Year		Adult		Total	
	Number	kg	Number	kg	Number	kg
1960	23,045.94	30.04	0.00	0.00	23,045.94	30.04
1964	2,539.85	6.82	2.71	0.10	2,542.56	6.92
1973	5,997.43	16.02	8.92	0.27	6,006.34	16.29
1975	205.52	0.48	101.97	2.82	307.49	3.29
1976	1,231.76	4.51	103.49	2.97	1,335.25	7.48
1977	241.52	1.42	0.52	0.02	242.04	1.43
1979	153.85	2.24	5.13	0.14	158.97	2.38
1980	5,830.20	5.19	0.00	0.00	5,830.20	5.19

TVA unpublished Data - ≈ 4100 ha of cove/embayment habitat Available in Watts Bar Reservoir.
- Total AREA Watts Bar Reservoir = 15,378 ha

- Therefore in 1960 there were 94,483,354 threadfin Shad found in 26.7% of the Reservoir.
- Likewise in 1980 there were 23,903,820 threadfin Shad found in 26.7% of the Reservoir.

Categorical Exclusion Checklist for Proposed TVA Actions

Categorical Exclusion Number Claimed	Organization ID Number	**Tracking Number** *(NEPA Administration Use Only)*
1		4569

Form Preparer	Project Initiator/Manager	Business Unit
Robert J Crawford	Robert J Crawford	Nuc - Watts Bar Nuclear Plant

Project Title	Hydrologic Unit Code
Increase in allowable UHS temperature to 88F	

Description of Proposed Action *(Include Anticipated Dates of Implementation)* ☒ Continued on Page 3 *(if more than one line)*

For Proposed Action See Attachments and References

Initiating TVA Facility or Office	TVA Business Units Involved in Project

Location *(City, County, State)*

Watts Bar Nuclear Plant, Chickamauga Resevoir

Parts 1 through 4 verify that there are no extraordinary circumstances associated with this action:

Part 1. Project Characteristics

Is there evidence that the proposed action---	No	Yes	Information Source
1. Is major in scope?	X		Nida D. B. 08/12/2003
2. Is part of a larger project proposal involving other TVA actions or other federal agencies?	X		Nida D. B. 08/12/2003
*3. Involves non-routine mitigation to avoid adverse impacts?	X		Nida D. B. 08/12/2003
4. Is opposed by another federal, state, or local government agency?	X		Nida D. B. 08/12/2003
*5. Has environmental effects which are controversial?	X		Nida D. B. 08/12/2003
*6. Is one of many actions that will affect the same resources?	X		Nida D. B. 08/12/2003
7. Involves more than minor amount of land?	X		Nida D. B. 08/12/2003

* If "yes" is marked for any of the above boxes, consult with NEPA Administration on the suitability of this project for a categorical exclusion.

Part 2. Natural and Cultural Features Affected

Would the proposed action---	No	Yes	Per-mit	Commit-ment	Information Source for Insignificience
1. Potentially affect endangered, threatened, or special status species?	X		No	No	Crawford R. J. 02/20/2004
2. Potentially affect historic structures, historic sites, Native American religious or cultural properties, or archaeological sites?	X		No	No	Nida D. B. 08/12/2003
3. Potentially take prime or unique farmland out of production?	X		No	No	Nida D. B. 08/12/2003
4. Potentially affect Wild and Scenic Rivers or their tributaries?	X		No	No	Nida D. B. 08/12/2003
5. Potentially affect a stream on the Nationwide Rivers Inventory?	X		No	No	Nida D. B. 02/20/2004
6. Potentially affect wetlands, water flow, or stream channels?	X		No	No	Nida D. B. 08/12/2003
7. Potentially affect the 100-year floodplain?	X		No	No	Nida D. B. 08/12/2003
8. Potentially affect ecologically critical areas, federal, state, or local park lands, national or state forests, wilderness areas, scenic areas, wildlife management areas, recreational areas, greenways, or trails?	X		No	No	Nida D. B. 08/12/2003
9. Contribute to the spread of exotic or invasive species?	X		No	No	Nida D. B. 08/12/2003
10. Potentially affect migratory bird populations?	X		No	No	Nida D. B. 08/12/2003
11. Involve water withdrawal of a magnitude that may affect aquatic life or involve interbasin transfer of water?	X		No	No	Nida D. B. 08/12/2003
12. Potentially affect surface water?	X		No	No	For comments see attachments
13. Potentially affect drinking water supply?	X		No	No	Nida D. B. 08/12/2003
14. Potentially affect groundwater?	X		No	No	Nida D. B. 08/12/2003
15. Potentially affect unique or important terrestrial habitat?	X		No	No	Nida D. B. 08/12/2003
16. Potentially affect unique or important aquatic habitat?	X		No	No	Crawford R. J. 02/20/2004

Part 3. Potential Pollutant Generation

Would the proposed action potentially (including accidental or unplanned)---	No	Yes	Per-mit	Commit-ment	Information Source for Insignificience
1. Release air pollutants?	X		No	No	Nida D. B. 02/20/2004
2. Generate water pollutants?	X		No	No	Crawford R. J. 02/20/2004
3. Generate wastewater streams?	X		No	No	Crawford R. J. 02/20/2004
4. Cause soil erosion?	X		No	No	Nida D. B. 02/20/2004
5. Discharge dredged or fill materials?	X		No	No	Nida D. B. 02/20/2004
6. Generate large amounts of solid waste or waste not ordinarily generated?	X		No	No	Nida D. B. 02/20/2004
7. Generate or release hazardous waste (RCRA)?	X		No	No	Nida D. B. 02/20/2004
8. Generate or release universal or special waste, or used oil?	X		No	No	Nida D. B. 02/20/2004
9. Generate or release toxic substances (CERCLA, TSCA)?	X		No	No	Nida D. B. 02/20/2004
10. Involve materials such as PCBs, solvents, asbestos, sandblasting material, mercury, lead, or paints?	X		No	No	Nida D. B. 02/20/2004
11. Involve disturbance of pre-existing contamination?	X		No	No	Nida D. B. 02/20/2004
12. Generate noise levels with off-site impacts?	X		No	No	Nida D. B. 02/20/2004
13. Generate odor with off-site impacts?	X		No	No	Nida D. B. 02/20/2004
14. Produce light which causes disturbance?	X		No	No	Nida D. B. 02/20/2004
15. Release of radioactive materials?	X		No	No	Nida D. B. 02/20/2004
16. Involve underground or above-ground storage tanks or bulk storage?	X		No	No	Nida D. B. 02/20/2004
17. Involve materials that require special handling?	X		No	No	Nida D. B. 02/20/2004

Part 4. Social and Economic Effects

Would the proposed action---	No	Yes	Commit-ment	Information Source for Insignificience
1. Potentially cause public health effects?	X		No	Nida D. B. 02/20/2004
2. Increase the potential for accidents affecting the public?	X		No	Nida D. B. 02/20/2004
3. Cause the displacement or relocation of businesses, residences, cemeteries, or farms?	X		No	Nida D. B. 02/20/2004
4. Contrast with existing land use, or potentially affect resources described as unique or significant in a federal, state, or local plan?	X		No	Nida D. B. 02/20/2004
5. Disproportionately affect minority or low-income populations?	X		No	Nida D. B. 02/20/2004
6. Involve genetically engineered organisms or materials?	X		No	Nida D. B. 02/20/2004
7. Produce visual contrast or visual discord?	X		No	Nida D. B. 02/20/2004
8. Potentially interfere with recreational or educational uses?	X		No	Nida D. B. 02/20/2004
9. Potentially interfere with river or other navigation?	X		No	Nida D. B. 02/20/2004
10. Potentially generate highway or railroad traffic problems?	X		No	Nida D. B. 02/20/2004

Part 5. Other Environmental Compliance/Reporting Issues

Would the proposed action---	No	Yes	Commit-ment	Information Source for Insignificience
1. Release or otherwise use substances on the Toxic Release Inventory list?	X		No	Nida D. B. 02/20/2004
2. Involve a structure taller than 200 feet above ground level?	X		No	Nida D. B. 02/20/2004
3. Involve site-specific chemical traffic control?	X		No	Nida D. B. 02/20/2004
4. Require a site-specific emergency notification process?	X		No	Nida D. B. 02/20/2004
5. Cause a modification to equipment with an environmental permit?	X		No	For comments see attachments

Description of Proposed Action *(Include Anticipated Dates of Implementation)*	☐ Continued from Page 1

Parts 1 through 4: If "yes" is checked, describe in the discussion section following this form why the effect is insignificant. Attach any conditions or commitments which will ensure insignificant impacts. Use of non-routine commitments to avoid significance is an indication that consultation with NEPA Administration is needed.

An ☐ EA or ☐ EIS will be prepared.

Based upon my review of environmental impacts, the discussions attached, and/or consultations with NEPA Administration, I have determined that the above action does not have a significant impact on the quality of the human environment and that no extraordinary circumstances exist. Therefore, this proposal qualifies for a categorical exclusion under Section 5.2.1 of TVA NEPA Procedures.

Project Initiator/Manager Robert J Crawford		Date 02/20/2004
TVA Organization TVAN	E-mail rjcrawfo@tva.gov	Telephone

Site Environmental Compliance Reviewer

Signature

Final Review/Closure

Robert J Crawford 02/20/2004

Signature

Other Review Signatures *(as required by your organization)*

Signature

Signature

Signature

Signature

Signature

Signature

Attachments/References

Description of Proposed Action

The proposed Tech Spec change will allow continued plant operation up to 88F Ultimate Heat Sink (UHS) temperature, a three degree increase over the existing limit of 85F. There will be no increase in net change in temperature across the plant, since the proposed change does not increase any heat load on the ERCW system within the plant. Current NPDES environmental temperature limits, which are monitored downstream of the plant to effect thermal environmental compliance, are not impacted by the proposed change.

CEC Comment Listing

Part 2 Comments

CEC Comment Listing

12. See SQN CEC 4575. NPDES permits are established to ensure protection of the environment. These limits are not being changed. Increasing the UHS limits at WBN will not impact Discharge Limitations established by WBN's NPDES permit. Additionally, WBN and SQN NPDES permits require periodic evaluation of the Chickamauga Resevoir and will likely continute to do so. If any adverse trends should be identified, they will be addressed under NPDES regulations and permits.
    By: Robert J Crawford 02/20/2004

Part 5 Comments

5. This would be used to modified temperature limit for Ultimate Heat Sink Tech Spec equipment.
    By: Diedre B Nida 02/20/2004

TENNESSEE VALLEY AUTHORITY

RESOURCE GROUP
WATER MANAGEMENT

AQUATIC ENVIRONMENTAL CONDITIONS IN THE VICINITY OF WATTS BAR NUCLEAR PLANT DURING THE FIRST YEAR OF OPERATION, 1996

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EXECUTIVE SUMMARY

As required by the National Pollutant Discharge Elimination System (NPDES) Permit Number TN0020168 for operation of Watts Bar Nuclear Plant (WBN), this report is a composite evaluation of nonradiological preoperational and operational aquatic monitoring conducted from 1973-1979, 1982-1985, and during 1996. The primary objective of the WBN Nonradiological Operational Monitoring Program is to evaluate and compare specific biological and chemical parameters during the first year of operation of WBN to those reported in the WBN Nonradiological Preoperational Assessment. The following biological and chemical components were monitored to detect and evaluate significant effects, if any, of WBN during the first year of operation; juvenile and adult fish, entrainment of fish eggs and larvae, impingement, tailwater fishery creel survey, benthic macroinvertebrates, native mussel fauna, and water quality analysis.

In the vicinity of WBN, occurrence and abundance of ichthyoplankton (fish eggs and larvae) is primarily the result of passage through the turbines at Watts Bar Dam. This is because most fish species are reservoir and not tailwater spawners. Densities and number of taxa of ichthyoplankton passing WBN were low and low-volume hydraulic entrainment resulted in insignificant losses due to plant operation. Macroinvertebrate, juvenile and adult fish relative abundance and species composition were also influenced by releases from Watts Bar Dam. Comparison of fish community sampling during preoperational and operational monitoring showed minimal variations comparing 12 important species. Reservoir Fish Assemblage Index (RFAI) values also remained relatively stable. It is apparent based on comparisons of species composition, relative abundance, catch per unit effort (CPUE), and RFAI scores between

preoperational and operational monitoring, WBN has not adversely impacted the tailwater fish population below Watts Bar Dam during the initial year of operation.

Total tailwater fishing pressure has increased dramatically in the past 23 years. During the first year of operation, a total of 277,284 fishing hours and 60,674 angler trips was estimated. Catfish, sauger, white bass, crappie, sunfish, striped bass/cherokee bass, and black bass were the most sought after species by fisherman. An estimated of 242,036 fish were caught and 108,216 fish harvested from April 1996-April 1997. Peak angling effort occurred in March 1996 and the peak angling trips occurred in June 1996. Temporal analyses showed that seasonal and yearly changes in abundance and other variables for all component populations, except freshwater mussels, were common.

The freshwater mussels in the vicinity of WBN are quite old and most of the 30 species found may not have reproduced in the past 50 years. The first year of operation of WBN has not impacted the benthic macroinvertebrate community or Watts Bar Dam Tailwater fishery. Abundance trends were noted during preoperational assessment for several communities of macroinvertebrates, plankton, periphyton and harvest of some fish species. These trends are mainly due to the wide range of flow and climatic conditions that occur.

Water quality in the vicinity of WBN, while generally satisfactory, was influenced by releases from Watts Bar Dam, located two miles upstream In 1996, TVA's Water Management installed an aeration device in the forebay of Watts Bar Reservoir. This will reduce stratification of the forebay in the summer and fall and will provide higher dissolved oxygen levels in the hydro

releases. The first year of operation of WBN has not impacted the water quality in Chickamauga Reservoir.

Overall, it was concluded that WBN operation had no effect on either the aquatic communities nor the water quality in upper Chickamauga Reservoir.

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1.0 INTRODUCTION

1.1 Purpose and Objective

The Tennessee Valley Authority, in accordance with the NPDES Permit Number TN0020168, initiated a six-year(1973-1979) nonradiological preoperational aquatic monitoring program after receiving construction permits for WBN on January 23, 1973, from the Atomic Energy Commission. Due to policy changes and various construction delays, TVA initiated an additional preoperational aquatic monitoring program from March 1982 through December 1985 to update the data base. Information collected provided a composite analysis of biological and water quality conditions for both monitoring periods. TVA completed one reactor unit and began testing Unit 1 in March 1996 and generating commercial power May 27, 1996. WBN operated at an 84% capacity factor and generated more than 8.5 billion kilowatt-hours of electricity during the first year of commercial operation.

Part III, Section C.b. of the NPDES permit requires that an operational monitoring plan be implemented not later than the start of the biological year in which 100% power is predicted for Unit 1. The current operational monitoring plan was submitted to the Tennessee Department of Environmental Conservation (TDEC) on September 8,1993 (Ref Letter fiom Wilson C. McArthur to Thomas Roehrn). This operational monitoring plan was revised fiom previous versions based on the following rationale: Numerous aquatic biological investigations were conducted in the vicinity of WBN and throughout Chickamauga Reservoir since the original operational monitoring plan was prepared in 1977. Some of these investigations which studied individual fish species and other

specific problem areas (e.g., dissolved oxygen, aquatic vegetation were conducted as a result of concerns expressed by the State of Tennessee. The cumulative results of these investigations changed the scope and focus of concerns regarding the potential effects of WBN operation on the ecology of Chickamauga Reservoir. In particular, results of species-specific investigations of sauger, white crappie, white bass, and channel catfish have provided information that tends to reduce earlier concerns about the likelihood of WBN operational effects on these species.

The previously approved WBN Operational Nonradiological (Aquatic Biological) Monitoring Program contained types and frequencies of sampling that essentially duplicated those used in the preoperational monitoring program. The rationale for the preoperational monitoring program was to provide a broad base of information on all aspects of the aquatic communities in the vicinity of WBN, regardless of whether or not the operation of the plant would reasonably be expected to significantly impact those communities. The rationale for the present operational monitoring program is to focus as much as possible on specific areas of concern to the State and TVA based on a realistic assessment of the likelihood of operational effects on a given community. It also provides sufficient data to indicate the presence of unexpected effects on other communities that might then become the subject of more intensive studies in the future. The purpose of operational aquatic monitoring is to evaluate plant effects on the aquatic environment for at least two years after commercial operation of Unit 1 as required by the NPDES permit. This monitoring program was designed to detect and evaluate

significant changes in water quality and biological communities which could be plant-induced.

Data analyzing spatial and temporal differences were compared with preoperational monitoring data when possible to detect and evaluate significant changes in water quality and biological communities. Spatial alterations were determined by comparing data from stations upstream and downstream of WBN. Temporal changes were determined by comparing operational (1996) to preoperational monitoring data (1973-1979 and 1982-1985). Data from additional investigations conducted between 1985 and 1996 were also used to supplement preoperational data.

During the first year of operation, WBN did not impact the aquatic communities nor water quality in Chickamauga Reservoir.

1.2 Plant Description

WBN is located on the west bank of Chickamauga Reservoir near Tennessee River Mile (TRM) 528 (Figure 1-1). This one-unit nuclear generating plant is designed for an electrical ouput of about 1270 megawatts (MWe). WBN is situated approximately two miles downstream of Watts Bar Dam (TRM 529.9) and one mile downstream of the four-unit Watts Bar Fossil Plant (WBF) that is also on the west bank of Chickamauga Reservoir (TRM 529). WBF was decommissioned on March 29, 1983, and has been off-line since 1981.

WBN is operated in closed cycle cooling mode, using one of the two cooling towers for heat dissipation. **Blowdown** fiom the cooling tower is discharged through **multiport** diffusers located in the main channel at **TRM 527.8.** Makeup water and other water supply requirements are obtained fiom an intake channel and pumping station at TRM **528.** These intake and discharge structures are shown in Figure **1-1.**

Maximum intake pumping **flowrate** is approximately **4.5** m^3/s **(160** cfs). The intake channel cross-section opening is approximately **155** m^2 **(1,650 ft^2)** at **Chickamauga** Reservoir winter pool elevation of **206** m **(675** A) mean sea level, and **293** m^2 **(3,159 ft^2)** at summer pool level of **208** m **(682.5** A). Corresponding average velocities into the intake channel are **0.03 m/s (0.1 ft/s)** and **0.015 m/s (0.05 ft/s).** Four gates lead to the traveling screens with a **combined** opening of 33 m^2 **(360 ft^2),** so the maximum screen velocity is approximately **0.15 m/s (0.5 ft/s).** These velocities represent about **0.6** % of the **long-term** average flow past **WBN** of **767** m^3/s **(27,100 cfs).**

Blowdown fiom the cooling tower is discharged directly to the diffiser or into a holding pond which in turn releases water through the diffisers. During periods of no releases fiom Watts Bar Dam, releases are stored in the holding pond. Releases during **normal** operation are approximately **2.0** m^3/s.

The diiser system consists of two pipes extending into the main channel. The downstream pipe segment extends 90 m into the channel with a **50** m long, **1.35** m

diameter diffiser section location in the deepest portion (5 or 6 m) of the 400 m wide channel. The upstream pipe segment extends 140 m with a 25 m long, 1.0 m diameter diiser section beginning where the downstream **diffuser** section ends. The diffiser sections are half buried in the river bottom with two rows of 2.5 cm (1 in) diameter ports at 7.5 m (25 ft) spacing oriented at a **45^0 angle** in the downstream **direction.** The exit jet velocity will be approximately 2 **m/s.** The expected discharge temperature varies, depending on cooling tower performance, **from** 17^{0}C in January to **35^{0}C** in July. The maximum **blowdown** temperature is **35^{0}C,** so the expected monthly average temperature **difference** varies **from** the discharge and the river from **10^{0}C** during winter and spring to **5^{0}C** during summer and fall. The **diffuser** system will result in a near-field dilution of at least **15^{0}C.** Far-field mixing will depend on releases from Watts Bar Dam. The permitted **diffuser** mixing zone at **WBN** is 240 feet wide and extends 240 feet downstream over the entire river depth. At the long-term average releases, maximum **diffuser** discharge represents 0.6 % of reservoir flow.

2.0 JUVENILE AND ADULT FISH

2.1 Entrainment-Larval Fish (and Eggs)

Introduction

Preoperational monitoring to determine spatio-temporal concentrations of ichthyoplankton in the vicinity of WBN was conducted from 1976-1979 and from 1982-1985. Preoperational data were compared with operational data collected during 1996 to determine and assess any effects of plant operation. The purpose of this sampling was to provide estimates of relative abundance by taxon to evaluate potential losses by determining the proportion of eggs and larvae passing the plant entrained in the condenser cooling water.

Materials and Methods

Data Collection

Ichthyoplankton samples during preoperational (1984 and 1985) and operational (1996) monitoring were collected biweekly, April-June at TRM 528.0, to assess temporal abundance of larval fish at five stations along a transect perpendicular to river flow just upstream of the plant intake channel (Table 2-1). Sampling was conducted biweekly on a diel schedule (day and night) during April-June, 1996 at Tennessee River Mile (TRM) 528.0 (Figure 2-1). Samples were taken with a beam net (0.5 m square, 1.8 m long, with 505 micron "nitex" mesh netting) towed upstream at a speed of 1.0 m/s for ten minutes. In addition, similar samples were collected in the plant cooling water intake channel in 1984 and 1996 at TRM 528.0. The volume of water filtered through the net was

measured with a large-vaned General Oceanics flowmeter®. Approximately 150 m^3 of water was filtered per ten minute sample, in the main channel upstream from the intake, and approximately 40-50 m^3 of water was filtered per intake sample. Preoperational (1984) intake channel samples consisted of 4 four-minute samples taken from the plant intake pump building to the mouth of the intake channel. Each operational intake sample was a composite of 4, one-minute samples taken from the trash boom to the mouth of the intake channel.

Laboratory Analysis

Ichthyoplankters were removed from the samples, identified to the lowest possible taxon, counted and measured to the nearest mm total length following procedures outlined in NROPS-FO-BR-24.1 (TVA 1983). Taxonomic decisions were based on TVA's "Preliminary Guide to the Identification of Larval Fishes in the Tennessee River," (Hogue et al., 1976) and other pertinent literature.

The term "unidentifiable larvae" applies to specimens too damaged or mutilated to identify, while "unspecifiable" before a taxon implies a level of taxonomic resolution (i.e., "unspecifiable catastomids" designates larvae within the family Catostomidae that currently cannot be identified to a lower taxon). The category "unidentifiable eggs" applies to specimens that cannot be identified due to damage or lack of taxonomic knowledge.

Taxonomic refinement is a function of specimen size and developmental stage. Throughout this report, the designation "unspecifiable clupeids" refers to clupeids less than 20 mm in total length and could include Dorosoma cepedianum (gizzard shad), D. petenense (threadfin shad), and/or Alosa chrysochloris (skipjack hemng), (Table 2-2). Any clupeid specimen identified to species level represents postlarva 20 mm or longer in total length.

Developmental stage of percichthyids also determines level of taxonomic resolution. Morone saxatilis (striped bass) hatch at a larger size than either M. chrysops (white bass) or M. mississippiensis (yellow bass). Although it is currently impossible to distinguish between larvae of the latter two species, M. saxatilis can be eliminated as a possibility based on developmental characteristics of specimens 6 mm or less in total length (hence, the taxonomic designation Morone, not saxatilis). Specimens identified as Morone spp. in most instances are greater than 6 mm total length.

Data Analysis

Temporal occurrence and relative abundance of eggs and larvae by taxon are presented and discussed for the entire preoperational and operational monitoring period. Densities of fish eggs and larvae are expressed as numbers per 1000 m^3 for diel comparisons. A two-way analysis of variance was performed for the important larval taxa using seasonal mean densities from each station across the sample transect to test for differences in horizontal distribution.

Estimated entrainment of fish eggs and larvae at WBN in 1996 was calculated by the following method: densities of eggs and larvae transported past the plant were estimated for each sample period by averaging densities (all stations) of eggs and larvae from TRM 528 and multiplying by the corresponding 24-hour flow past the plant. Percentage of transported ichthyofauna entrained by the plant was estimated fiom the formula:

$$E = \frac{100\, D_i\, Q_i}{D_r\, Q_r}$$

where D_i = mean density (N/1000 m^3) of eggs or larvae in intake samples;

D_r = mean density (N/1000 m^3) of eggs or larvae in river (TRM 528 transect);

Q_i = plant intake water demand (m^3/d);

Q_r = river flow (m^3/d).

Results and Discussion

Fish Eggs

During the two preoperational study periods, 2,881 fish eggs were collected in WBN ichthyoplankton samples. This total consisted of 67% unidentified eggs and 33% freshwater drum eggs (TVA 1986). Overall, egg densities were low and identifiable eggs were predominantly freshwater drum eggs (Table 2-3). Low numbers of drum eggs occurred in samples at WBN fiom early May to early September during preoperational monitoring with peak abundances occumng fiom May through early July (TVA 1986). Low numbers of drum eggs were also recorded during operational monitoring in 1996 with peak abundances during the same time period. Day and night densities were

variable during the study with no apparent trend in diel distribution. The planktonicity of freshwater drum eggs makes them highly vulnerable to capture by larval fish sampling gear; therefore, low abundance at the WBN site indicates little, if any, fieshwater drum spawning in the Watts Bar tailwater upstream of the WBN intake channel. The occurrence of freshwater drum eggs at WBN probably results from dam passage. This theory is supported by data collected at the Lowe Branch site above Watts Bar Dam in 1978, during the first phase of WBN preoperational monitoring (TVA 1980b).

Estimated Entrainment of ih ary

Estimated average hydraulic entrainment from WBN (proportion of the Tennessee River flow entrained) is very low (0.6%) compared to SQN (13%) (TVA 1996). Estimated percentage entrainment of eggs and larvae of fish larvae being transported past WBN during 1996 was 0.1%, compared to 7.5% at SQN during 1980-1984 (TVA 1984). Total transport of fish larvae and eggs past WBN during the six sample periods (April-June) was estimated using the entrainment formula to be 4.5 x 10' and 2.7 x 10^5, respectively. Total numbers of eggs and larvae entrained at WBN was also estimated using the entrainment formula to be 449 and 267, respectively. Due to the low hydraulic entrainment at WBN, larvae residing in the intake channel are most susceptible to entrainment. Larval shad represented 91% of the larval fish collected in the intake channel, followed in abundance by sunfish (7.7%), fieshwater drum (0.8%), and temperate basses (0.09%) (Table 2-4).

Tailwater Populations-Fish Larvae

Table 2-1 lists six sample periods during which 108 biweekly samples were collected at TRM 528.0 from April-June 1996. Mean water temperatures ranged from 10.7°C to 23.3°C. Table 2-5 shows occurrence spans of fish eggs and larvae collected at WBN during operational monitoring, 1996. Clupeids and freshwater drum larvae (Table 2-2) were present from the third through sixth sample period. Earlier larvae were Morone (not saxatilis), Percidae (not Stizostedion), and yellow perch which occurred during the first three sample periods (Table 2-5).

Taxonomic composition of larval fish samples collected near WBN was variable during preoperational and operational monitoring (Table 2-3). During preoperational and operational monitoring 20 and 14 taxa were collected, respectively (Table 2-3). Unspecifiable clupeids represented 84% of the total number collected (Table 2-3). Percent composition of five of the 13 remaining taxa found to exceed 1% were freshwater drum 6.6, temperate basses 3.4, sunfish 1.9, gizzard shad 1.5, and threadfin shad 1.0.

During preoperational monitoring, larval densities, measured from April-June, were highest (2,119/1000m^3) in 1984 and lowest (146/1000m^3) in 1976 with a mean preoperational density of 822/1000m^3 (Table 2-6). The highest and lowest peak density occurred May 29, 1984 (10,485/1000m^3) and May 22, 1979 (370/1000m^3), respectively. During operational monitoring, average larval density was 525/1000 m^3, and the peak

Two Centrachids, sunfish and crappie, were collected all six years of preoperational monitoring, and during operational monitoring. Sunfish were relatively abundant in all monitoring years (Table 2-3).

Preoperational data (TVA 1986) suggest that densities of sunfish larvae were found in greater numbers near the shoreline and in intake samples, indicating that these two areas serve as spawning and nursery areas for sunfish. A total of 35 sunfish larvae were estimated to be entrained during 1996.

Crappie larvae were collected in greatest densities during May and June for all of preoperational and operational monitoring. Size distributions of crappie larvae collected at WBN (Table 2-8) show that approximately 50% of the larvae collected were 5 mm specimens. Crappie larvae swim up from the nest when total length is between 4.1 and 4.6 mm (Siefert 1968 and Carlander 1977). Crappie spawning habitat has been well documented in Watts Bar Reservoir and a greater mean size of crappie larvae collected at WBN than at Lowe Branch in 1978 (TVA 1980a) suggests their occurrence at WBN is also via dam passage.

Freshwater drum comprised 6% of the total catch in 1996 and 0.3 to 18% during preoperational monitoring (Table 2-3). Mean densities of this species were the least variable of the abundant taxa and similar densities were observed during day and night samples (Table 2-7). As mentioned previously, freshwater drum were primarily spawned above Watts Bar Dam.

Relatively low densities of fish eggs and larvae collected in Watts Bar Tailwater, and minimal hydraulic entrainment by **WBN,** suggests no impact to the ichthyoplankton populations fiom plant operations.

2.2 **Electrofishing**

Introduction

Preoperational electrofishing at WBN was initiated in March 1977, continued through November 1979, and resumed fiom March 1982 to December 1985. Additional preoperational monitoring data were collected in the vicinity of **WBN** (TRM **526-529.9) from** 1990 to 1995 in conjunction with the **TVA** Reservoir Vital Signs Monitoring program. Vital signs monitoring activities provide information fiom key physical, chemical, and biological indicators. The Reservoir Fish Assemblage Index (RFAI) provides one biological measure of the status of the environmental quality of a particular area of a reservoir **(Hickman** and **McDonough** 1996). The sampling schemes between these two data sets (older preoperational and vital signs monitoring) were somewhat diierent, limiting potential **comparisons.**

Usefulness and validity of electrofishing data, as with other gear types, is dependent on efficiency and consistency of sample collection. Factors which influence electrofishing data can generally be broken into three categories: fish characteristics, habitat characteristics, and operating conditions (Reynolds 1983). Fish characteristics are not anticipated to influence **WBN** preoperational and operational electrofishing samples as the sampling schemes were **directed** at the same species. Influence of habitat

characteristics was minimized by both sampling schemes directed at proportionately covering all shoreline habitats available above and below WBN. Operational variations, such as seasonal differences in Watts Bar Dam water releases, were reduced by comparing only fall samples between the data sets (spring, summer and winter were also available for the 1977-1985 preoperational samples). Another operational diierence was the start-up of WBN in 1996, and this was the focus of determining plant impacts.

Materials and Methods

Fish stunned by a boat electrofishing unit were captured, identified, enumerated, and recorded prior to release. During vital signs monitoring samples (1990-1996), young-of-the-year (YOY) individuals of all species were not included in counts and percent composition aspects due to their highly fluctuating densities (especially shad species), inaccurate sampling by electrofishing, and the uncertainty of their recruitment to adult stocks. Earlier preoperational samples (1977-1985) did include YOY individuals. Individual lengths were not measured during these samples, therefore, determination of YOY densities was not possible. As a result, gizzard and threadfin shad were eliminated fiom all density and percent composition results fiom all data sets.

Data collected fiom 1977-1979 were based on timed (three minute duration) electrofishing runs, while samples collected during 1982-1985 were distance based (100 meters). Five electrofishing runs were collected monthly during both of these time periods. Vital signs samples were collected once during each fall and were distance-based (300 meter transects). Species occurrence and percent composition between the

two preoperational sample sets, after elimination of shad, are comparable. Since operational data are limited to one annual sample (1996), vital signs preoperational data are reported in average annual results to allow more realistic comparisons.

Catch per unit effort (CPUE) results are not comparable between 1977-1985 preoperational and 1990-1996 vital signs results due to the differences in sampling protocol. Therefore, discussions of operational impacts of WBN on fish species CPUE will be based on comparisons between 1990-1995 (preoperational) and 1996 (operational) vital signs monitoring results.

Data Analysis

General comparisons were made between the 1977-1985 preoperational, 1990-1995 preoperational, and 1996 operational data regarding species occurrence and relative composition of the resident fish population. Average CPUE results in electrofishing samples during vital signs preoperational and operational periods were compared using a univariate Analysis of Variance (ANOVA) to determine if there were significant differences ($P = 0.05$). Only species termed "important" (those occurring in 50% or more of the samples and comprising at least 1% of the total catch) are discussed in detail. RFAI scores between vital signs preoperational and operational years were compared to determine if the overall fish community had been impacted by the initial year of WBN operation.

Results and Discussion

Table 2-9 compares species occurrence and percent composition between preoperational electrofishing (1977-1979 and 1982-1985), preoperational vital signs monitoring data (1990-1995), and operational monitoring (1996) electrofishing data. During the 1977-1985 preoperational monitoring period at WBN, monthly electrofishing yielded 43 species fiom 12 families (Table 2-9). Fall vital signs electrofishing preoperational monitoring resulted in the collection of 39 species from 10 families and 32 species (9 families) were captured during fall 1996 operational monitoring. The higher diversity found during 1977-1985 preoperational monitoring was likely due to samples occurring on a monthly basis instead of only one fall sample taken per year during vital signs monitoring activities. Operational monitoring consisted of only one sample during 1996, however, species occurrence was just slightly lower than 1990-1995 preoperational results which included six annual fall samples.

Percent composition of the various preoperational and operational electrofishing samples (excluding gizzard and threadfin shad) revealed minimal differences in the fish community make-up fiom 1977-1996 (Table 2-9). Only emerald shiners appear to have declined substantially in numerical abundance over the course of the sample periods; making up 58.6% of the community during 1977-1985, 17.1% fiom 1990-1995, and only 0.3% during 1996. This decline began prior to WBN startup, therefore plant operation is not considered responsible. Bluegill, redear sunfish, yellow bass, and largemouth bass have consistently dominated the overall catch, with bluegill increasing in importance throughout the sampling period. Additional species of fish generally meeting

the important species criteria (comprising more than 1% of the population) included; white bass, common carp, spotted sucker, brook silversides, logperch, smallmouth bass, and spotted bass.

Comparisons of CPUE (catch per unit effort) results between vital signs preoperational (1990-1995) and operational (1996) monitoring are listed in Table 2-10.

Mean CPUE for all species during preoperational and operational monitoring was 76 and 57 fish per shocking run, respectively. Gizzard and threadfin shad were not included due to extreme variability of results caused by the schooling nature of these species. If a large school of shad is encountered during a particular electrofishing run, the catch rates are skewed out of proportion. Bluegill, redear sunfish, largemouth bass, yellow bass, and spotted bass dominated the catch during both periods. Only emerald shiners revealed any major change in abundance, and, as noted earlier, this decline began prior to WBN becoming operational. None of the differences between preoperational and operational sample results for 12 species meeting the criteria to be considered "important" were significant, P=0.05 level (Table 2-11).

RFAI values for the vicinity of WBN remained relatively stable with an average annual score of 44 during the 1991-1995 preoperational period and a score of 38 in 1996. The slight decline was not significant (P=0.05 level). Scores ranged from a maximum score of 56 in 1993 to a minimum score of 33 in 1991 (Figure 2-2). RFAI scores during preoperational years of 1991 and 1992 were similar to that obtained during the 1996

operational period. The maximum RFAI score of 56 obtained in 1993 was followed by a gradual decline to an RFAI score of 38 by 1996. This decline began two years before WBN became operational.

In conclusion, based on comparisons of species composition, relative abundance, CPUE, and RFAI scores between preoperational and operational monitoring, WBN has not adversely impacted the tailwater fish population below Watts Bar Dam during the initial year of operation.

2.3 Impingement

Introduction

Monitoring for impingement of fish on the WBN cooling water intake traveling screens began March 15, 1996, before Unit 1 became commercially operational. WBN operated in closed cycle cooling mode, with blowdown from the cooling tower being discharged through the multiport diffusers located in the main channel at TRM 527.8. Makeup water is pumped from the intake channel located at TRM 528.0 with a maximum flow rate of 4.5 m^3/s (160cfs), which represents 0.6% of the long-term average flow of 767 m^3/s (27,100 cfs) past WBN (TVA 1996). Results from the first year of fish impingement monitoring at WBN are compared with standing stocks of fish in Chickamauga Reservoir and previous impingement estimates from Sequoyah Nuclear Plant (SQN).

Material and Methods

Total numbers and species of fish impinged on the screens were estimated from weekly screen washings during December-May and biweekly during June-November. Protocol for impingement sampling at the WBN intake pumping station consists of four screens rotating and backwashing simultaneously to remove all fish and debris. Screens were left stationary for 24 hours to collect the sample and all four screens were rotated and backwashed again to remove impinged fish. These fish were collected from the screen backwash water as the water passed through a steel mesh basket at the end of the screen wash sluice pipe. Impinged fish were identified to species, measured, weighed and separated into 25 mm length classes. Number and total weight of fish in each length class were recorded. Thirty-six samples were collected between March 15, 1996, and February 28, 1997. Estimates of monthly and annual total impingement were calculated by multiplying average number of fish impinged per sample by number of days in each month and year.

A number of measures were taken to increase quality control of the data collected. These included: (1) improving conditions at the backwash sluice pipe and in the steel mesh basket where the debris and dead fish in the sluice were removed, (2) improving screen wash coordination and scheduling with WBN personnel by requesting that the Shift Operation Supervisor (SOS) on duty record the cellular telephone number of the technician at the steel mesh basket in the log so the next SOS on duty will have a telephone number to contact the technician if any delays or problems exist.

Results and Discussion

Thirty-six impingement samples collected between March 15, 1996, and February 28, 1997, yielded only 16 fish representing eight species (Table 2-12). Numbers of impinged fish were consistently low due to the low volume of water withdrawn through the intake channel. Total estimated annual impingement of 162.2 fish (Table 2-12) from March 1996-March 1997 was extremely low compared to 70,022-14,960 fish estimated impinged at SQN during 1981-1983 (Table 2-13). None of the species were impinged in sufficient numbers to impact Chickamauga Reservoir populations. Table 2-13 supports this conclusion by listing estimates (1981-1983) of standing stocks of each species in Chickamauga Reservoir. Impingement estimates were < 0.002% of reservoir standing stock for all impinged species. None of the species impinged are listed as threatened, endangered or of special concern by the State of Tennessee or the U. S. Fish and Wildlife Service.

Due to extremely low numbers of fish impinged during the first year of operation, it is recommended that impingement monitoring be discontinued at WBN for the rest of the operational monitoring period.

2.4 Fishery Creel Survey

Introduction

Specific objective of the creel survey were to determine recreational angler catch, harvest, and effort and provide insight into population characteristics of largemouth bass, smallmouth bass, spotted bass, channel catfish, blue catfish, black crappie, white crappie, sauger, striped bass, and white bass.

Due to the limited scope of the preoperational WBN vicinity creel (1982-1985), only annual catch rates could be compared with data obtained during the more intensive operational creel. Therefore, results of the operational monitoring creel are reported as a "baseline". Creel results from subsequent years will be used to establish trends which would allow further determination of WBN impacts on fishery use and success.

Materials and Methods

Recreational fishing data in the vicinity of WBN (TRM 523.2 to TRM 529.9) was collected during preoperational and operational monitoring using access point angler creel surveys. Preoperational creel survey results are limited to catch rate estimates, average weight of each species and percent composition. Fishing pressure was not estimated due to a limited sampling schedule. A modified bus stop angler survey was used during operational monitoring to assess harvest, catch, and effort data. Only catch rates between preoperational and operational creel results are used for comparison.

Study Area:

The Tennessee River from Watts Bar Dam (TRM 529.9) downstream to Yellow Creek (TRM 526.8) served as the study area during preoperational monitoring, April 1982 to December 1985. During operational monitoring (April 1996-March 1997), the study area was extended an additional 3.6 miles, increasing the creel area to include accesses at Sewee Creek and Eaves Ferry boat ramp (TRM 523.2). Six access points are available to anglers in the study area (Table 2-14). Anglers can bank fish from all six locations and launch a boat from four of these locations.

Survey Technique

A modified bus stop creel technique was employed. Anglers utilizing six access points were surveyed. Proportion of time surveyed at each access point is provided in Table 2-14. Creel surveys during preoperational monitoring used the same technique employing a creel clerk one day per week. During operational monitoring, a creel clerk surveyed three days per week (1 weekend and 2 weekdays) within the study area. The clerk was stationed onsite either in the morning, afternoon, or evening (May-July). All schedule times were randomly assigned. The clerk was instructed to seek out anglers on the bank and to encounter any boat anglers as they either came ashore or as they fished near shore. The clerk interviewed anglers during the assigned period, and when completed, traveled to the next location.

Instantaneous counts were made once per day at randomly assigned periods. The clerk counted at Watts Bar Dam, and all visible boat and bank anglers with the aid of binoculars. Directly following that count, the clerk traveled to the Eaves Ferry Boat Ramp and counted all visible boat and bank anglers. Providing a complete count of all anglers within a 15 minute period. In addition, all vehicles with boat trailers were counted at each access ramp at the beginning of each sample period. To validate instantaneous counts, the clerk traversed the entire three mile reach via boat on one out of five of the survey days to count all anglers.

Creel Data Analysis

Creel data analysis followed standard techniques reported in TVA, 1986 for preoperational monitoring and in Pollock et al., (1994) for operational monitoring. Annual catch and harvest rates were determined for all anglers, generalist anglers fishing for any species group, and for anglers directing their efforts toward a particular species group (i.e. black bass, crappie, catfish, ect.) during operational monitoring. Monthly rates were determined for only all anglers and directed species group anglers. In looking at catch and harvest rates for individual species (i.e., largemouth bass in the black bass group), only angler data from those indicating they were targeting largemouth bass were included.

Estimated effort (hours) was determined using instantaneous count data and using a standard expansion approach based on day of week, time of day probabilities, and an 8.5 hour sample period (Pollock et al., 1994). Estimated effort for specific directed species group was determined by partitioning the annual effort estimate by the proportion of effort accounted for each directed species group. Similarly, effort was determined by location, and boat or bank anglers. Estimated angling trips were determined by dividing the mean length of completed trips for a selected group (i.e., sauger anglers) into the estimated effort (hours) for that group. Estimated angling trips are provided only on an annual or monthly basis because of small sample size of completed trips by month for many directed species groups. All estimated values are reported with a standard error of the mean as a measurement of variation.

Length and weight were obtained fiom individuals of selected species. Length frequency analysis was conducted, and an age-length key was developed following the methods of Ricker (1975).

Results

During April 1982-December 1985 (preoperational monitoring), 4,745 individual fisherman were interviewed. Interviews were taken fiom 1,864 angling parties during operational monitoring (April 1996-March 1997). Monthly interviews exceeded 100 for each month except December 1996 (Table 2-15).

Boat verses bank angler information was not collected during preoperational monitoring. During the 1996 WBN operational creel, 71% of angling parties interviewed were fishing from the bank. A majority of both bank (64%) and boat (76%) anglers were fishing for a specific group of species. Bank anglers primarily sought sauger (15%), catfish (13%), and white bass (11%). Boat anglers primarily sought catfish (27%), sauger (14%), black bass (11%), and white bass (11%) (Table 2-16).

Of the six locations were selected as potential access points to the fishery, three were used primarily by bank anglers and three by boat anglers (Table 2-17). The majority of bank anglers utilized the two access points at the dam (Table 2-17). Bank anglers used the Sewee Creek boat ramp primarily during the spring white bass spawning period. All anglers used the public use areas below Watts Bar Dam greater than 96% of the time to gain access to the fishery.

Angling Effort

No comparison of angler use patterns prior to WBN becoming operational could be made as fishing pressure information was not collected during the preoperational phase. Anglers expended an estimated 277,284 hours during the WBN operational period (April 1996-March 1997). Mean length of an angling trip was 4.6 hours. Daily effort was 596.8 hours on weekdays and 1,208.8 hours on weekend days. An estimated 60,675 angling trips were conducted during the 12 month period.

Monthly angling effort varied from 31,832 hours in March 1997 to 13,343 hours in September 1996 (Table 2-18). Angling trips ranged from 8,131 in June 1996 to 2,718 trips in September 1996 (Table 2-18). Mean length of angling trip ranged from 5.50 hours in February 1997 to 3.11 hours in April 1996.

Anglers seeking any species expended an estimated 88,731 hours or 19,587 trips (Table 2-19). Directed species groups expending greater than 30,000 hours included catfish (61,002 hours), sauger (36,045 hours), and white bass (33,274 hours). Many bank anglers, although identifying themselves as any species anglers, were actually fishing for both sunfish and crappie; thus, the effort on crappie and sunfish most likely approached 114,000 hours.

Monthly angling effort by directed species group showed seasonal trends (Figures 2-3 and 2-4). Any species angler percent effort exceeded 20% of the total for each month.

Catfish angler effort peaked in June 1996 and was greatest during the summer months. **Sauger** angler effort was greatest in November 1996-January 1997.

Bank-user anglers expended **an** estimated 139,473 hours or 48,767 angling trips, as compared to 137,811 hours or 27,397 angling trips for boat anglers. Mean length of angling trips for bank anglers **was** 2.86 hours and 5.03 hours for boat anglers. An estimated 46,816 angling trips were taken at the two access points located at the dam.

Catch and Harvest

Overall annual catch rates (number per hour) in the vicinity of WBN during preoperational monitoring from 1982-1985 were **0.73, 0.83,** 1.00, and 1.16, respectively (TVA **1996).** By comparison annual catch rate for the first year of operational monitoring was 1.67 **(fish/hour).**

Catch rate comparisons for each species collected between preoperational and operational monitoring is listed in Table 2-20. During operational monitoring, catch rates increased for blue catfish, **bluegill,** spotted bass, white and yellow bass, and black crappie, but have decreased for white crappie. Abundance of white crappie has significantly decreased throughout **Chickamauga** Reservoir **(McDonough** and Buchanan 1991).

Monthly catch and harvest rates for directed species group anglers varied with season for **sauger,** blue catfish, and white bass during operational monitoring (Figure 2-5 and 2-6).

Sauger catch and harvest rates peaked in April 1996 and was lowest during summer months. The peak in April 1996 for sauger was not achieved in spring of 1997. Blue catfish catch and harvest rates were fairly consistent except during winter months. White bass catch and harvest rates peaked in the spring of both years and were lower during summer months.

Annual estimated numbers caught and harvested were determined for both directed species group anglers and any species group anglers (Figure 2-7). The greater catch and harvest rates for directed species group anglers allowed for a greater annual catch and harvest by this group. Overall estimated numbers caught and harvested for blue catfish, sauger, bluegill, and white bass are presented in Table 2-21. An estimated 41,411 sauger were caught from April 1996 through March 1997 of which 15% were harvested. Estimated number of blue catfish caught was 26,678 representing the largest portion of any catfish species.

Length and age frequency trends for largemouth bass, smallmouth bass, spotted bass, blue catfish, channel catfish, black crappie, white crappie, sauger, white bass, and striped bass were examined during the first year of WBN operation, but not during preoperational sampling.

Length frequency of the 3 black bass species harvested were similar. Anglers harvested mostly individuals from 275-300,300-325, and 325-350 mm (Figure 2-8). Few large largemouth bass or smallmouth bass were harvested. Largemouth bass were primarily

age 3 and 4 as were smallmouth bass (Figure 2-9). Spotted bass were dominated by age 2-4 individuals.

Length fiequency of both blue catfish and channel catfish were similar. Anglers harvested more individuals fiom 350-450 mm (Figure 2-10). Larger blue catfish (> 500 mm) were caught more frequently than channel catfish.

Angler harvested black crappie and white crappie were primarily from 250-275 mm (Figure 2-11). This corresponds to the newly enacted statewide size limit on crappie 250 mm or 10 inches. Age frequency of harvested crappie indicated that most harvested crappie were either age 3 or 4 (Figure 2-12), but black crappie as old as age 8 were harvested.

The length frequency of harvested sauger was dominated by individuals from 375 -425 mm (Figure 2-13). Age fiequency of harvested sauger was dominated by 3-6 year old individuals (Figure 2-14). Harvested white bass were mainly from 275-350 mm (Figure 2-15). The age frequency of white bass was dominated by 3 and 4 year old (Figure 2-16). Striped bass harvested were generally greater than 650 mm, but striped bass as small as 250 mm were harvested (Figure 2-17). Age fiequency displayed a wide range of ages (1-11) with most harvested striped bass being between the ages of 4 and 8 (Figure 2-18).

It is apparent, during the first year of operational monitoring, WBN did not significantly effect the tailwater fishery in the vicinity of the plant,

3.0 BENTHIC MACROINVERTEBRATES

3.1 Aauatic Insects

Introduction

Benthic aquatic macroinvertebrates are animals that live part or all of their life cycles on or near the bottom of streams or reservoirs. These organisms serve as an important food resource for other forms of aquatic life, especially fish, and studies of their abundance and distribution are useful for detecting major environmental perturbations. Because many have an attached, or sessile, mode of life in the aquatic environment and are neither subject to rapid migrations nor severe translocation by water mass displacement (except under flood conditions), these organisms reflect exposure history and serve as natural monitors of environmental conditions. Additionally, many species are sensitive to pollution and some have a relatively long and complex life cycle of a year or more; hence, their presence or absence and abundance pattern help describe environmental conditions over a period of time.

Hynes (1970) reports that evaluation of power plant effects on benthic macroinvertebrate communities requires good preoperational monitoring assessment of "natural" abundance and distribution patterns. Macroinvertebrate species composition and population levels respond readily to not only power plant effects but also naturally occurring factors such as availability of food, nature of benthic sediments, flow, reproductive success, floods, proximity of suitable habitats, temperature, and dissolved substances. The most obvious influential factors in the study reach encompassed in the

WBN environmental assessment are current speed and substrate composition, which are closely related. Traveling downstream fiom WBN, there is an obvious lessening of current velocity which is accompanied by a transition fiom hard rock and sand to softer, more silty substrates (TVA 1986). These factors are expected to greatly affect spatial distributions of macroinvertebrate populations.

Materials and Methods

To measure abundance and species composition, Hess® samplers were used to collect benthic macroinvertebrates during summer (July-September) and fall (October-December) quarters from TRM 521.0, 526.3, 527.4, 528.0, and 528.5 in upper Chickamauga Reservoir (Figure 3-1). Samples were collected during both preoperational (1983-1985) and operational (1996) periods. Each Hess sample represents an area (0.0856 m^2) of the substrate.

Divers collected 10 Hess samples at each station. The Hess sampler was pushed into the riverbed to a depth of 2.5 to 5.0 cm and the substrate within the confines of the sampler disturbed by hand or with a hand rake to a depth of approximately 15 cm. Dislodged organisms and detritus were carried by the current into a catch cup located on the down current side of the sampler. All large rocks, mussels, clams, etc., encountered in a sample were placed in an attached mesh bag. The Hess sampler's mesh net and collection cup were tied closed after the sample was collected to keep material fiom being back flushed out of the catch cup and net. Collected material was pulled to the

surface via a tether line connected to the sampler, transferred to plastic containers, and preserved with 10% formalin.

Laboratory Analysis

Samples were sorted and identified using standard operating procedures (Pennington and Associates, Inc. 1992). Benthic samples were washed in a 270 micron mesh screen, removed from the detritus and preserved in 85% ethanol. Organisms were identified to the lowest practical taxonomic level.

Data Analysis

Summer and fall operational monitoring Hess data (1996) were compared with preoperational monitoring Hess data (1983-1985). Sorensen's Quotient of Similarity (SQS) (McCain 1975) and Percentage Similarity (PS) (Pielou 1975) were used to evaluate similarity among stations based on quantitative and qualitative community structure. A criterion of 70% or greater was chosen to indicate similar community structure at stations being compared. Community diversity (D-Bar, diversity index) was calculated according to Patten (1962) and a one-way ANOVA and Duncan's Multiple Range Test (Steel and Tome 1960) were used to aid in evaluating station differences (number of taxa present and abundance/m^2) in summer and fall quarters. Abundance data were transformed (log_{10}) prior to the analysis.

Results and Discussion

Occurrence of macroinvertebrate taxa collected during preoperational and operational monitoring at **WBN** plant, **1973-1985** and **1996** is compared in (Table **3-1).** Densities of benthic macroinvertebrate increased considerably after **WBN** became operational at all five stations (Table 3-2). These increases are likely due to improvements in dissolved oxygen levels in water released through Watts Bar Dam as a result of aeration activities in the **forebay** at Watts Bar reservoir beginning in early summer, **1996.**

Three of the 59 taxa collected during preoperational monitoring, Corbicula fluminea (formerly C. **manilensis), Crynellus fraternus,** and Oligochaeta, comprised approximately 85% **of the** total community (Table 3-2). During operational monitoring, 5 of 86 taxa collected, **Corbicula** fluminea. **Dugesia tigrina, Gammarus** minus, Hydra americana and Oligochaeta, comprised **83%** of the total community. Corbicula fluminea, Asiatic clam, was consistently the most abundant **taxon** during preoperational **monitoring,** but was less dominant during operational monitoring. Duaesia **tigrina** was the most abundant **taxon** during **1996** operational monitoring especially in fall samples (Appendix **1). Crynellus fraternus** (caddisfly) met the dominant **taxon** criteria (Table 3-2) during preoperational monitoring but did not comprise 5% of the total at any location during operational monitoring. C. **fraternus** was, however, found at each station during both summer and **fall** operational monitoring.

Average number of taxa collected in preoperational summer and fall monitoring (1983, 1984 and 1985) was 11.5, 17.4, and 16.1, respectively (Table 3-3). Greatest number of taxa collected at a **single** station during preoperational monitoring was 24 in summer of 1985 at TRM 521.0. Community diversity index was low (<2.5) at all stations during preoperational monitoring and **frequently** below 1.00, especially downstream of TRM 528.0 (Table **3-3).** Low diversities generally reflected complete dominance by Corbicula fluminea at most stations. The greatest diversity value 2.20 was recorded at TRM 527.4 during fall 1985 when only 53% of the total community was composed of Corbicula **fluminea** (TVA 1986).

During 1996 operational monitoring, an average of 28.1 (summer and fall combined) taxa were collected per station, which was significantly greater ($a = 0.001$) than those collected during preoperational monitoring (Table 3-3). The greatest number of taxa collected at a single station in fall 1996 was 32 at TRM 528.5. The community diversity index during operational monitoring, as during preoperational monitoring, was low (<2.5) at all stations (Table 3-3). However, the number of taxa found at each station **increased.** The number of taxa found at **TRM's** 527.4 and 528.5 nearly **doubled** during 1996, yet the diversity index relatively stayed the same. These results indicate negative impacts on the benthic community of upper **Chickamauga** reservoir due to operation of WBN during 1996.

SQS and PS was used to determine similarity of benthic macroinvertebrate communities at stations above and below WBN, both during preoperational and operational periods.

Results indicate that degree of similarity changes between years and seasons with the preoperational data, and between seasons on the one year of operational data (Table 3-4). For example, during summer 1996 operational monitoring, benthic macroinvertebrate communities in 8 of 10 stations, expressed as SQS, were dissimilar. In fall 1996, SQS indicated that 7 out of 10 stations had similar benthic communities. PS results during 1996 were more consistent, 5 and 6 stations out of 10 were similar between summer and fall, respectively. However, some of the stations with similar benthic communities differed between periods. Preoperational data revealed the same inconsistencies. These results suggest that comparisons between preoperational and operational results must be made on an individual station to station basis.

Comparison of stations based upon analysis of variance and Duncan's Multiple Range Test of total benthic macroinvertebrate standing crop (Table 3-5) showed similar discrepancies. Stations in summer 1983 were alike except for a highly significant difference ($P>F = 0.0002$) at TRM 527.4, where a greater than 50% reduction in the dominant organism, Corbicula fluminea, occurred. Stations differences changed in summer 1984, with total abundance again tied closely to abundance of Corbicula fluminea. In summer, 1985, abundance of macroinvertebrates again changed, with abundance much higher than at other stations (Table 3-6). This station maintained exceptionally large numbers of the silt tolerant midge, Chironomus sp. (540 per m^2), and other silt-preferring organisms such as Branchiura sowerbyi, Tubificidae, Hexagenia, and Chironomidae, which were not present or abundant at other stations (TVA 1986)..

Sediment core samples collected during preoperational monitoring contained an average of 18.5 grams (dry weight) **silt/clay** at this site.

During operational **monitoring,** summer and **fall,** 1996, stations that had similar benthic communities varied with preoperational results (Table 3-5). Benthic community standing crops at stations adjacent to **WBN** and upstream (528.0 and 528.5) were significantly different fiom these stations below the plant during fall, 1996. However, station results were different during summer, 1996. Station similarities of total benthic macroinvertebrate standing crop were primarily due to abundance of Corbicula **fluminea,** Dugesia **tigrina, Gammarus** minus and Oligochaeta, (Table 3-3). Silt-prefemng organisms such as **Branchiura sowerbyi, Tubificidae,** and **Limnodrilus hoffmeisteri,** were somewhat abundant at **TRM's 521.0, 526.3,** and 527.4, (Appendix 1). The substrate of the five benthic macroinvertebrate stations, during operational monitoring, consisted primarily of **cobble/gravel mix** with dead mollusk shell deposits, very little silt was present.

During fall preoperational monitoring, no significant differences were identified among stations in 1983 and 1985 (Table 3-5). In 1984, total abundance in fall was greater upstream of TRM 526.3, **resulting** fiom a large increase in the caddisfly, Cyrnellus fiaternus, and amphipod, **Crangonyx**. During operational monitoring densities **(no/m^2)** of benthic macroinvertebrates collected at five stations near **WBN** nearly doubled from those observed during preoperational monitoring, 1983-1985, (Table 3-2).

In addition to the increased number of taxa found during operational monitoring, Hess samples found (Zebra Mussel) Dreissena polymorpha at each station. Zebra mussels were most abundant (60 /m^2) in the fall of 1996 at TRM 528.0 (adjacent to the WBN intake channel) (Table 3-4). Zebra mussels were first found near WBN plant June 1, 1995, at TRM 528.0. Samples collected on that date indicated a density of 4.8/m^2. During July and October 1996, quantitative samples estimated zebra mussel densities to be 15.4/m^2 and 28.6/m^2, respectively (TVA 1995).

Based on comparisons of species composition, occurrence, and mean number of aquatic insects per square meter values between preoperational and operational monitoring, WBN has not significantly effected the tailwater benthic macroinvertebrate population during the first year of operation.

3.2 Freshwater Mussel Fauna

Introduction

Preoperational monitoring of the freshwater mussel community in the vicinity of WBN was conducted at various intervals from 1983 through 1994. On each occasion, the same four locations on each of three mussel beds were examined by divers. Results of most of the preoperational examinations of these beds have been presented in various reports (TVA 1986; Ahlstedt 1989, 1991).

In 1996, this study was conducted to add the first year of information during WBN operations to the mussel community data set. The purpose of this work was to conduct

an examination of the mussel fauna at the same locations on the same beds using the same procedures as those used during the preoperational monitoring period.

Study Area Description

In 1983, the mussel monitoring sites (Figure 3-2) were established in three known concentrations of mussels ("mussel beds"): TRM 520L (along the left descending bank), 526-527R, and 528-529L (Figure 3.2). The most upstream of these beds (TRM 528-529L) is located on the opposite side of the river and upstream from WBN and its discharges. The middle bed (TRM 526-527R) is on the same side of the river as WBN and is just downstream from Yellow Creek and the WBN diffiser discharges. The downstream bed (TRM 520-521L) is six river miles downstream from WBN and is located on the opposite side of the river. All three beds exist on submerged gravel and cobble bars in water approximately 3 to 7 m (10 to 20 feet) deep.

Four linearly-arranged sampling stations were established on each bed (Figure 3.2). Initially, each sampling station was located as precisely as possible using river mile markers, navigation buoys, and bankside landmarks. During the 1996 survey, original notes and the original crew leader assisted in adding GPS coordinates to these station locations.

Methods

Between 1983 and 1985, the examination of each station was conducted by two pairs of SCUBA divers collecting mussels for 11 minutes each (for an aggregate total of

approximately 45 minutes of search time). Over the years, improvements in communications and diver safety equipment have allowed this search commitment to be met using two independent divers, each collecting mussels for approximately 22 minutes. In 1996, two divers collected all of the live native mussels (thus excluding the Asiatic clam, Corbicula fluminea) they encountered during 22-minutes of bottom time at each of the 12 sample stations. All of the mussels found at each station were brought to the surface where they were sorted by species, identified, and counted. Up to 50 specimens of each species fiom each bed were measured in three dimensions (length, height, and thickness). All specimens were returned to the station fiom which they were collected. The numbers of each species found at each station and the measurement data fiom each bed were recorded on field sheets and, later, added to the existing WBN mussel database.

Results and Discussion

Results fiom the examination of these mussel beds (Table 3-8) indicate that 846 live mussels, representing 17 native species, were encountered during 1996. Of this total, 268 animals (31.6%) were found in the downstream bed (TRM 520-521L), 207 (24.5 %) were found in the middle bed (TRM 526-527R), and 371 (43.8 %) were found in the upstream bed (TRM 528-529L). Seven of the 17 species were found on all three beds, and four species were each found on only one of the beds. On each bed, the most abundant species was the elephant ear, Elliptio crassidens (70.2 % of the combined total). On the upstream and downstream beds, the second most abundant species was the Ohio pigtoe, Pleurobema cordatum (11.1% of the combined total); however, the pink

heelsplitter, Potamilus alatus, occupied second place on the middle bed (13.5% on this bed, 4.1% overall). Each bed contributed to a total of four specimens of the pink mucket, Lampsilis abrupta, the only species encountered this year which is on the federal endangered species list. While they were not included in the native mussel totals, 24 specimens of the introduced zebra mussel (Dreissena polymorpha) were found on two of the mussel beds during this survey.

For comparative purposes, Table 3-9 presents the results from the most-recent preoperational examination of these beds (1994). In that year, a very similar number of live mussels was found (880) representing the same number of native mussel species (17). Numerical results from each of the three beds also were similar, with 34.0% of the total found on the downstream bed (compared to 30.8% in 1996), 24.1 % were found on the middle bed (25.7% in 1996), and 41.9 % were found on the upstream bed (43.9 % in 1996). The elephant ear was also the most abundant species encountered during the 1994 examination (66.2% of the combined total). The Ohio pigtoe was second in overall abundance (10.8%); however, that species was second in abundance only on the upstream bed. During 1994, the second most abundant species on the downstream bed was the purple wartyback, Cyclonaias tuberculata (15.4% on that bed, 7.3% overall), and the second in abundance on the middle bed was the pimpleback, Quadrula pustulosa (14.2% on the bed, 7.4% overall). Two specimens of the endangered pink mucket and no zebra mussels were encountered during the 1994 mussel monitoring work (however, a number of zebra mussels were observed near WBN in 1994 as a part of other studies).

Overall, the numerical and relative abundance results **from** 1994 and 1996 are quite similar to each other.

Statistical analysis of the numerical data, and of the measurement data collected during the 1996 examination of these mussel beds, is being deferred until the data from the second year of WBN operational monitoring (1997) can be included. At that time, the two years of operational data will be compared with the 13-year span in the preoperational data set. That evaluation will document the long-term trends which have been occurring in these mussel populations and evaluate the impact of WBN operation on the tailwater native mussel fauna.

4.0 INSTREAM WATER QUALITY

4.1 Water Quality Analysis

Introduction

Preoperational instream water quality data collected during the period 1982-1991 were compared to 1996 operational data to determine any significant changes to the nonradiological water quality of Watts Bar tailwater since WBN became operational. Earlier data were not included in the comparative analysis because of revisions to analytical methods.

Materials and Methods

Water samples for chemical analysis were collected six times from April-September, 1996, at four locations in the vicinity of WBN, TRM's 529.9, 529.5, 527.4, and 518.0 (Figure 4-1). These locations correspond to preoperational sampling locations.

During May, June, and July, 1996, samples were collected for analysis of pH, turbidity, total solids, dissolved solids, ammonia, nitrogen, nitrate-nitrite nitrogen, organic nitrogen, total phosphorous, dissolved phosphorous, total organic carbon, chemical oxygen demand, and total alkalinity. Samples for chlorophyll-a analysis were collected during April, May, June, and July, 1996. Samples for pH, turbidity, and total solids were collected at a depth of 1 meter. All other samples were collected from multiple depths at each location and the data averaged for analysis purposes.

During April, August, and September 1996, samples were also collected for analysis of calcium, magnesium, arsenic, boron, cadmium, chromium, copper, iron, lead, nickel, zinc, aluminum, selenium, mercury, and hardness. One grab sample was collected from mid-depth at each location for metals analysis.

Results and Discussion

In Tables 4-1 and 4-2, summary statistics are presented for the preoperational and operational data for each of the four sampling locations. The concentrations measured for each parameter during preoperational and operational monitoring were also plotted for each sampling location over time (Figures 4-2 through 4-5). The data exhibit high variability in the preoperational data for all parameters at all locations. The operational data tended to be less variable than the preoperational data. Dissolved phosphorous and chlorophyll-a were the exceptions to this, which could be an artifact of the sample size.

Further analysis of the preoperational and operational data was performed using the Analysis of Variance with Duncan's Multiple Range Test (Table 4-3). The analysis indicates that, for most parameters, no significant difference (α=0.05) exist between preoperational and operational data. For those parameters where a significant difference was found, the concentrations were lower in operational samples. The only constituent with a consistent significant difference is chlorophyll-a, which has an upward trend during the operational period at all sampling locations. Chlorophyll-a concentrations (a measure of plankton biomass) below Watts Bar Dam and in the vicinity of the WBN are a function of chlorophyll-a concentrations above Watts Bar Dam in the forebay of Watts

Bar Reservoir. The increase in operational chlorophyll-a concentrations at TRM 529.9 (Watts Bar forebay) could result from many factors, none of which are related to WBN.

The preoperational and operational concentrations of metals were plotted over time and are shown in Appendix 1-7. Concentrations of arsenic, boron, cadmium, chromium, copper, lead, nickel, zinc, selenium, and mercury were less than detectable in nearly all samples. The plots show that all measurable values of operational water quality data were well within the variability of the preoperational data and no changes or trends of any magnitude were indicated. A statistical summary of the preoperational and operational metals data is presented in Tables 4-4 and 4-5.

The first year of operation of WBN has not adversely impacted the nonradiological water quality of the Watts Bar tailwater.

5.0 SUMMARY AND CONCLUSIONS

WBN unit 1 began commercial generation May 27, 1996, and operated at an 84% capacity factor during the first year of operation. Trends and similarities noted during preoperational monitoring, in addition to comparisons with operational data, were used to provide insight into potential plant-induced effects to aquatic communities and water quality.

Evaluation of entrainment of ichthyoplankton (fish eggs and larvae) by **WBN** revealed the presence of few taxa and relatively low densities. Eggs and larvae passing **WBN** were primarily spawned in Watts Bar Reservoir and exposed to passage through the turbines at Watts Bar Dam. Larval samples were dominated by clupeids (shad). Freshwater drum, sunfish, and the temperate basses were the only **additional** taxa to exceed one percent composition of total larvae collected throughout the study. Very few eggs or larvae of species known to spawn in **tailwaters** were collected, indicating most spawning in **Chickamauga** Reservoir occurred downstream of WBN. Sunfish **(Lepomis)** spawning in the littoral zone near WBN (including plant intake and shoreline stations) **was** indicated by significantly higher larval densities of this **taxon**. The proportion of the Tennessee River flow entrained by WBN (0.6%) is very low compared to SQN (13%). Percentage entrainment of fish larvae passing WBN was estimated to be 0.1% compared to 7.5% at SQN, 1981-1984. Total entrainment of larval fish and eggs at WBN during the period sampled was estimated to be 449 and 267, respectively. These represent extremely low numbers and would constitute no impact to the ichthyoplankton passing WBN or the fish community of Chickamauga Reservoir.

Fish community sampling results revealed only minor differences in species occurrence and percent composition between preoperational and operational samples. These differences were attributed to variations in sampling design with 1977-1985 data collected on a monthly basis throughout each year and 1990-1996 data collected only once during fall of each year. Operational data included only one sample.

Comparison of catch per electrofishing run (CPUE) during 1990-1995 preoperational and 1996 operational monitoring also showed minimal variation (76 and 57 fish per shocking run, respectively). Only emerald shiners revealed any major change in abundance, and this decline began prior to WBN becoming operational. None of the differences between preoperational and operational CPUE for 12 species meeting the criteria to be considered "important" were significant, P=0.05 level.

Reservoir Fish Assemblage Index (RFAI) values for the vicinity of WBN remained relatively stable with an average annual score of 44 during the 1991-1995 preoperational period and a score of 38 in 1996. A gradual decline in RFAI values occurred from 1993-1996. Since this decline began prior to WBN becoming operational, the plant is not considered responsible.

It is apparent based on comparisons of species composition, relative abundance, CPUE, and RFAI scores between preoperational and operational monitoring, WBN has not adversely impacted the tailwater fish population below Watts Bar Dam during the initial year of operation.

Fish impingement on the **WBN** cooling water intake traveling screens was virtually nonexistent. A total of 162 fish were estimated to be impinged during the first year of operation. Impingement at **WBN** has obviously not effected the fish community **Chickamauga** Reservoir and it is recommended that this monitoring activity be discontinued.

The operation of WBN has had no impact on the Watts Bar **Tailwater** fishery. Total tailwater fishing pressure in the Watts Bar tailwater has increased dramatically during the past 23 years. A total of 277,284 **fishing** hours and 60,674 angler trips was estimated during the first year of WBN operation. Caffish, sauger, white bass, crappie, sunfish, striped **bass/Cherokee** bass, and black bass were the most nought **after** species by anglers. An estimate of 242,036 fish were caught and an estimated 108,216 fish were harvested **from April** 1996-March 1997. **Angling** trips peaked in June 1996 and peak angling effort occurred in March 1997. The increased fishing pressure and potential overharvest of popular species are likely to have greater impact on the fishery than operation of **WBN.**

Total number of benthic macroinvertebrate(aquatic insects) taxa collected in Watts Bar Tailwater has increased **from** 59 recorded during preoperational monitoring to 86 collected during operational monitoring, 1996. The average number of taxa per station in 1996 (28) was also greater than the average number (15) collected during preoperational monitoring. Based upon organism abundance and taxonomic occurrence, stations upstream and adjacent to the plant **(TRM's** 528.0 and 528.5) and below the plant **(TRM's** 526.3 and 527.4) were similar in the summer and fall samples in 1996. In addition to the increased number of taxa found during operational monitoring, zebra mussels were found at each station at an average

density of **28.6/m²**. Zebra mussels were most abundant (60/m²) in the fall of 1996 at TRM 528.0 (adjacent to the WBN intake channel). Temporal analyses showed that seasonal and yearly changes in abundance and other variables for benthic macroinvertebrate populations, except fieshwater mussels, were common.

The **freshwater** mussels in the vicinity of WBN are quite old and most of the 30 species found may not have reproduced in the past 50 years. On each mussel bed, the most abundant species was the elephant **ear, Elliptio** crassidens (70.2 percent of the combined total). Each bed contributed to **a total** of four specimens of the pink mucket, **Lampsilis** abrupta, the only species encountered which is on the federal endangered species list. The numerical and relative abundance results comparing preoperational and operational monitoring were similar. These results indicate the first year of operation of WBN has not impacted the benthic macroinvertebrate community below Watts Bar Dam.

Water quality in the vicinity of WBN, while generally satisfactory, is influenced by releases **from** Watts Bar Dam, located two miles upstream. In 1996, **TVA's** Water Management installed an aeration device in the **forebay** of Watts Bar Reservoir. This will reduce stratification of the **forebay** during the summer and fall and provide higher dissolved oxygen levels in the hydro releases. Concentrations of selected metals were less than detectable in nearly **all** samples. Measurable water quality data **values** during operational monitoring were well within the variability of the preoperational data. The first year of operation of WBN has not impacted the water quality in upper Chickamauga Reservoir.

Overall, it was concluded that WBN had no effect on either the aquatic communities nor the water quality in upper Chickamauga Reservoir from the first year of operation.

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Table 2-1. Sample period, dates, number of samples, and mean temperatures for larval fish collections near Watts Bar Nuclear Plant during preoperational monitoring 1976 through 1979,1982 through 1985 and operational monitoring 1996.

PREOPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1976			
1	03/24/76	7	12.3
2	04/07/76	20	14.3
3	04/21/76	20	15.4
4	05/05/76	21	18.1
5	05/18/76	25	19.1
6	06/03/76	28	20.1
7	06/17/76	27	22.4
8	06/29/76	19	23.6
9	07/14/76	25	24.3
10	07/28/76	28	25.3
11	08/09/76	28	24.1
12	08/25/76	28	25.3
13	09/09/76	21	24.6
	Total	297	
1977			
1	03/16/77	10	10.9
2	03/23/77	10	12.2
3	03/29/77	10	13.6
4	04/12/77	10	15.1
5	04/19/77	10	16.5
6	04/26/77	10	17.2
7	05/04/77	10	17.7
8	05/10/77	10	18.4
9	05/16/77	10	19.0
10	05/24/77	10	19.7
11	06/02/77	10	21.3
12	06/08/77	10	21.9
13	06/15/77	10	23.0
14	06/21/77	10	23.0
15	07/07/77	10	26.1
16	07/19/77	16	26.5
17	08/01/77	10	26.8
18	08/16/77	10	24.8
	Total	186	

Table 2-1. (Continued)

PREOPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1978			
1	03/28/78	10	10.1
2	04/11/78	10	14.4
3	04/25/77	10	16.8
4	05/09/78	10	16.6
5	05/23/78	10	17.9
6	06/06/78	10	20.9
7	06/20/78	10	23.1
8	07/05/78	10	25.6
9	07/18/78	10	25.4
10	08/01/78	10	25.5
11	08/15/78	10	N/A
12	08/29/78	10	26.2
13	09/12/78	10	26.4
	Total	**130**	
1979			
1	03/13/79	10	9.0
2	03/28/79	10	11.6
3	04/10/79	10	13.3
4	04/23/79	10	15.4
5	05/10/79	10	18.3
6	05/22/79	10	N/A
7	06/06/79	10	19.1
8	06/18/79	10	22.2
9	07/02/79	10	23.0
10	07/17/79	10	24.2
11	07/30/79	10	22.9
12	08/13/79	10	24.2
13	08/28/79	10	24.6
	Total	**130**	

Table 2-1. (Continued)

PREOPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1982			
1	03/15/82	10	10.5
2	03/29/82	10	12.8
3	04/12/82	10	13.1
4	04/26/82	10	15.2
5	05/10/82	10	16.5
6	05/24/82	10	18.5
7	06/07/82	10	23.9
8	06/21/82	10	26.6
9	07/06/82	10	24.9
10	07/19/82	10	27.8
11	08/02/82	10	28.0
12	08/16/82	10	27.3
	Total	**120**	
1983			
1	03/07/83	20	10.6
3	04/04/83	10	11.5
4	04/18/83	10	11.7
5	05/03/83	10	16.0
6	05/17/83	10	20.0
7	05/31/83	10	21.8
8	06/14/83	10	23.0
9	06/27/83	10	N/A
10	07/11/83	10	28.0
11	07/25/83	10	25.5
12	08/08/83	10	25.9
13	08/23/83	10	28.0
	Total	**130**	

Table 2-1. (Continued)

PREOPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1984			
1	03/06/84	10	7.8
2	03/20/84	10	9.1
3	04/03/84	18	11.1
4	04/16/84	10	N/A
5	04/30/84	10	14.3
6	05/29/84	18	18.8
7	06/11/84	18	20.8
8	06/25/84	18	23.6
9	07/09/84	18	23.1
10	07/23/84	18	26.7
11	08/06/84	18	24.4
12	08/20/84	18	25.7
	Total	**184**	
1985			
1	03/14/85	18	9.7
2	03/27/85	18	11.5
3	04/10/85	16	13.9
4	04/24/85	18	15.1
5	05/08/85	18	16.8
6	05/22/85	18	19.2
7	06/04/85	18	22.6
8	06/18/85	18	23.5
9	07/02/85	18	25.3
10	07/16/85	18	26.0
11	08/01/85	18	26.1
12	08/13/85	18	25.7
13	08/28/85	18	25.0
	Total	**232**	

Table 2-1. (Continued)

OPERATIONAL MONITORING			
Sample period	Date	Number of Samples	Mean Water Temperatures (°C)
1996			
1	04/08/96	20	10.7
2	04/02/96	16	15.1
3	05/06/96	18	17.3
4	05/20/96	18	21.3
5	06/03/96	18	23.3
6	06/17/96	18	22.6
	Total	108	

Table 2-2. List of scientific and common names for fish egg and larval taxa collected near Watts Bar Nuclear Plant during 1976 through 1979,1982 through 1985, and 1996.

Scientific Name	Common Name
Eggs	
Unidentifiable fish eggs	
Hiodon spp. eggs	Unidentifiable mooneye eggs
Aplodinotus grunniens eggs	Freshwater drum eggs
Larvae	
Unidentified fish larvae*	
Clupeidae	
Unspecifiable clupeids	Unspecified shad and/or herring
Alosa chrysochloris	Skipjack herring
Dorosoma sp.	Unidentified shad
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Hiodontidae	
Hiodon tergisus	Mooneye
Cyprinidae	
Unspecifiable cyprinids	Unspecified minnow or carp
Cyprinus carpio	Common carp
Macrhybopsis storeriana	Silver chub
Notropis sp.	Unidentified shiner
Notropis atherinoides	Emerald shiner
Catostornidae	
Unspecifiable catostomids	Unspecified suckers
Ictiobinae	Unspecified Ictiobines**
Minytrema melanops	Spotted sucker
Ictąluridae	
Ictalurus furcatus	Blue catfish
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Percichthyidae	
Morone sp.	Unspecified temperate bass
Morone chrysops	White bass
Morone mississippiensis	Yellow bass
Morone (not *saxatilis*)	Unspecified temperate bass(not striped bass)

Table 2-2. (Continued)

Scientific Name	Common Name
Centrarchidae	
Lepomis or *pomoxis*	Unspecified crappie or sunfish
Lepomis sp.	Unspecified sunfish
Micropterus dolomieu	Smallmouth bass
Pomoxis sp.	Unspecified crappie
Pomoxis annularis	White crappie
Percidae	
Unspecifiable darter	Unspecified darter
Perca flavescens	Yellow perch
Stizostedion sp.	Walleye or sauger
Stizostedion canadense	Sauger
Sciaenidae	
Aplodinotus grunniens	Freshwater drum
Atherinidae	
Labidesthes sicculus	Brook silverside

* Damaged specimens.

** Members of the subfamily Ictiobinae (buffalo, carpsuckers).

Table 2-3. Total numbers and percent composition of fish eggs and larvae collected during 1976 through 1985 and 1996 in the vicinity of Watts Bar Nuclear Plant.

Taxon	1976 Total Collected	1976 % Comp.	1977 Total Collected	1977 % Comp.	1978 Total Collected	1978 % Comp.	1979 Total Collected	1979 % Comp.	1982 Total Collected	1982 % Comp.
EGGS										
Unidentifiable fish eggs	5	2.00	40	23.39	722	81.58	4	5.63	8	4.17
Hiodon spp. *eggs*	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Aplodinotus *grunniens* eggs	245	98.00	131	76.61	162	18.31	67	94.37	184	95.83
Total	250	100.00	171	100.00	885	100.00	71	100.00	192	100.00
LARVAE										
Unidentified fish	1	0.01	8	0.02	7	0.19	0	0.00	0	0.00
Clupeidae										
Unspecifiable clupeids	9913	91.17	31679	92.94	1569	42.44	1976	77.04	1259	38.86
Alosa chrysochloris	0	0.00	6	0.02	0	0.00	0	0.00	0	0.00
Dorosoma sp.	0	0.00	68	0.20	73	1.97	0	0.00	0	0.00
Dorosoma ***cepedianum***	2	0.02	637	1.87	334	9.03	0	0.00	324	10.00
Dorosoma petenense	32	0.29	1	T	0	0.00	0	0.00	20	0.62
Hiodontidae										
Hiodon tergisus	0	0.00	4	0.01	0	0.00	1	0.04	0	0.00
Cyprinidae										
Cyprinidae	8*	0.07	14	0.04	28	0.76	5	0.19	5	0.15
Cyprinus carpio	27	0.25	16	0.05	0	0.00	8	0.31	1	0.03
Macrhybopsis storeriana*	0	0.00	1	T	0	0.00	0	0.00	0	0.00
Notropis sp.	0	0.00	1	T	0	0.00	0	0.00	0	0.00
Notropis atherinoides	0	0.00	4	0.01	5	0.14	0	0.00	0	0.00
Catostomidae										
Unspecifiable catostomids	0	0.00	0	0.00	1	0.03	1	0.04	0	0.00
Ictiobinae**	0	0.00	82	0.24	0	0.00	0	0.00	0	0.00
Minytrema ***melanops***	2	0.02	1	T	0	0.00	0	0.00	0	0.00
Ictaluridae										
Ictalurus ***furcatus***	1	0.01	0	0.00	1	0.03	1	0.04	1	0.03
Ictalurus punctatus	45	0.41	27	0.08	38	1.03	8	0.31	9	0.28
Pylodictis *olivaris*	1	0.01	2	0.01	0	0.00	0	0.00	0	0.00
Percichthyidae										
Morone sp.	1	0.01	62	0.18	73	1.97	13	0.51	16	0.49
Morone chrysops	0	0.00	0	0.00	1	0.03	0	0.00	0	0.00
Morone ***mississippiensis***	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Morone (not ***saxatilis***)	5	0.05	50	0.15	7	0.19	31	1.21	199	6.14
Centrarchidae										
Lepomis ox ***pomoxis***	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Lepomis sp.	209	1.92	428	1.26	873	23.61	57	2.22	857	26.45
Micropterus dolomieu	0	0.00	0	0.00	0	0.00	0	0.00	1	0.03
Pomoxis *sp.*	24	0.22	281	0.82	334	9.03	9	0.35	328	10.12
Pomoxis *annularis*	0	0.00	1	T	0	0.00	0	0.00	0	0.00

Table 2-3. (Continued)

Taxon	1976 Total Collected	1976 % Comp.	1977 Total Collected	1977 % Comp.	1978 Total Collected	1978 % Comp.	1979 Total Collected	1979 % Comp.	1982 Total Collected	1982 % Comp.
Percidae										
Unidentifiable darter	0	0.00	4	0.01	5	0.14	1	0.04	4	0.12
Perflavescens	0	0.00	0	0.00	5	0.14	0	0.00	3	0.09
Stizostedfon sp.	1	0.01	5	0.01						
Stizostedion canadense	0	0.00	0	0.00	1	0.03	0	0.00	0	0.00
Sciaenidae										
Aplodinotus grunniens	601	5.53	704	2.07	310	8.39	454	17.70	205	6.33
Atherinidae										
Labidesthes sicculus	0	0.00	0	0.00	32	0.87	0	0.00	8	0.25
Total	10873	100.00	34086	100.00	3697	100.00	2565	100.00	3240	100.00

Taxon	1983 Total collected	1983 % Comp.	1984 Total Collected	1984 % Comp.	1985 Total Collected	1985 % Comp.	OPERATIONAL 1996 Total collected	OPERATIONAL 1996 % Comp.
EGGS								
Unidentifiable fish eggs	1143	87.12	26	27.66	16	51.61	2908	99.28
Hiodon spp. eggs	0	0.00	0	0.00	1	3.23	0	0.00
Aplodinotus grunnlens eggs	169	12.88	68	72.34	14	45.16	21	0.72
Total	1312	100.00	94	100.00	31	100.00	2929	100.00
LARVAE								
Unidentified fish	38	0.49	0	0.00	0	0.00	0	0.00
Clupeidae								
Unspecifiable clupeids	5658	73.01	22435	93.33	5890	68.63	4135	83.89
Alosa chrysochloris	0	0.00	0	0.00	0	0.00	0	0.00
Dorosoma sp.	0	0.00	1	T	0	0.00	0	0.00
Dorosoma cepedianum	1	0.01	114	0.47	0	0.00	74	1.50
Dorosoma petenense	2	0.03	0	0.00	8	0.09	50	1.01
Hiodontidae								
Hiodon tergisus	0	0.00	7	0.03	0	0.00	0	0.00
Cyprinidae								
Unspecifiable cyprinids	110	1.42	1*	T	9*	0.10	2	0.04
Cyprinus carpio	15	0.19	7	0.03	0	0.00	2	0.04
*Macrhybopsis storeriana***	0	0.00	0	0.00	0	0.00	0	0.00
Notropis sp.	0	0.00	0	0.00	0	0.00	0	0.00
Notropis atherinoides	0	0.00	0	0.00	0	0.00	0	0.00
Catostomidae								
Unspecifiable catostomids	0	0.00	0	0.00	0	0.00	0	0.00
Ictiobinae	0	0.00	0	0.00	0	0.00	0	0.00
Minytrema melanops	0	0.00	0	0.00	0	0.00	3	0.06

Table 2-3. **(Continued)**

Taxon	1983 Total Collected	1983 0 Comp.	1984 Total Collected	1984 0 Comp.	1905 Total Collected	1905 % Comp.	OPERATIONAL 1996 Total Collected	OPERATIONAL 1996 0 Comp.
Ictaluridae								
Ictalurus furcatus	0	0.00	0	0.00	0	0.00	0	0.00
Ictalurus punctatus	11	0.14	0	0.00	2	0.02	2	0.04
Pylodictis olivaris	0	0.00	0	0.00	0	0.00	0	0.00
Percichthyidae								
Morone sp.	50	0.65	108	0.45	24	0.28	41	0.83
Morone chrysops	0	0.00	0	0.00	0	0.00	5	0.10
Morone mississippiensis	0	0.00	0	0.00	0	0.00	16	0.3
Morone (not *saxatilis*)	244	3.15	283	1.18	29	0.34	161	3.27
Centxarchidae								
Lepomis or *pomoxis*	20	0.26	0	0.00	0	0.00	0	0.00
Lepomis sp.	309	3.99	247	1.03	2427	28.28	95	1.93
Micropterus dolomieu	0	0.00	0	0.00	0	0.00	0	0.00
Pomoxis sp.	220	2.84	90	0.37	158	1.84	8	0.16
Pomoxis annularis	0	0.00	0	0.00	0	0.00	0	0.00
Percidae								
Unidentifiable darter	4	0.05	0	0.00	0	0.00	0	0.00
Perca flavescens	12	0.15	9	0.04	9	0.10	6	0.12
Stizostedion sp.	0	0.00	0	0.00	0	0.00	0	0.00
Stizostedion canadense	0	0.00	0	0.00	0	0.00	0	0.00
Sciaenidae								
Aplodinotus grunniens	1056	13.63	737	3.07	25	0.29	324	6.57
Atherinidae								
Labidesthes sicculus	0	0.00	0	0.00	1	0.01	0	0.00
Total	7750	100.00	24039	100.00	8582	100.00	4929	100.00

T = Less than 0.01 percent composition.
* Number collected changed or was previously missing.
** Scientific name changed.

Table 2-4. Seasonal densities of dominant fish larvae collected in the cooling water intake channel at the Watts Bar Nuclear Plant Site, 1984 through 1985, and 1996.

	Preoperational		Operational	
TAXON	Year		Year	
Freshwater Drum	1984	5.05	1996	20.63
	1985	0.87		
Sunfish	1984	31.33	1996	187.94
	1985	66.68		
Shad	1984	3411.48	1996	2223.24
	1985	460.69		
Gizzard and Threadfin	1984	3.03	1996	20.63
	1985	--------		
White and Yellow Bass	1984	20.21	1996	2.29
	1985	2.62		
White, Yellow and Striped Bass	1984	2.62	1996	-------
	1985	2.29		

Table 2-5. **Species list, total number collected, and occurrence spans of fish eggs and larvae collected during operational monitoring at Watts Bar Nuclear Plant, 1996.**

TAXON	TOTAL COLLECTED	PERCENT COMPOSITION	SAMPLING PERIODS					
FISH EGGS			1	2	3	4	5	6
Unidentifiable fish eggs	2908	99.28	x	x	x	x	x	
Aplodinotus grunniens eggs	21	0.72				x	x	x
Total	2929	1000						
FISH LARVAE								
Clupeidae	4135	83.89			x	x	x	x
Dorosoma cepedianum	74	1SO					x	x
Dorosoma petenense	50	1.01					x	x
Pimephales sp.	2	0.04						x
Cyprinus carpio	2	0.04				x	x	
Minytrema melanops	3	0.06			x			
Ictalurus punctatus	2	0.04						x
Morone sp.	41	0.83				x	x	x
Morone chrysops	5	0.10					x	
Morone mississippiensis	16	0.32					x	
Morone (not *saxatilis*)	161	3.27	x	x	x			
Lepomis sp.	95	1.93					x	x
Pomoxis sp.	8	0.16			x	x	x	
Percidae (not stizostedion)	5	0.10	x	x	x			
Perca favescens	6	0.12		x	x			
Aplodinotus grunniens	324	6.57				x	x	x
TOTAL	4929	100						

T = less than 0.01 percent composition

Table 2-6. Average and peak density (number per 1,000 m^3) of larval fish with mean water temperatures collected in the vicinity of Watts Bar Nuclear Plant during preoperational and operational monitoring.

	PREOPERATION								OPERATIONAL
	1976	1977	1978	1979	1982	1983	1984	1985	1996
Seasonal Density	444	1,960	358	146	365	835	2,119	347	525
Seasonal Mean Water Temperature (°C)	19.1	19.3	18.3	17.7	19.0	17.3	23.9	18.5	18.4
Peak Density	1,334	4,559	624	370	731	3,011	10,485	1,007	1,392
Date of Peak Density	5/19	4/26	6/6	5/22	6/7	6/14	5/29	6/4	6/3

Table 2-7. Day snd night densities of larval fish collected during preoperational and operational monitoring in the vicinity of Watts Bar Nuclear Plant.

	PREOPERATIONAL																OPERATIONAL	
	1976		1977		1978		1979		1982		1983		1984		1985		1996	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
EGGS																		
Unidentifiable-																		
eggs	4.46	0.00	12.75	36.84	697.18	259.79	1.17	4.02	1.21	0.00	492.84	864.82	11.36	18.06	12.70	4.31	2911.38	570.94
Aplodinotus																		
grunniens eggs	61.34	35.75	109.67	55.26	37.04	68.65	8.18	12.05	1.21	79.42	73.57	132.82	1.14	73.37	0.00	8.60	13.37	8.60
LARVAE																		
Aplodinotus grunniens	78.06	20.29	232.08	380.21	43.66	102.30	16.36	13.39	25.44	134.19	347.71	456.02	118.18	135.46	6.35	4.31	201.84	135.30
Centrarchidae	26.76	35.75	374.90	406.53	210.35	969.17	9.35	16.07	333.13	1211.83	246.93	357.14	159.09	128.68	108.99	348.99	36.09	59.44
Clupeidae	3071.26	2041.55	17978.83	23096.96	703.80	1391.84	578.47	867.59	574.20	1072.16	3010.48 357.14	3580.28	11354.55 13792.75		1423.28	2250.11	2101.32	2004.54
Dorosoma sp.	0.00	0.00	25.50	136.82	1.32	487.28	0.00	0.00	18.96	438.18	0.00	0.00	114.77	12.42	0.00	1.08	0.00	96.98
Morone (not *saxatilis*)	0.00	0.00	24.23	38.15	3.97	5.38	22.20	14.73	119.93	136.93	97.74	184.47	111.36	208.83	20.11	10.77	49.46	96.98
Morone sp.	1.12	0.00	33.15	47.36	9.26	87.49	2.34	10.71	4.65	15.06	31.24	25.09	70.45	51.92	6.35	19.39	18.71	37.54

*Densities for 1976 based on samples taken from four (dawn, midday, dusk, midnight) diel periods.

**Includes unspecifiable clupeids, *Alosa chrysochloris*, *Dorosoma spp.*, and *Dorosoma petenense*.

***Includes *all Morone spp.*, Morone *Chrysops*, *Morone Mississippiensis* and *Morone (not saxatilis)*.

Table 2-8. Distribution of larval fishes by size group collected at Watts Bar Nuclear Plant, during 1996.

TAXON	3	4	5	6	7	8	9	10	11	12	13	14	15	16-19	20-30	>30
Clupeidae		10	172	346	364	498	562	525	461	367	253	119	111	347		
Dorosoma cepedianum															73	1
Dorosoma petenense															50	
Pimephales sp.			1	1												
Cyprinus carpio					2											
Minytrema melanops									3							
Ictalurus punctatus														1	1	
Morone sp.			4	2	5	10	5	6	5	4						
Morone chrysops									2			1		2		
Morone mississippienis									1	5	9	1				
Morone (not *saxatilis*)	119	42														
Lepomis sp.		1	6	64	13	6	3	1		1						
Pomoxis sp.			4	1		1		1	1							
Unidentified Darter				1	2	2										
Perca flavescens				2	1	1	1	1								
Aplodinotus grunniens	1	4	164	81	19	22	25	5	2					1		

NOTE: These numbers represent expanded subsample measurements.

Table 2-9. Comparison of percent composition of the catch from preoperational(1977-1985 and 1990-1995) and operational (1996) monitoring periods.

Common Name	1977-1985 Preoperational	1990-1995 Preoperational	1996 Operational
Spotted gar	0.1%	--	--
Longnose gar	0.5%	0.0%	0.2%
Mwneye	0.2%	--	0.2%
American eel	0.0%	--	--
Skipjack herring	1.5%	0.7%	--
Gizzard shad	--	--	--
Threadfin shad	--	--	--
Spotfin shiner	0.1%	1.8%	0.8%
Steelcolor shiner	--	2.5%	--
Common carp	1.2%	1.0%	1.2%
Striped shiner	--	0.0%	--
Silver chub	0.0%	--	--
Golden shiner	0.2%	0.4%	0.2%
Emerald shiner	58.6%	17.1%	0.3%
Bluntnose minnow	--	0.1%	0.2%
Bullhead minnow	0.0%	0.1%	--
River carpsucker	0.0%	--	--
Northern hogsucker	0.1%	0.1%	0.2%
Smallmouth buffalo	0.0%	0.1%	--
Spotted sucker	1.2%	1.3%	1.5%
River redhorse	0.0%	--	--
Black redhorse	--	0.2%	0.5%
Golden redhorse	0.5%	0.5%	0.8%
Blue catfish	0.0%	0.1%	--
Channel catfish	0.0%	1.6%	0.8%
Flathead catfish	0.0%	0.6%	1.0%
Brook silversides	5.4%	1.1%	--
White bass	1.3%	1.7%	1.5%
Yellow bass	4.1%	4.3%	6.0%
Striped bass	0.1%	0.2%	0.2%
Rock bass	0.0%	--	--
Redbreast sunfish	0.9%	1.3%	0.5%
Green sunfish	0.0%	0.4%	0.3%
Warmouth	0.1%	0.7%	0.2%
Bluegill	10.0%	32.4%	53.2%
Longear sunfish	0.2%	0.1%	0.3%
Redear sunfish	7.2%	13.4%	10.7%
Hybrid sunfish	--	0.0%	0.2%
Smallmouth bass	0.3%	1.8%	2.2%
Spotted bass	1.0%	3.1%	4.6%
Largemouth bass	3.4%	7.8%	5.2%
White crappie	0.8%	0.2%	0.7%
Black crappie	0.0%	0.8%	1.9%
Yellow perch	0.4%	0.4%	0.1%
Logperch	0.1%	1.5%	2.2%
Sauger	0.1%	0.1%	0.6%
Walleye	0.0%	--	--
Freshwater drum	0.2%	0.6%	1.0%

Table 2-10. Comparison of average catch per effort (CPUE) and percent composition of the catch from vital signs preoperational (1990-1995) and operational results (1996).

Common Name	1990-1995 Preoperational		1996 Operational	
	Average CPUE	Percentage of CPUE	CPUE	Percentage of CPUE
Longnose Gar	0.03	0.04%	0.13	0.23%
Mooneye	--	--	0.13	0.23%
Skipjack herring	0.51	0.67%	--	--
Gizzard shad	--		--	
Threadfin shad	--		--	
Spotfin shiner	1.41	1.85%	0.47	0.82%
Steelcolor shiner	1.91	2.51%	--	--
Common Carp	0.76	1.00%	0.67	1.17%
Striped shiner	0.03	0.04%	--	--
Golden shiner	0.28	0.37%	0.13	0.23%
Emerald shiner	13.03	17.13%	0.20	0.35%
Bluntnose minnow	0.04	0.05%	0.13	0.23%
Bullhead minnow	0.04	0.05%	--	--
Northern hogsucker	0.07	0.09%	0.13	0.23%
Smallmouth buffalo	0.07	0.09%	--	--
Spotted sucker	0.97	1.27%	0.87	1.51%
Black redhorse	0.18	0.24%	0.27	0.47%
Golden redhorse	0.41	0.54%	0.47	0.82%
Blue catfish	0.05	0.07%	--	--
Channel catfish	1.19	1.56%	0.47	0.82%
Flathead catfish	0.49	0.64%	0.60	1.04%
Brook silverside	0.82	1.08%	--	--
White bass	1.26	1.66%	0.87	1.51%
Yellow bass	3.26	4.28%	3.47	6.04%
Striped bass	0.18	0.24%	0.13	0.23%
Redbreast sunfish	0.97	1.27%	0.27	0.47%
Green sunfish	0.30	0.39%	0.20	0.35%
Warmouth	0.50	0.66%	0.13	0.23%
Bluegill	24.68	32.44%	30.60	53.24%
Longear sunfish	0.08	0.11%	0.20	0.35%
Redear sunfish	10.20	13.41%	6.13	10.66%
Hybrid sunfish	0.03	0.04%	0.13	0.23%
Smallmouth bass	1.36	1.79%	1.27	2.21%
Spotted bass	2.35	3.09%	2.67	4.65%
Largemouth bass	5.92	7.78%	3.00	5.22%
White crappie	0.12	0.16%	0.40	0.70%
Black crappie	0.61	0.80%	1.07	1.86%
Yellow perch	0.28	0.37%	0.07	0.12%
Logperch	1.16	1.52%	1.27	2.21%
Sauger	0.11	0.14%	0.33	0.57%
Freshwater drum	0.42	0.55%	0.60	1.04%
Total	76	100%	57	100%
RFAI score	51		38	

Table 2-11. Summary of one-way univariate ANOVA testing of effects of comparing preoperational to operational results and interactions of these for important species important species collected by electrofishing near Watts Bar Nuclear Plant.

Species	F-Value	P-Value	Preoperational 1990-1995	Operational 1996
Largemouth Bass	3.3400	0.0711	5.9	3.0
Redear Sunfish	2.4886	0.1183	10.2	6.1
Emerald Shiner	1.3753	0.2441	13.0	0.2
Brook Silversides	0.8204	0.3676	0.8	0
Bluegill	0.4336	0.5120	24.7	30.6
Spotted Sucker	0.2003	0.6556	1.3	0.9
Spotted Bass	0.1138	0.7367	2.4	2.7
White Bass	0.1023	0.7498	1.3	0.9
Common Carp	0.0559	0.8137	0.8	0.7
Logperch	0.0245	0.8761	1.2	1.3
Smallmouth Bass	0.0065	0.9359	1.4	1.3
Yellow Bass	0.0061	0.9379	3.3	3.5

Table 2-12. Actual number of fish observed in 36 impingement samples and at estimated numbers impinged at Watts Bar Nuclear Plant between March 15,1996, and March 15,1997 in 36 samples.

Common Name	Total Number of Fish Impinged	Estimated Number of Fish Impinged	Percentage Composition
Gizzard shad	4	40.6	25.0
Threadfin shad	2	20.3	12.5
Freshwater drum	3	30.4	18.7
Channel catfish	1	10.1	6.3
Flathead catfish	1	10.1	6.3
Bluegill	2	20.3	12.6
Redear sunfish	1	10.1	6.3
White crappie	2	20.3	12.6
. Total	16	162.2	100.3

Table 2-13. Estimated total impingement of **fishes** at Sequoyah Nuclear Plant (1981 through 1983).

COMMMON NAME	1981	1982	1983
Unidentified Fish	0	7	0
Lamprey	0	0	37
Chestnut lamprey	29	0	0
Unidentified shad	0	0	183
Skipjack herring	73	149	270
Gizzard shad	453	9,967	2,365
Threadfin shad	56,582	15,829	4,687
Mooneye	37	60	15
Minnow, carp	0	7	0
Carp	0	0	7
Silver chub	102	30	0
River chub	7	0	0
Golden shiner	153	15	15
Emerald shinner	22	7	22
Mimic shiner	0	0	15
Bluntnose minnow	22	238	37
Bullhead minnow	110	350	241
Spotted sucker	7	0	0
Golden redhorse	0	0	7
Blue catfish	102	127	146
Black bullhead	0	7	0
Yellow bullhead	7	7	7
Channel catfish	387	179	387
Flathead catfish	58	97	22
Mosquitofish	7	0	0
White bass	51	782	95
Yellow bass	212	1,862	350
Unidentified sunfish	0	37	0
Warmouth	153	45	37
Redbreast sunfish	51	97	7
Green sunfish	2,759	74	22
Bluegill	4,672	3,553	2,613
Longear sunfish	110	0	7
Redear sunfish	256	216	73
Spotted bass	117	670	22
Largemouth bass	44	67	29
White crappie	190	97	139
Yellow perch	445	387	190
Logperch	22	268	15
Sauger	22	7	7
Freshwater drum	2,759	5,706	2,891
Total	70,022	40,944	14,960

Table 2-14. Location of access points, percent of clerk time allotted for interviews, and angler type encountered for the Watts Bar tailwater creel survey.

Access Point Location	Percent of Time Allotted	Type of Anglers Intercepted
B a n 'Lock	30	Bank
Bank@ Power Plant	30	Bank
TVA Ramp	20	Boat
Unimproved ramp	5	Boat
TWRA Sewee Creek Ramp	10	Bank
Eaves Ferry Ramp	5	Boat

Table 2-15. Number of days surveyed and number of interviews for the Watts Bar tailwater creel survey, April 1996 through March 1997.

Month	Number of Days Surveyed	Number of Interviews	Percent of Participation
		1996	
April	14	152	8
May	15	208	11
June	13	168	9
July	14	144	8
August	12	120	6
September	12	115	6
October	12	128	7
November	13	128	7
December	8	80	4
		1997	
January	16	182	10
February	16	211	11
March	16	228	12

Table 2-16. Directed species percentage for bank and boat fishermen within the Watts Bar Tailwater, April 1996 through March 1997.

Directed Species Group	Percent Participation	
	Bank Anglers	Boat Anglers
Any Species	36	24
Black Bass	1	11
Catfish	13	27
Crappie	9	4
Sauger	15	14
Striped Bass/Cherokee Bass	7	5
Sunfish	8	4
White Bass	11	11

Table 2-17. Number of interviews and percent angler use at six access points within the Watts Bar Tailwater, April 1996 through March 1997.

Access Point	Number of Interviews	Percent Participation
Bank Anglers		
Bank@Lock	614	47
Bank@Power Plant	647	49
TVA Ramp	28	2
TWRA Sewee Creek Ramp	21	1
Eaves Feny Ramp	6	< 1
Boat Anglers		
TVA Ramp	526	96
Unimproved Ramp	1	< 1
TWRA Sewee Creek Ramp	6	1
Eaves Ferry Ramp	10	2

Table 2-18. Monthly estimated effort, percent effort, and estimated number of angling trips for Watts Bar tailwater fishery, April 1996 through March 1997.

Month	Estimated Effort (hrs)	Standard Error	Percent Effort	Estimated Trips	Standard Error
1996					
April	20,139	722	7	6,476	232
May	27,904	1169	10	6,756	283
June	31,790	1064	11	8,131	272
July	26,308	697	9	6,279	166
August	16,830	762	6	4,115	186
September	13,343	441	5	2,7 18	90
October	20,572	576	7	3,918	110
November	15,138	781	5	2,911	150
December	25,807	1589	9	6,145	378
1997					
January	20,080	1013	7	4,747	240
February	24,956	1059	9	4,538	192
March	31,832	1359	12	5,984	255

Table 2-19. Estimated effort, number, and length of trips for selected species groups by fishermen in the Watts Bar tailwater fishery, April 1996 through March 1997.

Directed Species Group	Percent Effort	Estimated Effort (hrs)	Estimated Trips	Mean Length of Trip (hrs)	Standard Error
Any Species	32	88,731	19,587	4.53	0.19
Black Bass	6	16,637	2,955	5.63	0.29
Catfish	22	61,002	13,801	4.42	0.16
Crappie	4	11,091	2,509	3.57	0.37
Sauger	13	36,045	7,853	4.59	0.22
Striped/Cherokee Bass	6	16,637	4,413	3.77	0.31
Sunfish	5	13,864	2,818	4.93	0.42
White Bass	12	33,274	6,681	4.98	0.31

Table 2-20. Catch rates of 16 species of fish estimated from tailwater creel surveys conducted during preoperational and operational monitoring in the vicinity of Watts Bar Nuclear Plant.

	Catch Rate (Fish/hr)	
Common Name	**Preoperational**	**Operational**
	April 1982-December 1985	**April 1996-March 1997**
Blue Catfish	0.04	0.11
Channel Catfish	0.08	0.08
Bluegill	0.34	0.52
Redear Sunfish	0.03	0.05
Smallmouth Bass	0.01	0.02
Spotted Bass	0.00	0.01
Largemouth Bass	0.03	0.05
White Bass	0.10	0.37
Yellow Bass	0.06	0.18
Striped Bass	0.01	0.01
Yellow Perch	0.02	0.01
White Crappie	0.11	0.06
Black Crappie	0.00	0.03
Flathead Catfish	0.00	0.00
Sauger	0.11	0.17
Walleye	0.00	0.00

Table 2-21. Estimated number caught and harvested of selected species from the Watts Bar tailwater fishery, April 1996 through March 1997.

Species	Caught		Harvested	
	Estimated Number	Standard Error	Estimated Number	Standard Error
Blue Catfish	26,678	5,032	19,710	4,526
Sauger	41,141	5,691	6,422	1,398
Bluegill	106,112	16,111	50,264	8,4 19
White Bass	68,105	10,923	31,820	6,677

Table 3-1. Benthic macroinvertebrate taxa collected during preoperational (1973 through 1985) and operational (1996) monitoring at Watts Bar Nuclear Plant.

	Preoperational	Operational
Nematoda		X
Hydrozoa		
Hydroida		
Clavidae		
Cordylophora lacustris		X
Hydridae		
Hydra americana		X
Turbellaria		
Tricladida		
Planariidae	X	
Dugesia tigrina	X	X
Oligochaeta	X	
Haplotaxida		
Lumbricidae		X
Naididae	X	X
Dero sp.		X
Nais communis		X
Nais simplex		X
Pristina sp.		X
Slavina appendiculata		X
Tubificidae	X	X
Branchiura sowerbyi	X	X
Limnodrilus sp.	X	
Limnodrilus hoffmeisteri		X
Lumbriculida		
Lumbriculidae		X
Lumbriculus sp.		X
Hirudinea	X	X
Rhynchobdellida		
Glossiphoniidae	X	
Helobdella triserialis		X
Pharyngobdellida		
Erpobdellidae	X	
Erpobdella punctata		X
Crustacea		
Isopoda		
Asellidae		
Caecidotea sp.	X	X

Table 3-1 (Continued)

	Preoperational	Operational
Lirceus sp.	X	
Amphipoda		
Crangonyctidae		
Crangonyx sp.	X	
Gammaridae		
Gammarus sp.	X	
Gammarus minus		X
Decapoda		
Carnbaridae		
Orconectes sp.	X	X
Cladocera		
Daphnidae		
Daphnia lumholtzi		X
Sididae		
Sida crystallina		X
Podocopa		X
Candoniidae		
Candona sp.		X
Insecta		
Plecoptera		
Perlidae		X
Odonata		
Coenagrionidae	X	
Argia sp.		X
Enallagma sp.	X	
Ischnura sp.	X	
Gomphidae		
Dromogomphus sp.	X	
Gomphus sp.	X	
Ephemeroptera		
Baetidae		X
Baetis amplus		X
Caenidae		
Caenis sp.	X	
Ephemeridae		
Hexagenia sp.	X	
Heptageniidae		X

Table 3-1 (Continued)

	Preoperational	Operational
Stenacron sp.	X	X
Stenacron interpunctatum		X
Stenonema sp.		X
Tricorythidae		
Tricorythodes sp.	X	
Heteroptera		
Corixidae		X
Trichoptera		
Hydropsychidae		
Cheumatopsyche sp.	X	X
Hydropsyche sp.	X	
Hydroptilidae		
Hydroptila sp.		X
Leptoceridae		
Ceraclea sp.	X	X
Oecetis sp.		X
Polycentropodidae		
Cyrnellus fraternus	X	X
Megaloptera		
Corydalidae		
Nigronia sp.		X
Sialidae		
Sialis sp.	X	X
Diptera		
Chaoboridae		
Chaoborus sp.	X	
Chironomidae	X	X
Ablabesmyia sp.	X	
Ablabesmyia mallochi		X
Ablabesmyia parajanta		X
Chironomus sp.	X	X
Cladotanytarsus sp.		X
Coelotanypus sp.	X	
Coelotanypus tricolor		X
Conchapelopia sp.	X	
Cryptochironomus sp.	X	
Cryptochironomus fulvus		X
Dicrotendipes sp.	X	X
Glyptotendipes sp.	X	X

Table 3-1 (Continued)

	Preoperational	Operational
Harnischia sp.		X
Microtendipes sp.		X
Nanocladius sp.		X
Parachironomus sp.	X	X
Phaenopsectra obediens		X
Polypedilum convictum		X
Polypedilum halterale		X
Procladius sp.	X	
Pseudochironomus sp.		X
Rheotanytarsus sp.		X
Stenochironomus sp.		X
Stictochironomus sp.		X
Synorthocladius semivirens		X
Tanytarsus sp.		X
Thienemanniella xena		X
Tvetenia discoloripes sp. gp.		X
Coleoptera		
Elmidae		
Macronychus sp.	X	
Arachnoidea		
Hydrachnellae		
Hydrachnidae	X	
Gastropoda		
Mesogastropoda		
Hydrobiidae		X
Amnicola sp.	X	X
Somatogyrus sp.		X
Pleuroceridae		
Leptoxis praerosa		X
Pleurocera sp.	X	X
Pleurocera canaliculata		X
Viviparidae		
Campeloma sp.	X	
Basommatophora		
Ancylidae		
Ferrissia rivularis		X
Physidae		
Physa sp.	X	
Physella sp.		X

Table 3-1. (Continued)

Planorbidae		X
Gyraulus sp.	X	
Gyraulus parvus		X
Menetus sp.		X
Bivalvia		
Unionoida		
Unionidae		
Actinonaias ligamentina		X
Amblema plicata	X	
Anodonta imbecillis	X	X
Cyclonaias tuberculata	X	
Ellipsaria lineolata	X	
Elliptio crassidens	X	X
Fusconaia ebena	X	
Obliquaria reflexa	X	X
Pleurobema cordatum	X	
Pleurobema pyramidatum	X	
Quadrula pustulosa pustulosa	X	X
Veneroida		
Corbiculidae		
Corbicula fluminea	X	X
Dreissenidae		
Dreissena polymorpha		X
Sphaeriidae		X
Musculium transversum		X
Sphaerium sp.	X	

Table 3-2. Average densities (number/m^2) of dominant* macroinvertebrates collected with Hess samples near Watts Bar Nuclear Plant, during summer and fall 1983 through 1985 (preoperational) and 1996 (operational).

Season	Organism	Tennessee River Mile 521.0	526.3	527.4	528.0	528.5
1983-1985 (Preoperational)						
Summer	*Chironomus*	5.2	180.0	5.6	0.0	1.2
	*Corbicula fluminea**	681.6	901.2	616.0	552.4	796.8
	Cyrnellus fraternus	12.4	14.4	31.6	53.2	55.2
	Oligochaeta❖	45.6	114.0	65.2	47.6	61.2
	Total	853.6	1283.2	791.6	770.4	1008.4
Fall	*Corbicula fluminea**	640.4	704.4	676.0	509.6	511.6
	Crangonyx	13.6	3.2	13.6	79.6	38.0
	Cyrnellus fraternus	59.6	106.0	219.2	426.0	415.6
	Oligochaeta	43.6	88.8	61.2	9.2	31.2
	Total	883.2	965.6	1064.0	1212.0	1148.4
1996 (Operational)						
Summer	*Corbicula fluminea**	713	726	716	767	633
	Dugesia tigrina	632	208	1293	962	296
	Gammarus minus	786	307	1066	850	552
	Oligochaeta❖	562	430	329	121	12
	Total	2693	1671	3404	2700	1493
Fall	*Corbicula fluminea**	409	353	643	1091	755
	Dugesia tigrina	1131	1420	1103	1285	1449
	Gammarus minus	279	38	139	141	416
	Hydra americana	252	71	2	82	297
	Oligochaeta	235	30	87	76	500
	Total	2306	1912	1974	2675	3417

***Taxa** comprising 25 percent of the total at any location.
❖Includes Branchiura sowerbyi and Tubificidae

Table 3-3. Number of taxa and diversity index ($\overline{d}$) values of benthic macroinvertebrates from Hess samples collected during preoperational monitoring (1983 through 1985), and operational monitoring (1996) at Watts Bar Nuclear Plant.

		Tennessee River Mile									
		521.0		526.3		527.4		528.0		528.5	
Year	Quarter	No. trxa	$\overline{d}$	No. taxa	$\overline{d}$	No. taxa	$\overline{d}$	No. taxa	$\overline{d}$	No. taxa	$\overline{d}$
Preoperational											
1983	Summer	12	0.77	8	0.60	14	1.76	12	1.30	14	1.21*
	Fall	10	0.93	13	0.99	12	0.97	9	1.47	11	1.55
1984	Summer	19	1.03	20	0.66	15	0.84	18	1.27	17	0.75
	Fall	16	1.95	14	1.59	17	1.65	20	2.10	18	2.02
1985	Summer	24	2.11	19	2.12	13	1.88	18	2.18	12	2.11
	Fall	18	2.02	16	1.87	14	2.20	13	2.05	14	2.16
Operational											
1996	Summer	31	2.13	27	2.03	31	2.20	24	2.10	26	1.89
	Fall	29	2.15	25	1.97	27	2.12	29	2.34	32	2.46

*Data collected from TRM 528.8 in summer 1983.

Table 3-4. Similarity of benthic macroinvertebrate community composition from Hess samples collected during preoperational (1983 through 1985) and operational monitoring (1996) based on Sorensen's Quotient of Similarity and Percentage Similarity, Watts Bar Nuclear Plant, Chickamauga Reservoir.

Year	Quarter	Station	NT*	Station Comparison	CS♦	NC❖	Sorensen's Quotient of Similarity (%)	Percentage Similarity
1983	Summer	528.8	14	TRM 528.8-528.0	17	9	69.23	83.78
		528.0	12	TRM 528.8-527.4	17	11	78.57	62.11
		527.4	14	TRM 528.8-526.3	15	7	63.64	80.00
		526.3	8	TRM 528.8-521.0	16	10	76.92	82.92
		521.0	12	TRM 528.0-527.4	15	11	84.62	70.79
				TRM 528.0-526.3	14	6	60.00	81.77
				TRM 528.0-521.0	16	8	66.67	83.91
				TRM 527.4-526.3	16	6	54.55	58.38
				TRM 527.4-521.0	16	10	76.92	62.81
				TRM 527.3-521.0	13	7	70.00	95.22
	Fall	528.5	11	TRM 528.8-528.0	14	6	60.00	89.99
		528.0	9	TRM 528.8-527.4	16	7	60.87	80.79
		527.4	12	TRM 528.8-526.3	17	7	58.33	76.05
		526.3	13	TRM 528.8-521.0	15	6	57.14	74.80
		521.0	10	TRM 528.0-527.4	15	6	57.14	84.54
				TRM 528.0-526.3	16	6	54.55	79.86
				TRM 528.0-521.0	12	7	73.68	78.71
				TRM 527.4-526.3	17	8	64.00	94.58
				TRM 527.4-521.0	16	6	54.55	92.51
				TRM 527.3-521.0	17	6	52.17	93.39
1984	Summer	528.5	17	TRM 528.8-528.0	22	13	74.29	68.74
		528.0	18	TRM 528.8-527.4	21	11	68.75	95.36
		527.4	15	TRM 528.8-526.3	25	12	64.86	94.70
		526.3	20	TRM 528.8-521.0	24	12	66.67	72.85
		521.0	19	TRM 528.0-527.4	22	11	66.67	65.84
				TRM 528.0-526.3	27	11	57.89	63.07
				TRM 528.0-521.0	26	11	59.46	80.98
				TRM 527.4-526.3	25	10	57.14	94.42
				TRM 527.4-521.0	22	13	70.59	73.48
				TRM 526.3-521.0	26	12	66.67	73.81
	Fall	528.5	17	TRM 528.8-528.0	24	14	73.68	86.90
		528.0	20	TRM 528.8-527.4	24	11	62.86	72.50
		527.4	17	TRM 528.8-526.3	22	10	62.50	61.03
		526.3	14	TRM 528.8-521.0	21	13	76.47	64.35
		521.0	16	TRM 528.0-527.4	25	12	64.86	62.40
				TRM 528.0-526.3	22	12	70.59	50.58
				TRM 528.0-521.0	24	12	66.67	51.97
				TRM 527.4-526.3	22	9	58.06	84.78
				TRM 527.4-521.0	23	10	60.61	66.77
				TRM 526.3-521.0	19	11	73.33	74.07

Table 3-4 (Continued)

Year	Quarter	Station	NT*	Station Comparison	CS♦	NC❖	Sorensen's Quotient of Similarity (%)	Percentage Similarity
1985	Summer	528.5	12	TRM 528.8-528.0	21	9	60.00	89.72
		528.0	18	TRM 528.8-527.4	16	9	72.00	81.69
		527.4	13	TRM 528.8-526.3	24	7	45.16	50.72
		526.3	19	TRM 528.8-521.0	26	10	55.56	71.20
		521.0	24	TRM 528.0-527.4	21	10	64.52	80.62
				TRM 528.0-526.3	29	8	43.24	47.87
				TRM 528.0-521.0	31	11	52.38	70.27
				TRM 527.4-526.3	21	11	68.75	46.88
				TRM 527.4-521.0	26	11	59.46	73.90
				TRM 527.4-521.0	27	16	74.42	57.06
	Fall	528.5	14	TRM 528.8-528.0	19	8	59.26	75.23
		528.0	13	TRM 528.8-527.4	15	13	92.86	72.65
		527.4	14	TRM 528.8-526.3	19	11	73.33	63.76
		526.3	16	TRM 528.8-521.0	21	11	68.75	59.91
		521.0	18	TRM 528.0-527.4	22	10	59.26	68.69
				TRM 528.0-526.3	21	8	55.17	60.49
				TRM 528.0-521.0	24	7	45.16	58.64
				TRM 527.4-526.3	19	11	73.33	78.16
				TRM 527.4-521.0	20	12	75.00	68.72
				TRM 526.5-521.0	22	12	70.59	78.96
1996	Summer	526.3	27	TRM 526.3-527.4	42	16	55.17	76.98
		527.4	31	TRM 526.3-528.0	36	15	58.82	69.23
		528.0	24	TRM 526.3-528.5	38	15	56.60	58.92
		528.5	26	TRM 526.3-521.0	40	18	62.07	73.06
		521.0	31	TRM 527.4-528.0	39	16	58.18	74.81
				TRM 527.4-528.5	41	16	56.14	62.15
				TRM 527.4-521.0	41	21	67.74	73.31
				TRM 528.0-528.5	32	18	72.00	74.68
				TRM 528.0-521.0	35	20	72.73	67.68
				TRM 528.5-521.0	39	18	63.16	56.56
	Fall	526.3	25	TRM 526.3-527.4	33	19	73.08	73.23
		527.4	27	TRM 526.3-528.0	35	19	70.37	68.10
		528.0	29	TRM 526.3-528.5	37	20	70.18	61.13
		528.5	32	TRM 526.3-521.0	35	19	70.37	69.05
		521.0	29	TRM 527.4-528.0	32	24	85.71	85.53
				TRM 527.4-528.5	37	22	74.58	75.68
				TRM 527.4-521.0	37	19	67.86	72.54
				TRM 528.0-528.5	36	25	81.97	85.47
				TRM 528.0-521.0	38	20	68.97	73.14
				TRM 528.5-521.0	41	20	65.57	67.07

*Number of taxa found at each station.
♦Total number of taxa found at stations being compared.
❖Number of taxa in common between stations being compared.

Table 3-5. Results of one-way analysis of variance and Duncan's new multiple range test on total benthic macroinvertebrate standing crop (number/m^2) estimated from Hess sample during preoperational (1983 through 1985) and operational (1996) monitoring, Watts Bar Nuclear Plant, Chickamauga Reservoir.

				Tennessee River Mile				
Year	Quarter	F-Ratio	P>F	Low $\bar{x}$				High $\bar{x}$
Preoperational								
1983	Summer	7.1	0.0002	527.4	521.0	526.3	528.0	528.8
	Fall	1.3	0.2818	N.S.D.*				
1984	Summer	5.5	0.0011	528.0	521.0	528.5	526.3	527.4
	Fall	11.2	0.0001	521.0	526.3	527.4	528.5	528.0
1985	Summer	27.2	0.0001	527.4	528.5	528.0	521.0	526.3
	Fall	0.8	0.5663	N.S.D.*				
Operational								
19%	Summer	4.7	0.0030	528.5	526.3	521.0	528.0	527.4
	Fall	7.6	0.0001	526.3	527.4	521.0	528.0	528.5

*No significant difference.

Table 3-6. Total densities of benthic macroinvertebrates (number/m^2) collected in Hess samples near Watts Bar Nuclear Plant, summer and fall, 1983 through 1985 (preoperational) and 1996 (operational).

		Tennessee River Mile				
Season	Year	521.0	526.3	527.4	528.0	528.5
Preoperational						
Summer	1983	793	790	514	863	**1,082***
	1984	766	1,172	1,194	654	1,162
	1985	1,002	1,888	667	794	781
Fall	1983	881	826	834	866	752
	1984	901	1,130	1,392	1,754	1,654
	1985	868	941	966	1,015	1,039
Operational						
Summer	1996	2,963	2,156	3,705	3,001	1,775
Fall	1996	2,603	2,222	2,552	3,920	4,558

*Collected at TRM 528.8

Table 3-7. Results of the 1996 survey of mussel stocks in three long-term monitoring beds near Watts Bar Nuclear Plant.

NAME	Tennessee River Mile 520					Tennessee River Mile 526					Tennessee River Mile 528					Grand Total	%
	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total		
Native Mussels																	
Elliptio crassidens	88	22	76	26	212	10	54	27	23	114	24	71	73	100	268	594	70.2
Pleurobema cordatum	6	4	8	9	27	0	12	7	1	20	9	10	7	21	47	94	11.1
Cyclonaias tuberculata	5	6	5	2	18	0	3	4	0	7	3	6	1	3	13	38	4.5
Potamilus alatus	0	0	2	1	3	8	6	9	5	28	0	0	1	3	4	35	4.1
Quadrula pustulosa	0	0	0	1	1	1	1	3	4	9	8	10	0	2	20	30	3.5
Ellipsaria lineolata	0	0	1	1	2	1	3	0	0	4	0	4	4	1	9	15	1.8
Amblema plicata	0	0	0	2	2	1	4	1	0	6	1	2	0	0	3	11	1.3
Anodonta grandis	0	0	0	0	0	3	0	2	1	6	0	0	0	1	1	7	0.8
Obliquaria reflexa	0	0	0	0	0	0	0	6	0	6	0	0	0	0	0	6	0.7
Lampsilis abrupta	1	0	0	0	1	0	1	1	0	2	0	0	1	0	1	4	0.5
Tritogonia verrucosa	0	0	0	0	0	1	1	0	1	3	0	0	1	0	1	4	0.5
Ligumia recta	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	2	0.2
Quadrula metanevra	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	2	0.2
Elliptio dilatata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.1
Lasmigona costata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.1
Leptodea fragilis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.1
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.1
Total Specimens	100	33	92	43	268	25	86	61	35	207	47	104	89	131	371	846	99.8
Species Included	4	4	5	8	10	7	10	10	6	13	7	7	8	7	14	17	
Zebra Mussel																	
Dreissena polymorpha	0	0	0	0	0	1	3	3	10	17	2	2	0	3	7	24	

Table 3-8. Results of the 1994 survey of mussel stocks in three long-term monitoring beds near Watts Bar Nuclear Plant.

NAME	Tennessee River Mile 520					Tennessee River Mile 526					Tennessee River Mile 528					Grand Total	%
	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total		
Elliptio crassidens	85	31	52	29	197	24	50	11	25	110	23	56	75	122	276	583	66.2
Pleurobema cordatum	14	3	7	11	35	1	13	2	3	19	8	6	12	15	41	95	10.8
Quadrula pustulosa	0	1	1	4	6	1	6	11	12	30	1	14	3	11	29	65	7.4
Cyclonaias tuberculafa	6	16	13	11	46	1	2	3	2	8	0	6	1	3	10	64	7.3
Amblema plicata	0	1	0	1	2	3	2	4	2	11	0	0	0	0	0	13	1.5
Ellipsaria lineolata	1	0	4	2	7	0	0	0	1	1	0	2	0	1	3	11	1.3
Obliquaria reflexa	0	0	0	0	0	0	1	7	3	11	0	0	0	0	0	11	1.3
Potamilus alatus	0	1	0	1	2	2	1	1	1	5	1	1	0	1	3	10	1.1
Anodonta grandis	0	0	0	0	0	2	0	1	4	7	0	0	0	0	0	7	0.8
Tritogonia verrucosa	0	0	0	0	0	0	0	1	4	5	0	0	1	1	2	7	0.8
Quadrula metanevra	0	1	1	1	3	0	0	0	0	0	0	0	0	1	1	4	0.4
Leptodea fragilis	0	0	0	0	0	0	1	1	0	2	0	1	0	0	1	3	0.3
Lampsilis abrupta	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	2	0.2
Megalonaias nervosa	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	2	0.2
Ligumia recta	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0.1
Plethobasus cyphyus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.1
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.1
Total Specimens	106	54	78	61	299	34	77	43	58	212	33	87	92	157	369	880	99.9
Species Included	4	7	5	9	9	7	9	11	11	14	4	8	5	10	12	17	

Table 4-1. Watts Bar Nuclear operational monitoring water quality values during 1996.

Tennessee River Mile 518.0					
Parameter	**N**	**Mean**	**Std Dev**	**Min**	**Max**
pH (standard units)	4	7.33	0.10	7.2	7.4
Turbidity (NTU)	3	4.33	1.53	3.0	6.0
Total Solids (mg/L)	3	106.7	30.8	90	130
Dissolved Solids (mg/L)	3	90.0	17.3	80	110
Ammonia Nitrogen (mg/L	14	0.051	0.010	0.03	0.06
Nitrate+Nitrite Nitrogen (mg/L)	14	0.318	0.068	0.25	0.42
Organic Nitrogen (mg/L)	14	0.149	0.052	0.07	0.23
Total Phosphorus (mg/L)	14	0.0320	0.0108	0.008	0.050
Dissolved Phosphorus (mg/L)	14	0.0165	0.0072	0.002	0.030
Total Organic Carbon(mg/L)	14	1.65	0.21	1.5	2.0
COD (mg/L)	3	7.0	2.6	5	10
Total Alkalinity (mg/L)	4	66.8	3.2	64	70
Chlorophyll a (ug/L)	32	6.4	3.8	2	18
Tennessee River Mile 527.4					
Parameter					
pH (standard units)	4	7.68	0.15	7.5	7.8
Turbidity (NTU)	3	4.00	1.00	3.0	5.0
Total Solids (mg/L)	4	102.5	18.9	90	130
Dissolved Solids (mg/L)	4	90.0	20.0	80	120
Ammonia Nitrogen (mg/L	13	0.038	0.012	0.02	0.05
Nitrate+Nitrite Nitrogen (mg/L)	13	0.302	0.054	0.23	0.37
Organic Nitrogen (mg/L)	13	0.180	0.052	0.09	0.25
Total Phosphorus (mg/L)	13	0.0254	0.0052	0.020	0.030
Dissolved Phosphorus (mg/L)	13	0.0105	0.0029	0.008	0.020
Total Organic Carbon(mg/L)	13	1.74	0.27	1.5	2.2
COD (mg/L)	4	6.5	2.4	5	10
Total Alkalinity (mg/L)	4	62.8	5.9	58	70
Chlorophyll a (ug/L)	32	8.1	4.0	4	18

Table 4-1. (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Min**	**Max**
pH (standard units)	3	7.63	0.15	7.5	7.8
Turbidity (NTU)	3	4.00	1.00	3.0	5.0
Total Solids (mg/L)	4	102.5	18.9	90	130
Dissolved Solids (mg/L)	4	95.0	17.3	80	120
Ammonia Nitrogen (mg/L	13	0.035	0.016	0.01	0.06
Nitrate+Nitrite Nitrogen (mg/L)	13	0.309	0.054	0.24	0.38
Organic Nitrogen (mg/L)	13	0.174	0.072	0.07	0.27
Total Phosphorus (mg/L)	13	0.0231	0.0048	0.020	0.030
Dissolved Phosphorus (mg/L)	13	0.0085	0.0030	0.002	0.010
Total Organic Carbon(mg/L)	13	1.75	0.27	1.5	2.1
COD (mg/L)	4	6.8	1.5	5	8
Total Alkalinity (mg/L)	3	65.0	7.5	58	73
Chlorophyll a (ug/L)	32	7.7	3.1	3	15
Tennessee River Mile 529.9					
Parameter					
pH (standard units)	4	8.65	0.33	8.2	8.9
Turbidity (NTU)	4	1.75	0.50	1.0	2.0
Total Solids (mg/L)	4	100.0	11.5	90	110
Dissolved Solids (mg/L)	4	95.0	12.9	80	110
Ammonia Nitrogen (mg/L	12	0.018	0.008	0.01	0.03
Nitrate+Nitrite Nitrogen (mg/L)	12	0.190	0.054	0.10	0.26
Organic Nitrogen (mg/L)	12	0.273	0.359	0.09	1.40
Total Phosphorus (mg/L)	12	0.0183	0.0039	0.010	0.020
Dissolved Phosphorus (mg/L)	12	0.0081	0.0016	0.005	0.010
Total Organic Carbon(mg/L)	12	1.90	0.46	1.6	3.1
COD (mg/L)	4.0	9.0	1.8	7.0	11.0
Total Alkalinity (mg/L)	4.0	65.5	1.9	64.0	68.0
Chlorophyll a (ug/L)	32.0	10.7	3.7	5.0	21.0

Table 4-2. Watts Bar Nuclear preoperational monitoring water quality values during 1996.

Tennessee River Mile 518.0					
Parameter	N	Mean	Std Dev	Min	Max
pH (standard units)	459	7.55	0.36	6.8	8.7
Turbidity (NTU)	115	5.40	2.98	1.1	16.0
Total Solids (mg/L)	0	-	-	-	-
Suspended Solids (mg/L)	79	4.6	2.3	1	9
Volatile suspended Solids (mg/L)	52	2.4	1.0	1	5
Dissolved Solids (mg/L)	19	96.8	23.6	40	130
Ammonia Nitrogen (mg/L	140	0.047	0.032	0.01	0.28
Nitrate+Nitrite Nitrogen (mg/L)	140	0.291	0.081	0.17	0.48
Organic Nitrogen (mg/L)	140	0.209	0.099	0.04	0.63
Total Phosphorus (mg/L)	116	0.0341	0.0162	0.010	0.110
Dissolved Phosphorus (mg/L)	125	0.0139	0.0058	0.010	0.030
Total Organic Carbon(mg/L)	139	2.50	0.86	1.1	5.8
COD (mg/L)	19	7.9	3.4	2	15
Total Alkalinity (mg/L)	133	63.0	8.4	46	78
Chlorophyll a (ug/L)	85	4.7	3.9	1	19.07
Tennessee River Mile 527.4					
Parameter					
pH (standard units)	553	7.48	0.39	6.5	9.0
Turbidity (NTU)	105	5.01	2.40	0.8	12.0
Total Solids (mg/L)	0	-	-	-	-
Suspended Solids (mg/L)	69	3.4	1.3	1	6
Volatile suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	69	98.1	18.3	50	150
Ammonia Nitrogen (mg/L	114	0.042	0.027	0.01	0.21
Nitrate+Nitrite Nitrogen (mg/L)	114	0.333	0.338	0.02	3.50
Organic Nitrogen (mg/L)	114	0.196	0.102	0.04	0.62
Total Phosphorus (mg/L)	79	0.0284	0.0126	0.010	0.060
Dissolved Phosphorus (mg/L)	109	0.0114	0.0037	0.010	0.030
Total Organic Carbon(mg/L)	114	3.00	2.58	1.2	26.0
COD (mg/L)	69	6.9	3.0	1	22
Total Alkalinity (mg/L)	103	62.5	8.6	46	76
Chlorophyll a (ug/L)	76	5.8	3.3	2.32	17.8

Table 4-2. (Continued)

Tennessee River Mile 529.5					
Parameter	N	Mean	Std Dev	Min	Max
pH (standard units)	163	7.50	0.45	6.4	9.1
Turbidity (NTU)	78	5.40	2.82	1.2	14.0
Total Solids (mg/L)	0	-	-	-	-
Suspended Solids (mg/L)	43	3.6	1.4	1	6
Volatile Suspended Solids (mg/L)	0	-	-	-	-
Dissolved Solids (mg/L)	43	99.1	20.9	70	180
Ammonia Nitrogen (mg/L)	104	0.038	0.023	0.01	0.13
Nitrate+Nitrite Nitrogen (mg/L)	104	0.301	0.118	0.02	0.85
Organic Nitrogen (mg/L)	104	0.191	0.091	0.01	0.48
Total Phosphorus (mg/L)	80	0.0285	0.0120	0.010	0.050
Dissolved Phosphorus (mg/L)	95	0.0118	0.0041	0.010	0.030
Total Organic Carbon(mg/L)	103	2.71	1.02	1.3	10.0
COD (mg/L)	45	7.3	2.8	2	14
Total Alkalinity (mg/L)	91	63.1	8.8	46	76
Chlorophyll a (ug/L)	76	5.7	3.7	2.2	19.33
Tennessee River Mile 529.9					
Parameter					
pH (standard units)	195	7.61	0.40	5.8	8.8
Turbidity (NTU)	42	5.38	2.79	1.5	13.0
Total Solids (mg/L)	0	-	-	-	-
Suspended Solids (mg/L)	31	4.9	1.9	1	9
Volatile Suspended Solids (mg/L)	22	2.5	0.8	1	4
Dissolved Solids (mg/L)	1	100.0	-	100	100
Ammonia Nitrogen (mg/L)	42	0.034	0.021	0.01	0.11
Nitrate+Nitrite Nitrogen (mg/L)	51	0.262	0.098	0.07	0.61
Organic Nitrogen (mg/L)	42	0.203	0.078	0.03	0.42
Total Phosphorous (mg/L)	51	0.0320	0.0165	0.010	0.100
Dissolved Phosphorous (mg/L)	33	0.0142	0.0144	0.010	0.090
Total Organic Carbon(mg/L)	42	2.28	0.67	1.2	4.1
COD (mg/L)	1.0	9.0	-	9.0	9.0
Total Alkalinity (mg/L)	38.0	64.7	9.8	41.0	82.0
Chlorophyll a (ug/L)	17.01	5.4	2.6	2.0	12.0

Table 4-3. ANOVA with Duncan's multiple range test comparing preoperational and operational water quality data.

	TRM 518.0	<--F Prob	TRM 527.4	<--F Prob	TRM 529.5	<--F Prob	TRM 529.9	<--F Prob	All	<--F Prob
pH		0.2202	-	0.3190	-	0.6079	Up	0.0001	Up	0.0026
Turbidity	-	0.5411	-	0.4711	-	0.3961	Down	0.0136	Down	0.0141
Dissolved Solids	-	0.6377	-	0.3941		0.7085	-	0.7519	-	0.2920
Ammonia Nitrogen	-	0.6911	-	0.6681		0.6674	Down	0.0128	-	0.1426
Nitrite+Nitrate Nitrogen	-	0.2265	-	0.7414	-	0.8157	Down	0.0169	-	0.4818
Organic Nitrogen	Down	0.0248	-	0.5902	-	0.5187	-	0.2329	-	0.6030
Total Phosphorus	-	0,6448	-	0.4041	-	0.1132	Down	0.0063	Down	0.0040
Dissolved Phosphorus	-	0.1263	-	0.4351	Down	0.0059	-	0.1485	-	0.0901
Total Organic Carbon	Down	0.0003	-	0.0821	Down	0.0010	-	0.0759	Down	0.0001
Chemical Oxygen Demand	-	0.6484	-	0.7796	-	0.6799	-	1.0000	-	0.8894
Total Alkalinity	-	0.3804	-	0.9515	-	0.7181	-	0.8781	-	0.3963
Chlorophyll a	Up	0.0373	Up	0.0022	Up	0.0119	Up	0.0001	Up	0.0001

(<--F Prob) **Probablity** columns above are the "significance probability associated with the F value" in an **Analysis** of **Variance.**

If there is a "-" in a column, **the** analysis of **variance** found no **significant** difference (0.05 level) **between** the **preoperational** and operational means for **the** indicated parameter at the indicated station,

If there is **a** "Down" **in** a column, the analysis of variance found a significant difference (0.05 level) between the preoperational and operational means for **the** indicated parameter at **the** indicated station with the mean decreasing from the preoperational period.

If there is a "Up" in a column, the analysis of variance found a significant **difference** (0.05 level) **between** the preoperational **and** operational means for the indicated parameter at **the** indicated **station with the** mean increasing from the preoperational period.

Table 4-4. Watts Bar Nuclear operational monitoring water quality values for metals during 1996.

Tennessee River Mile 518.0					
Parameter	N	Mean	Std Dev	Min	Max
Total Calcium (mg/L)	7	17.3	4.5	12.0	23.0
Total Magnesium (mg/L)	7	5.5	0.8	4.4	6.2
Total Arsenic (ug/L)	7	1.0	0.0	1.0	1.0
Total Boron (ug/L)	7	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	7	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	7	1.0	0.0	1.0	1.0
Total Copper (ug/L)	7	10.0	0.0	10.0	10.0
Total Iron (ug/L)	7	707.1	746.6	260.0	1800.0
Total Lead (ug/L)	7	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	7	70.0	33.5	30.0	110.0
Total Nickel (ug/L)	7	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	7	10.0	0.0	10.0	10.0
Total Antimony (ug/L)	7	165.7	80.4	50.0	240.0
Total Selenium (ug/L)	7	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	7	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	7	65.8	11.5	55.5	82.5
Tennessee River Mile 527.4					
Parameter					
Total Calcium (mg/L)	7	20.3	3.0	16.0	23.0
Total Magnesium (mg/L)	7	5.4	0.7	4.4	5.9
Total Arsenic (ug/L)	7	1.1	0.4	1.0	2.0
Total Boron (ug/L)	7	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	7	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	7	1.0	0.0	1.0	1.0
Total Copper (ug/L)	7	10.0	0.0	10.0	10.0
Total Iron (ug/L)	7	212.9	21.4	180.0	240.0
Total Lead (ug/L)	7	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	7	53.0	25.4	20.0	82.0
Total Nickel (ug/L)	7	1.1	0.4	1.0	2.0
Total Zinc (ug/L)	7	11.4	3.8	10.0	20.0
Total Antimony (ug/L)	7	157.1	24.3	130.0	190.0
Total Selenium (ug/L)	7	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	7	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	7	72.8	10.4	58.1	81.7

Table 4-4. (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Total Calcium (mg/L)	6	20.7	3.8	16.0	25.0
Total Magnesium (mg/L)	6	5.4	0.8	4.4	6.4
Total Arsenic (ug/L)	6	1.0	0.0	1.0	1.0
Total Boron (ug/L)	6	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	6	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	6	1.0	0.0	1.0	1.0
Total Copper (ug/L)	6	10.0	0.0	10.0	10.0
Total Iron (ug/L)	6	210.0	26.1	180.0	240.0
Total Lead (ug/L)	6	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	6	10.0	0.0	10.0	10.0
Total Nickel (ug/L)	6	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	6	10.0	0.0	10.0	10.0
Total Antimony (ug/L)	6	166.7	27.3	140.0	210.0
Total Selenium (ug/L)	6	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	6	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	6	73.9	12.8	58.1	88.8
Tennessee River Mile 529.9					
Parameter					
Total Calcium (mg/L)	7	19.4	3.3	16.0	23.0
Total Magnesium (mg/L)	7	5.2	0.7	4.4	5.9
Total Arsenic (ug/L)	7	1.0	0.0	1.0	1.0
Total Boron (ug/L)	7	500.0	0.0	500.0	500.0
Total Cadmium (ug/L)	7	0.1	0.0	0.1	0.1
Total Chromium (ug/L)	7	1.0	0.0	1.0	1.0
Total Copper (ug/L)	7	10.0	0.0	10.0	10.0
Total Iron (ug/L)	7	178.6	32.9	150.0	220.0
Total Lead (ug/L)	7	1.0	0.0	1.0	1.0
Total Manganese (ug/L)	7	37.6	12.6	24.0	52.0
Total Nickel (ug/L)	7	1.0	0.0	1.0	1.0
Total Zinc (ug/L)	7	10.0	0.0	10.0	10.0
Total Antimony (ug/L)	7	110.0	51.6	50.0	180.0
Total Selenium (ug/L)	7	1.0	0.0	1.0	1.0
Total Mercury (ug/L)	7	0.2	0.0	0.2	0.2
Ca/Mg Hardness (mg/L)	7	70.0	11.1	58.1	81.7

Table 4-5. Watts Bar Nuclear preoperational monitoring water quality values for metals during 1996.

Tennessee River Mile 518.0					
Parameter	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Total Calcium (mg/L)	25	21.8	3.2	11.0	25.7
Total Magnesium (mg/L)	25	5.6	1.2	2.3	7.3
Total Arsenic (ug/L)	25	1.2	0.5	1.0	3.0
Total Boron (ug/L)	25	50.0	0.0	50.0	50.0
Total Cadmium (ug/L)	25	0.1	0.1	0.1	0.8
Total Chromium (ug/L)	25	1.4	0.7	1.0	4.0
Total Copper (ug/L)	25	11.0	9.0	5.0	50.0
Total Iron (ug/L)	25	189.2	139.2	50.0	590.0
Total Lead (ug/L)	25	2.8	3.9	1.0	20.0
Total Manganese (ug/L)	25	57.1	33.4	10.0	134.0
Total Nickel (ug/L)	25	2.2	2.0	1.0	9.0
Total Zinc (ug/L)	25	10.5	7.6	1.0	36.0
Total Antimony (ug/L)	25	189.2	118.9	50.0	410.0
Total Selenium (ug/L)	25	1.1	0.6	1.0	4.0
Total Mercury (ug/L)	25	0.2	0.1	0.2	0.5
Ca/Mg Hardness (mg/L)	25	77.6	12.7	37.0	92.0
Tennessee River Mile 527.4					
Parameter					
Total Calcium (mg/L)	78	22.5	3.6	16.0	38.0
Total Magnesium (mg/L)	78	5.4	0.9	3.7	8.4
Total Arsenic (ug/L)	79	1.3	0.6	1.0	3.0
Total Boron (ug/L)	79	45.3	16.7	6.0	130.0
Total Cadmium (ug/L)	79	0.3	0.5	0.1	2.0
Total Chromium (ug/L)	79	1.4	0.9	1.0	4.0
Total Copper (ug/L)	79	12.6	13.6	5.0	90.0
Total Iron (ug/L)	79	177.0	120.3	10.0	610.0
Total Lead (ug/L)	75	3.9	5.7	1.0	40.0
Total Manganese (ug/L)	75	64.9	34.5	12.0	180.0
Total Nickel (ug/L)	79	2.0	1.8	1.0	10.0
Total Zinc (ug/L)	79	18.8	43.4	5.0	330.0
Total Antimony (ug/L)	79	148.4	95.0	50.0	480.0
Total Selenium (ug/L)	79	1.1	0.4	1.0	3.0
Total Mercury (ug/L)	79	0.2	0.0	0.2	0.3
Ca/Mg Hardness (mg/L)	79	78.2	12.0	56.0	130.0

Table 4-5. (Continued)

Tennessee River Mile 529.5					
Parameter	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Total Calcium (mg/L)	53	22.9	4.9	17.0	40.0
Total Magnesium (mg/L)	53	5.7	1.3	3.9	8.7
Total Arsenic (ug/L)	53	1.3	1.1	1.0	8.0
Total Boron (ug/L)	53	71.1	125.7	50.0	940.0
Total Cadmium (ug/L)	53	0.1	0.1	0.1	0.6
Total Chromium (ug/L)	53	1.7	1.7	1.0	12.0
Total Copper (ug/L)	53	11.2	10.2	5.0	59.0
Total Iron (ug/L)	53	201.5	163.3	10.0	700.0
Total Lead (ug/L)	53	2.0	2.2	1.0	14.0
Total Manganese (ug/L)	53	63.1	35.4	5.0	174.0
Total Nickel (ug/L)	53	1.7	1.5	1.0	9.0
Total Zinc (ug/L)	53	15.7	29.5	2.0	220.0
Total Antimony (ug/L)	53	166.2	102.7	50.0	390.0
Total Selenium (ug/L)	53	1.3	0.9	1.0	6.0
Total Mercury (ug/L)	53	0.2	0.0	0.2	0.3
Ca/Mg Hardness (mg/L)	53	80.6	17.3	58.0	130.0
Tennessee River Mile 529.9					
Parameter					
Total Calcium (mg/L)	1	22.0	-	22.0	22.0
Total Magnesium (mg/L)	1	5.5	-	5.5	5.5
Total Arsenic (ug/L)	1	1.0	-	1.0	1.0
Total Boron (ug/L)	1	8.0	-	8.0	8.0
Total Cadmium (ug/L)	1	0.1	-	0.1	0.1
Total Chromium (ug/L)	1	2.0	-	2.0	2.0
Total Copper (ug/L)	1	40.0	-	40.0	40.0
Total Iron (ug/L)	1	130.0	-	130.0	130.0
Total Lead (ug/L)	0	-	-	-	-
Total Manganese (ug/L)	0	-	-	-	-
Total Nickel (ug/L)	1	1.0	-	1.0	1.0
Total Zinc (ug/L)	1	10.0	-	10.0	10.0
Total Antimony (ug/L)	1	100.0	-	100.0	100.0
Total Selenium (ug/L)	1	1.0	-	1.0	1.0
Total Mercury (ug/L)	1	0.2	-	0.2	0.2
Ca/Mg hardness (mg/L)	1	78.0	-	78.0	78.0

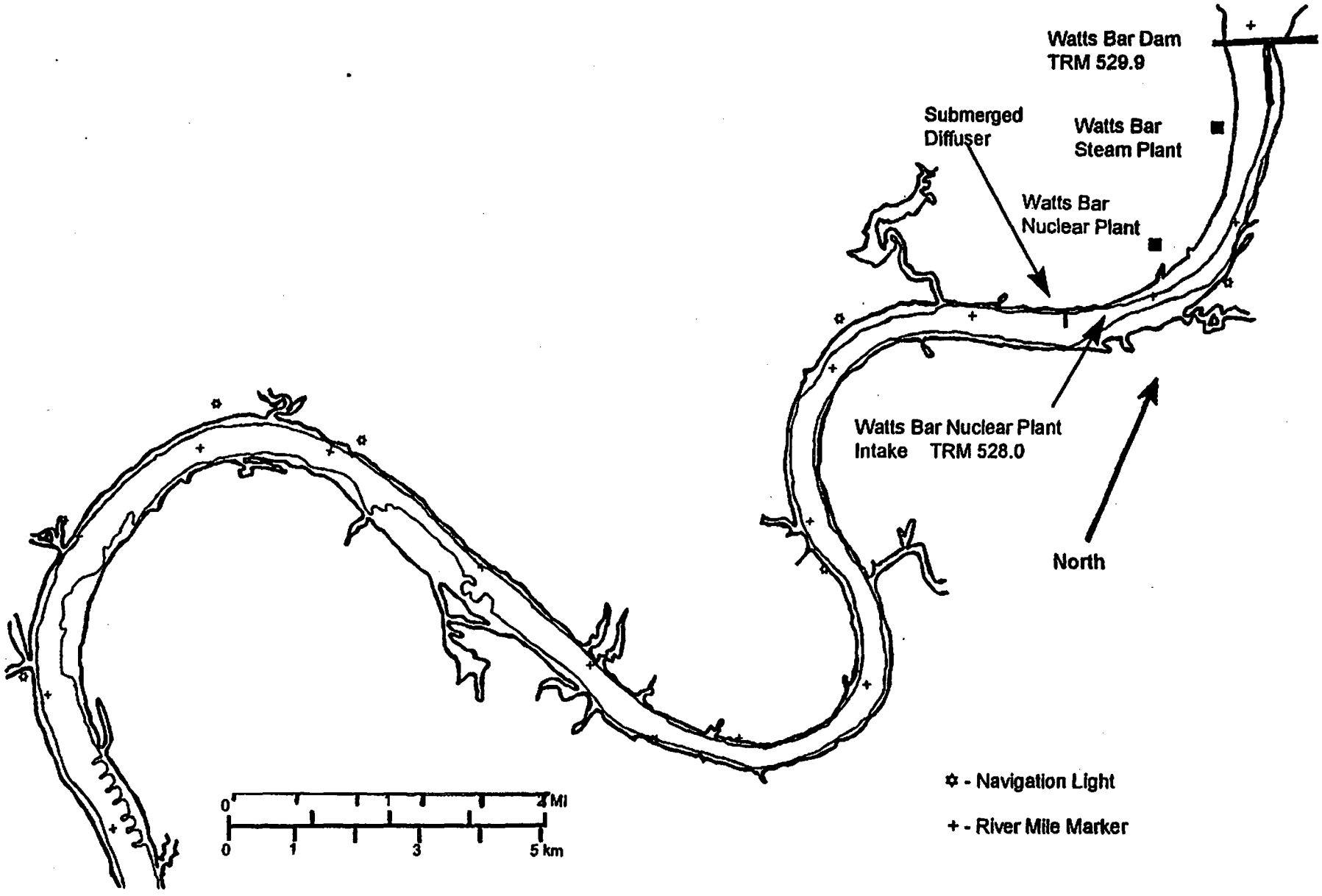


Figure 1-1. Location of Watts Bar Nuclear Plant on Chickamauga Reservoir.

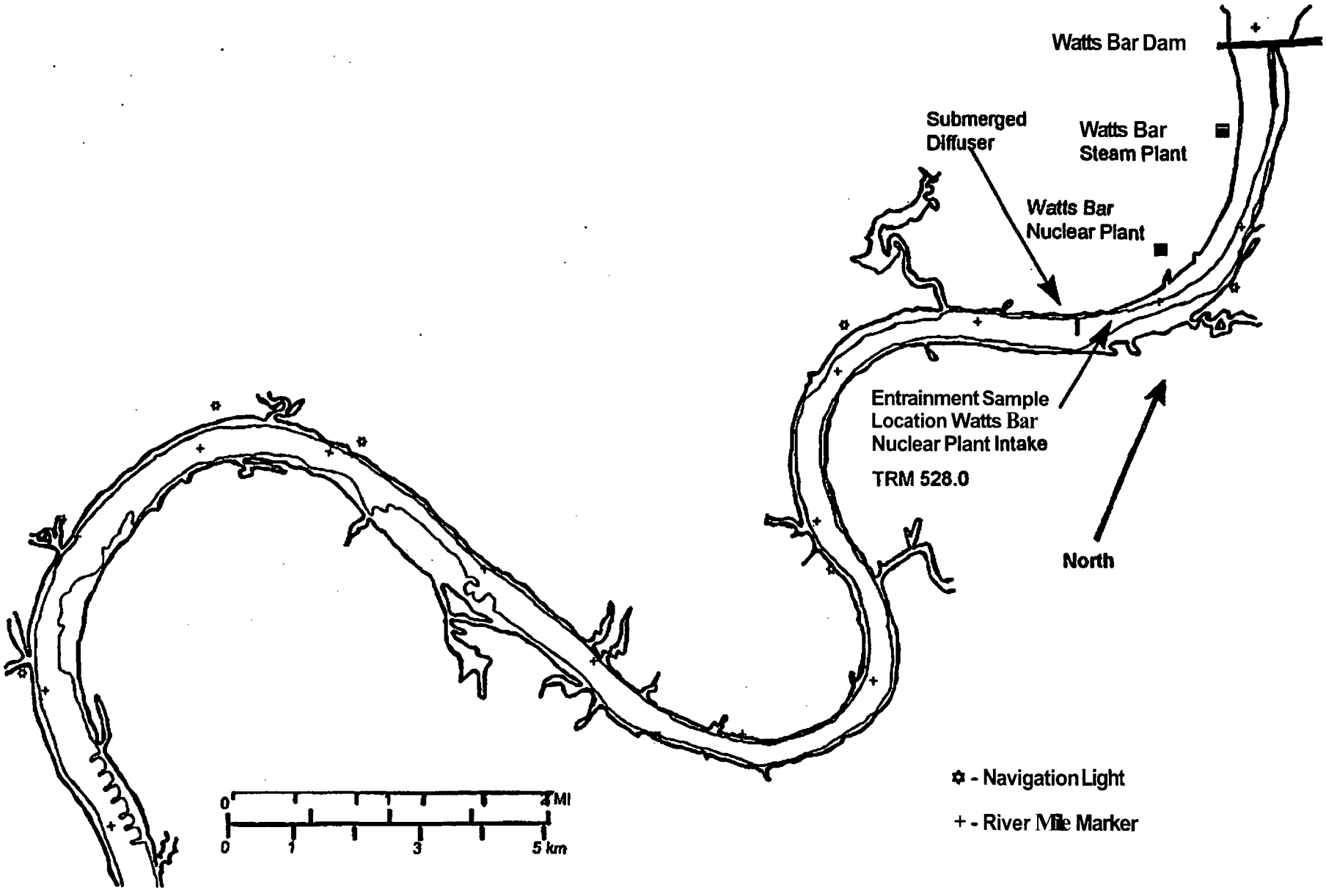


Figure 2-1. Sample Locations for Entrainment Samples in the vicinity of Watts Bar Nuclear Plant. 1996.

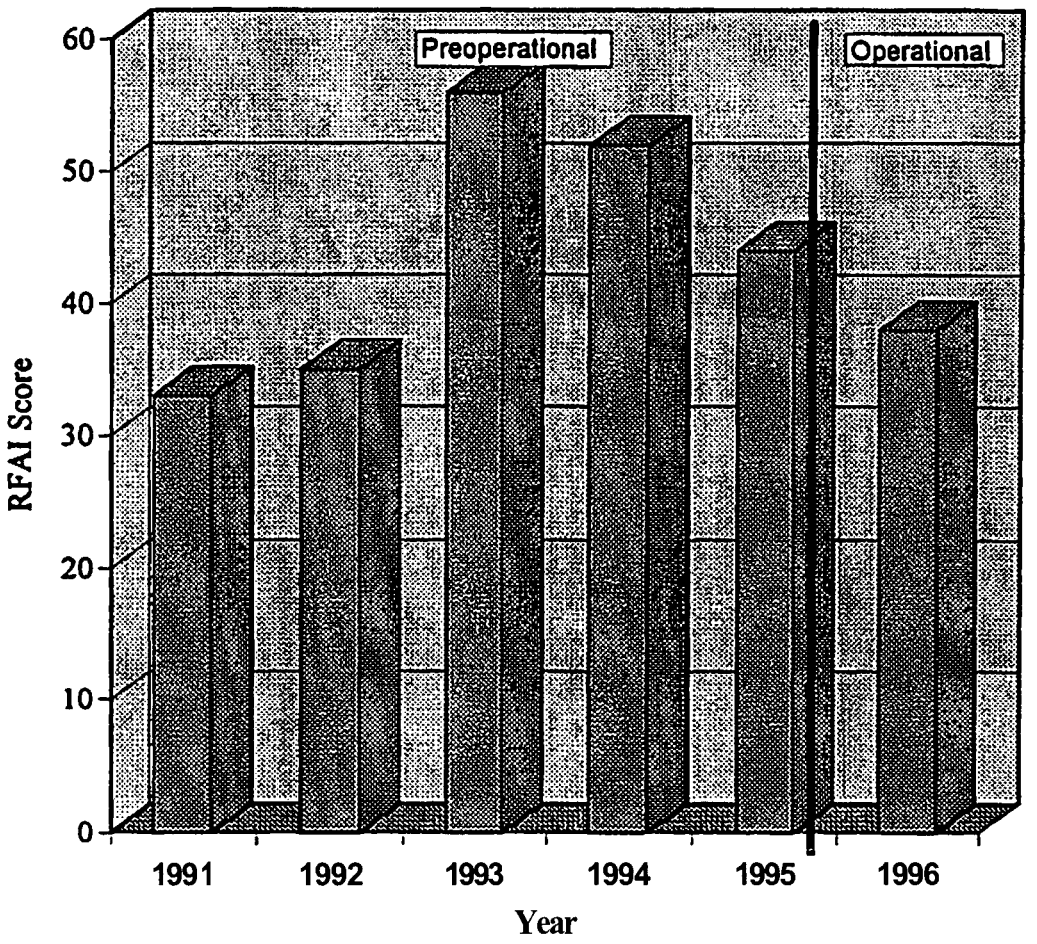


Figure 2-2. Reservoir Fish Assemblage Index (RFAI) scores from preoperational (1991-1995) and operational (1996) periods on Chickamauga Reservoir in the vicinity of Watts Bar Nuclear Plant.

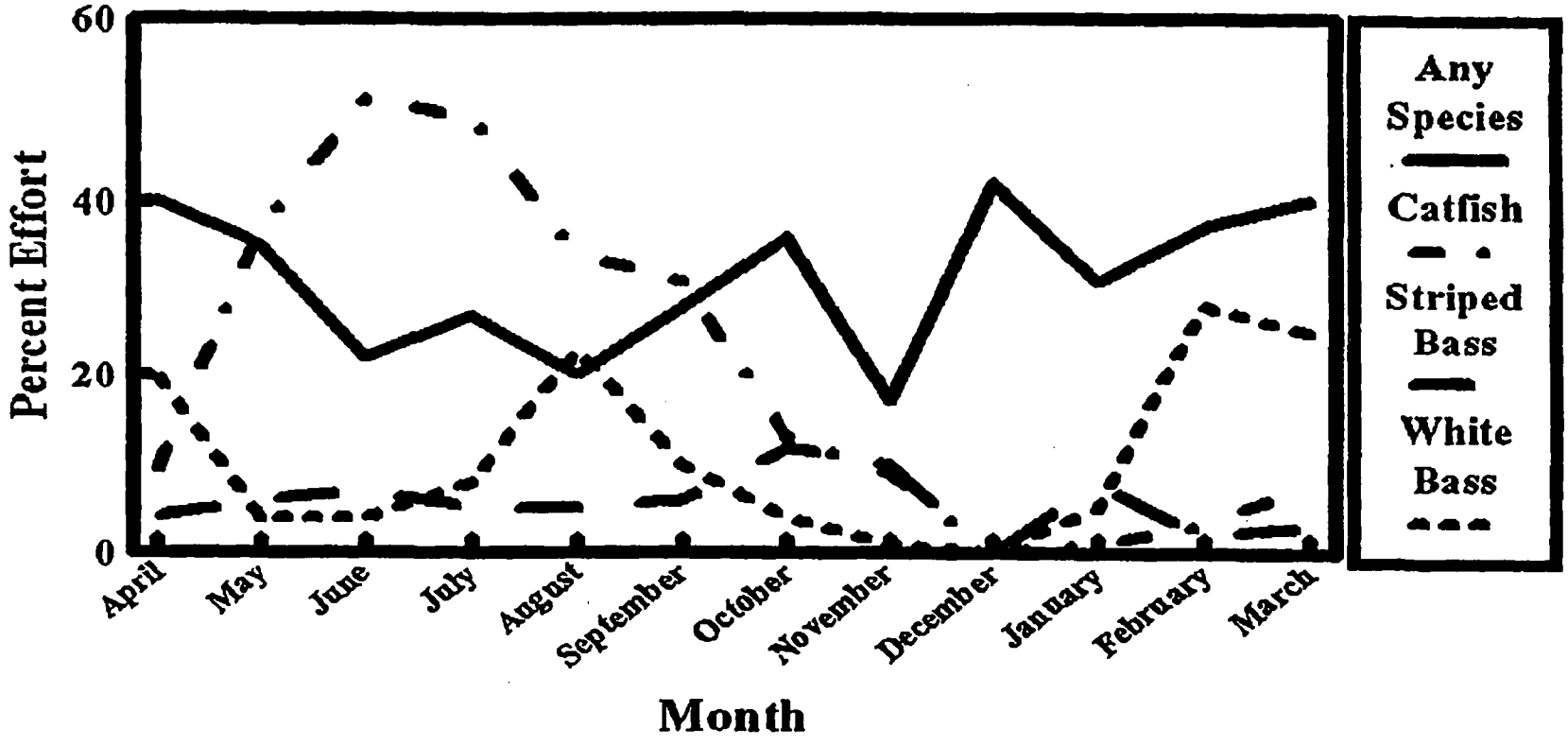


Figure 2-3. Percent effort for any species group and three directed species groups from the Watts Bar Tailwater fishery. April 1996 though March *1997.*

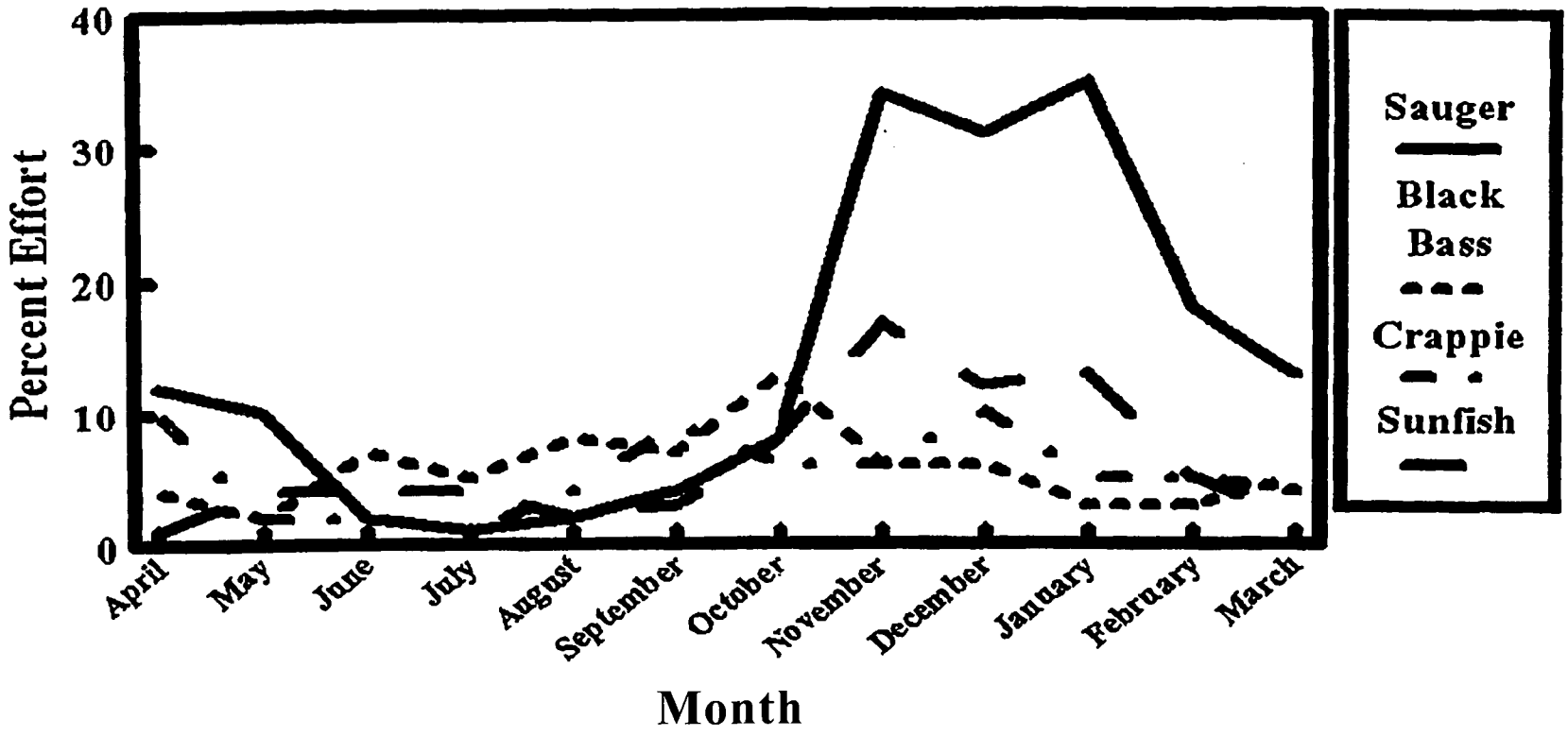


Figure 2-4. Percent of effort for four directed species group from the Watts Bar Tailwater Fishery. April 1996 though March 1997.

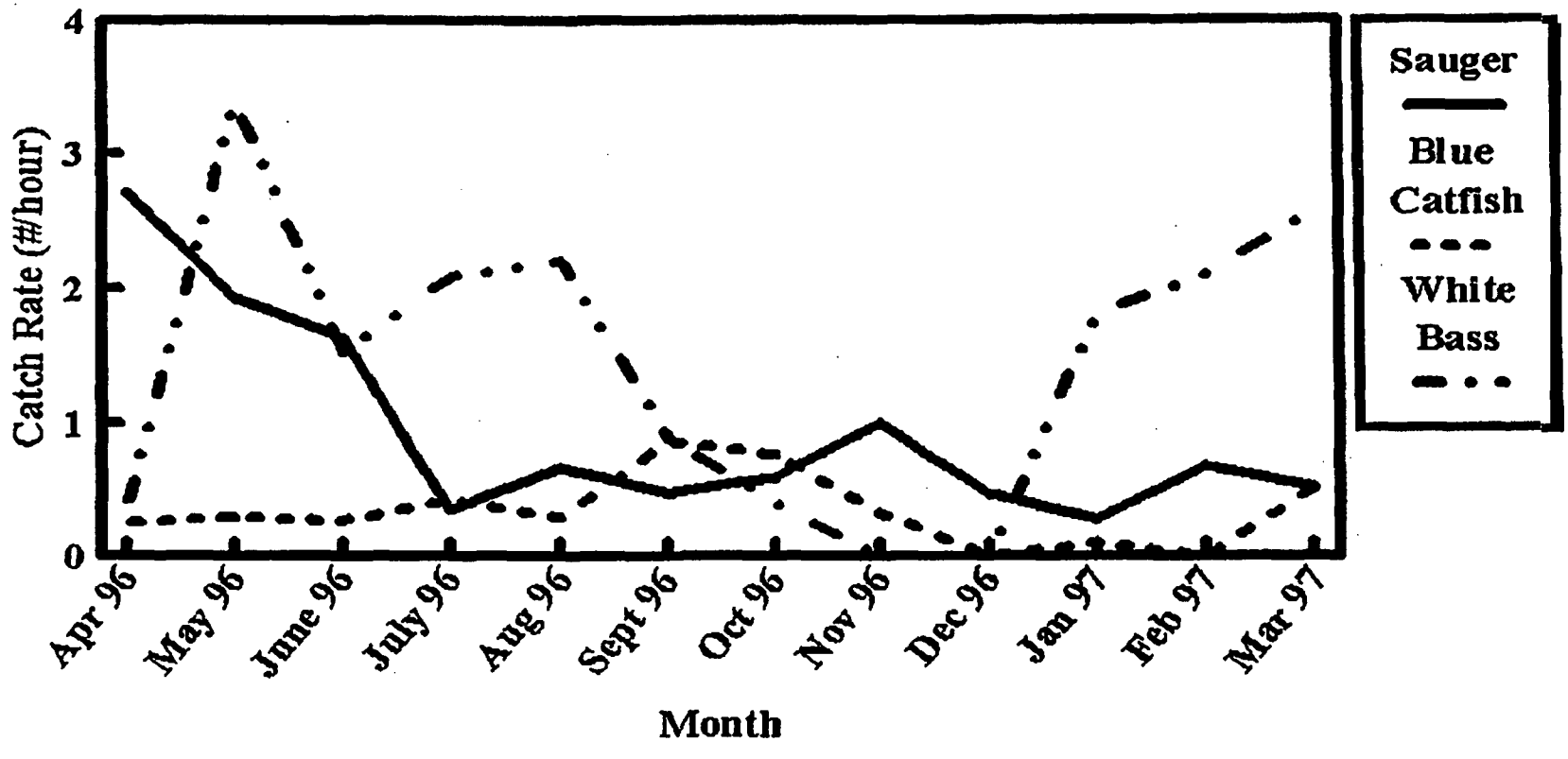


Figure 2-5. Mean monthly catch rate for selected species from the Watts Bar Tailwater fishery. April 1996 through March 1997.

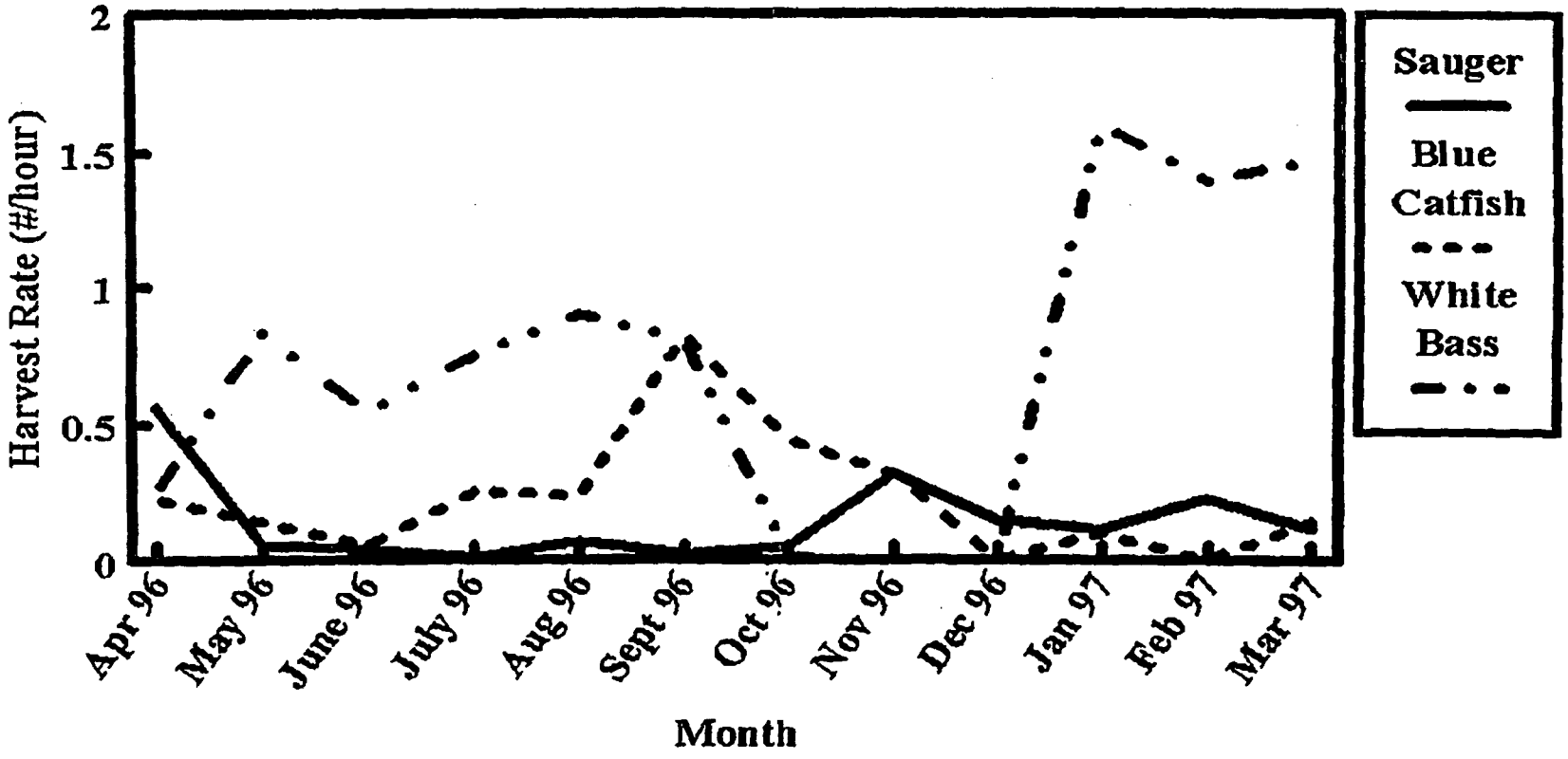


Figure 2-6. Mean monthly harvest rate for selected species from the Watts Bar Tailwater fishery. April 1996 through March 1997.

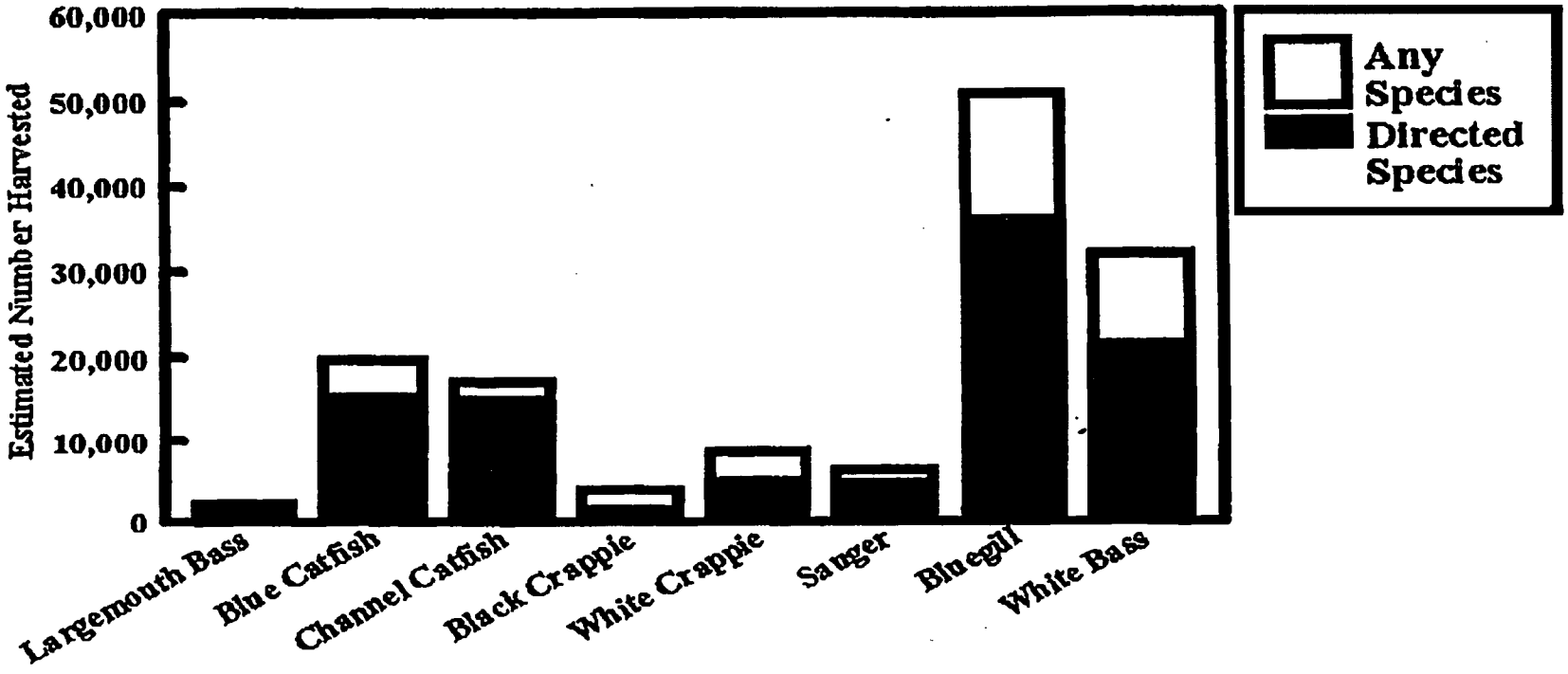


Figure 2-7. Estimated number harvested by any species group and directed species group for the Watts Bar Tailwater fishery. April 1996 through March 1997.

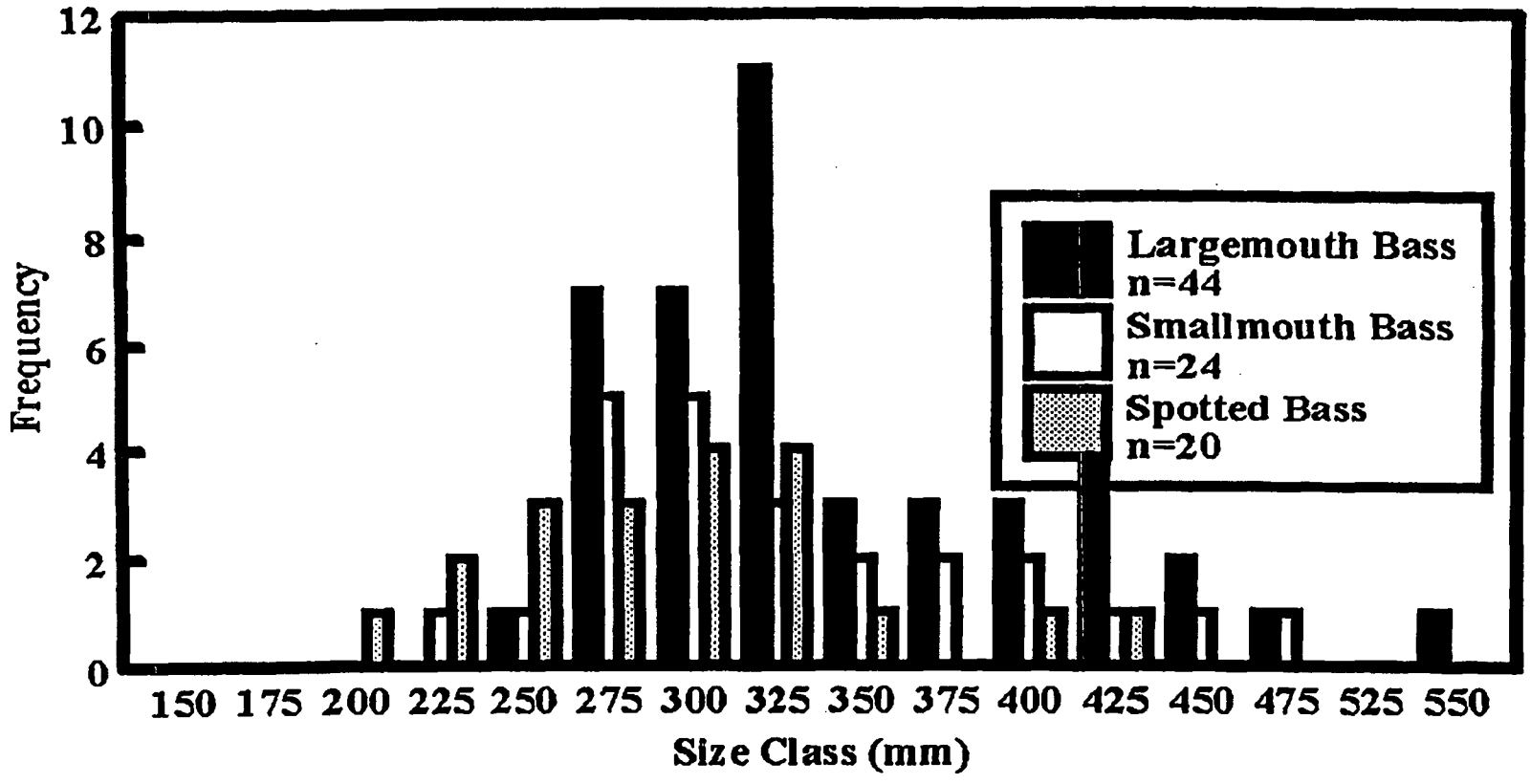


Figure 2-8. Length frequency of harvested largemouth bass, smallmouth bass, and spotted bass from the Watts Bar Tailwater. April 1996 though March 1997.

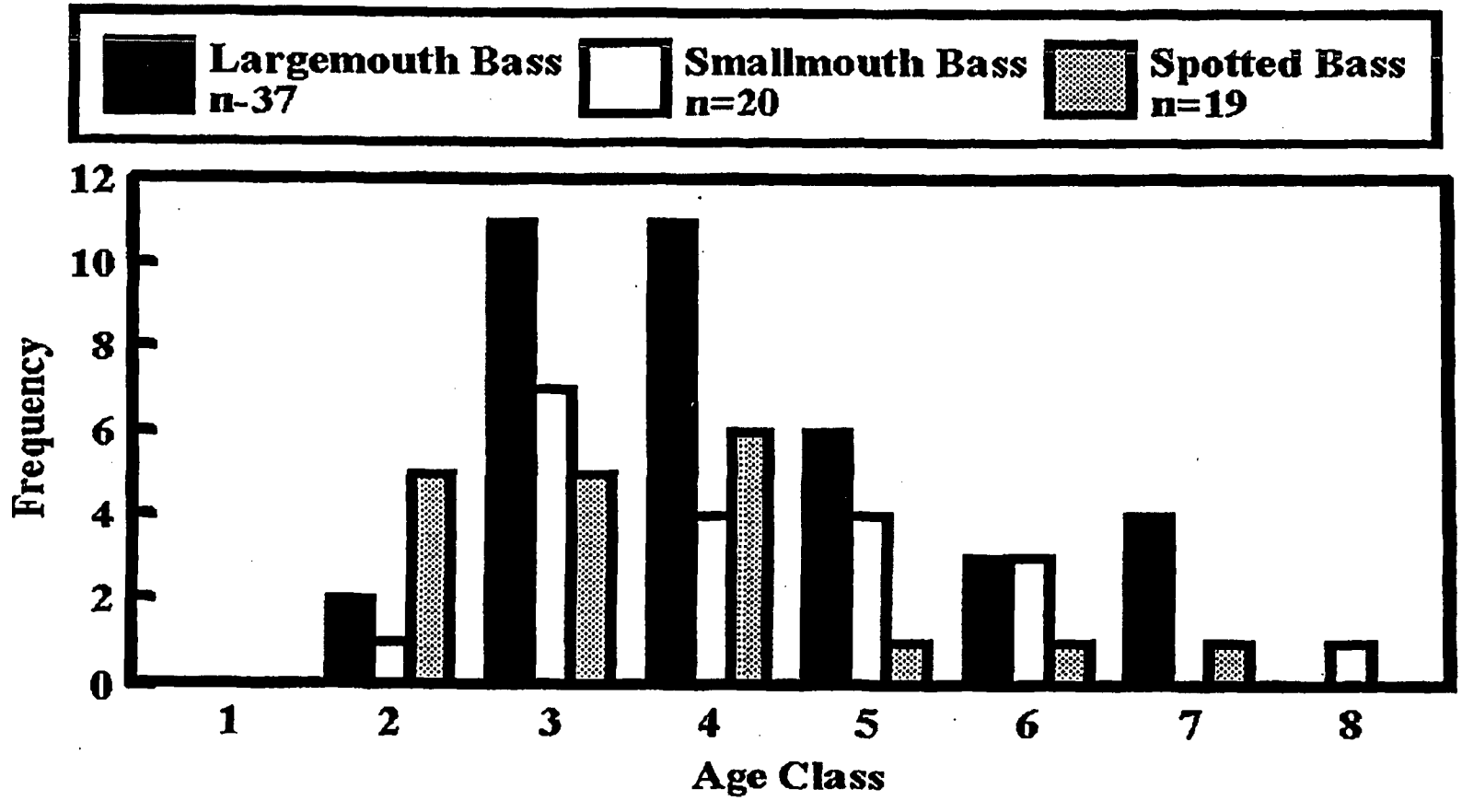


Figure 2-9. Age frequency of harvested largemouth bass, smallmouth bass, and spotted bass from the Watts Bar Tailwater. April 1996 though March 1997.

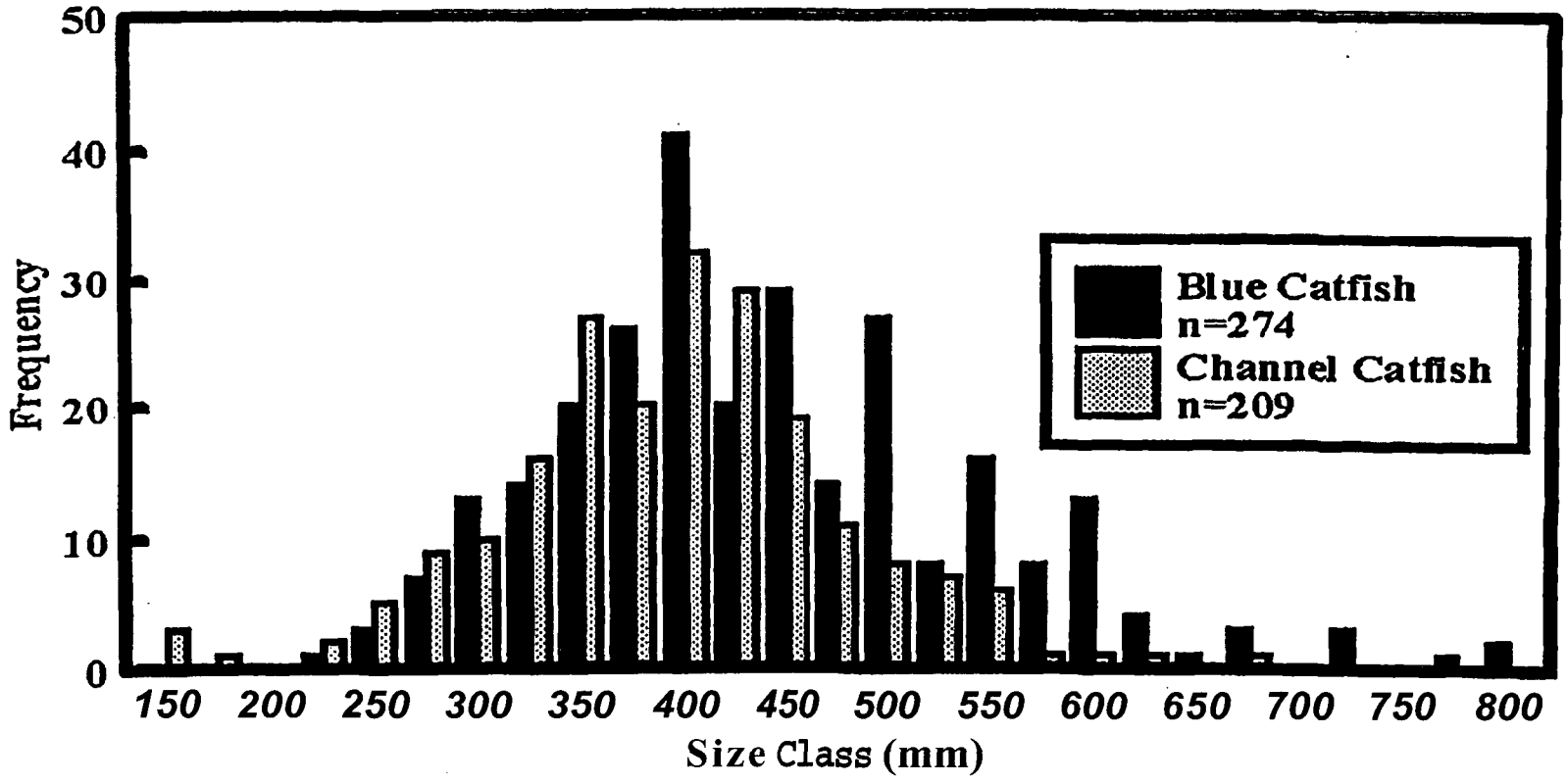


Figure 2-10. Length frequency of harvested blue catfish and channel chatfish from the Watts Bar Tailwater fishery. April 1996 through March 1997.

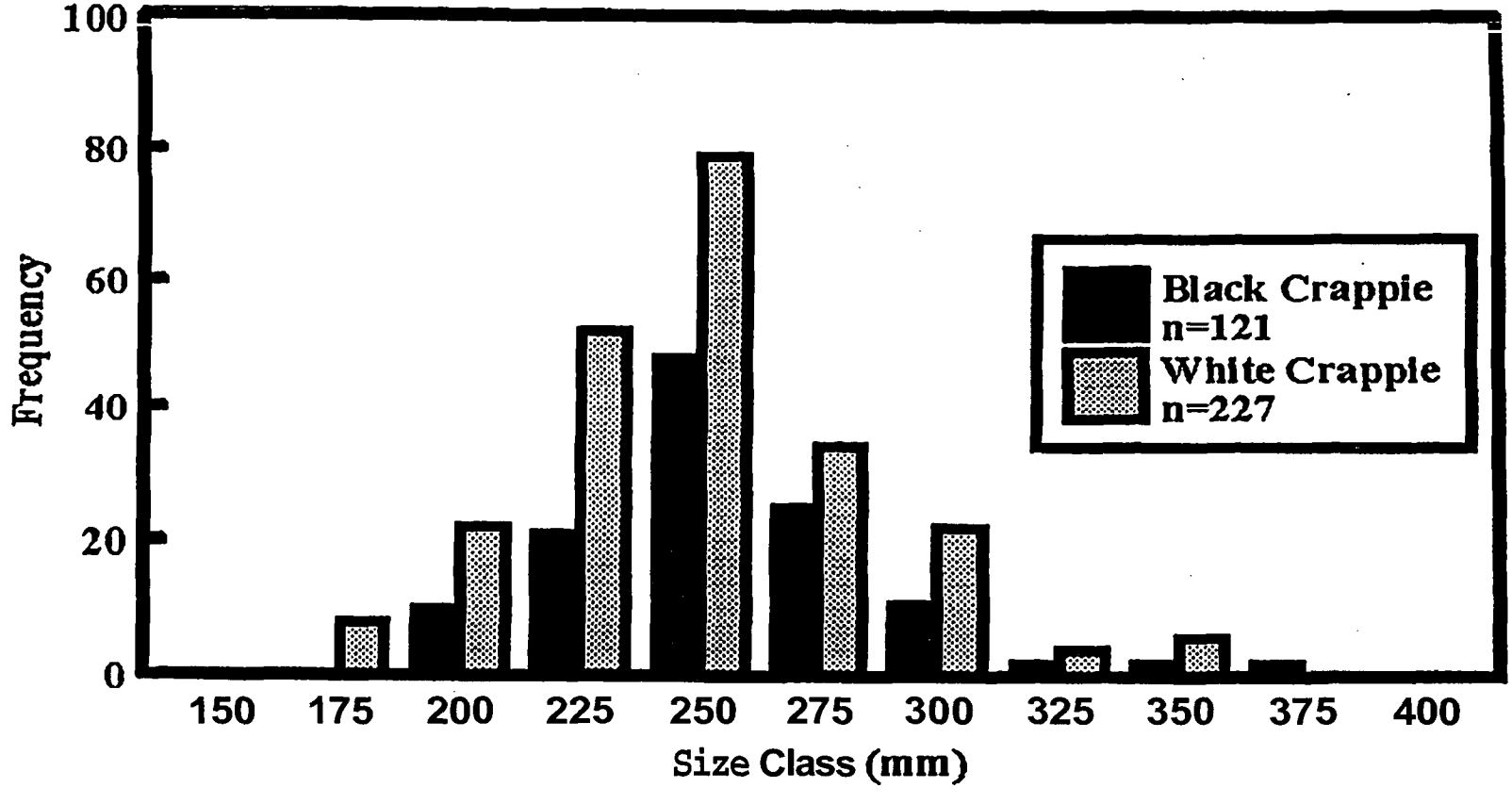


Figure 2-11. Length frequency of harvest of black and white crappie from Watts Bar tailwater. April 1996 through March 1997.

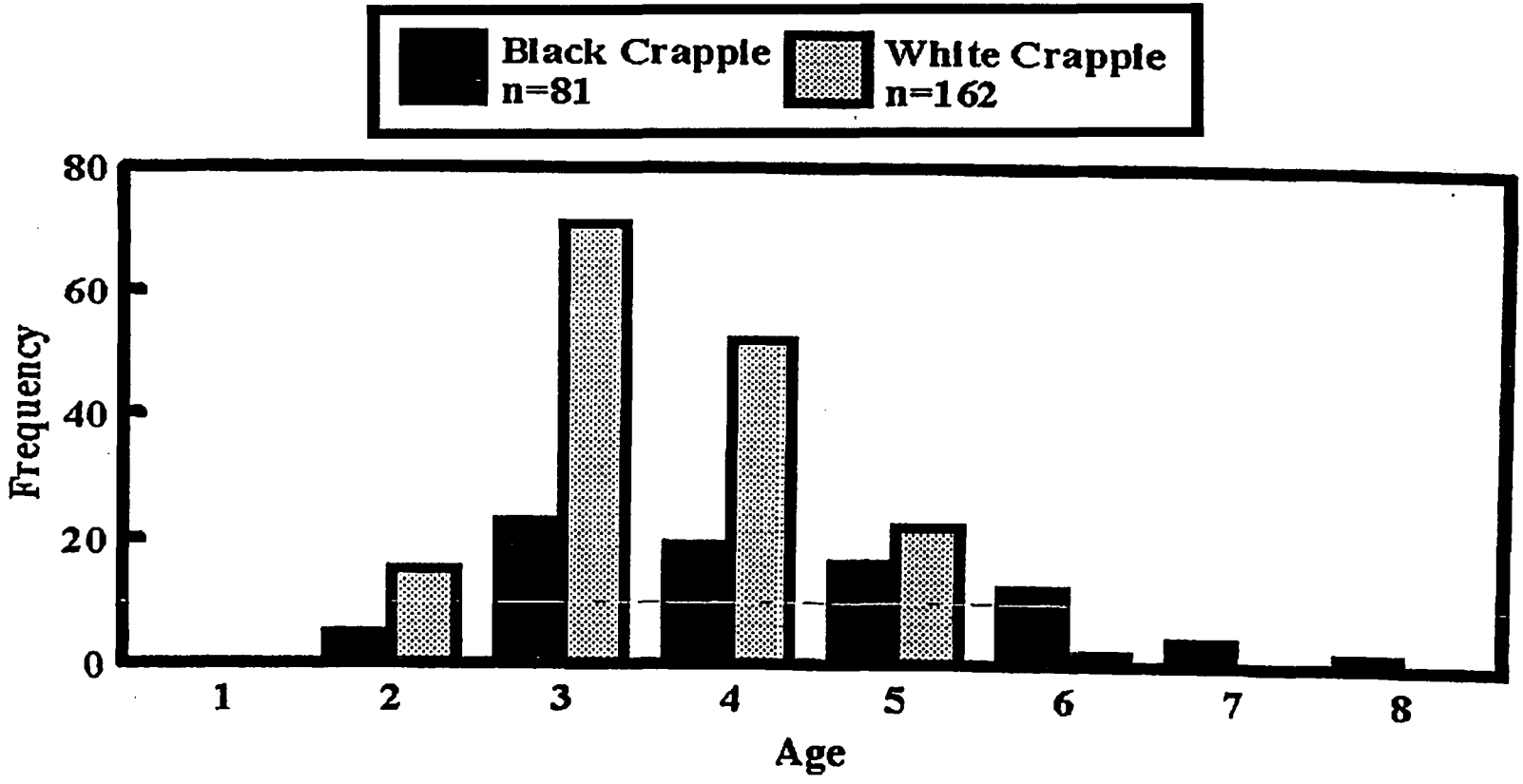


Figure 2-12. Age frequency of harvested black and white crappie from Watts Bar Tailwater. April 1996 through March 1997.

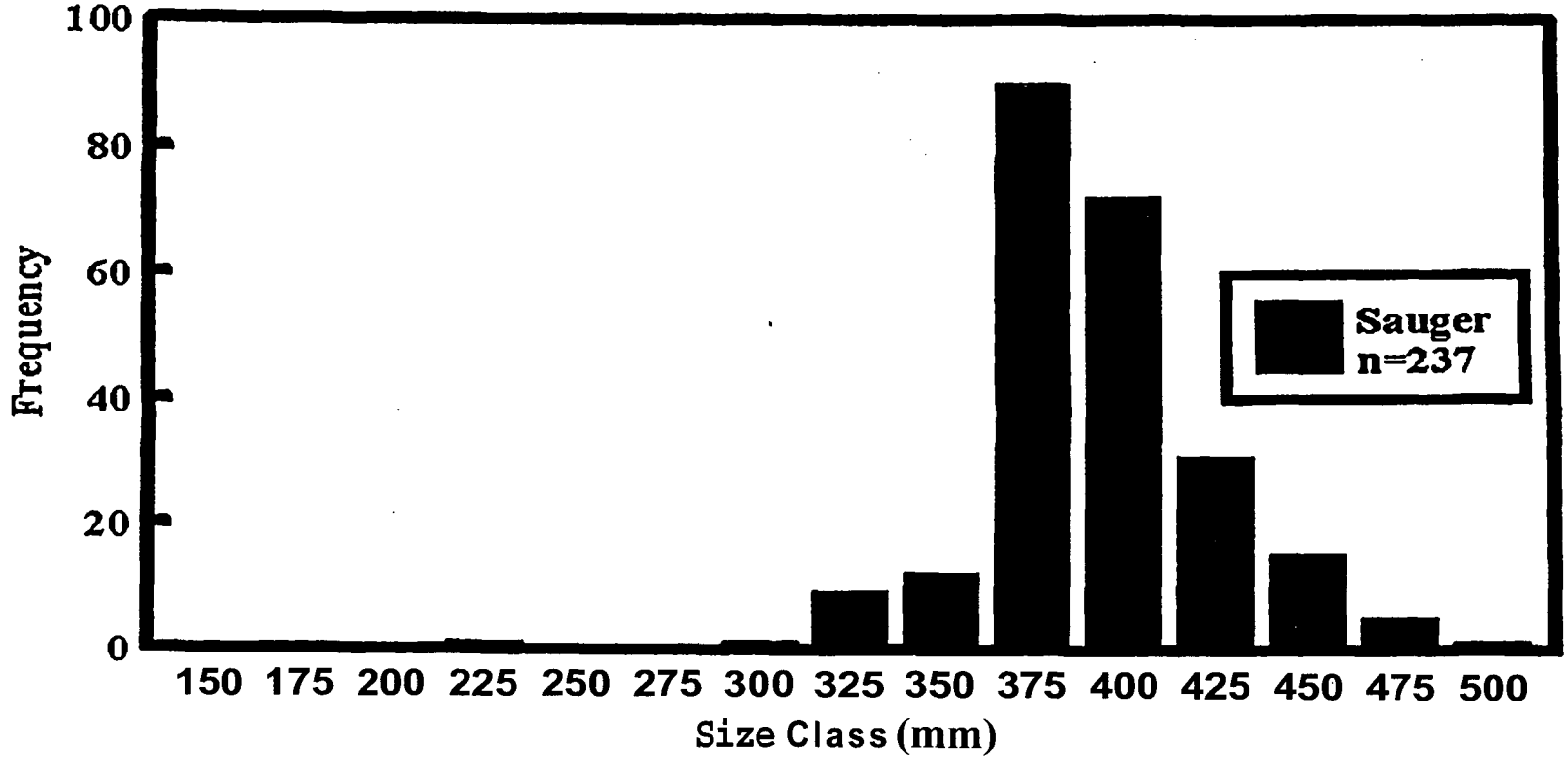


Figure 2-13. Length frequency of harvested sauger from the Watts Bar Tailwater fishery. April 1996 through March 1997.

Figure 2-14. Age frequency of harvested sauger from the Watts Bar Tailwater fishery. April 1996 through March 1997.

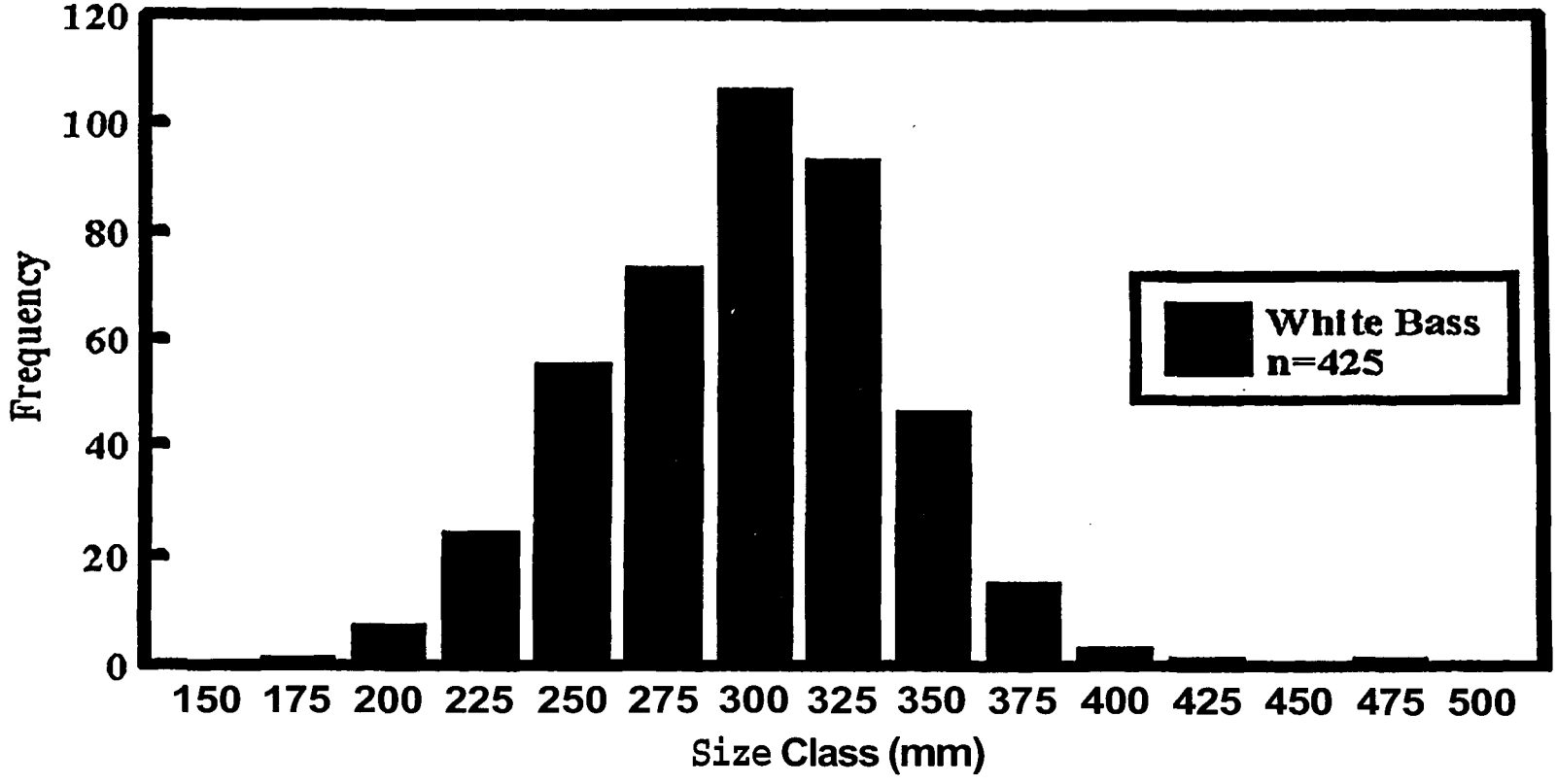


Figure 2-15. Length frequency of harvested white bass from the Watts Bar Tailwater. April 1996 through March 1997.

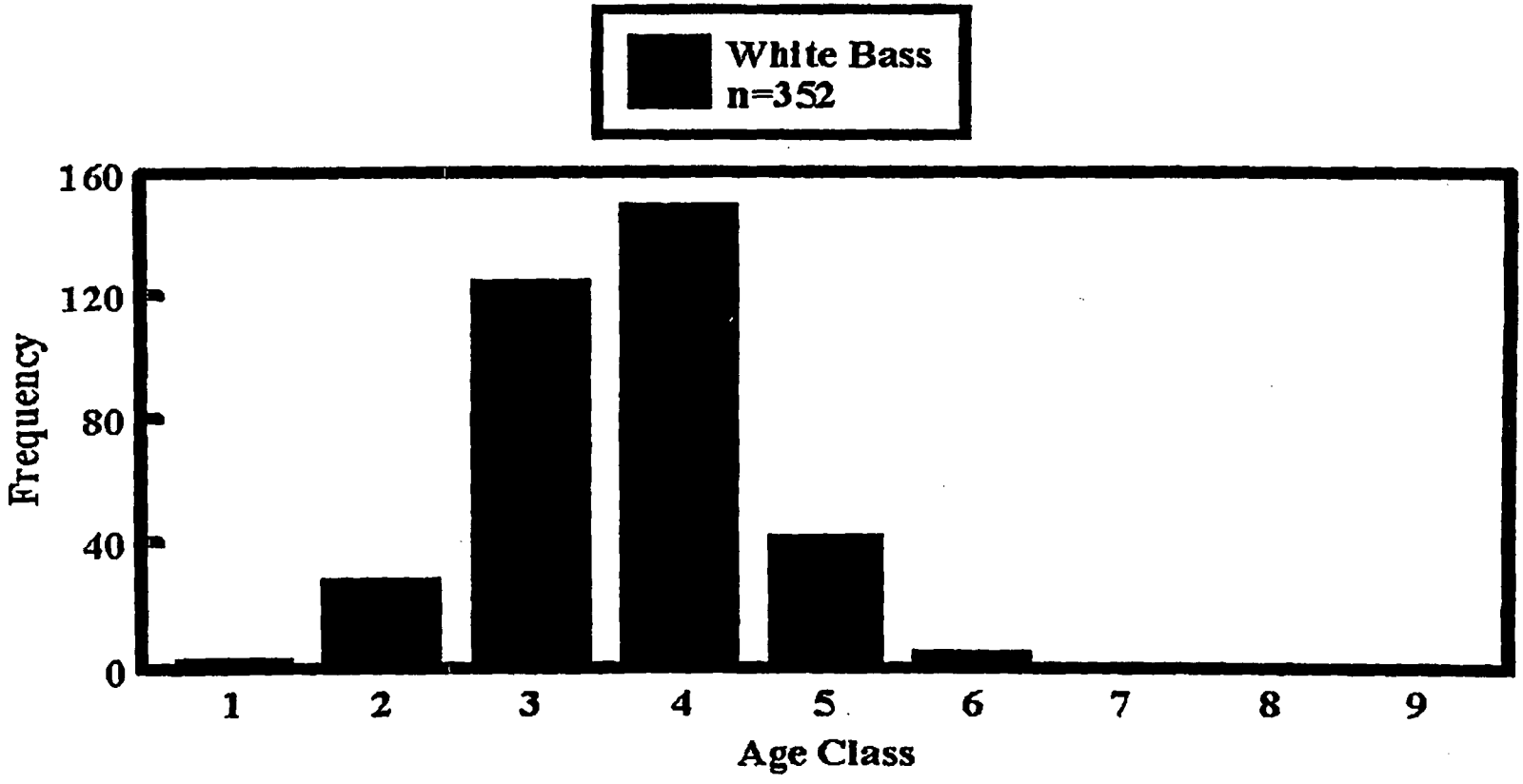


Figure 2-16. Age frequency of harvested white bass from the Watts Bar Tailwater. April 1996 through March 1997.

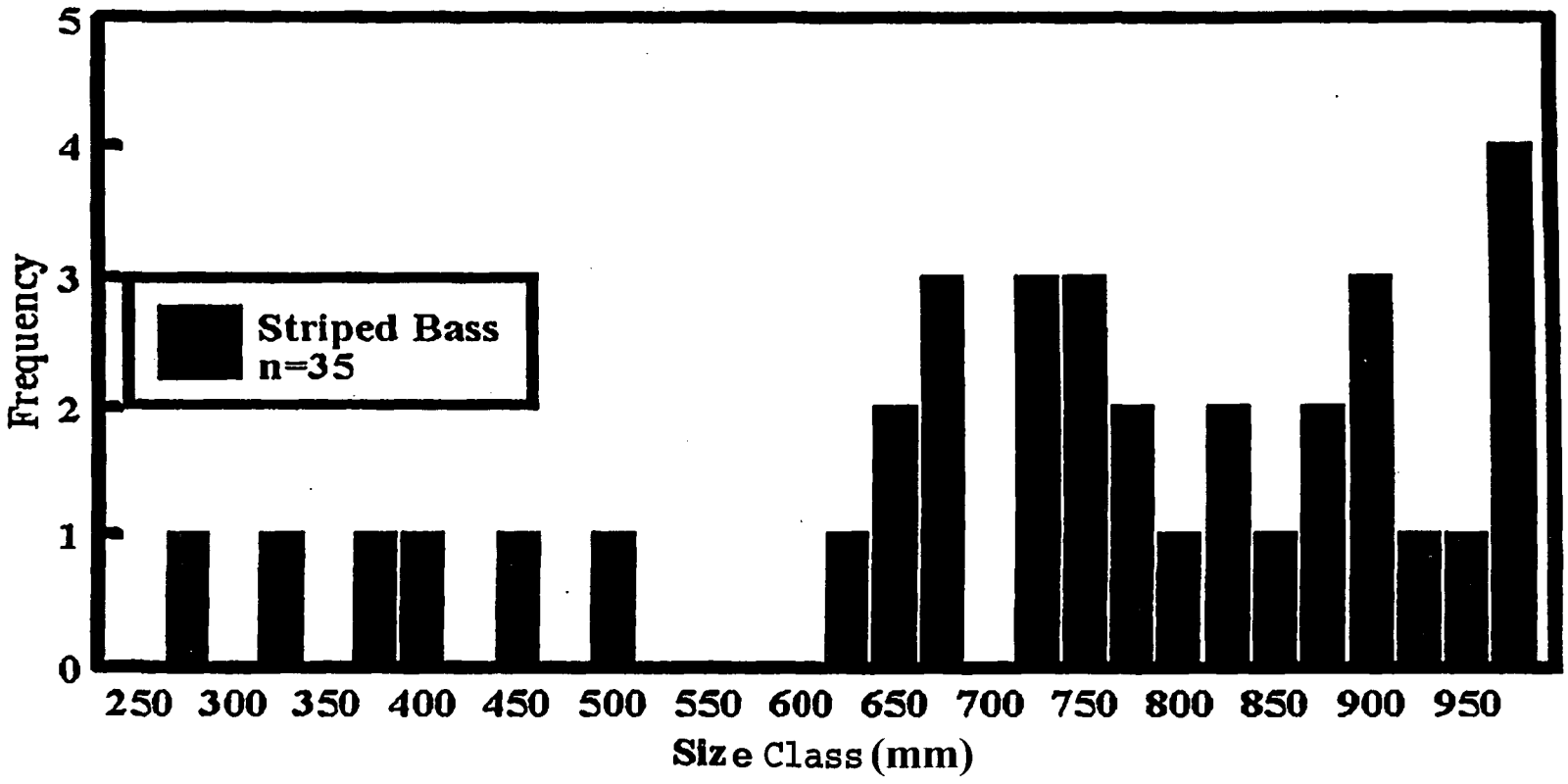


Figure 2-17. Length frequency of harvested striped bass from the Watts Bar Tailwater. April 1996 through March 1997.

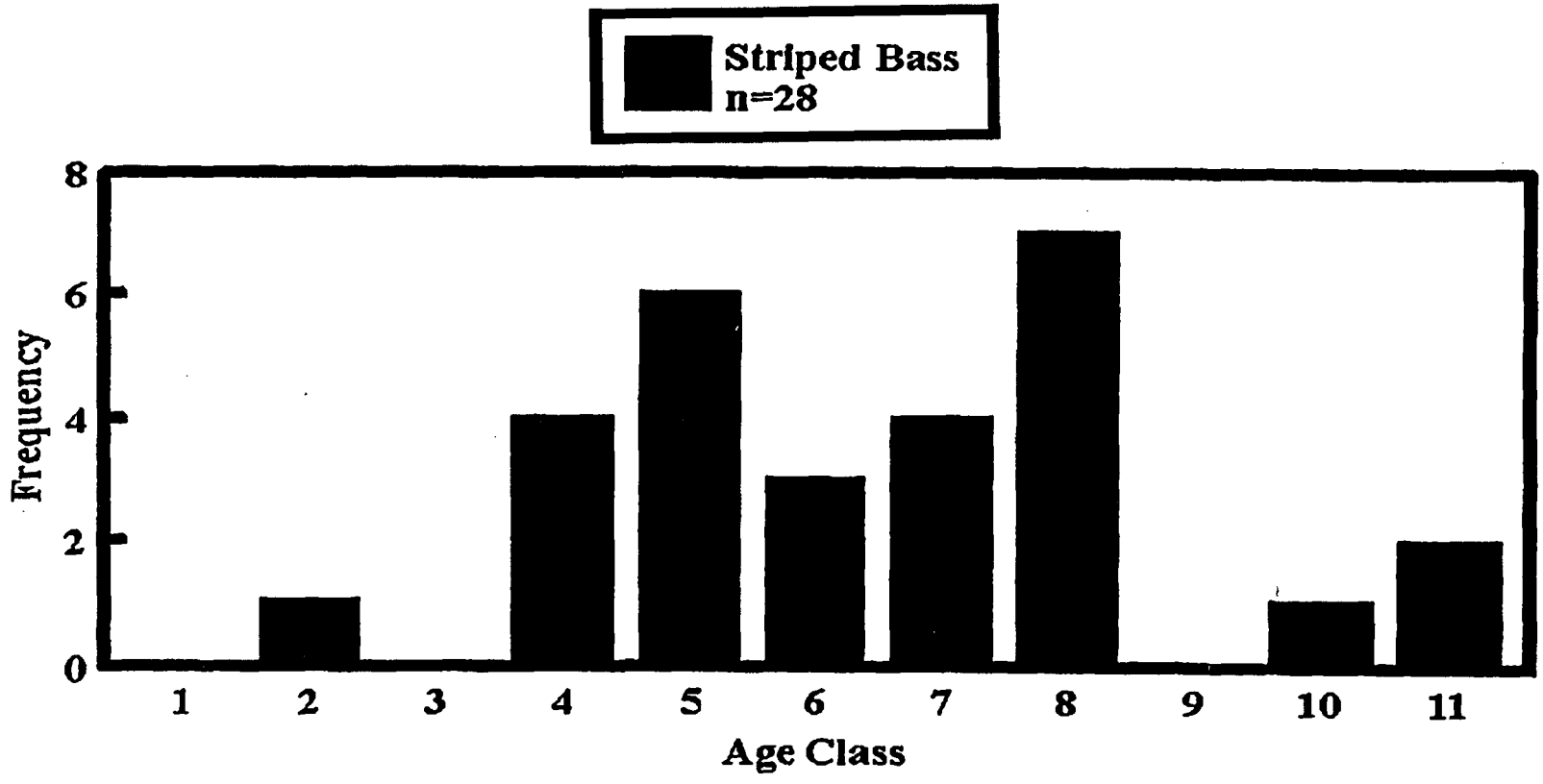


Figure 2-18. Age frequency of harvested striped bass from the Watts Bar Tailwater. April 1996 thorugh March 1997.

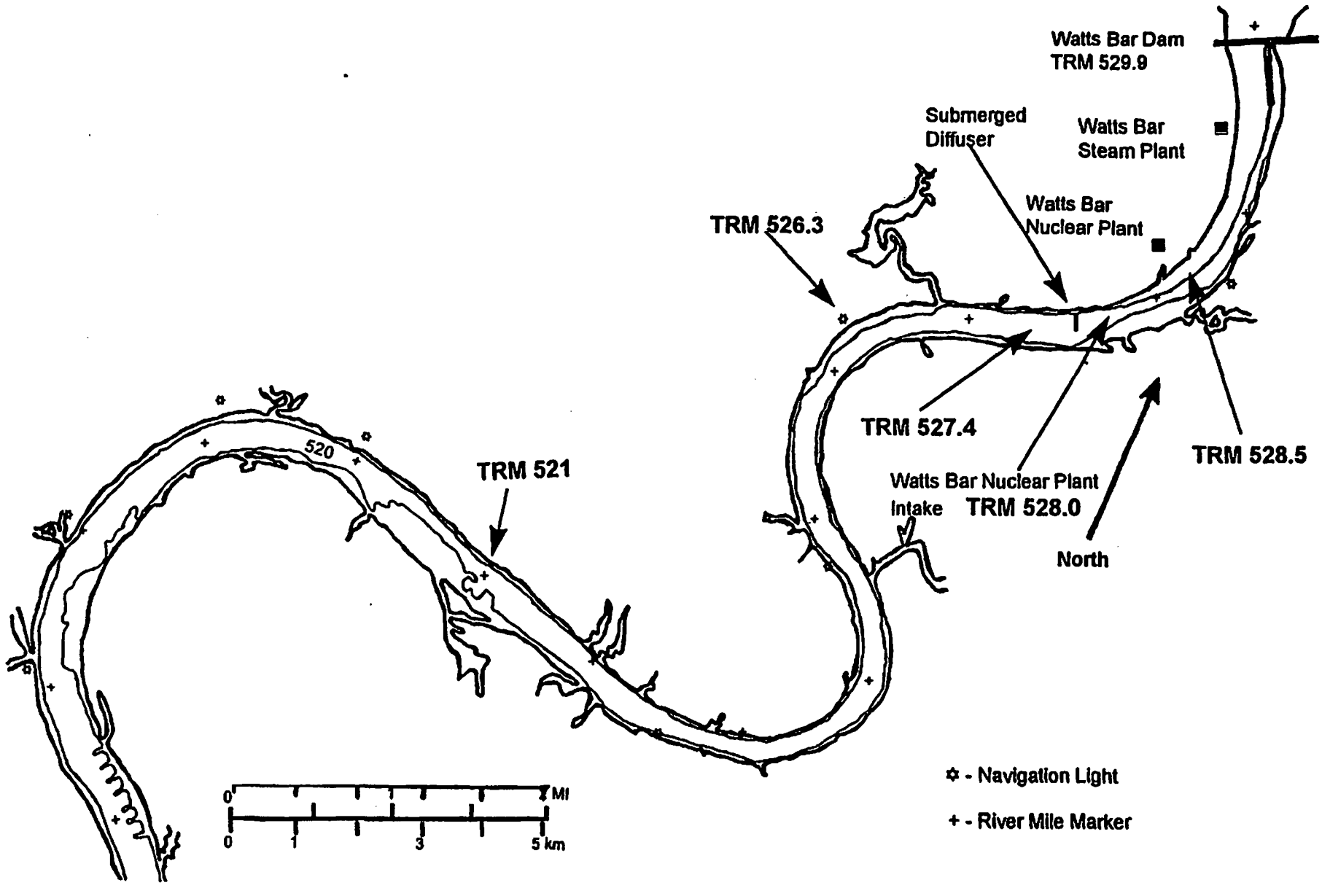


Figure 3-1. Sample location for benthic macroinvertebrates near Watts Bar Nuclear Plant , 1998.

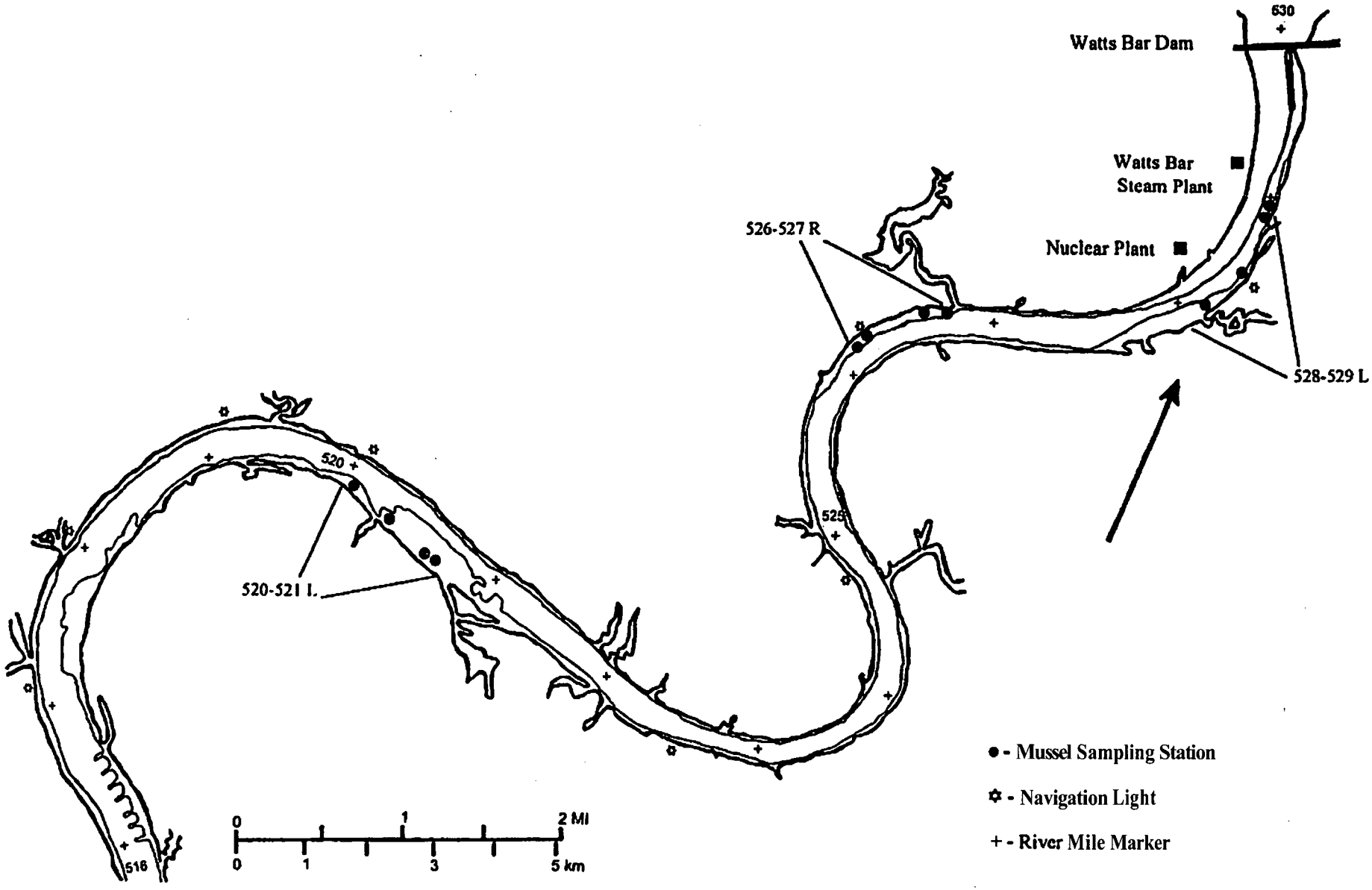


Figure 3-2. Locations of mussel sampling stations at three mussel beds surveyed during the preoperational and operational monitoring program for Watts Bar Nuclear Plant.

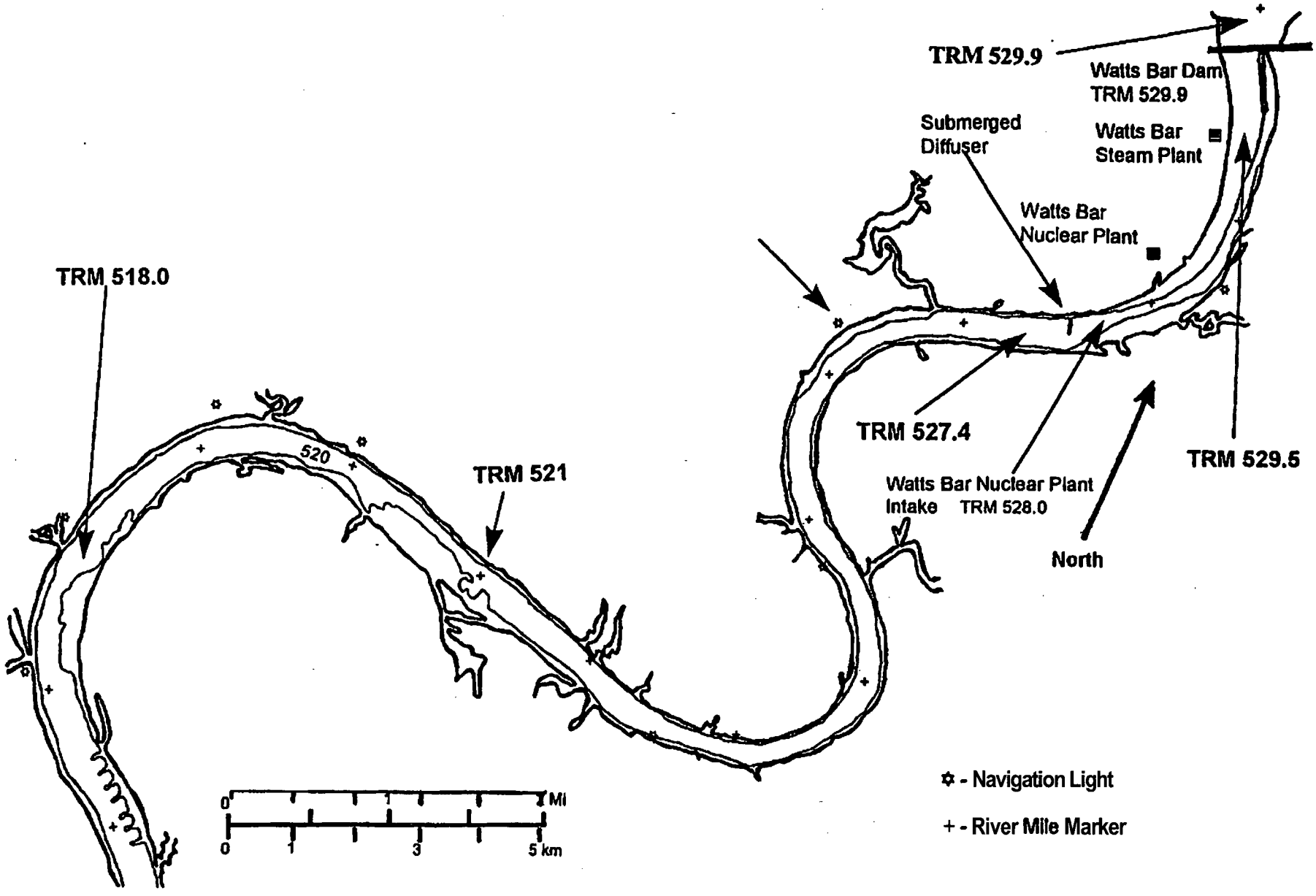


Figure 4-1. .Watts Bar Nuclear Operational monitoring Water Quality Sampling Locations , 1996.

Appendix A. List of scientific names and densities (number/m^2) of benthic macroinvertebrates collected at five locations in the vicinity of Watts Bar Nuclear Plant during operational monitoring in summer and fall 1996.

Date	July 1996					October 1996				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Nematoda		1								
Hydrozoa										
Hydroida										
Clavidae						6	7	9	7	2
Cordylophora lacustris										
Hydridae										
Hydra americana	4		1	4	3	252	71	2	82	297
Turbellaria										
Tricladida										
Planariidae										
Dugesia tigrina	632	208	1293	962	296	1131	1420	1103	1285	1449
Oligochaeta										
Haplotaxida										
Naididae			1					1	4	2
Dero sp.	41	56	62	37	3	31	6	6	8	34
Nais communis		1	5	1						1
Nais simplex										1
Pristina sp.				2				1	6	4
Salvina appendiculata					1				5	
Tubificidae	243	249	149	70	8	169	21	68	48	383
Branchiura sowerbyi	13	10	6			8	3	3		21
Limnodrilus hoffmeisteri	265	113	106	11		27		8	2	54
Lumbriculida										
Lumbriculidae		1								
Lumbriculus sp.									3	

Appendix A. (Continued)

Date	July 1996					October 1996				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Hirudinea	1	6	11	18	4	3		1		
Rhynchobdellida										
Glossiphoniidae										
Helobdella triserialis	14		1	2	2		7	5	2	9
Pharyngobdellida										
Erpobdellidae										
Erpobdella punctata	17		7	1		11	1	21	15	13
Crustacea										
Isopoda										
Asellidae										
Caecidotea sp.		1		31	102			3	40	28
Amphipoda										
Gammaridae										
Gammarus minus	786	307	1066	850	552	279	38	139	141	416
Decapoda										
Cambaridae										
Orconectes sp.	1			2	4			3	1	1
Insecta										
Plecoptera										
Perlidae		1								
Odonata										
Coenagrionidae										
Argia sp.								1	2	
Ephemeroptera										
Baetidae			1							
Baetis amplus						1				

Appendix A. (Continued)

Date	July 1996					October 1996				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Heptageniidae				1	1	2			1	1
Stenacron sp.		2							1	
Stenacron interpunctatum	3		1		1	2		7	19	28
Stenonema sp.					1					
Heteropterr										
Corixidae	1									
Trichoptera										
Hydropsychidae										
Cheumatopsyche sp.					2					
Hydroptilidae										
Leptoceridae										
Ceraclea sp.				1		1				
Oecetis sp.	1		1							
Polycentropodidae										
Cyrnellus fraternus	32	215	63	119	63	6	42	279	780	478
Megaloptera										
Corydalidae										
Nigronia sp.			1							
Sialidae										
Sialis sp.		2								
Diptera										
Chironomidae	1	6		1	1	5	5	9	14	13
Ablabesmyia mallochi		4				2			1	
Ablabesmyia parajanta										1
Chironomus sp.			1			1				
Cladotanytarsus sp.		1	1							
Coelotanypus tricolor		1								

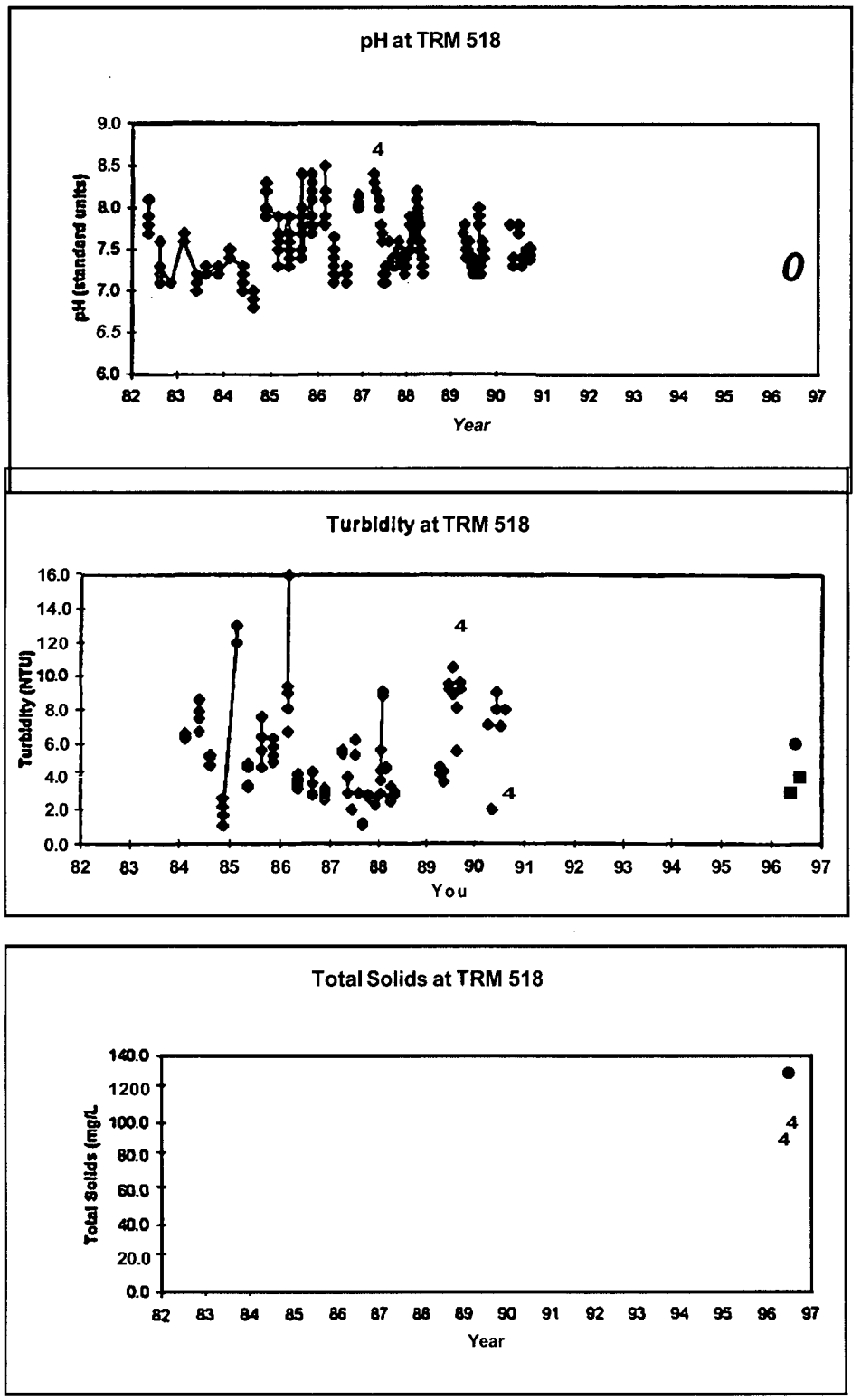
Appendix A. (Continued)

Date	July 1996					October 1996				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Cryptochironomus fulvus	1	1	2			11	1			3
Dicrotendipes sp.	35	56	67	60	13	23	61	95	77	104
Glyptotendipes sp.	8	122	23	2		1	3	3	5	4
Harnischia sp.	3									
Microtendipes sp.	2	2								
Nanocladius sp.	9	2	5	6	2	109	75	70	129	270
Parachironomus sp.	1			2	1	7	16	9	12	31
Phaenopsectra obediens										2
Polypedilum convictum			1							
Polypedilum halterale	1		3	1						
Pseudochironomus sp.	3									
Rheotanytarsus sp.	2					1	1			
Stenochirohomus sp.										1
Stictochironomus sp.			1							
Synorthocladius semivire										1
Tanytarsus sp.	3	1	1			1	1			
Thienemanniella xena							1			1
Tvetenia discoloripes sp.	1									
Gnstropoda										
Mesogastropoda										
Hydrobiidae								1		
Amnicola sp.									1	1
Somatogyrus sp.									1	93
Pleuroceridae										
Leptoxis praerosa						1				
Pleurocera sp.					9					

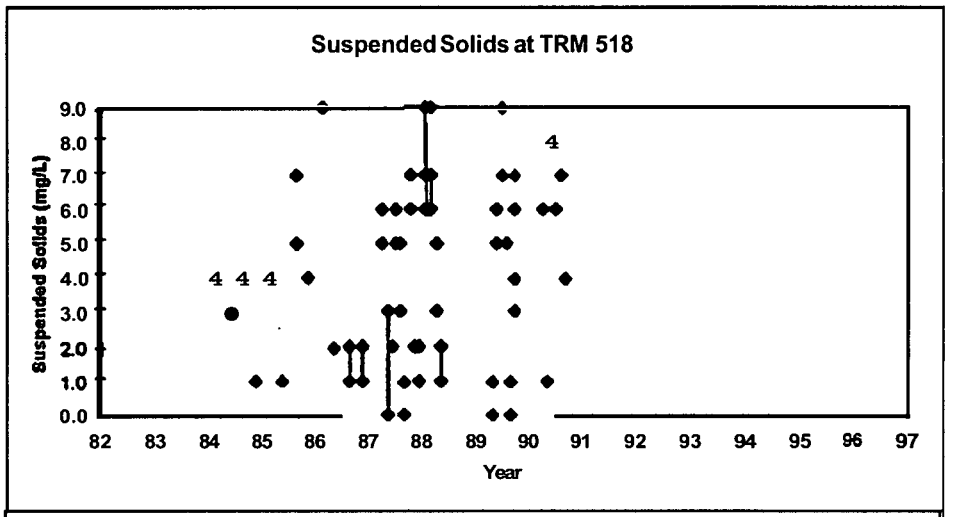
Appendix A. (Continued)

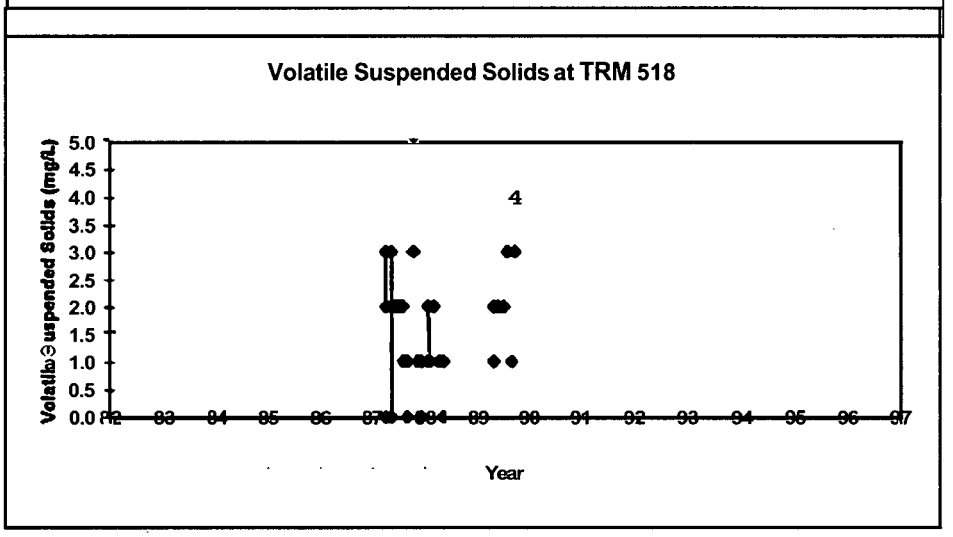
Date	July 1996					October 1996				
Tennessee River Mile	521.0	526.3	527.4	528.0	528.5	521.0	526.3	527.4	528.0	528.5
Pleurocera canaliculata	115	22	37	12	8	91	49	3	3	1
Basommatophora										
Ancylidae										
Ferrissia rivularis				3		1		1	3	7
Physidae										
Physella sp.	1	1	36	13	16		4	3	5	8
Planorbidae		1			3		3	1	2	
Gyraulus parvus			1		2					
Menetus sp.								1		
Bivalvia										
Unionoida										
Unionidae										
Actinonaias ligamentina							1			
Anodonta imbecillis			1			2				
Elliptio crassidens	4	4		1			1			
Obliquaria reflexa			1							
Quadrula pustulosa pustu			2							
Veneroida										
Corbiculidae										
Corbicula fluminea	713	726	716	767	633	409	353	643	1091	755
Dreissenidae										
Dreissena polymorpha	2	11	28	21	38	8	15	46	60	36
Sphaeriidae					4					
Musculium transversum	4	22	3		2	1	16	7	64	3
Number of samples	10	10	10	10	10	10	10	10	10	10
Sum (Total number)	2963	2156	3705	3001	1775	2603	2222	2552	3920	4558
Number of species	34	32	36	28	28	32	27	32	35	39

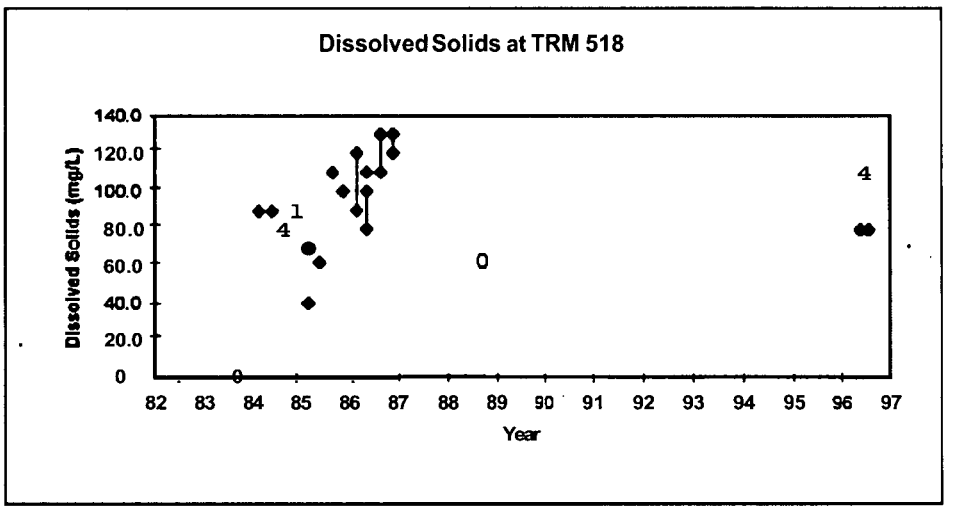
Appendix B-1. Selected water quality values measured during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 518.



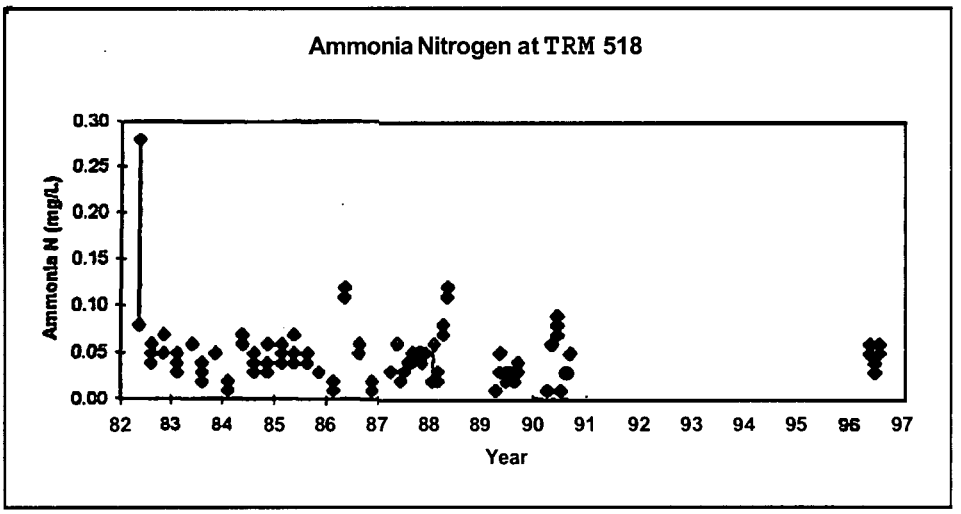
Appendix **B-1.** (Continued)

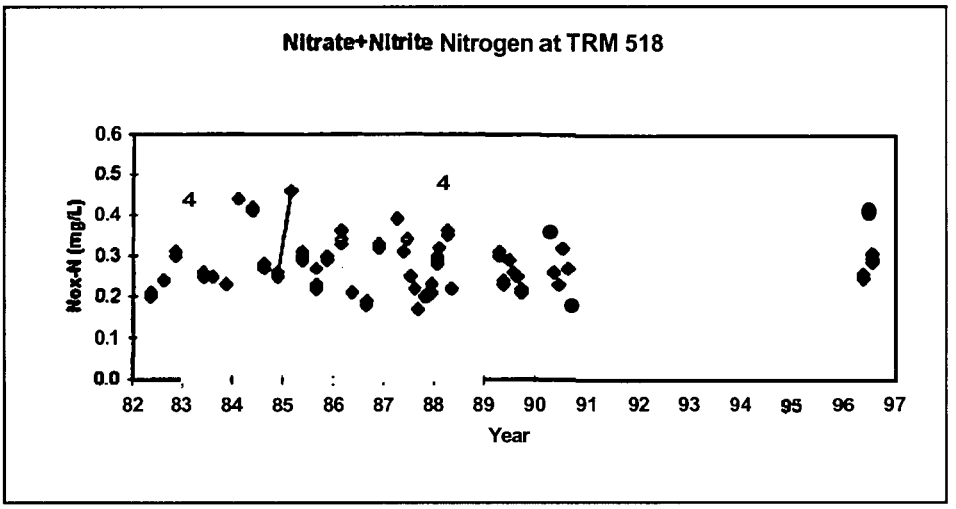


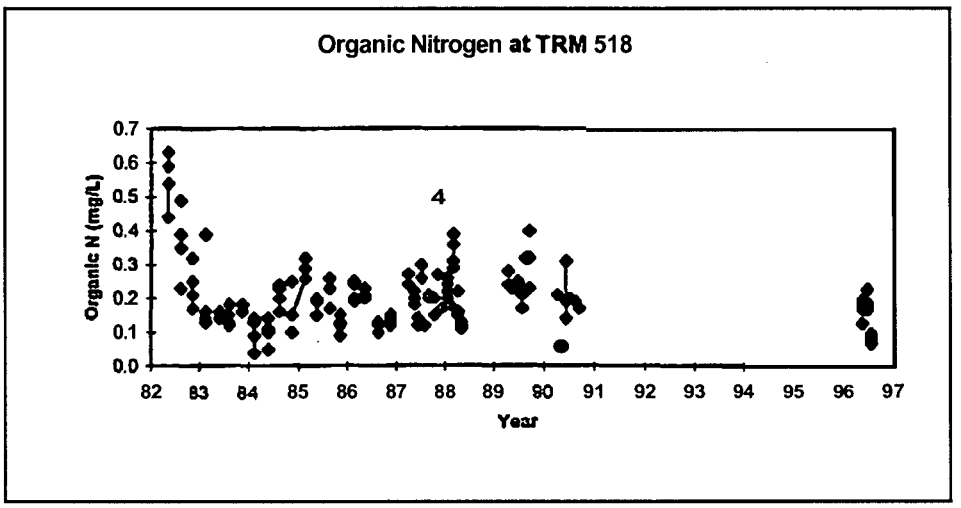




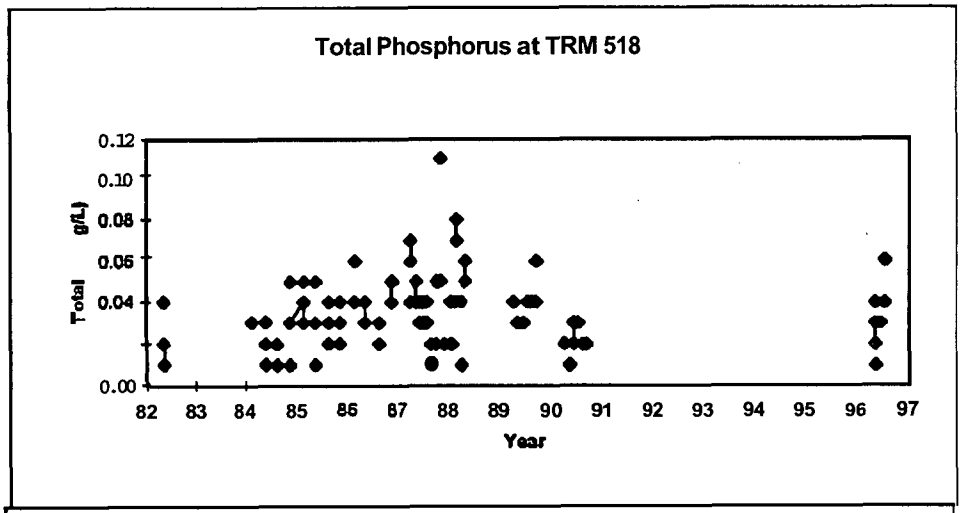
Appendix B-1. (Continued)

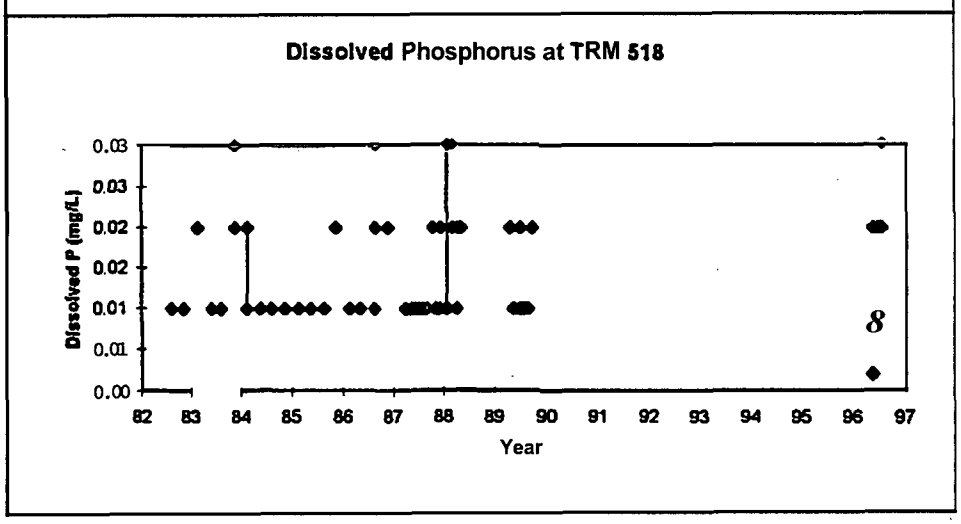


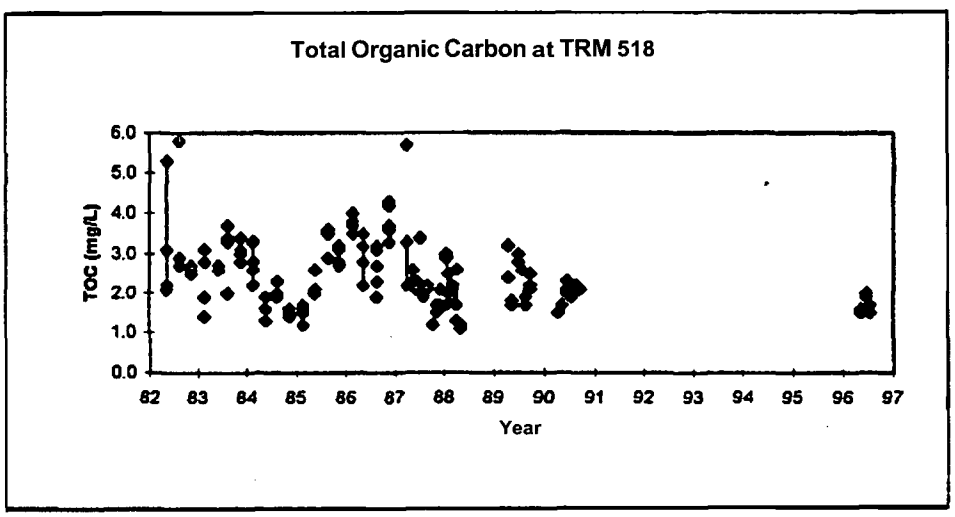


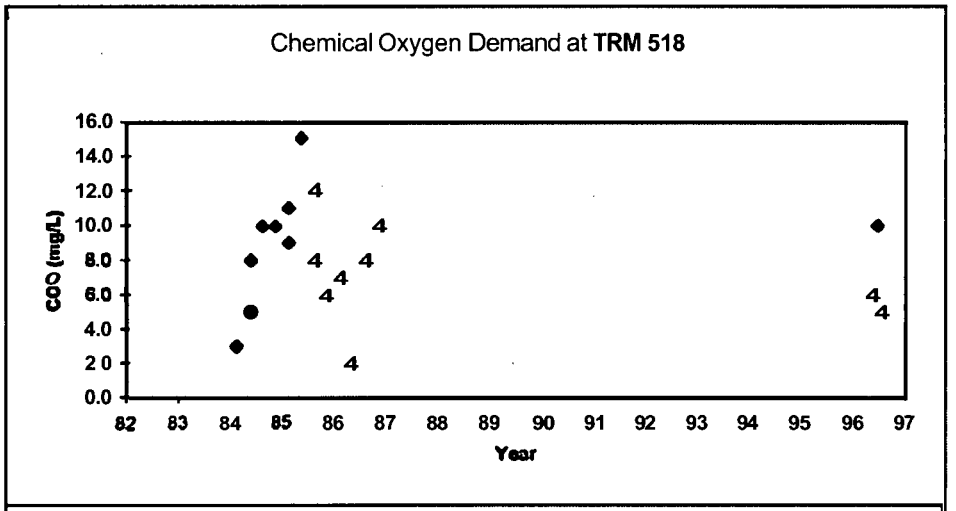


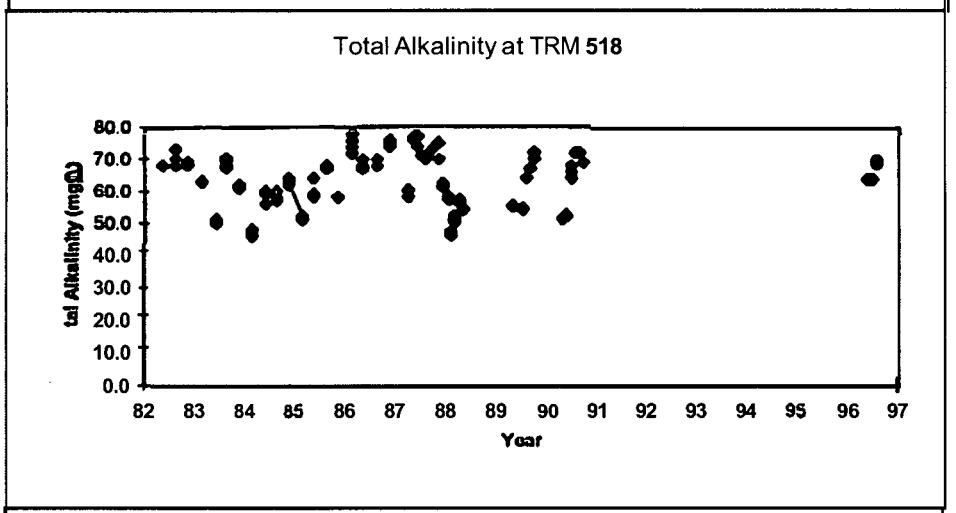
Appendix B-1. (Continued)

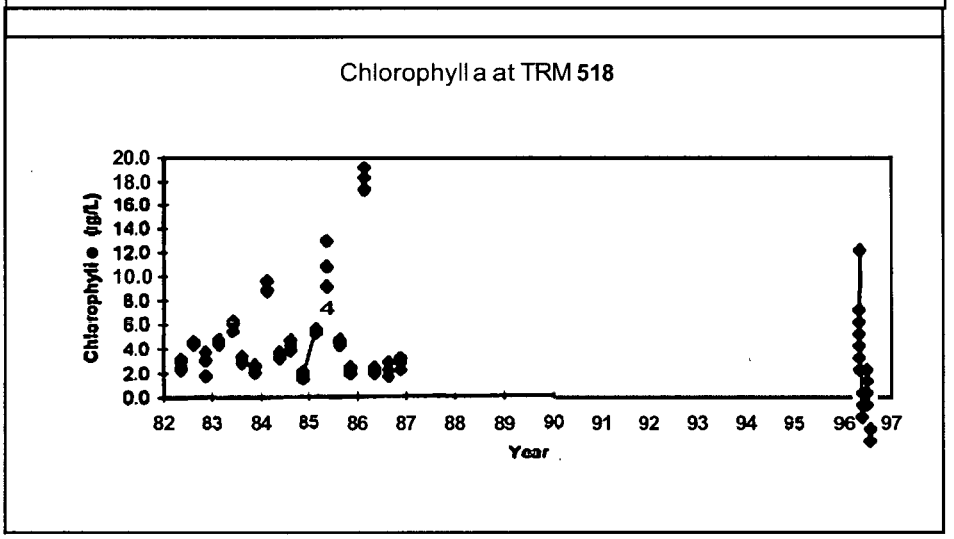




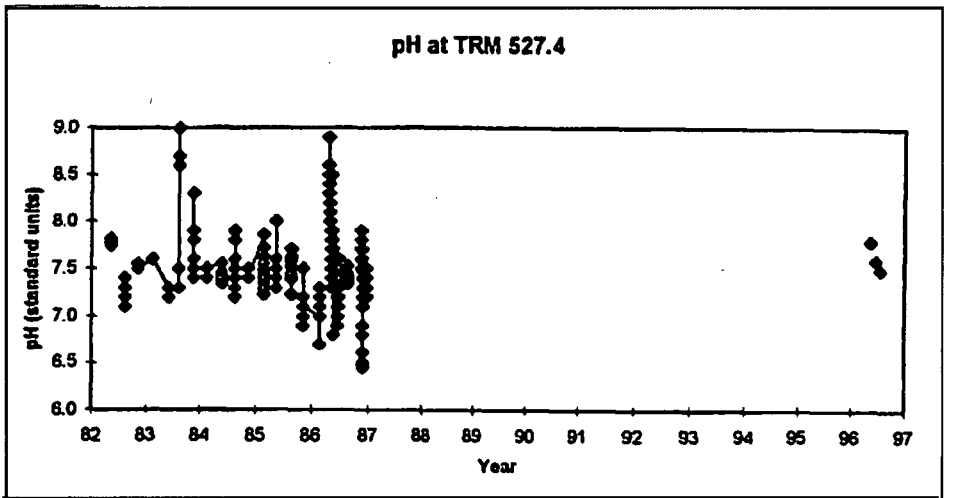


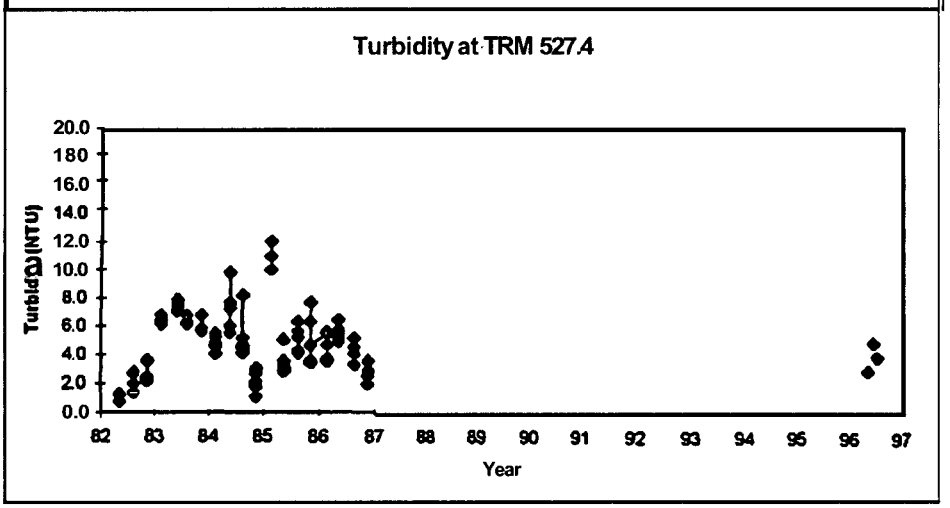

Chemical Oxygen Demand at TRM 518
COD (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

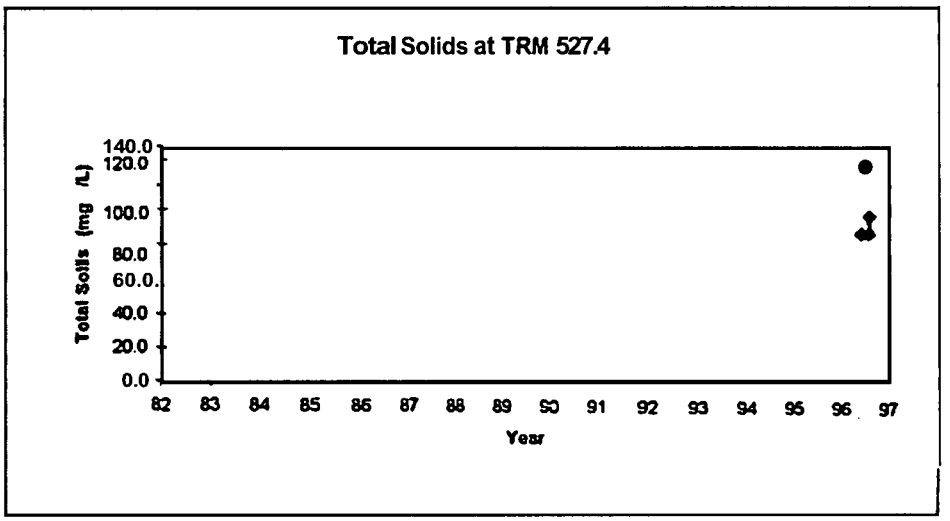

Total Alkalinity at TRM 518
tal Alkalinity (mg/L)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year


Chlorophyll a at TRM 518
Chlorophyll a (µg/L)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

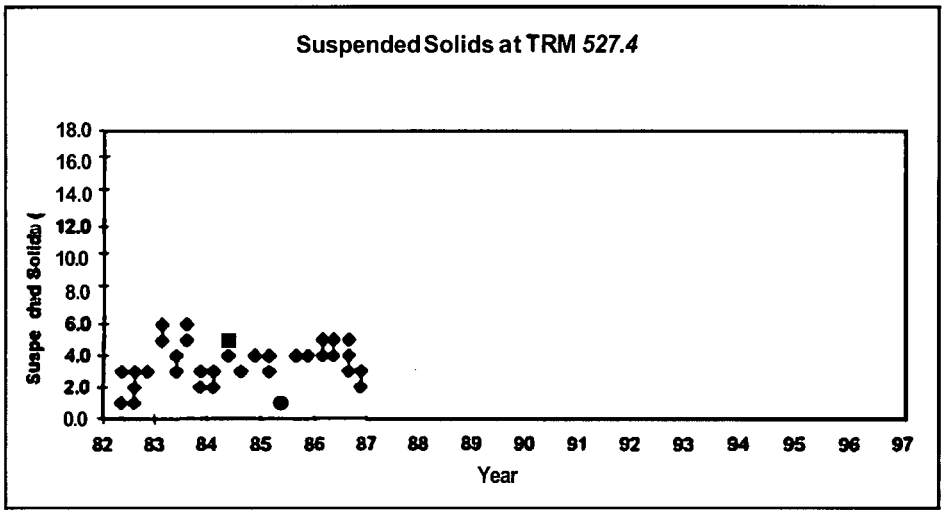
Appendix B-2. Selected water quality values measured during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 527.4.

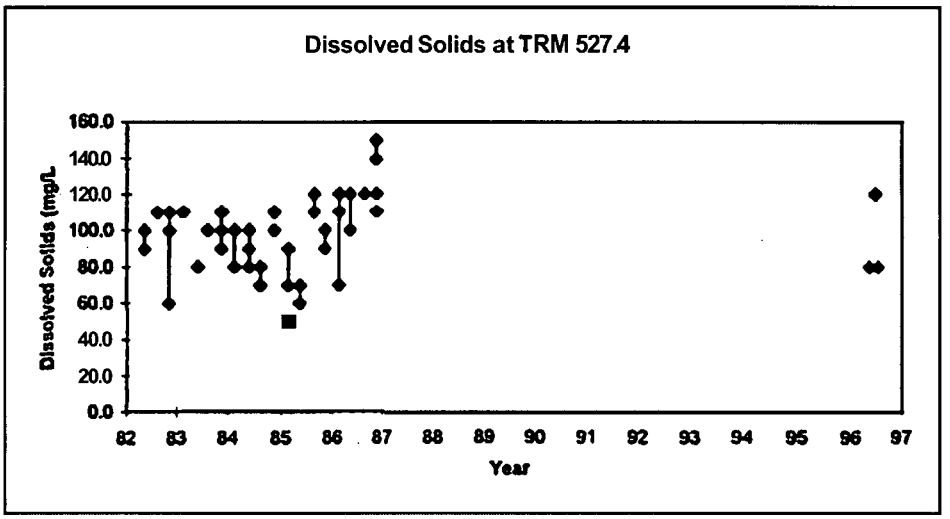




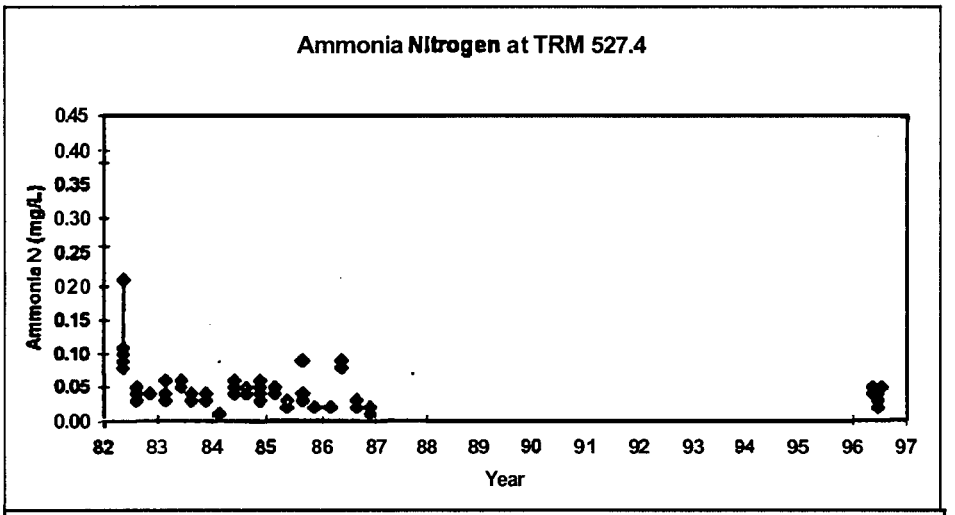


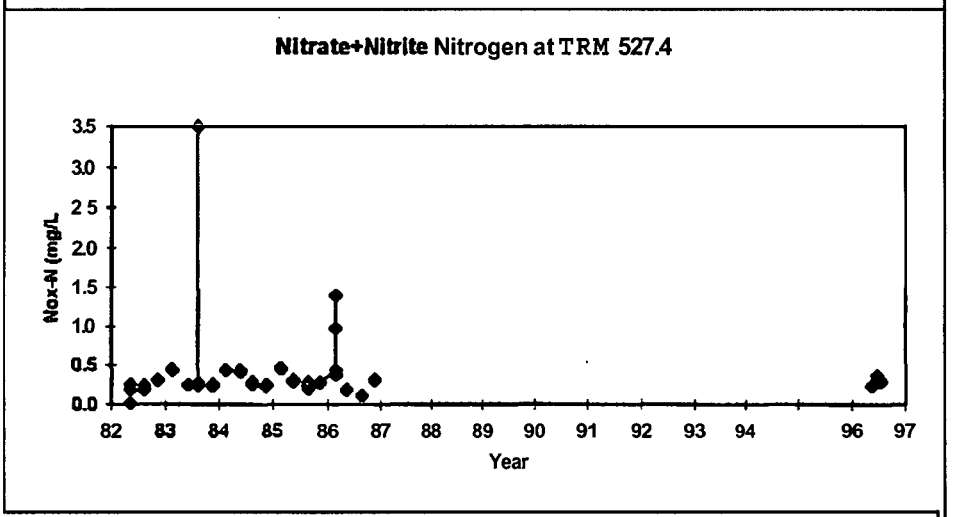
Appendix B-2. (Continued)

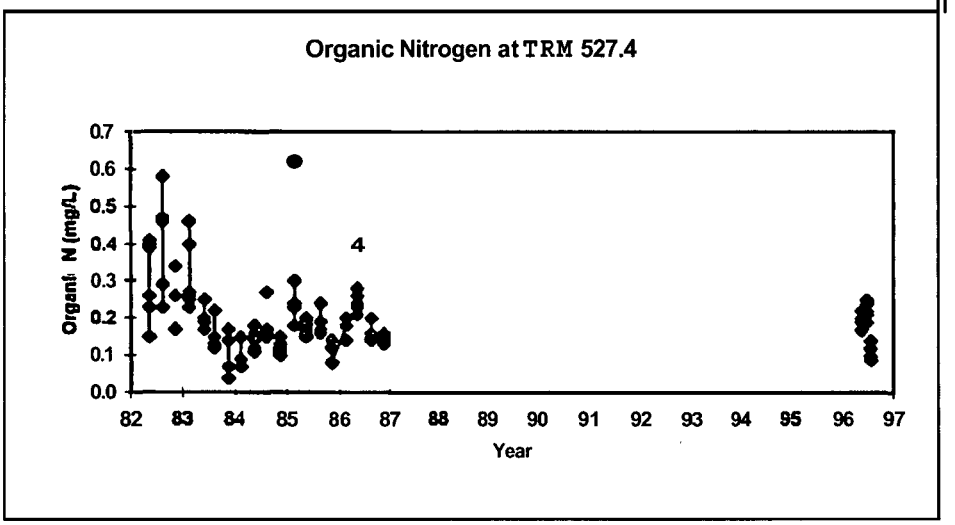




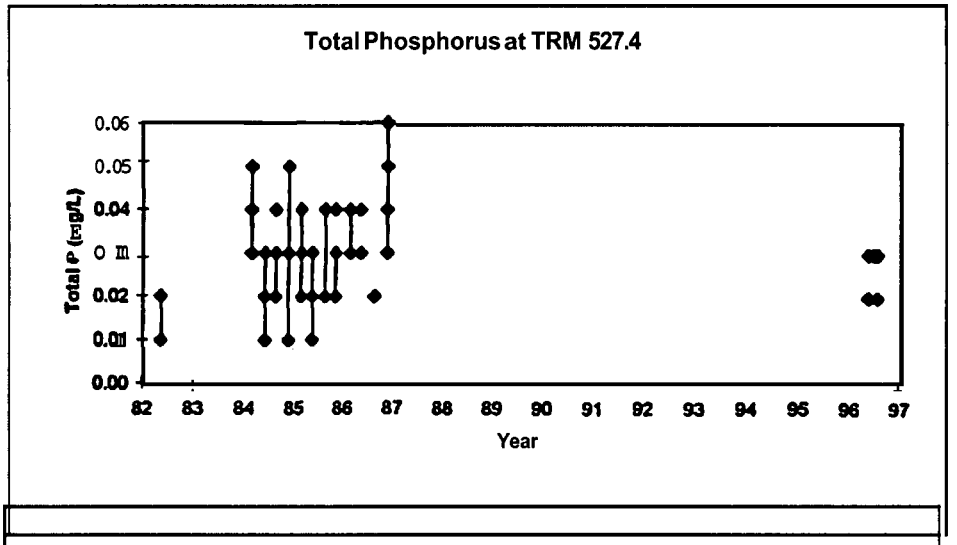
Appendix B-2. (Continued)

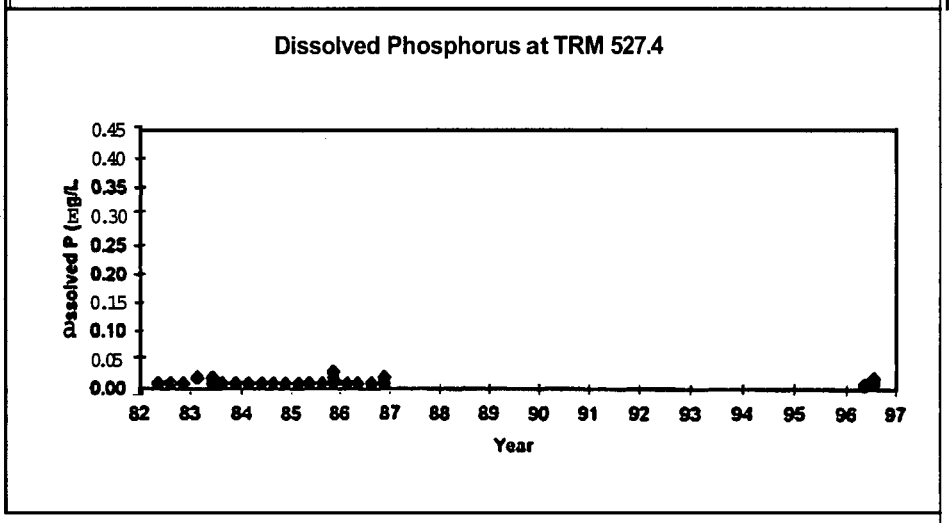


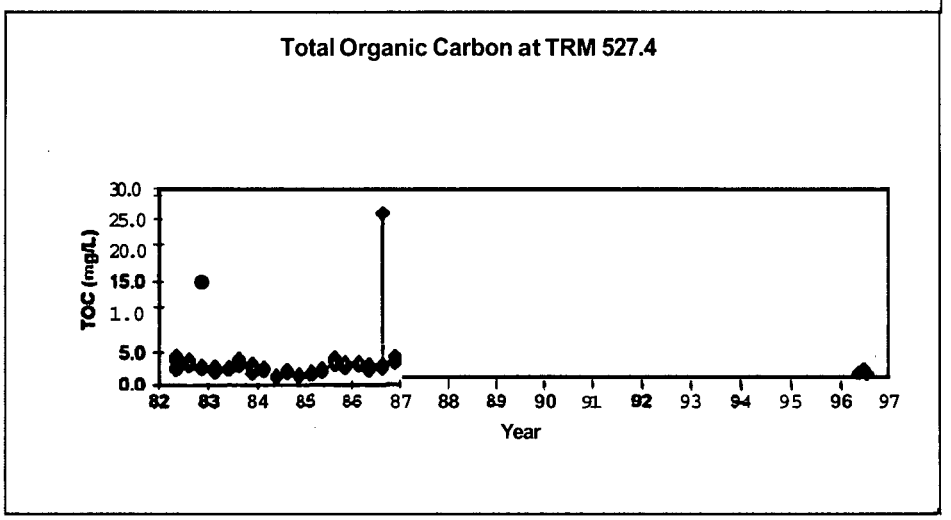




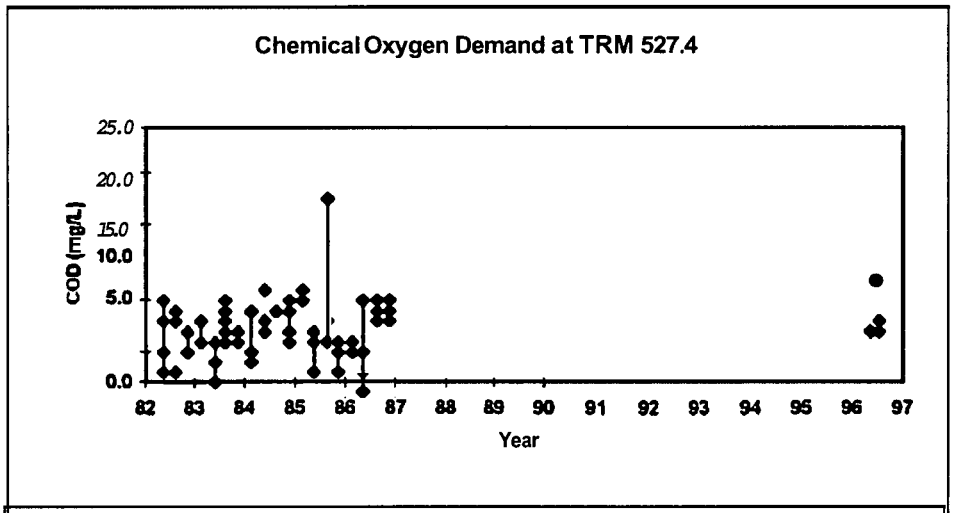
Appendix B-2. (Continued)

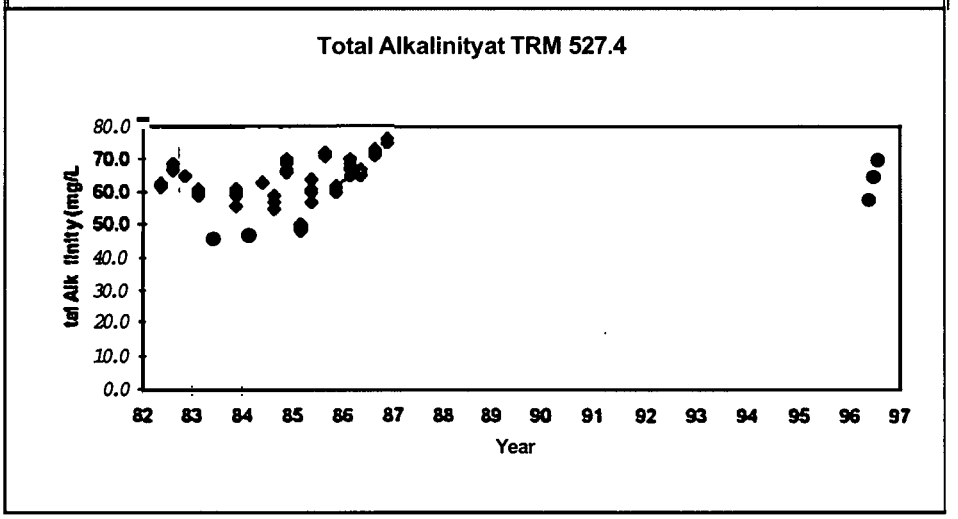


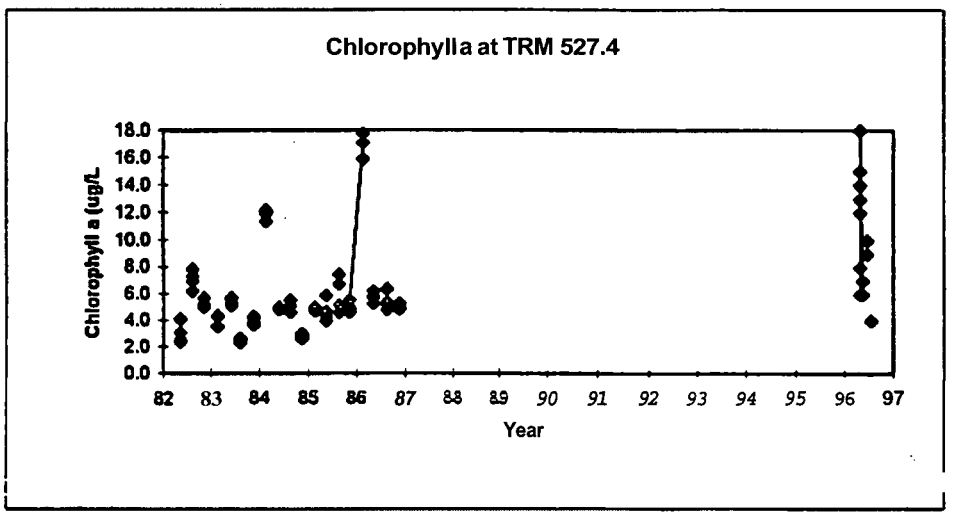




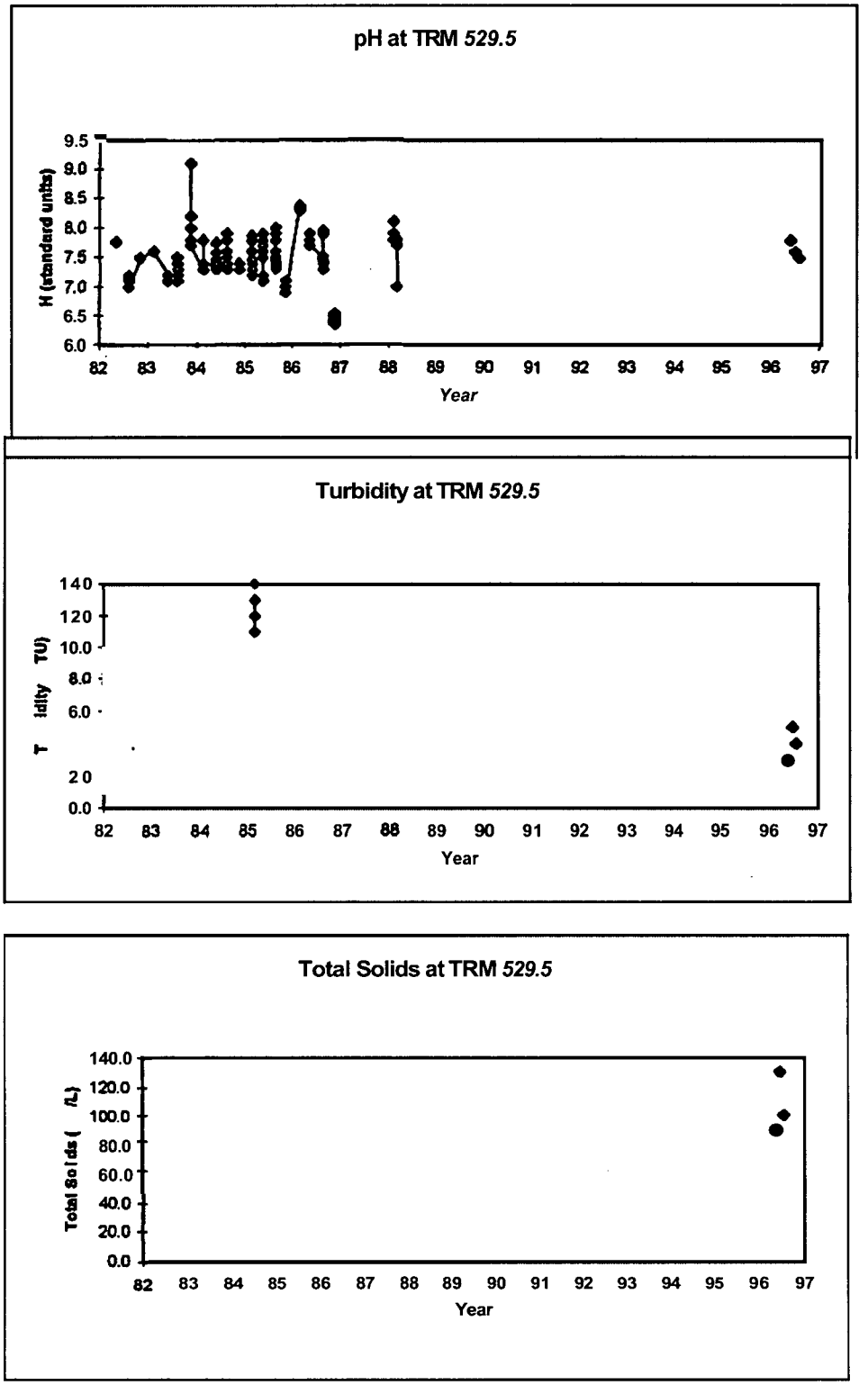
Appendix B-2. (Continued)



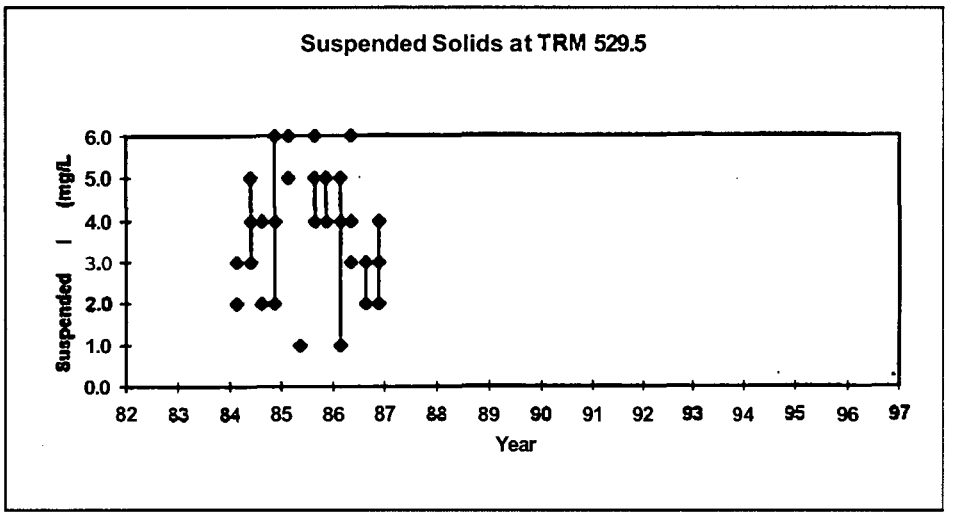


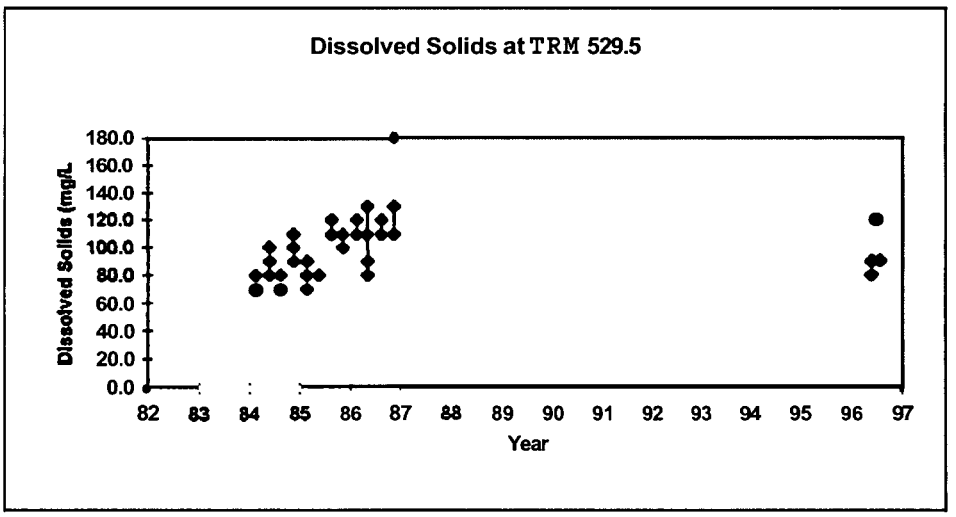


Appendix B-3. Selected water quality values measured during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.5.

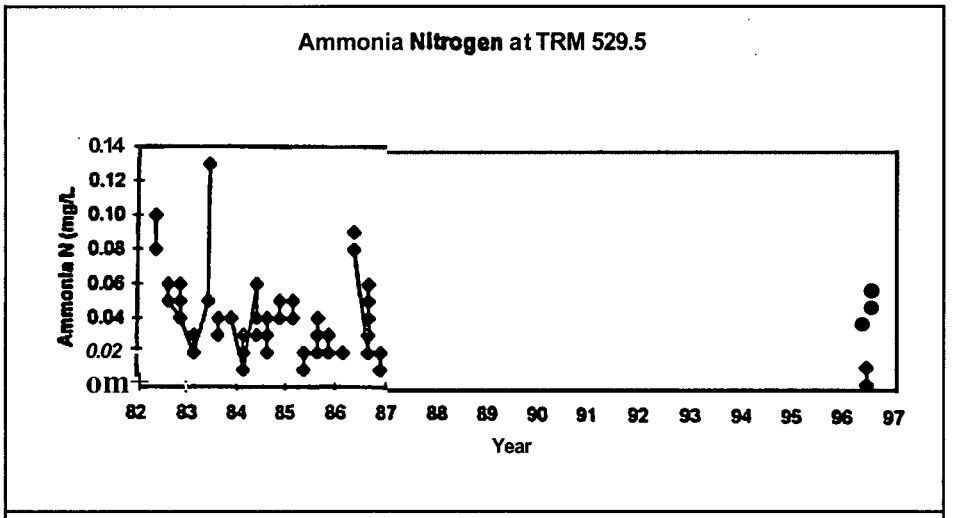


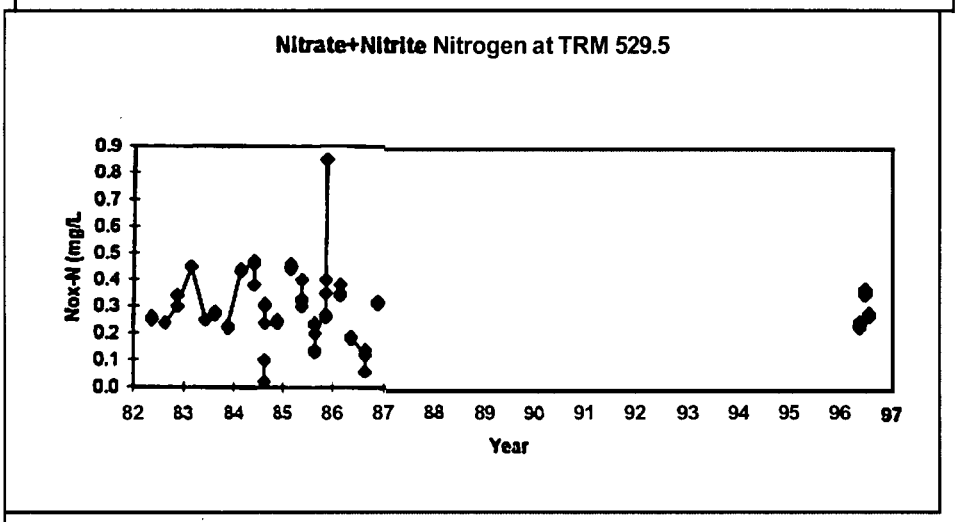
Appendix B-3. (Continued)

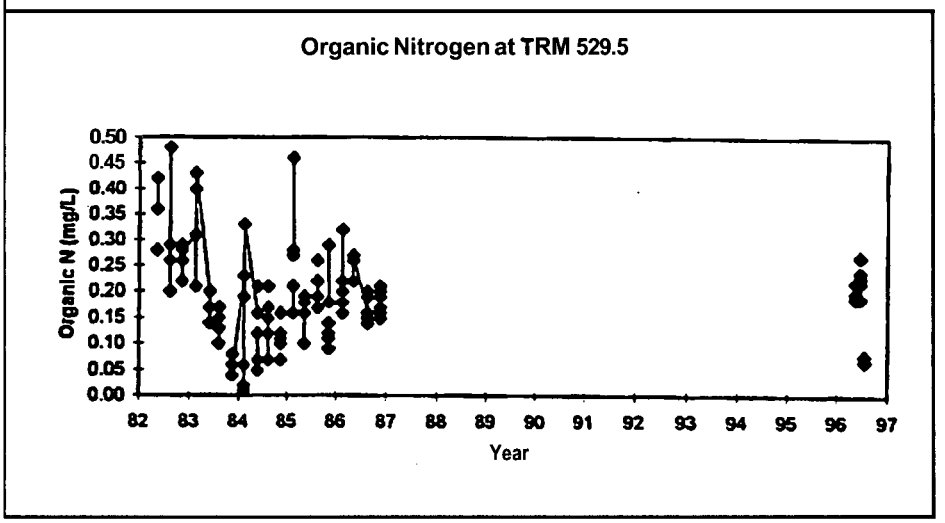




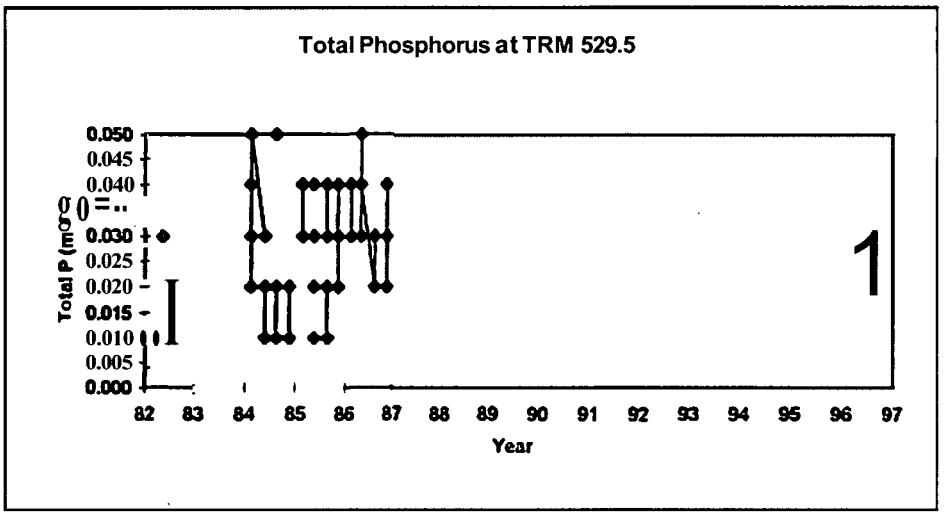
Appendix B-3. (Continued)

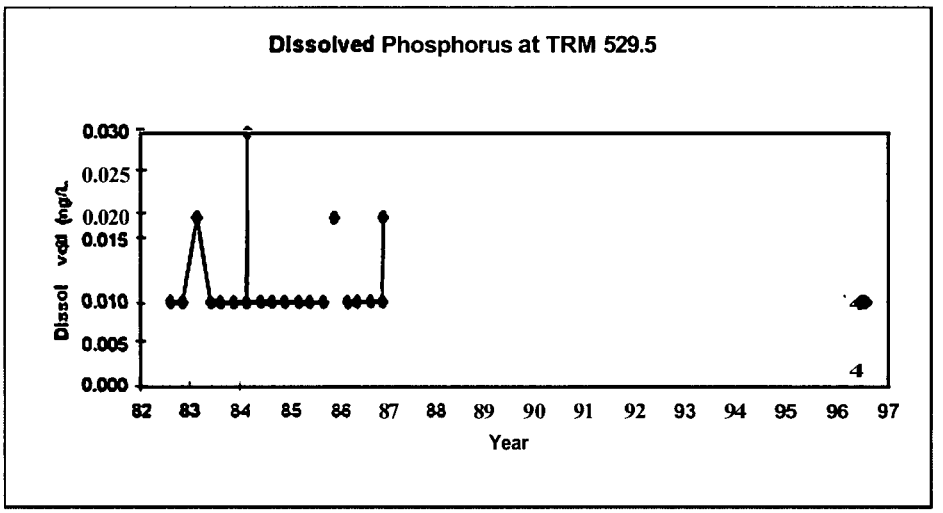


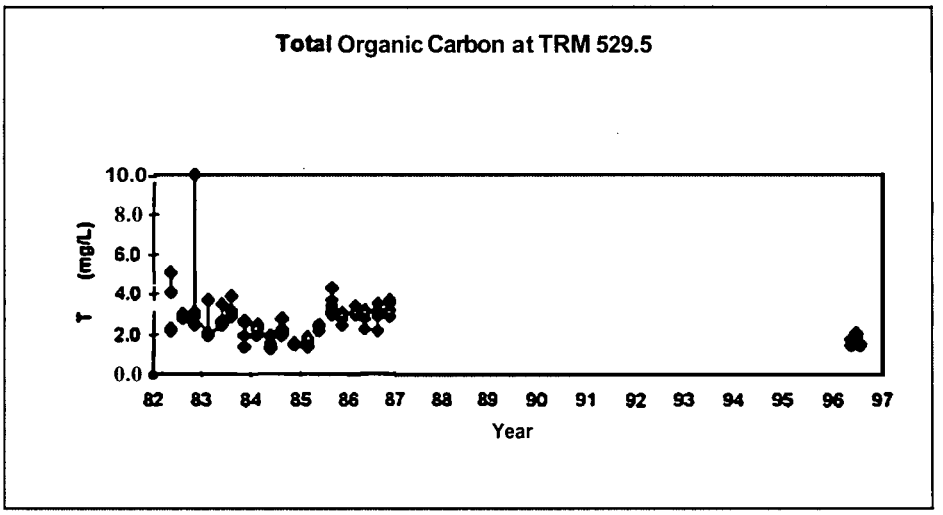




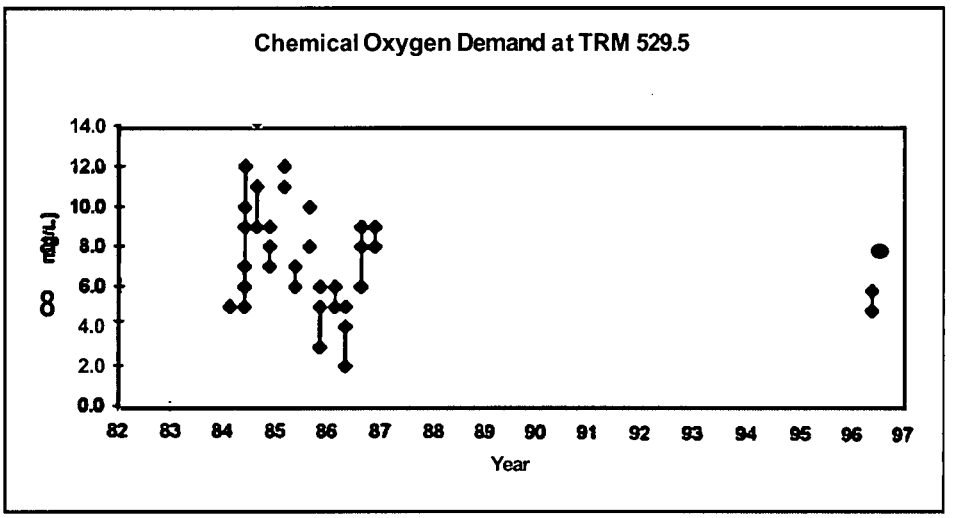
Appendix B-3. (Continued)

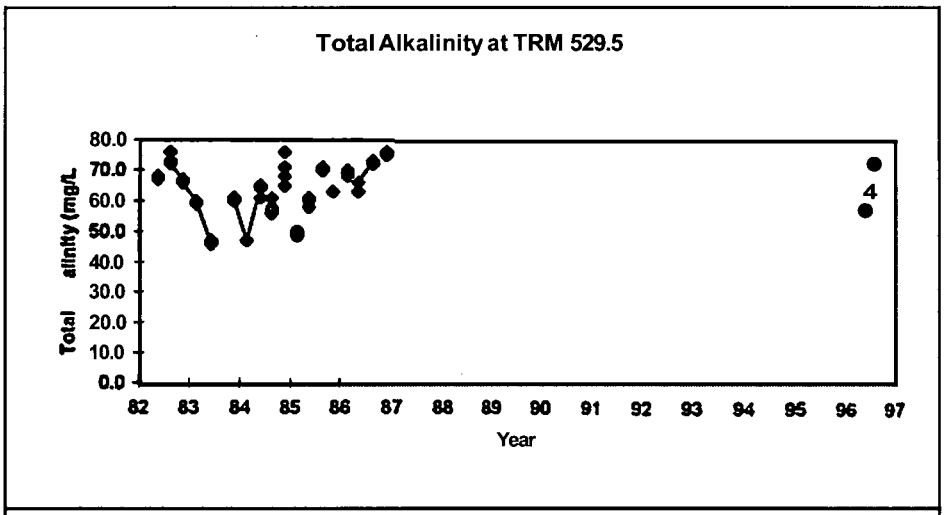


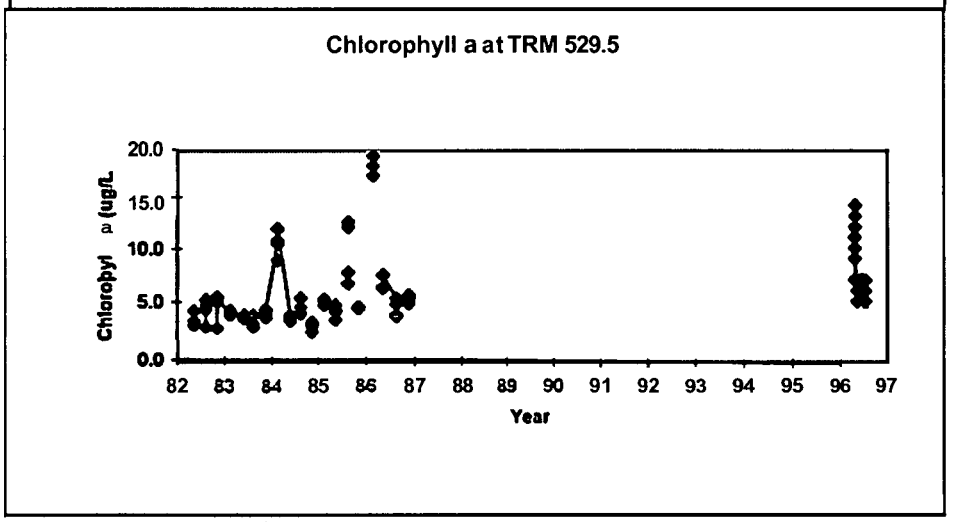




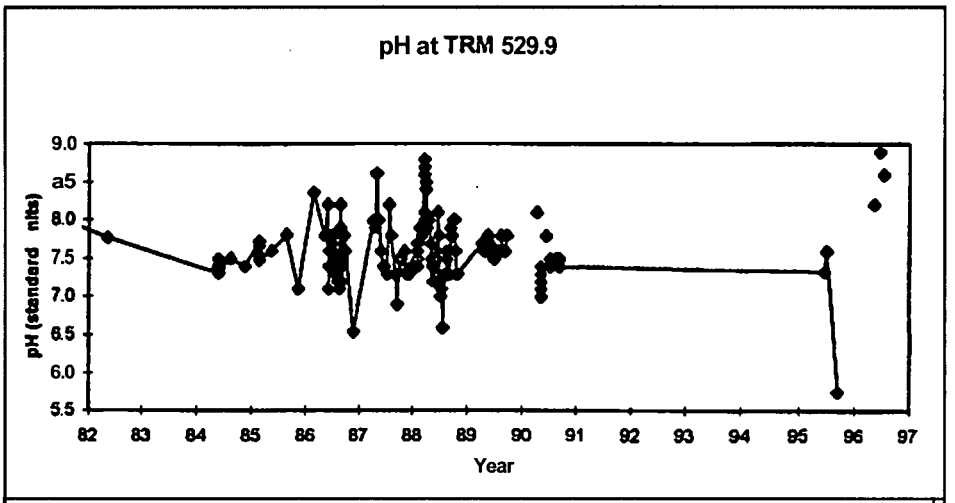
Appendix B-3. (Continued)

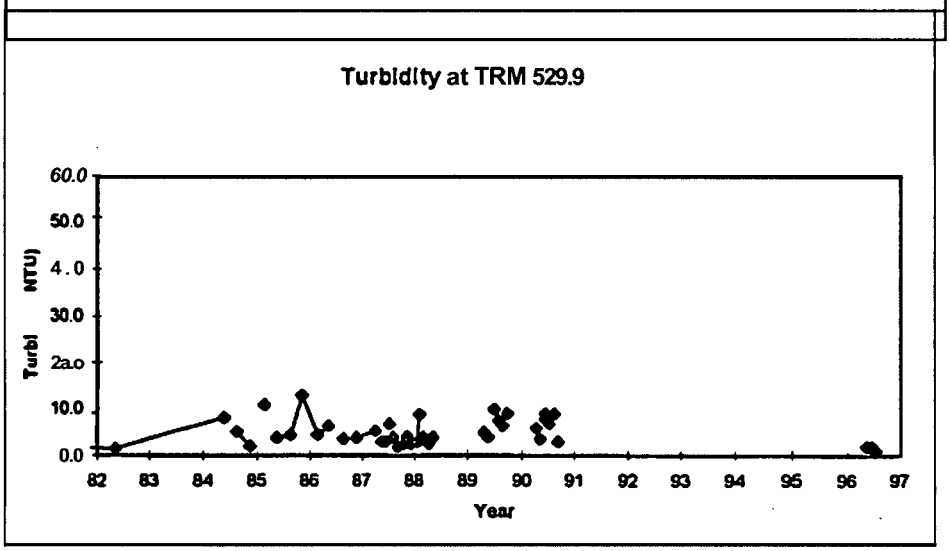


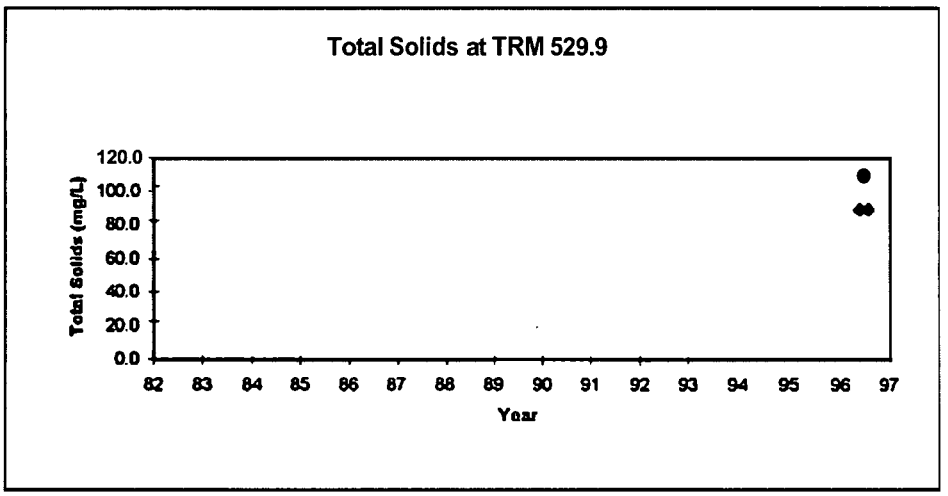


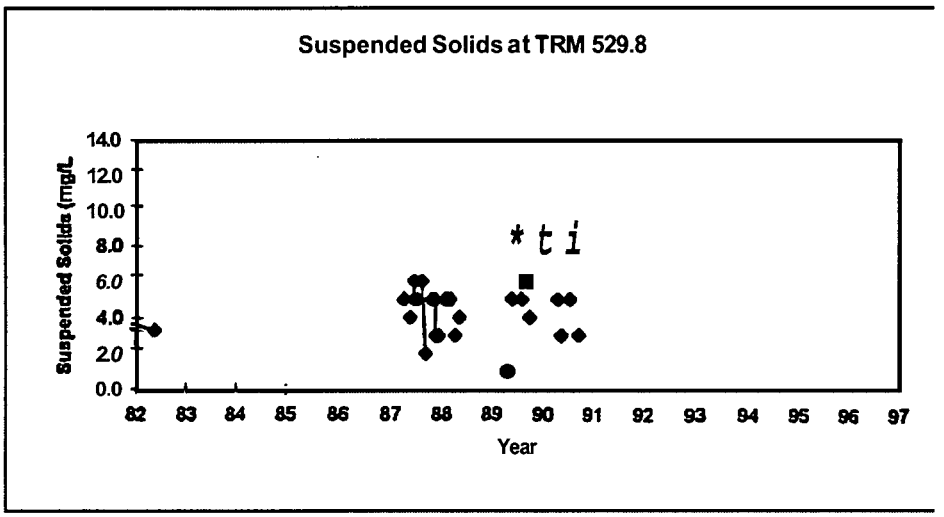


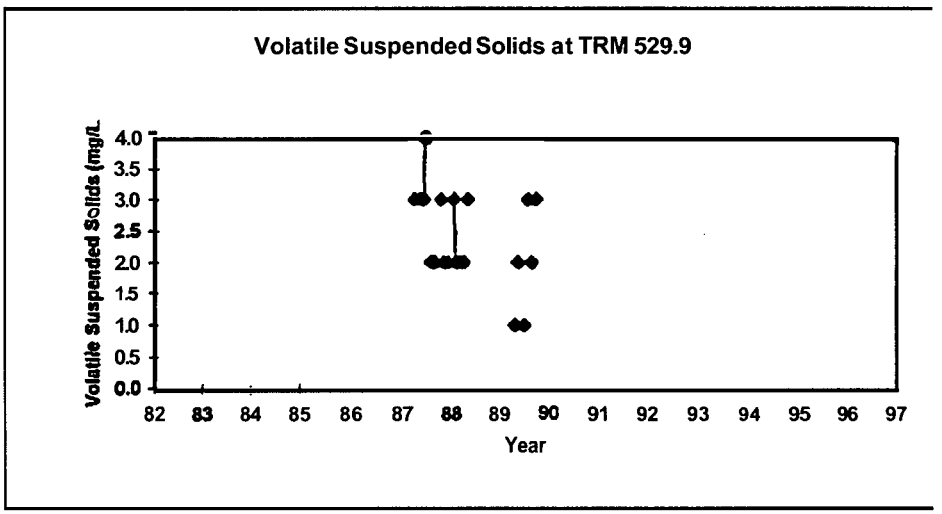
Appendix B-4. Selected water quality values measured during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.9.

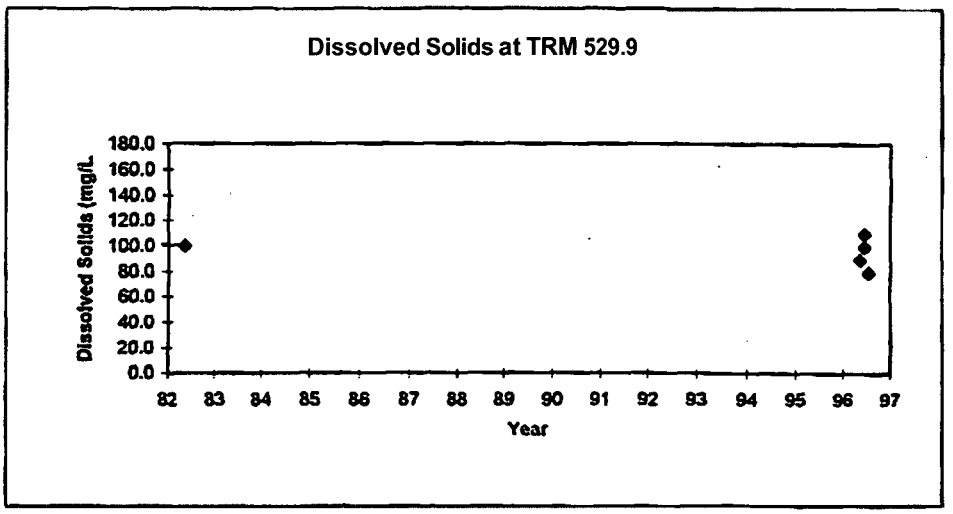


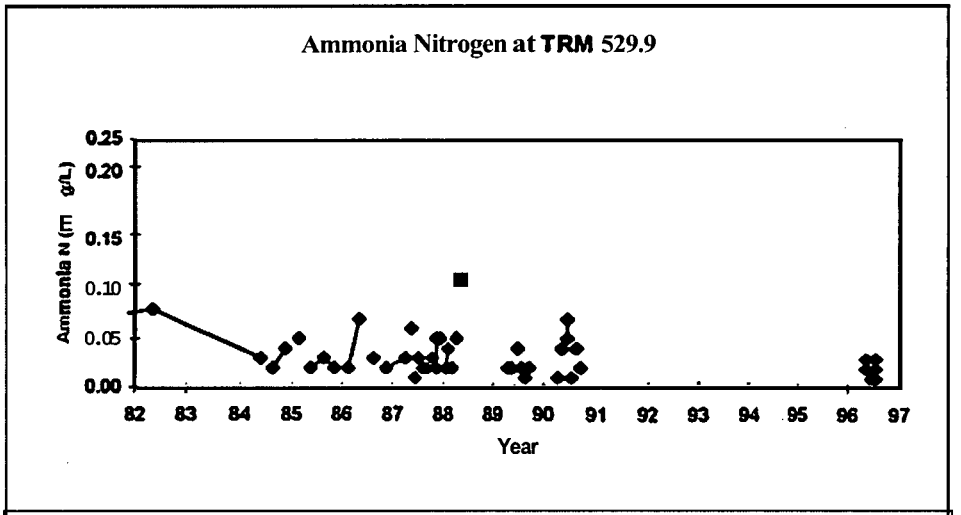


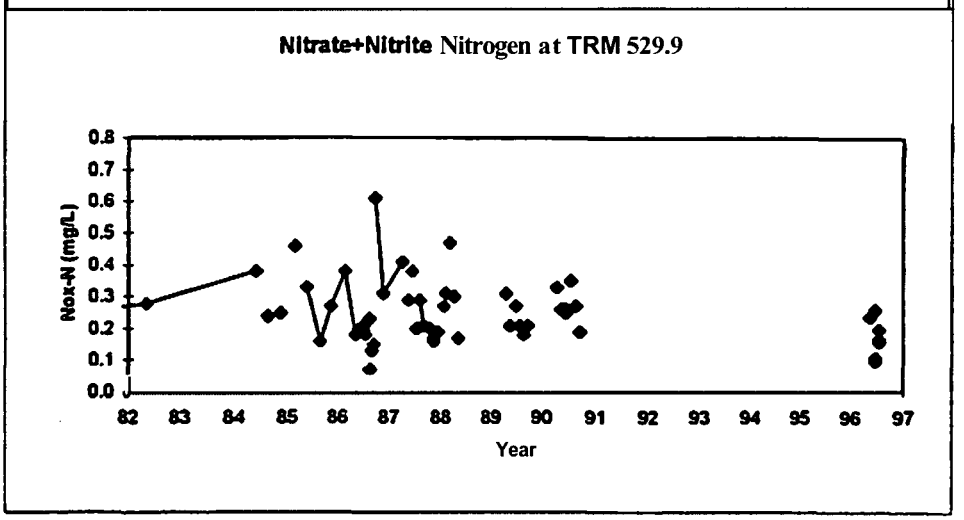


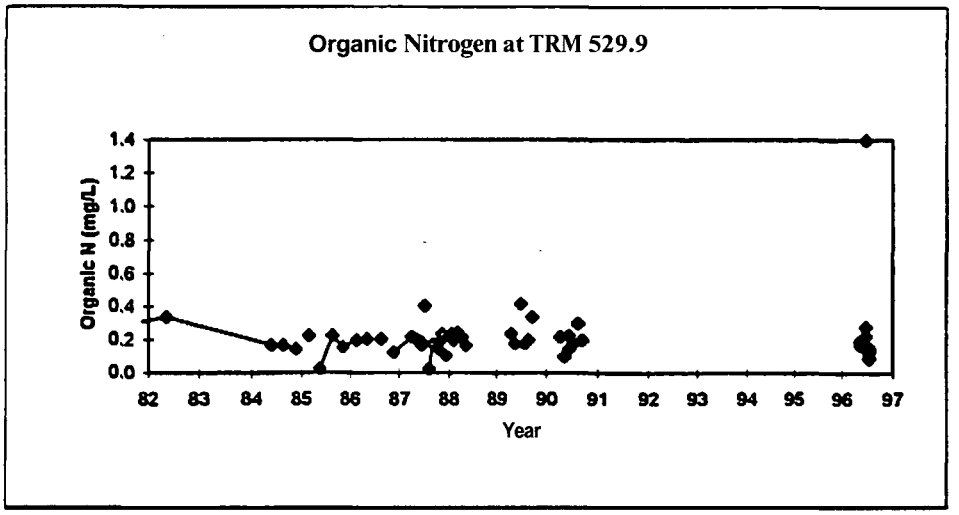

Suspended Solids at TRM 529.8
Suspended Solids (mg/L
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year


Volatile Suspended Solids at TRM 529.9
Volatile Suspended Solids (mg/L
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

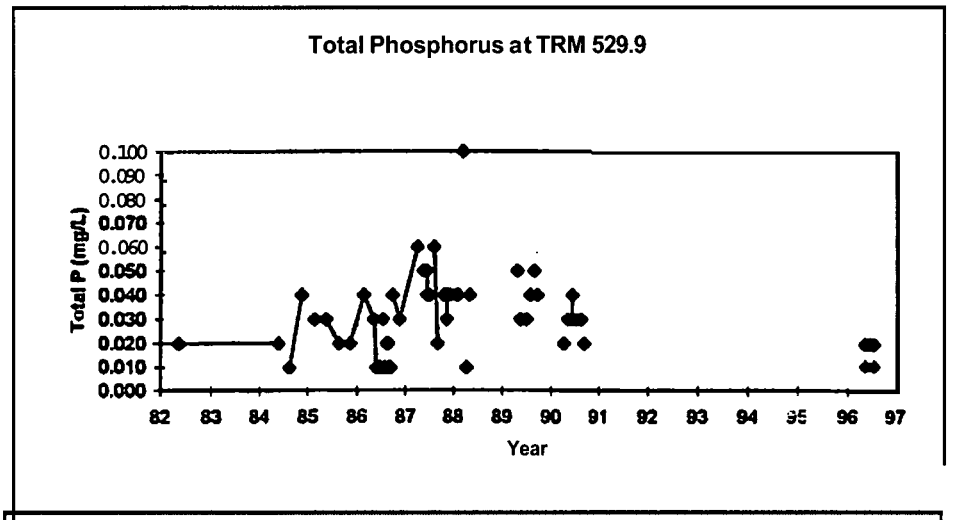

Dissolved Solids at TRM 529.9
Dissolved Solids (mg/L
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

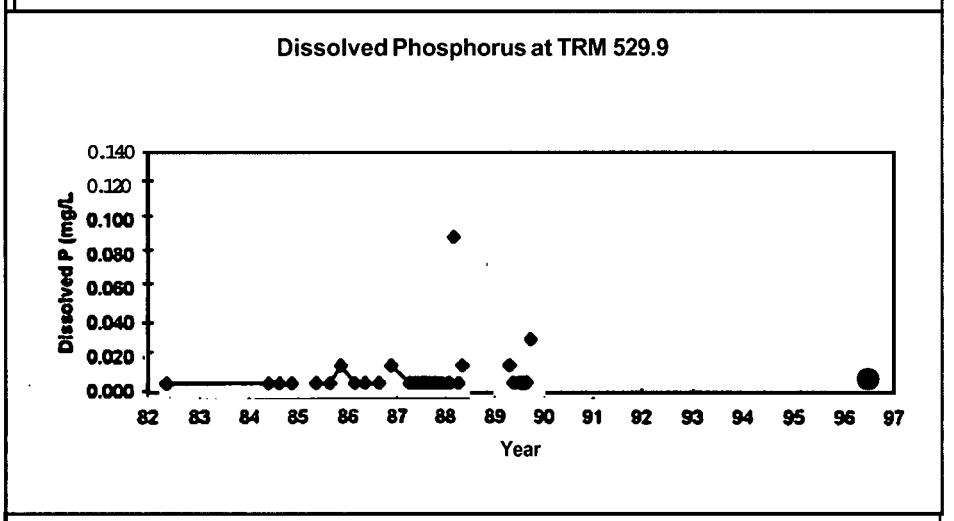

Ammonia Nitrogen at TRM 529.9
Ammonia N (mg/L)
0.25
0.20
0.15
0.10
0.05
0.00
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

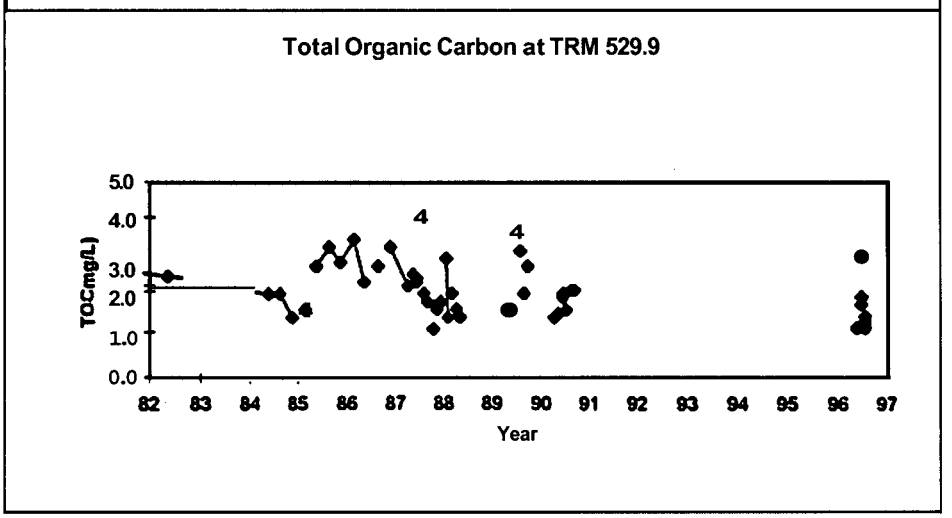

Nitrate+Nitrite Nitrogen at TRM 529.9
Nox-N (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year


Organic Nitrogen at TRM 529.9
Organic N (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
Year

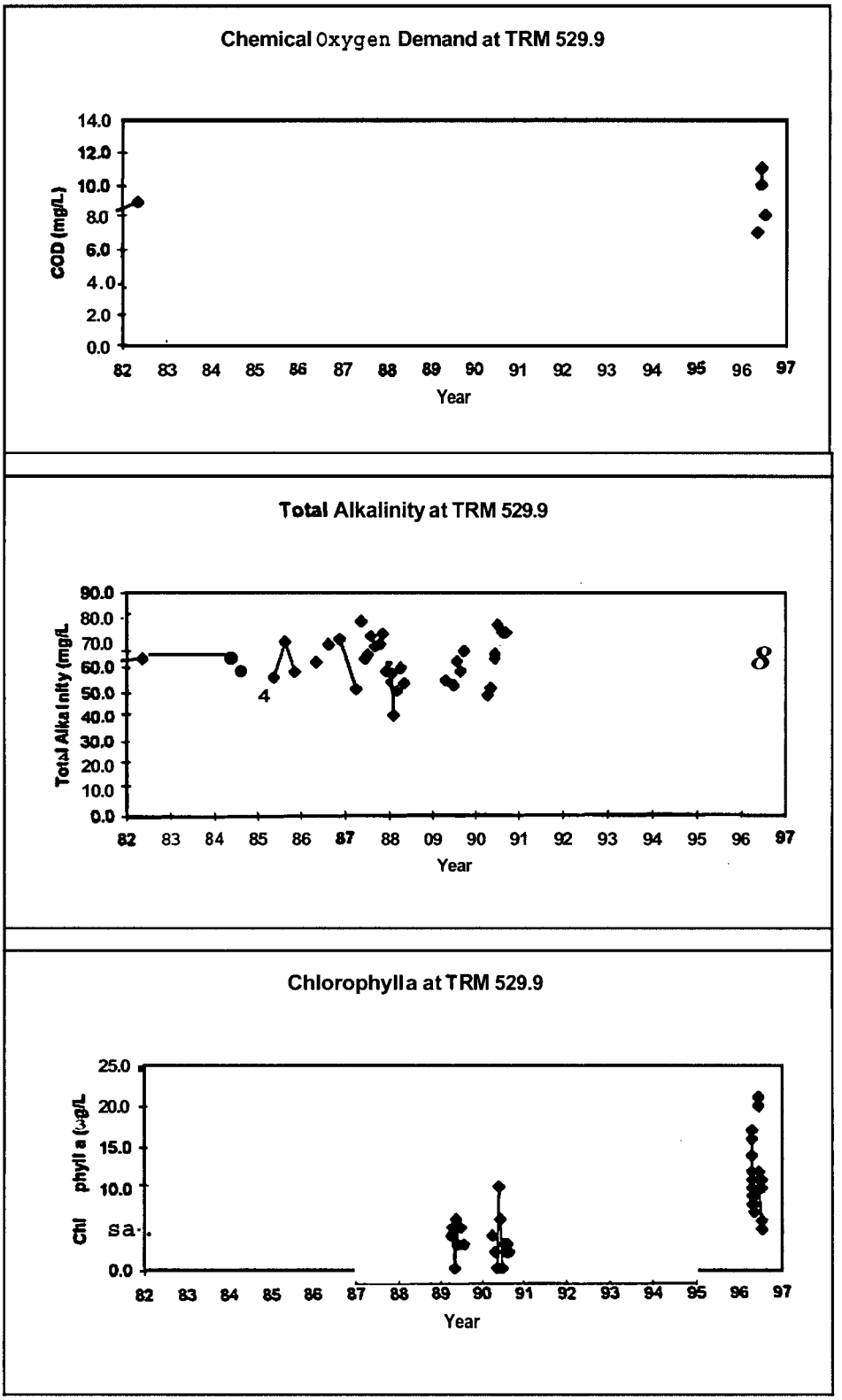
Appendix B-4. (Continued)



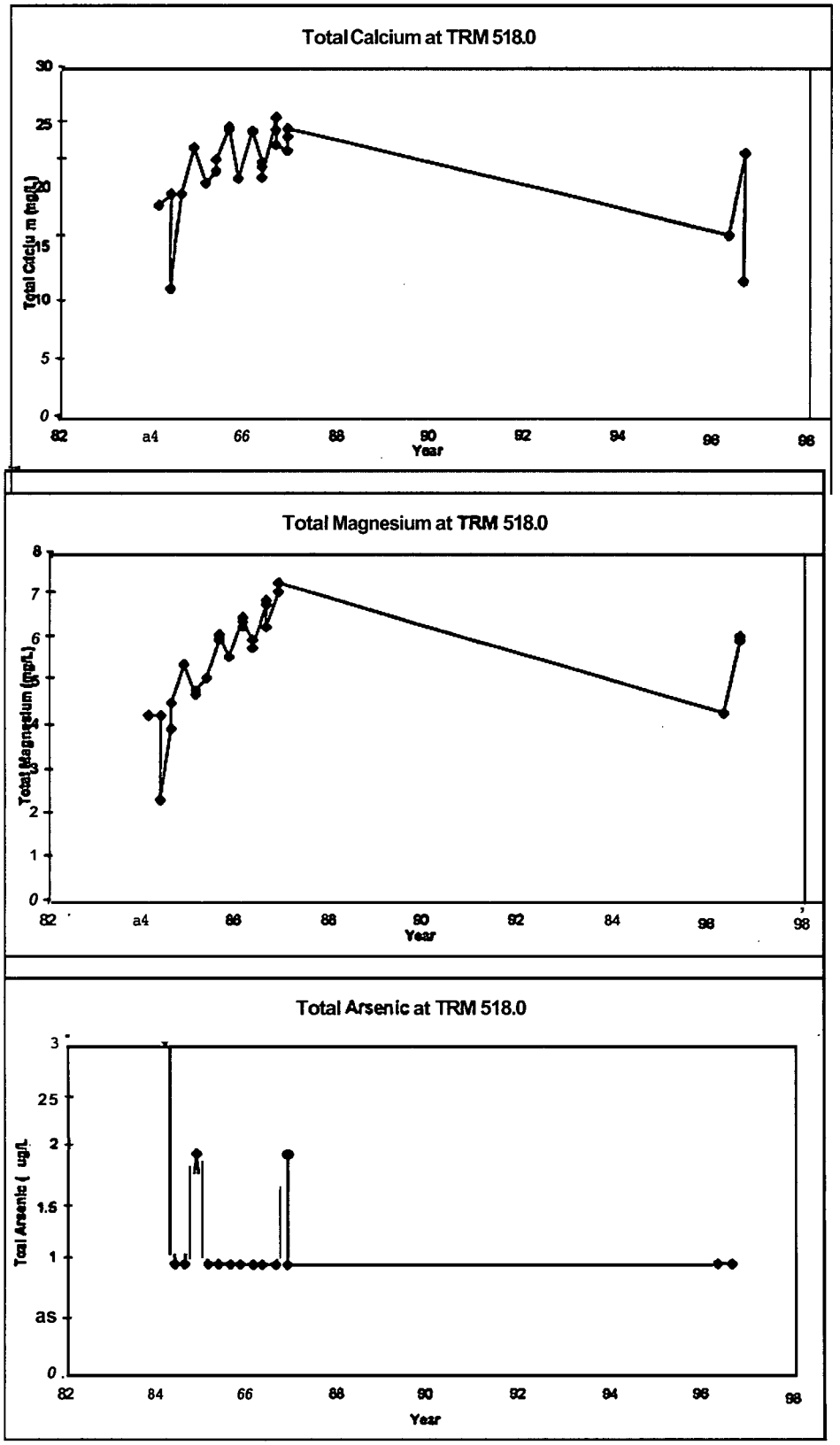


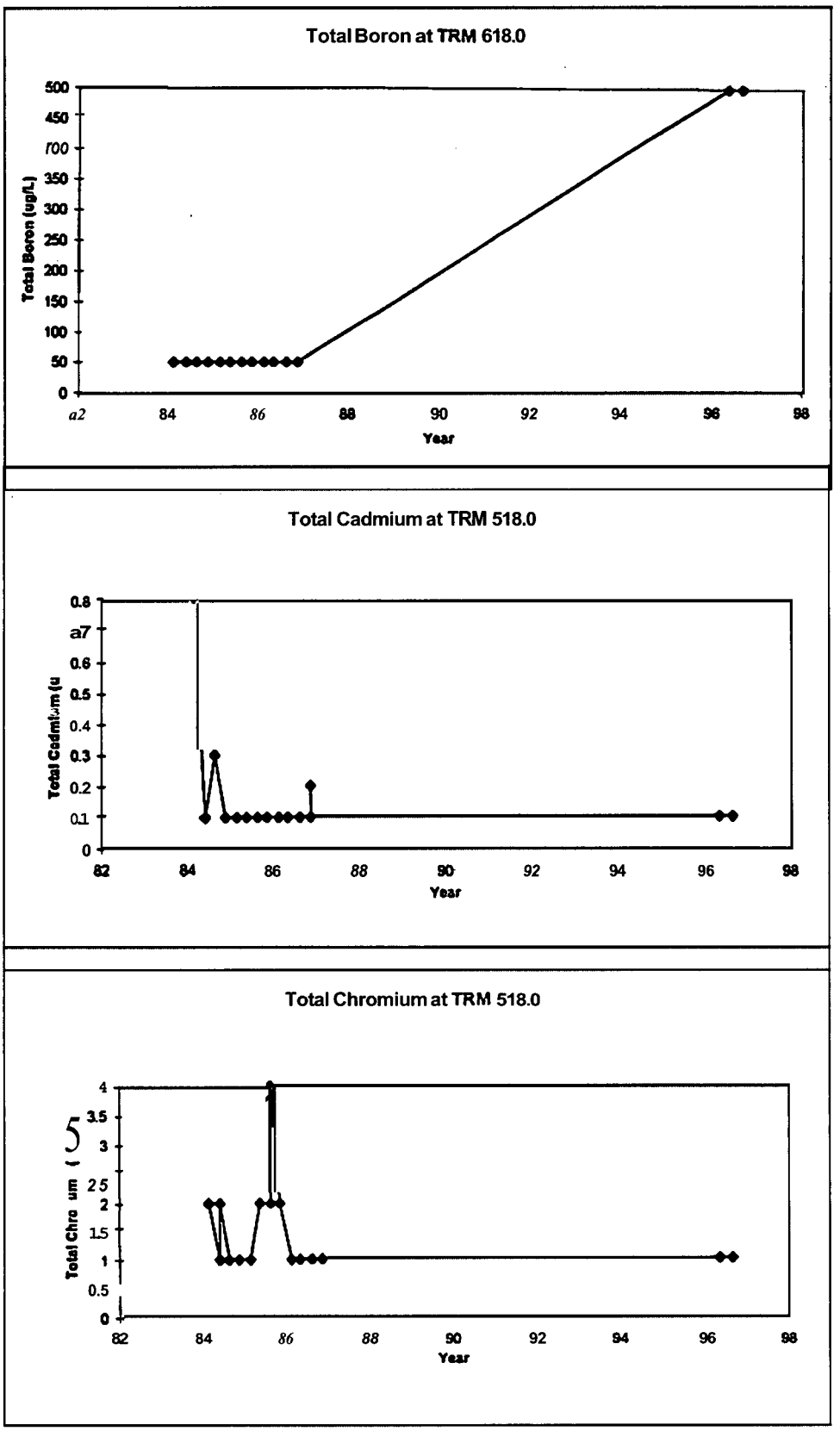


Appendix **B-4.** (Continued)

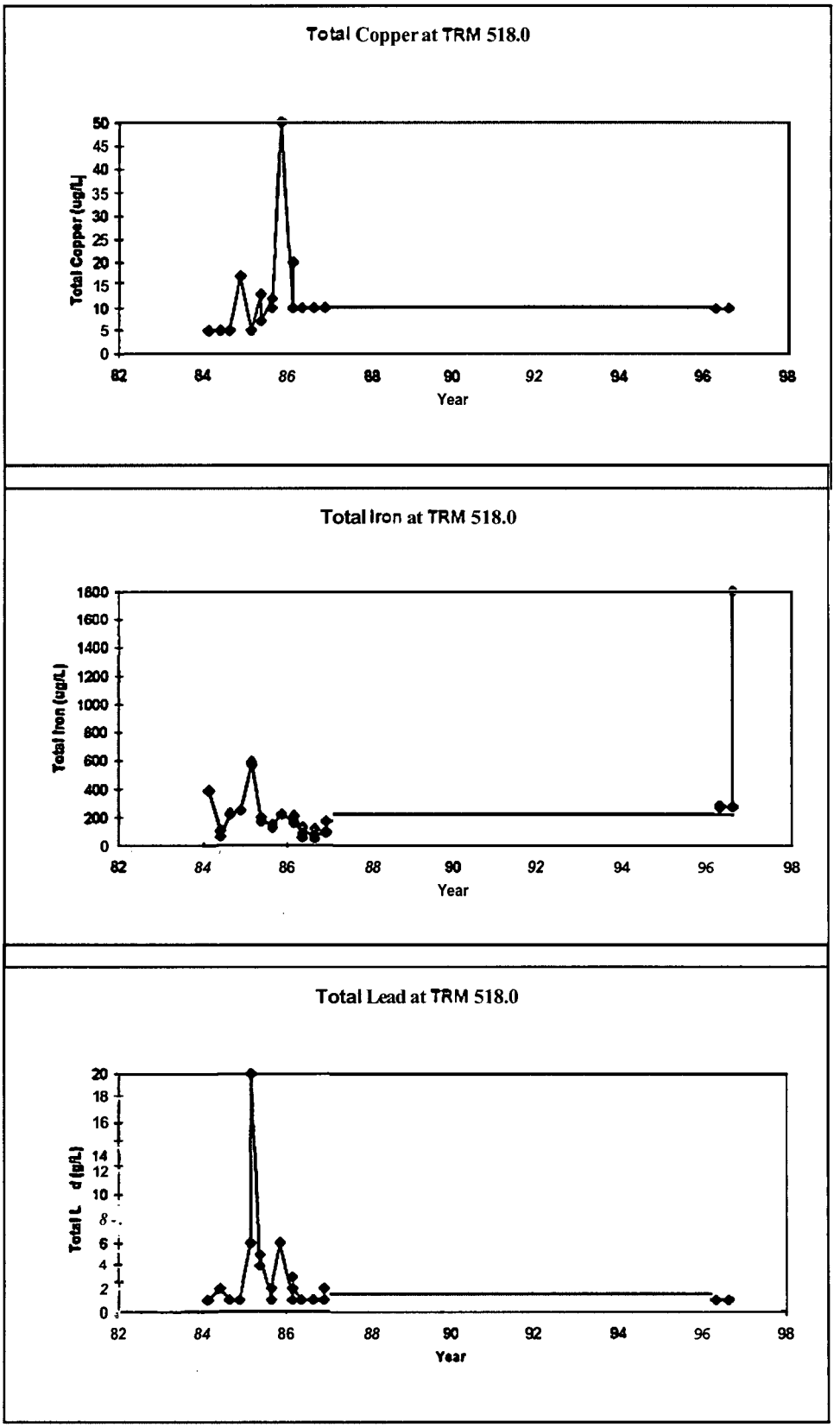


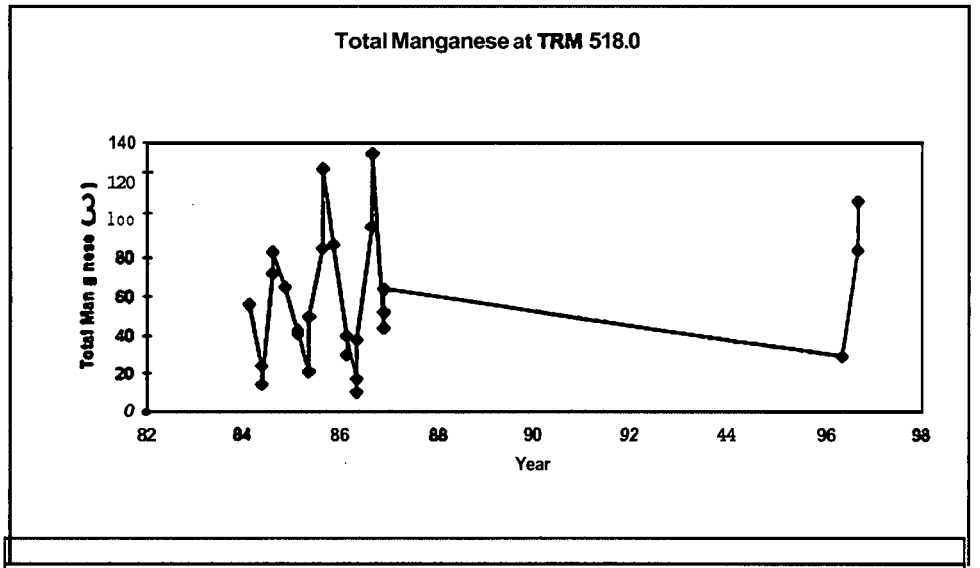
Appendix B-5. Concentrations of selected metals during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 518. Appendix B-4. (Continued)

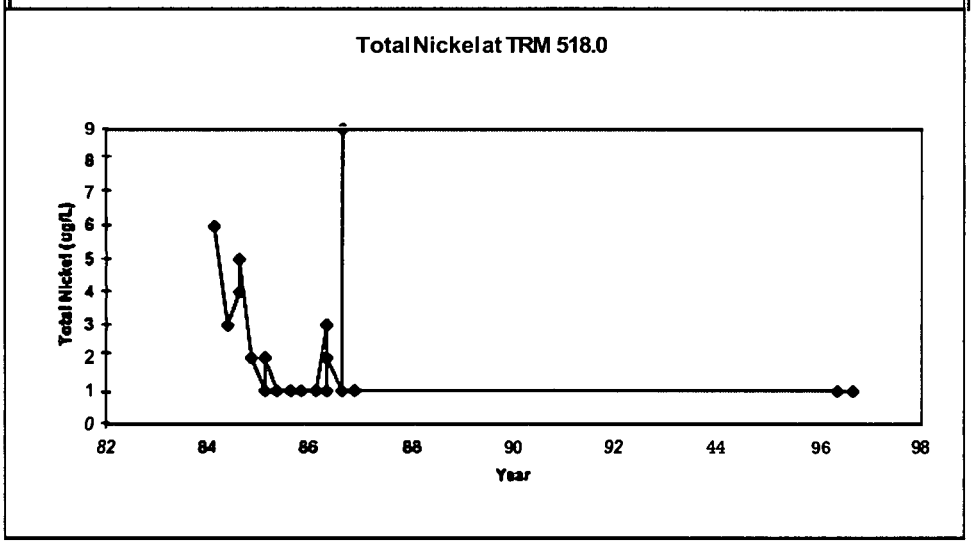


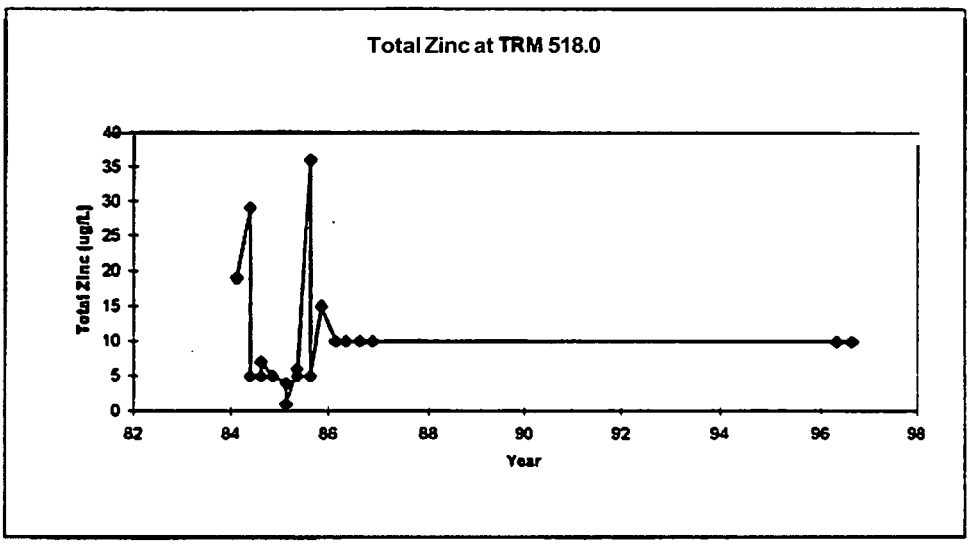

Total Boron at TRM 618.0
Total Boron (ug/L)
500
450
350
300
250
200
150
100
50
0
84
86
88
90
92
94
96
98
Year
Total Cadmium at TRM 518.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0
82
84
86
88
90
92
94
96
98
Year
Total Chromium at TRM 518.0
4
3.5
3
2.5
2
1.5
1
0.5
0
82
84
86
88
90
92
94
96
98
Year

Appendix B-5. (Continued)

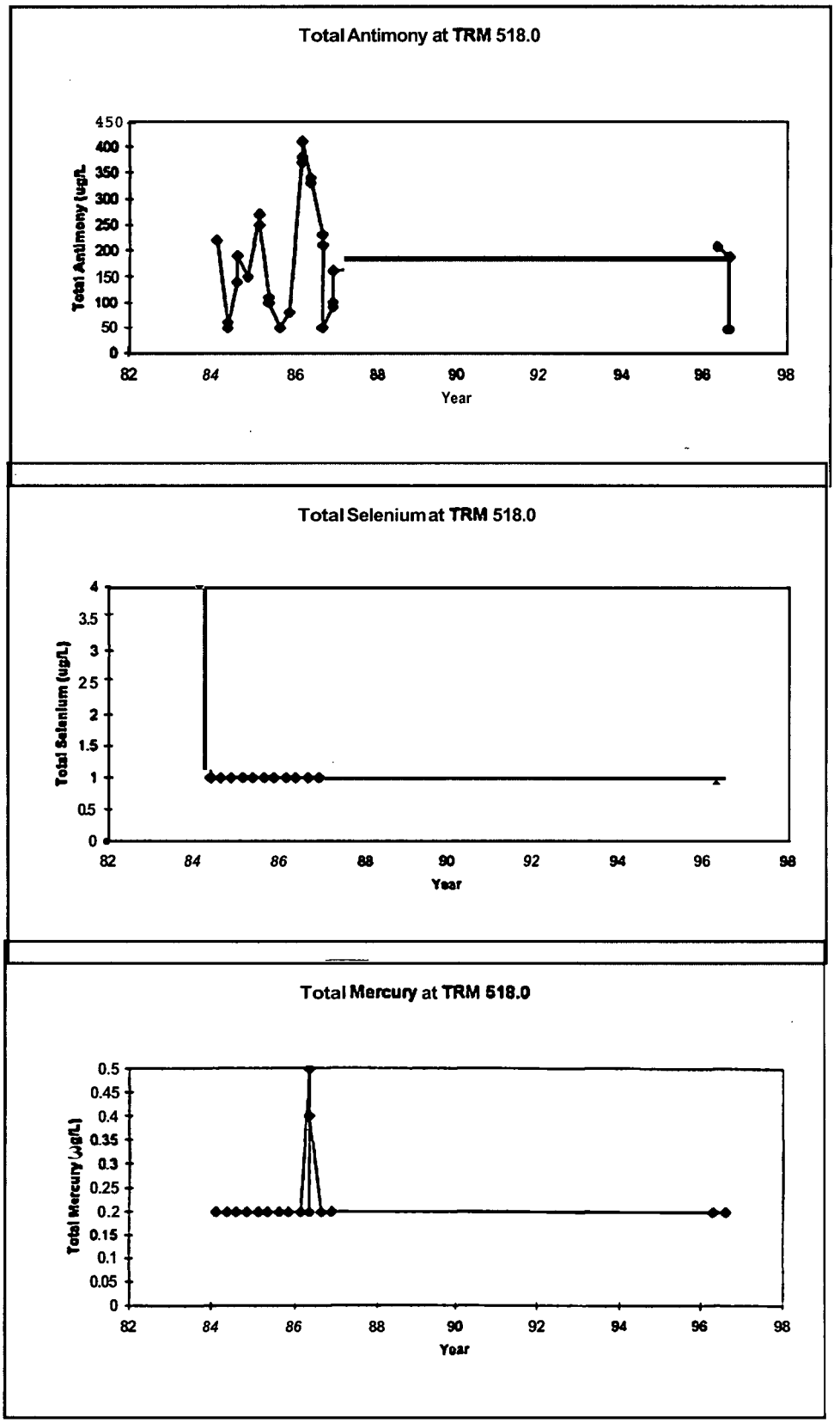



Total Manganese at TRM 518.0
Total Manganese (ug/L)
140
120
100
80
60
40
20
0
82
84
86
88
90
92
44
96
98
Year

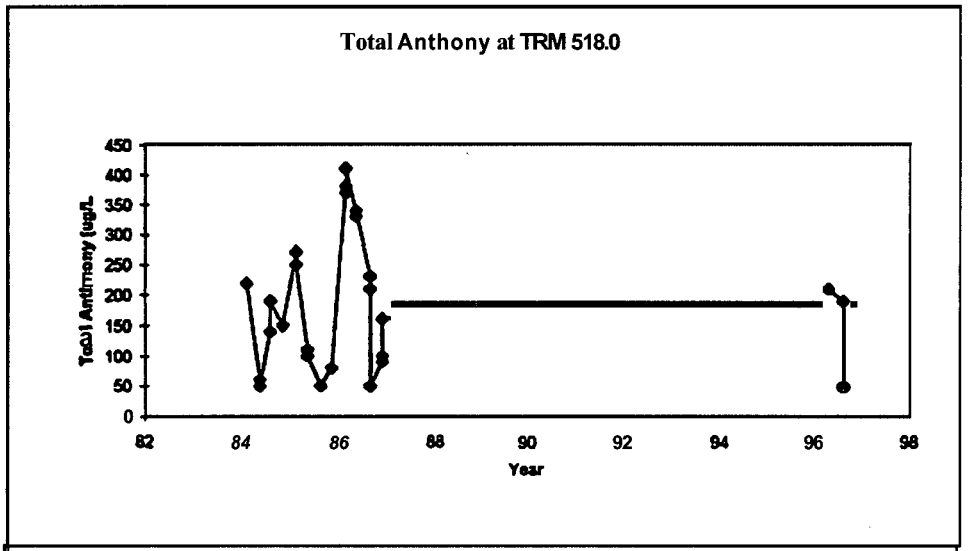

Total Nickel at TRM 518.0
Total Nickel (ug/L)
9
8
7
6
5
4
3
2
1
0
82
84
86
88
90
92
44
96
98
Year

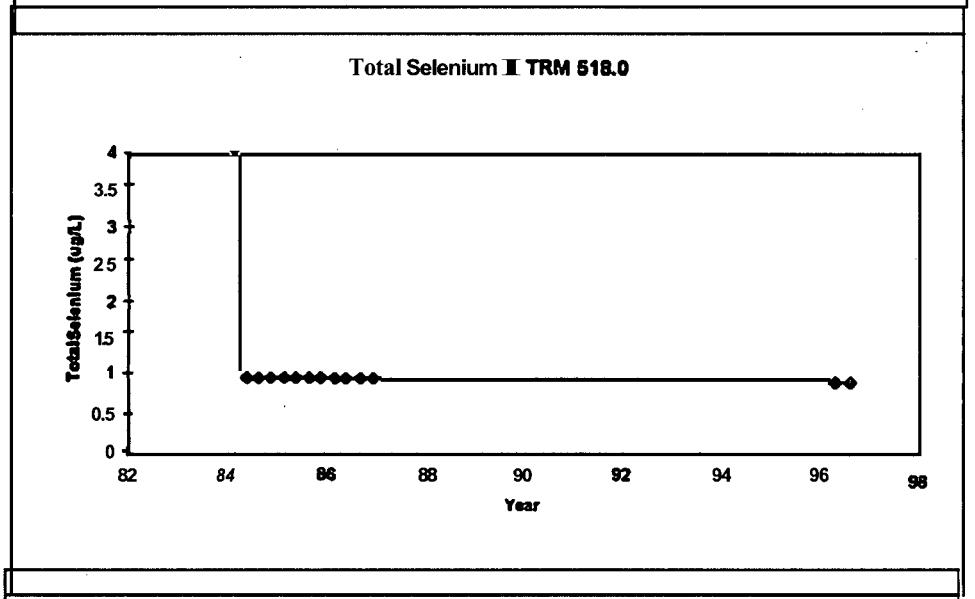

Total Zinc at TRM 518.0
Total Zinc (ug/L)
40
35
30
25
20
15
10
5
0
82
84
86
88
90
92
94
96
98
Year

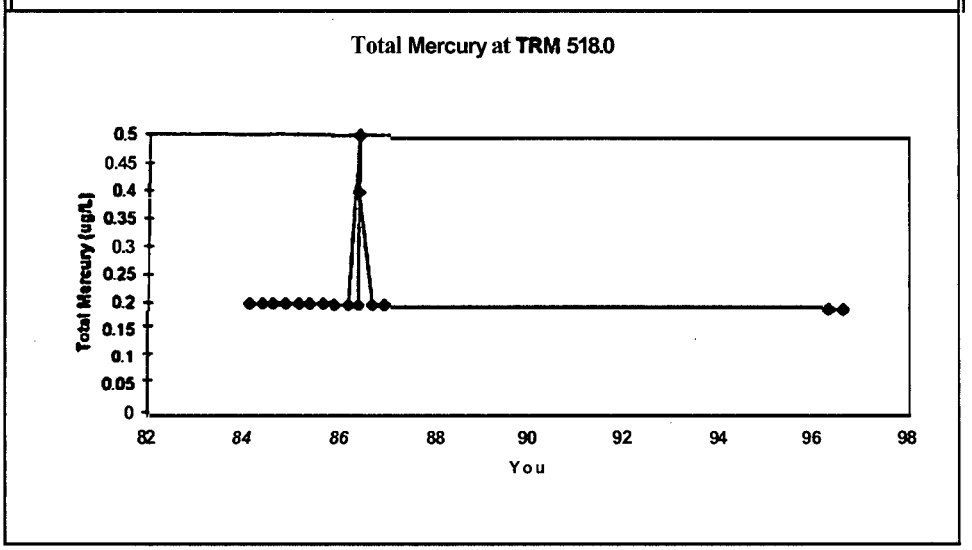
Appendix B-5. (Continued)



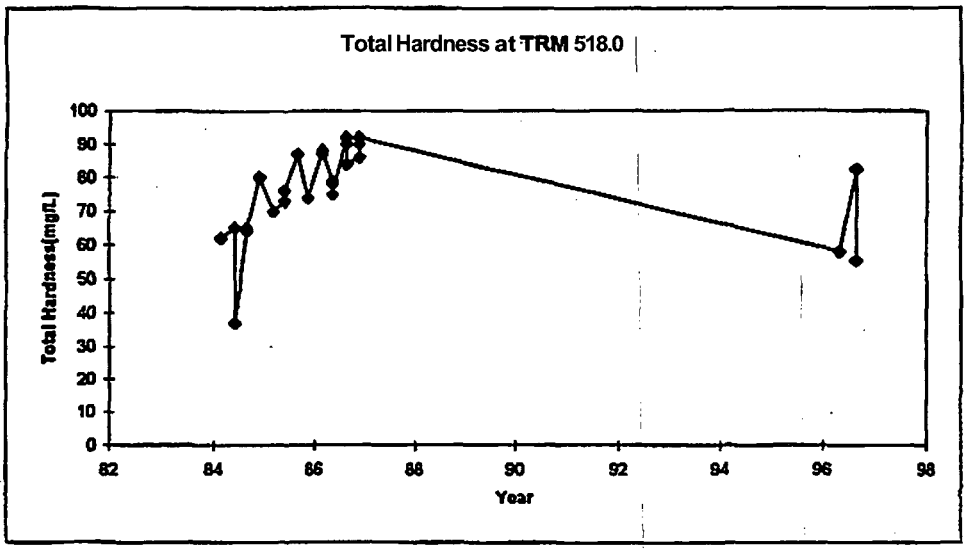
Appendix B-5. (Continued)



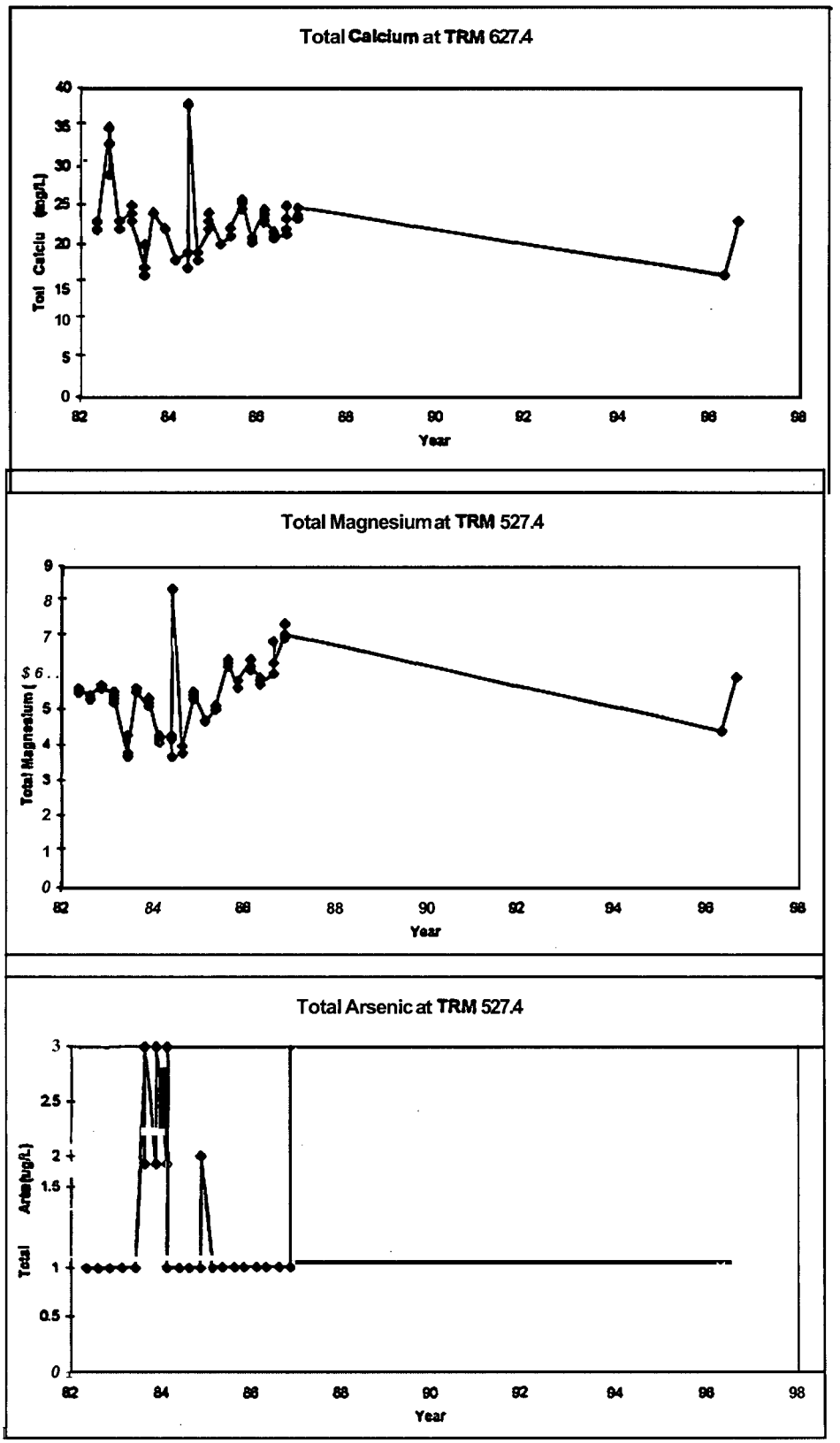




Appendix B-5. (Continued)



Appendix B-6. Concentrations of selected metals during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 527.4. Appendix B-4. (Continued)



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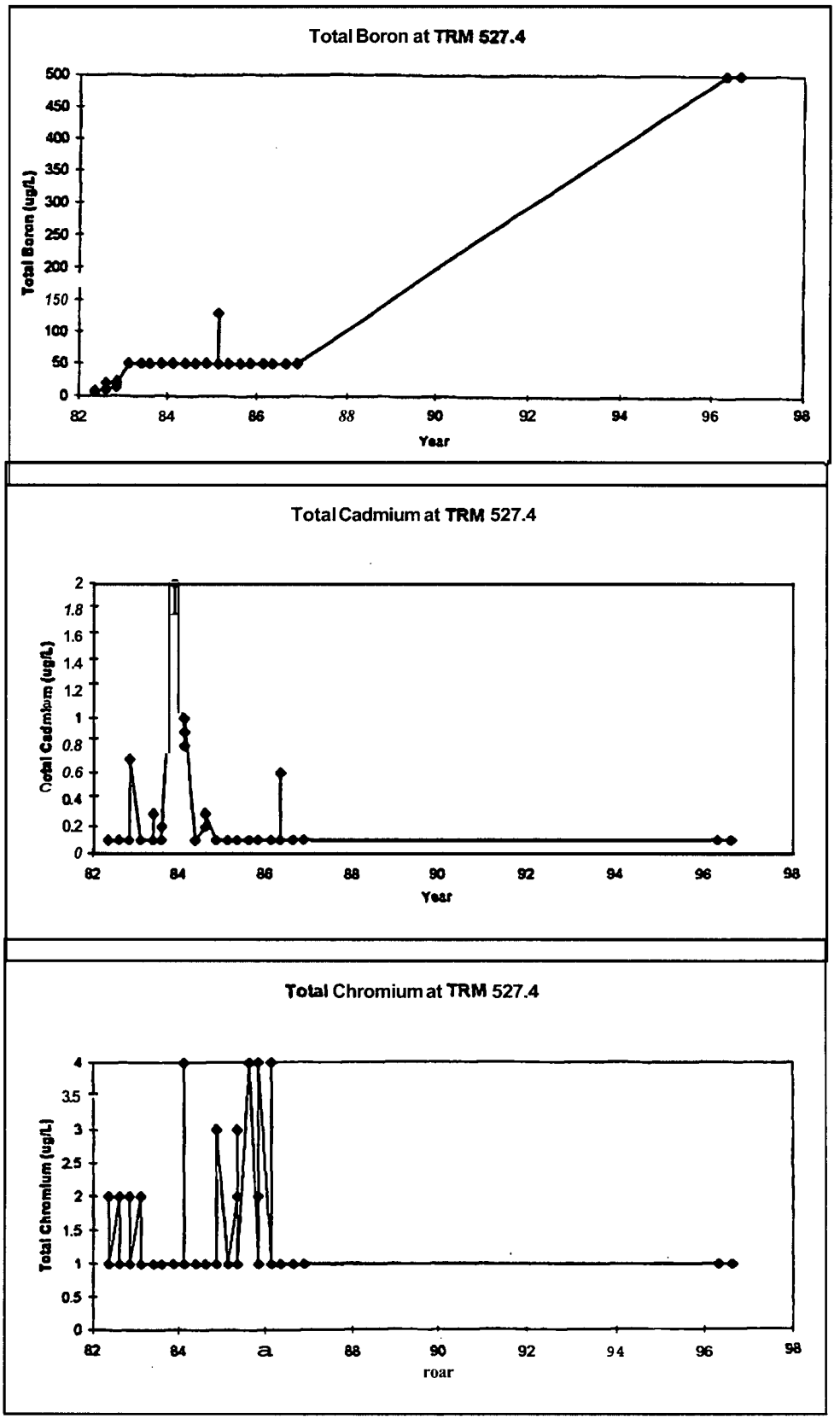

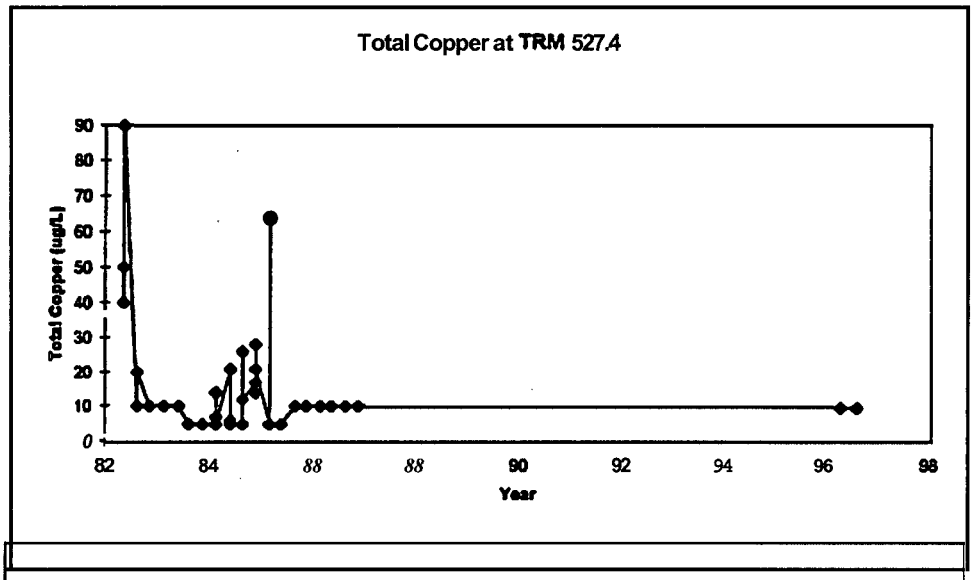
Total Copper at TRM 527.4
Total Copper (ug/L)
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80
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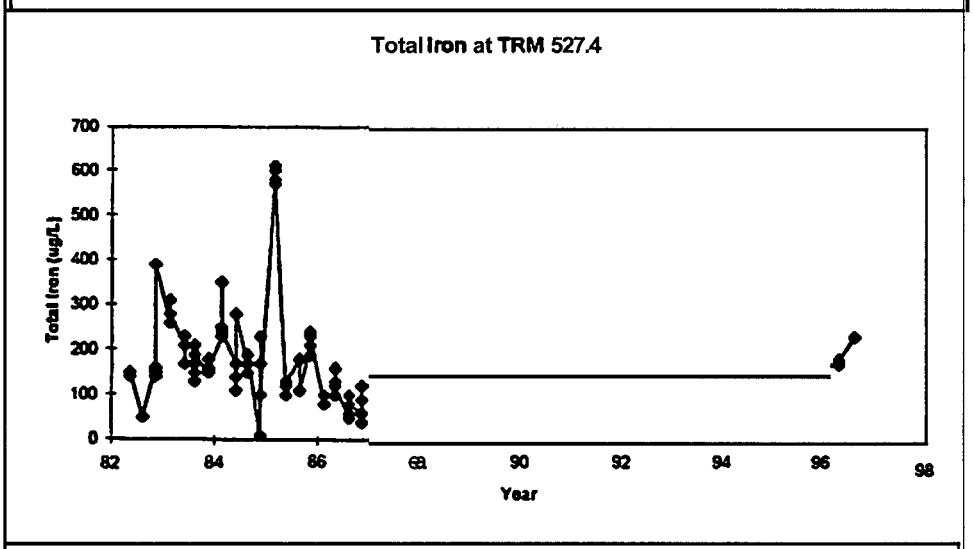
90
92
94
96
98
Year


Total Iron at TRM 527.4
Total Iron (ug/L)
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400
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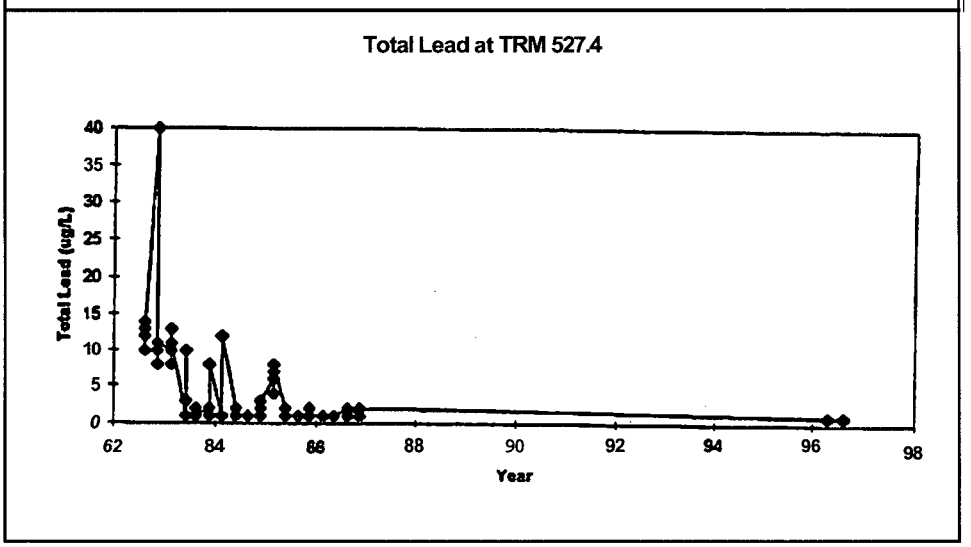
94
96
98
Year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Total Lead (ug/L)
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35
30
25
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15
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5
0
62
84
86
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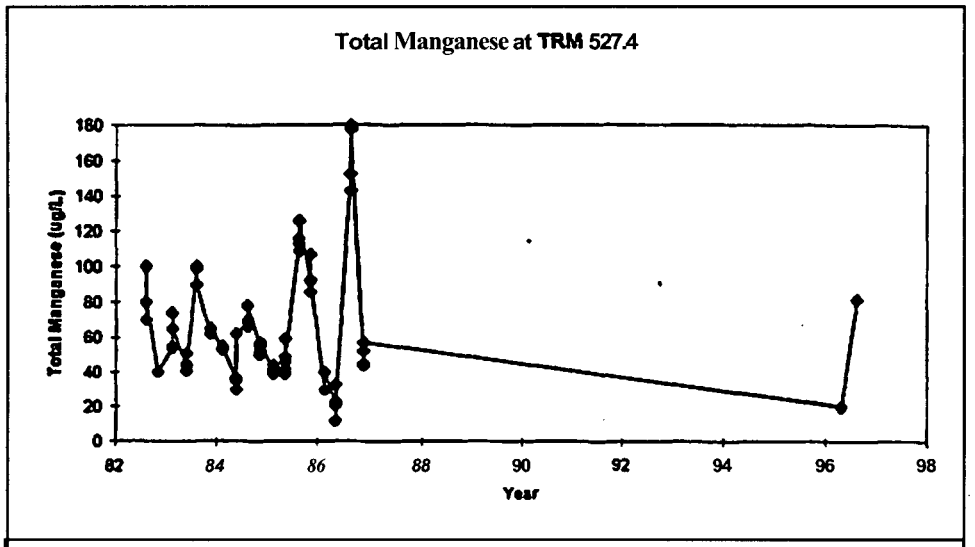
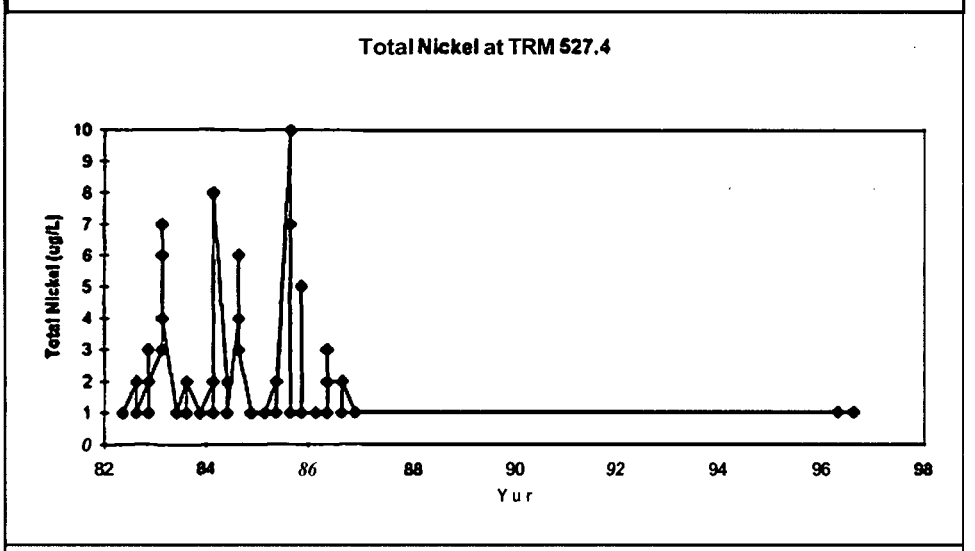
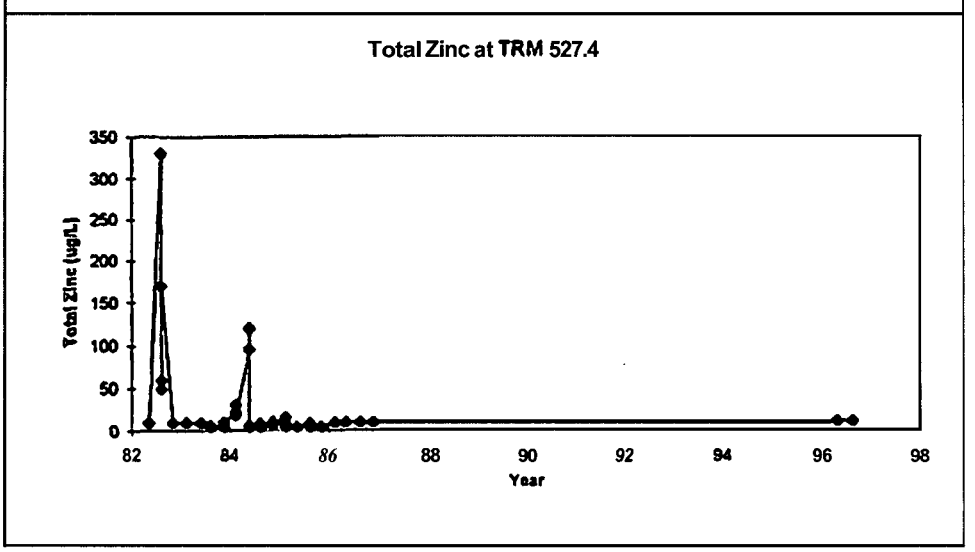
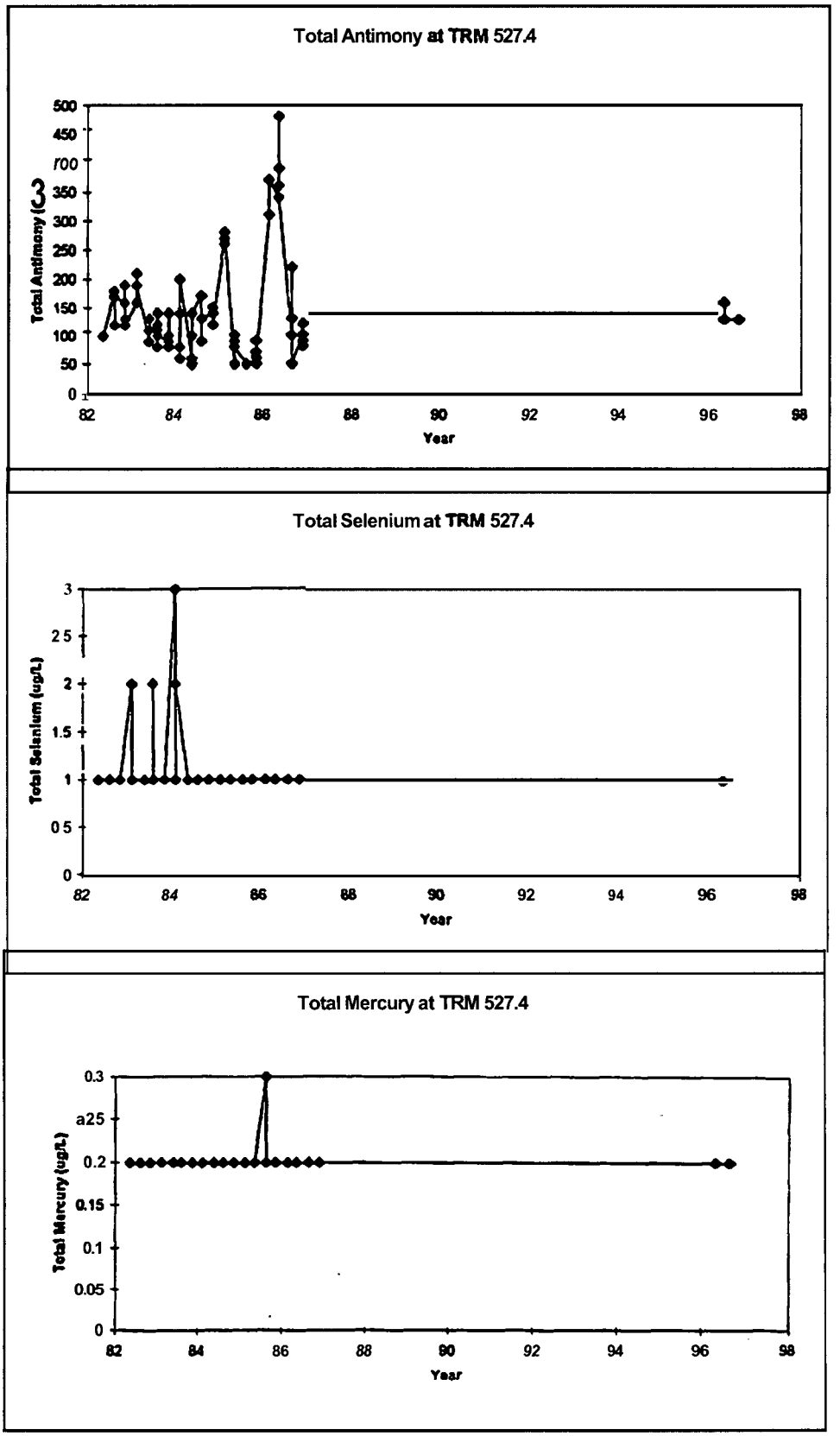
Year

Appendix B-6. (Continued)





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90
92
94
96
98
Year
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Total Selenium (ug/L)
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2
1.5
1
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0
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90
92
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98
Year
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Total Mercury (ug/L)
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92
94
96
98
Year

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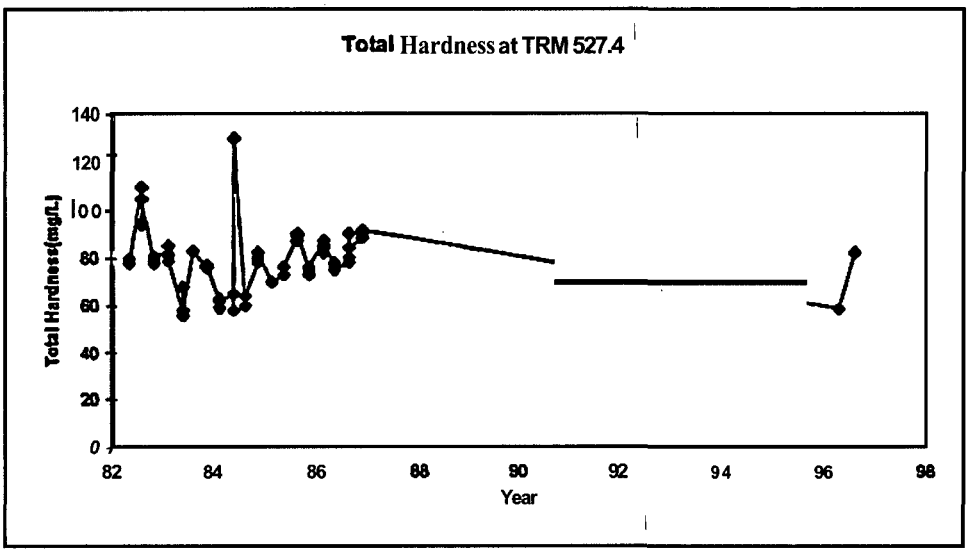
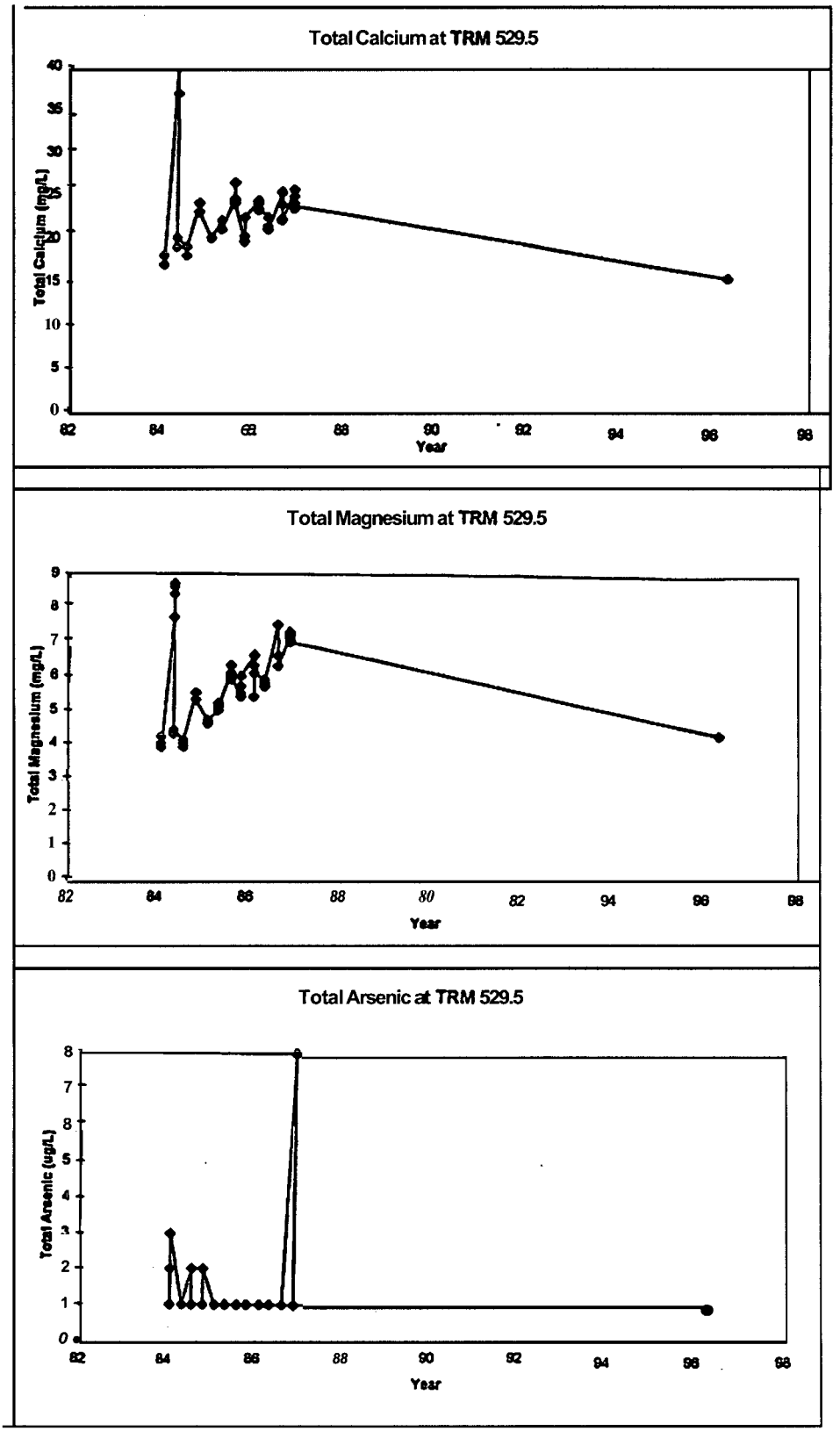


Appendix B-7. Concentrations of selected metals during preoperational (1982 through 1986) and operational (1996) monitoring near Watts Bar Nuclear Plant at Tennessee River Mile 529.5.



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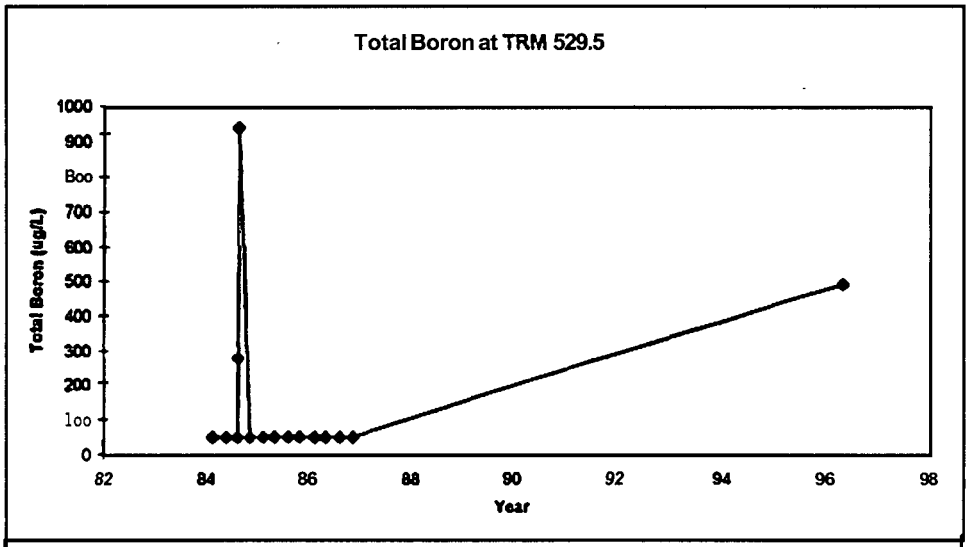

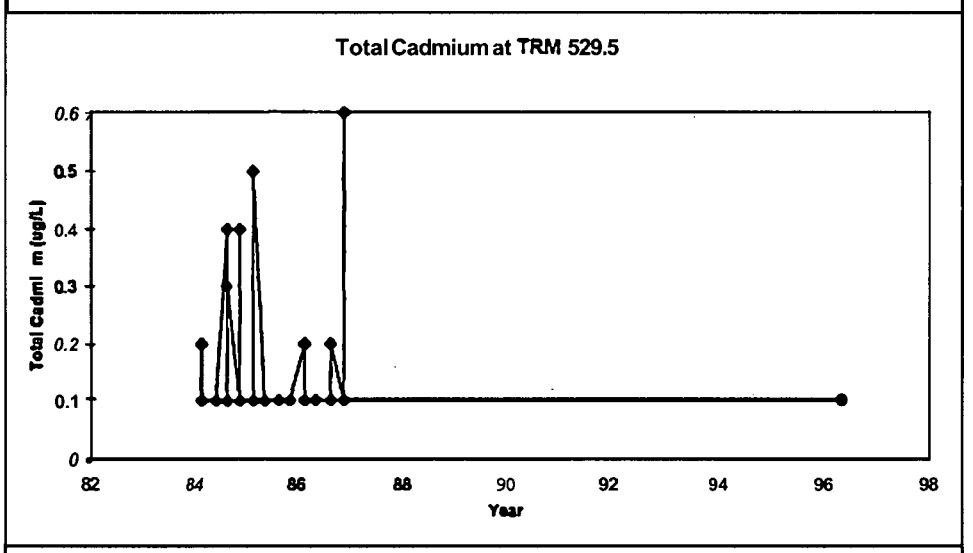

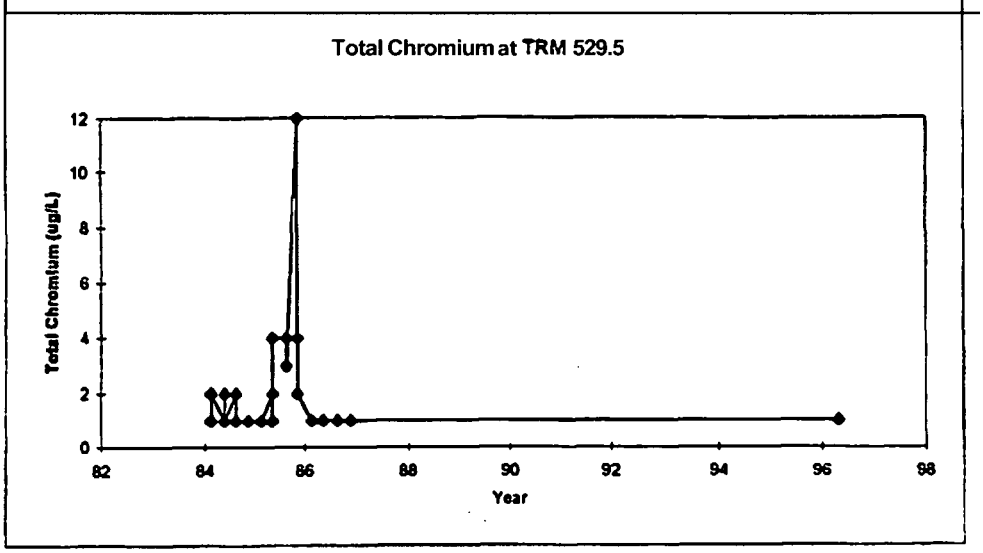

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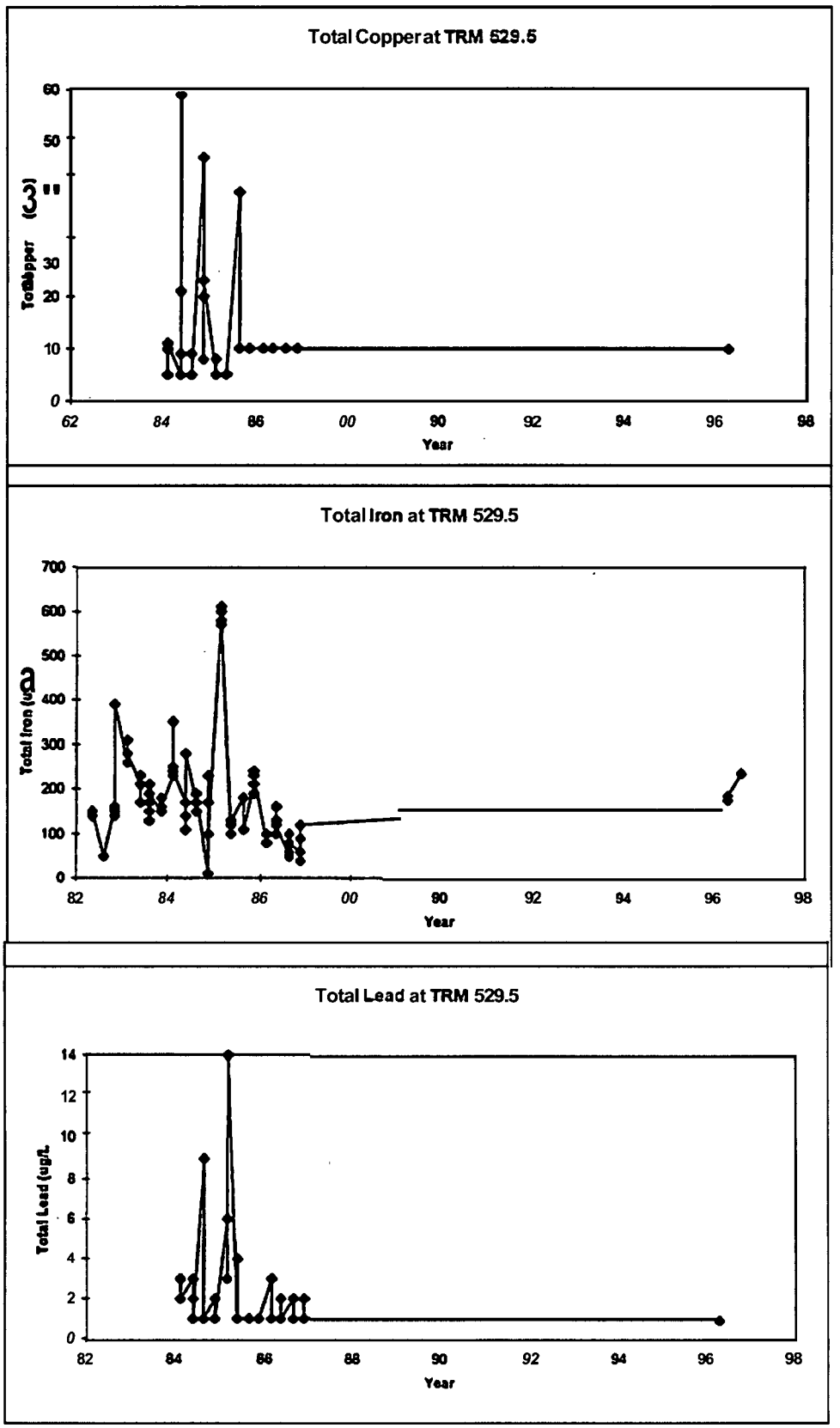

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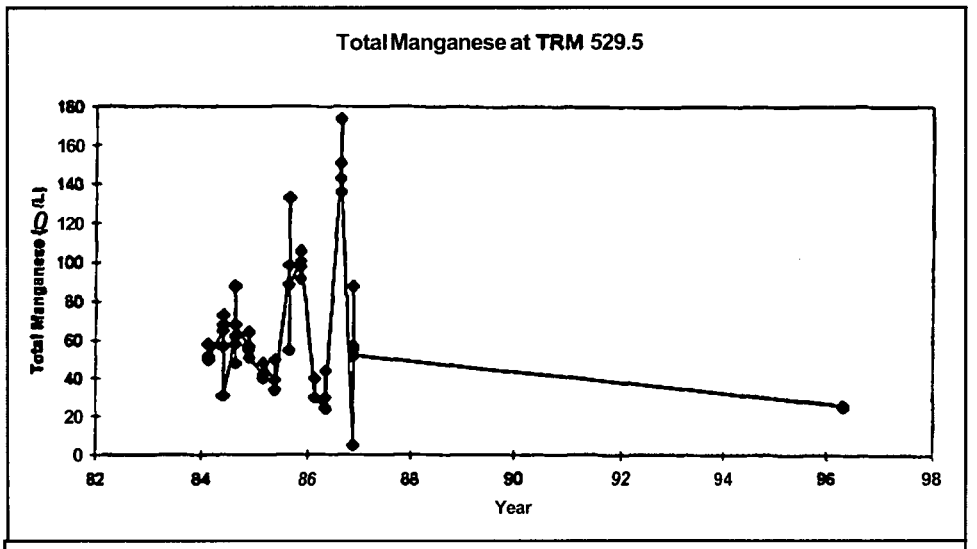

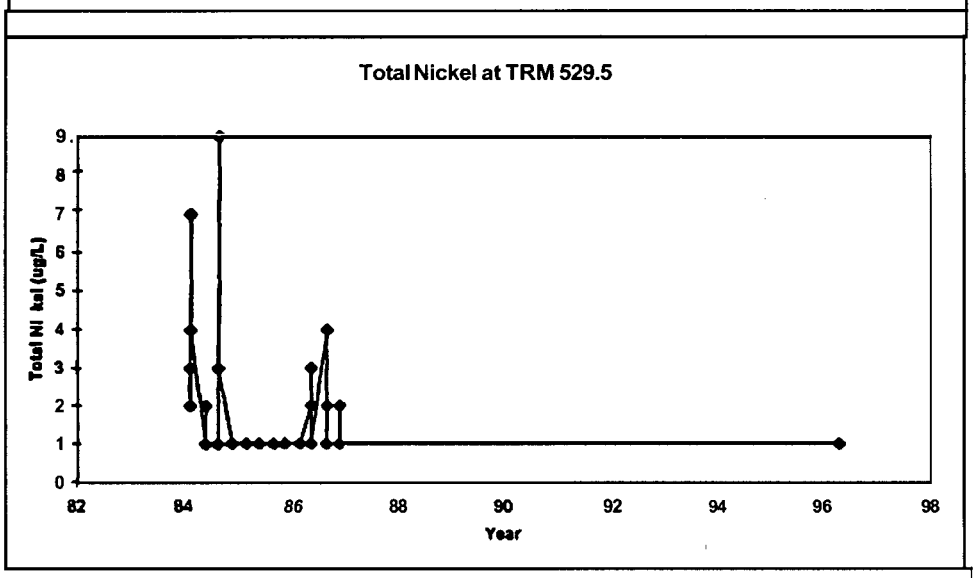

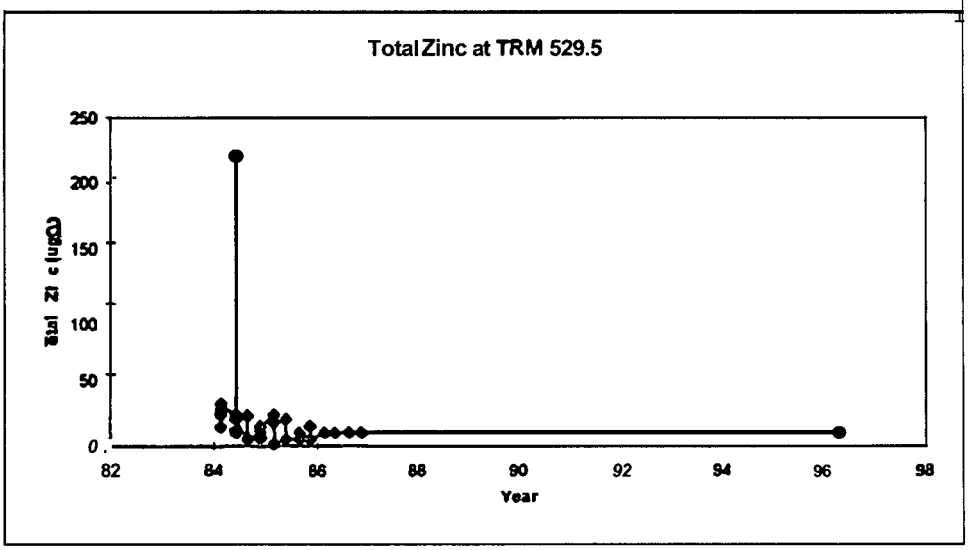

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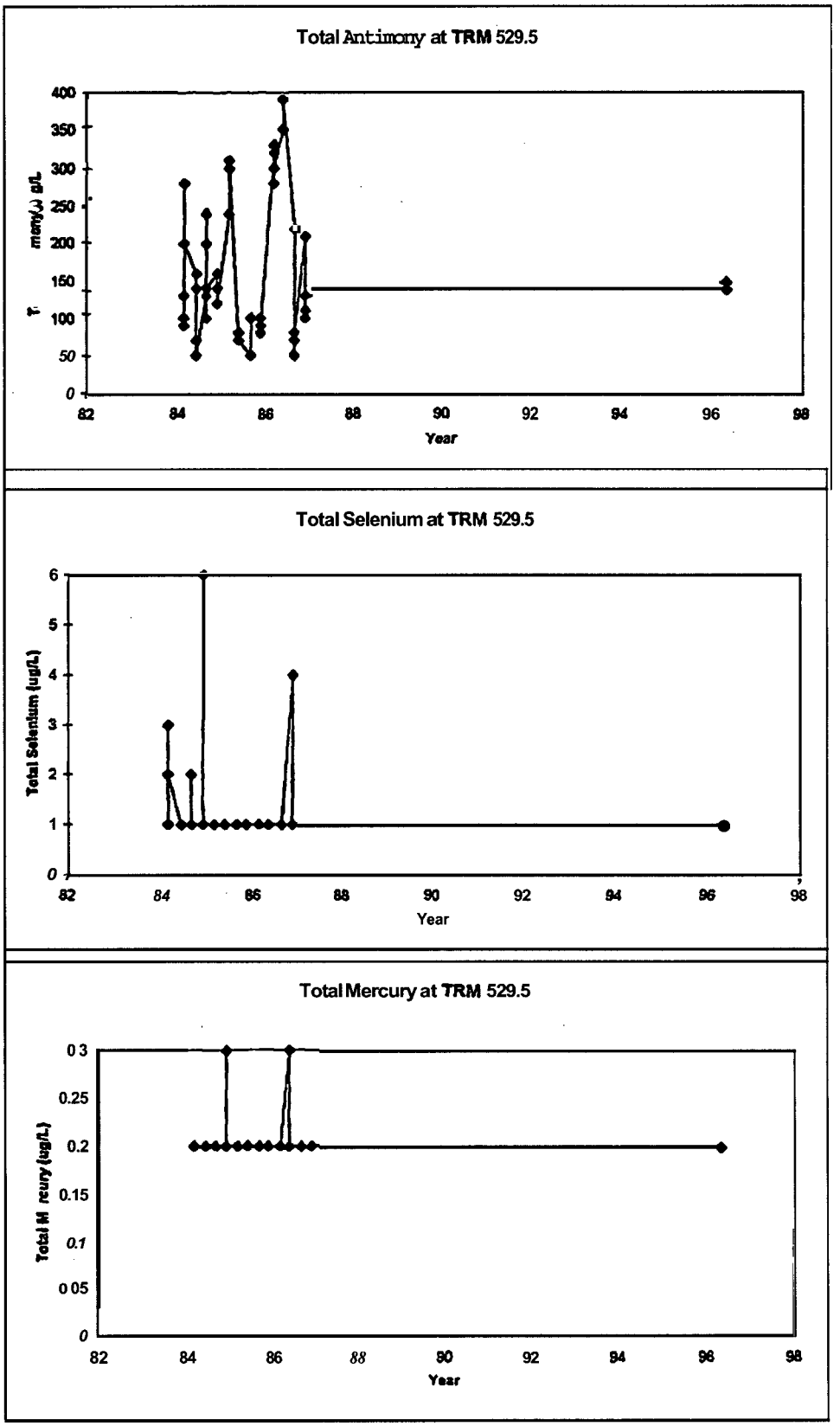

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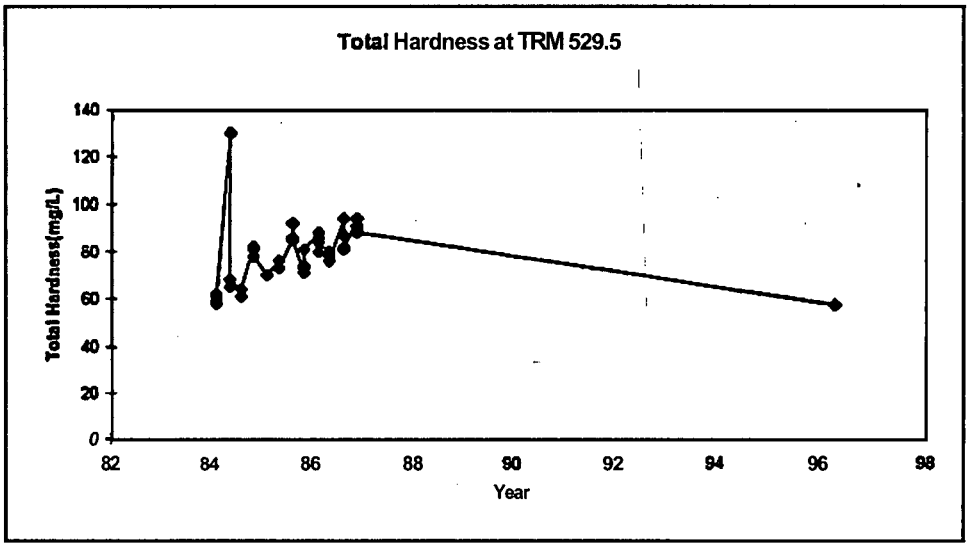

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IMPINGEMENT AT WATTS BAR STEAM PLANT

Watts Bar Steam Plant, TVA's first fuel-burning electric power plant, is located on the right bank of the Tennessee River (Tennessee River Mile 529.2) near the upper end of Chickamauga Reservoir about 1,036 meters downstream of Watts Bar Dam (Figures 1 and 2). The four-unit plant, rated at 240,000 kW total capacity with a 280,000 gpm condenser cooling water requirement, became fully operational in April 1945. Although the plant operated on base load during much of its early history, it currently operates as a peaking plant.

Physical Data

Pumping Station - The intake screen house for the circulating water supply system is continuous with the upstream face of the service bay at the Watts Bar hydroplant and contains six intake openings at 90° to the axis of the dam. Each of the six $18.3m^2$ intake openings is equipped with a steel trashrack 6.3 meters high by 2.9 meters wide. The trashrack bars are 12.70 cm wide by ? 0.95 cm thick and are spaced 7.62 cm on centers. Following the trashracks, the water passes through the vertical traveling screens. These are made of 0.61 by 1.83 meter screen panels interlocked and attached to chains operating between sprockets at the bottom and drive sprockets supported on the intake deck. These panels are made of 12-gauge galvanized wire with 0.95-cm (3/8 inch) mesh openings.

Circulating water for the condensers is supplied by gravity from the Watts Bar Reservoir through a conduit system approximately 1,036 meters long. The circulating water supply system is designed to produce a maximum flow through from condensers of 17.67 cubic meters per second (624 cfs) when the Watts Bar Reservoir is at elevation 733 (ft) and the tailwater at the steam plant discharge is at elevation

699, a gross head of 10.36 meters. With this flow through the six screens, there is a calculated velocity throug the trashracks of 25.60 cm/sec (.83 fps).

Biological Data

1. Sampling methods

Samples were collected weekly between August 8, 1974, and May 29, 1975, as follows: at the beginning of the sample period (1,100 hours, Wednesday), all traveling screens were simultaneously rotated and washed clean of fish and debris. Twenty-four hours later, the screens were washed individually, and the impinged fish were collected in a catch basket installed in the screen was sluiceway. All individuals were separated by species into 25 mm length categories and counted. Total weights (grams) for each length class were recorded.

2. Results

Below are listed (Table 1) the total number of each of the 19 species collected from the 33 samples taken at Watts Bar Steam Plant during the sampling period August 8, 1974 through May 29, 1975. Seventy-three percent of the total 2,130 fish collected were shad. The remaining 16 nonshad species which totaled 575 individuals were impinged at an average rate of 17.4 fish per sample.

Since sampling was done on a fixed schedule, independent of plant operation, the average number of screens counted per twenty-four hour sample is assumed to approximate the average number of screens in operation per day throughout the entire sampling period. In addition, the average number of fish collected per sample through the 10-month sampling period is assumed to approximate the average daily impingement for that period. Since Watts Bar is a peaking plant there were several sampling dates on which the plant was not in operation. The percent

of time the plant was not operating on the sampling days (30.3%) is assumed to approximate the percent of time the plant did not operate during the entire 10-month sampling period. Extrapolating the average impingement counts per sample for the number of days the plant presumably operated during the 10-month period August 1974 - May 1975 and will operate during June and July 1975 yields the estimated annual numbers (Table 2) and biomass (Table 3) impinged.

Figure 3 depicts the total number of fish impinged during each of the thirty-three 24-hour samples. The greatest number of fish for a single sample (438) occurred on March 27, 1975, in which 79.9 percent were threadfin shad.

Table 1. Total Number of Each Species Impinged on the Intake Screens of Watts Bar Steam Plant in 33 Samples Collected Between August 8, 1974, and May 29, 1975

Scientific Name	Common Name	Total Number
Alosa chrysochloris	Skipjack Herring	187
Dorosoma cepedianum	Gizzard Shad	36
D. petenense	Threadfin shad	1,333
Hiodon tergisus	Mooneye	13
Notropis antherinoides	Emerald Shiner	1
N. whipplei	Steelcolor Shiner	3
Pimephales vigilax	Bullhead Minnow	1
Ictiobus bubalus	Smallmouth Buffalo	1
Ictalurus furcatus	Blue Catfish	8
I. punctatus	Channel Catfish	17
Pylodictis olivaris	Flathead Catfish	3
Morone chrysops	White Bass	25
M. mississippiensis	Yellow Bass	1
M. saxitilis	Striped bass	1
Lepomis macrochirus	Bluegill	235
Micropterus dolomieui	Smallmouth Bass	5
Pomoxis annularis	White Crappie	19
Apoldinotus grunniens	Freshwater drum	232
Percina caprodes	Logperch	9
Total		2,130

Table 2. Estimated Annual Number of Fish Impinged at Watts Bar Steam Plant (Plant Operating 69.7 Percent of the Time)

Species	Total Number
Clupeidae	11,995
Bluegill	1,812
All other species	2,613
Total	16,421

Table 3. Estimated Annual Biomass (kg) of Fish Impinged at Watts Bar Steam Plant (Plant Operating 69.7 Percent of the Time)

Species	Biomass (kg)
Clupeidae	355.43
Bluegill	25.47
All other species	87.21
Total	468.11

Discussion and Conclusion

Only five of the samples contained more than 100 fish during the sampling period (August 8, 1974, to May 29, 1975). Of the 16 non-shad species collected only bluegill (7.1 per sample) and drum (7.0 per sample) were impinged at an average rate exceeding one individual per 24 hours.

Because Watts Bar is a peaking plant and is of comparatively low generating capacity, its cooling water requirement is low resulting in a low total annual volume of water passed through the plant. These factors undoubtedly account for the low impingement at this plant. Based on the results of this study, we conclude that the impingement of fish at Watts Bar Steam Plant does not constitute an adverse environmental impact to the fish population of Watts Bar Reservoir.

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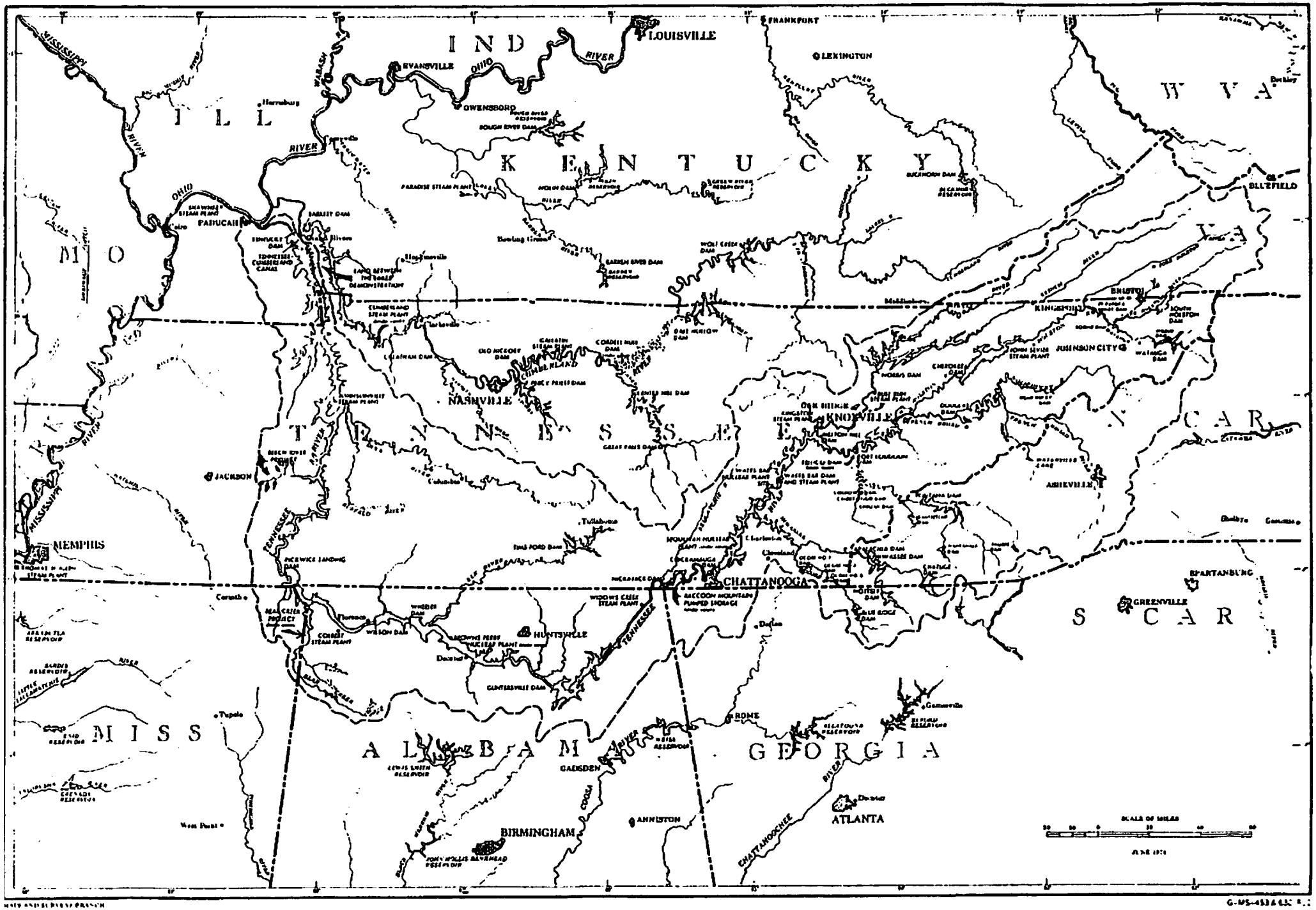
IND
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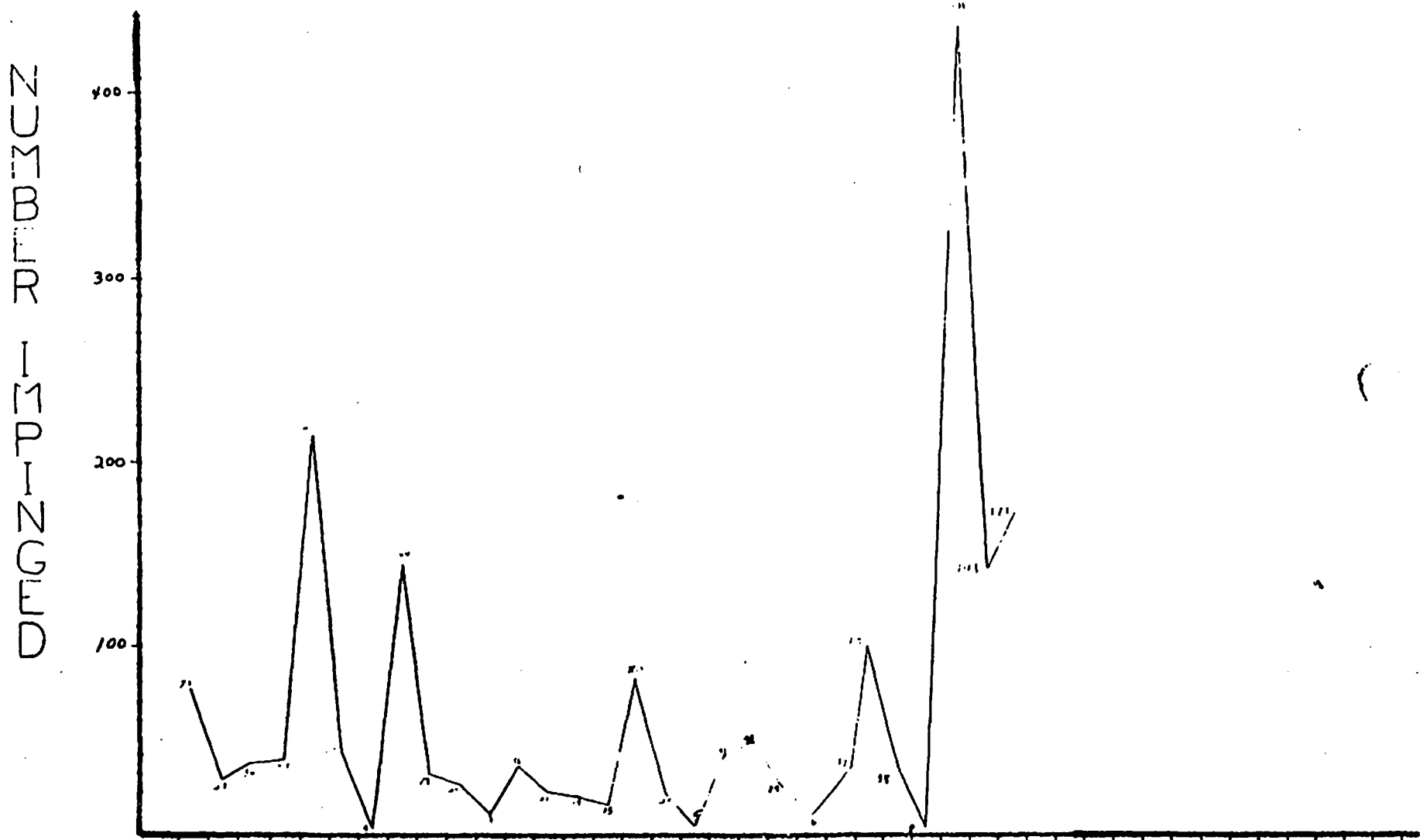
FRANKFORT
LEXINGTON
EVANSVILLE
OWENSBORO
PADUCAH
BLUEFIELD
BRISTOL
KINGSPORT
JOHNSON CITY
KNOXVILLE
NASHVILLE
JACKSON
MEMPHIS
ASHEVILLE
CHATTANOGA
SPARTANBURG
GREENVILLE
HUNTSVILLE
ROME
GADSDEN
ANNISTON
BIRMINGHAM
ATLANTA
OHIO RIVER
MISSISSIPPI RIVER
TENNESSEE RIVER
CUMBERLAND RIVER
CHATTAHOOCHEE RIVER
COOSA RIVER
SCALE OF MILES



Date	8/8	8/15	8/22	8/29	9/5	9/12	9/19	9/26	10/3	10/10	10/24	10/31	11/7	11/14	11/21	12/5	12/12	12/19	1/9	1/16	1/23	1/30	2/6	2/13	2/20	2/27	3/6	3/13	4/1
• Screens	6	6	6	5	5	5	5	5	5	4	3	4	5	5	5	5	4	5	5	5	5	·	5	5	5	5	5	·	5
• Species	6	6	3	5	10	7	5	11	6	6	4	4	6	6	5	13	3	2	4	5	3	4	4	5	8	2	7	·	8

WATIS BAR

7853

TENNESSEE VALLEY AUTHORITY
Water Management

The Effects of Aquatic Macrophytes on Fish Populations of Chickamauga Reservoir Coves, 1970-90

Prepared by
Edwin M. Scott, Jr.

Norris, Tennessee
September 1993

TVA/WM--93/24

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Many Tennessee Valley Authority (TVA) employees contributed to the preparation of this report. James Parsly, Hydraulic Engineering Laboratory, Norris, provided seasonal average daily discharges of the Tennessee River from Chickamauga Dam for 1970-83. Tom McDonough, Water Management, Knoxville, provided the computer program for the regression analyses of rotenone data and consultation. Wayne Hamberger, Systems Engineering, Knoxville, provided percentages of possible sunshine measured at the Chattanooga airport, and Ellen Hammond, Chattanooga Engineering Services, retrieved water temperature, secchi depths, and phytoplankton data from STORET. Tom McDonough and Gary Lucas, Systems Engineering, Hydraulic Engineering Laboratory, Norris, provided additional water temperatures. Leon Bates and David Webb, Water Management, Muscle Shoals, provided macrophyte coverages in Chickamauga Reservoir. Earl Burns and Lee Hill, Water Management, Muscle Shoals, supplied recent information about aquatic macrophyte coverage and aquatic plant management on Chickamauga Reservoir. Sportfishing harvest of bluegill and largemouth bass were obtained from Tennessee Wildlife Resources Agency (TWRA) creel surveys, through Todd St. John, Nashville. Neil Woomer, Water Management, Chattanooga, David Webb, and Leon Bates provided extensive review of this manuscript. Julie Madison, Water Management, Norris, supplied the graphics, and with Libby Bailey, also of Norris, prepared the report. Murrie Graser, Water Management, Norris, designed the cover.

EXECUTIVE SUMMARY

The expansion of submersed aquatic macrophytes in Chickamauga Reservoir had a dramatic effect on the resident fish community between 1970 and 1990. Although the original intent of studies upon which this report is based was to monitor the effects of a nuclear power plant on reservoir fish populations, an additional, unforeseen use of data arose when coverages of aquatic macrophytes expanded from less than 2 percent to 21 percent of the surface area of Chickamauga Reservoir during the study period. The primary purpose of this report is to investigate the relationship of submersed aquatic macrophyte coverage to the abundance of selected fish species in cove rotenone surveys. Species whose abundances significantly correlate with aquatic macrophyte coverage are discussed in detail according to the amount and dominant species of macrophyte present during four designated periods. A secondary purpose looks at the possibility of a relationship between the operation of Sequoyah Nuclear Plant (SQN) and the coverage of aquatic macrophytes in Chickamauga Reservoir.

During Period I (1970-75) aquatic macrophyte coverage in Chickamauga Reservoir was less than 100 hectares (ha). Macrophyte coverage increased greatly in Period II (1976-81) to nearly 2200 ha. Coverages of approximately 2800 ha existed during Period III (1982-88) which coincided with several drought years. Coverage of aquatic vegetation was negatively correlated to flows of the Tennessee River, and increased flows and associated factors (such as scouring and turbidity) during Period IV (1989-90) caused vegetation to decrease to approximately 1400

and 869 ha, respectively. This pattern continued in the 1991 and 1992 seasons when coverage dropped to 275 and 155 ha, respectively.

In the 1960s and 1970s the perennial Eurasian watermilfoil was the dominant species of submersed aquatic vegetation in Chickamauga Reservoir. Then annual species began to increase in abundance, especially spinyleaf naiad which became the most common submersed macrophyte in Chickamauga Reservoir during the 1980s.

Certain fish species became more abundant with increased vegetation coverage. Golden shiner, warmouth, bluegill, redear sunfish, brook silverside, yellow bass, black crappie, and yellow perch are mid-water insectivores which benefited from an increased invertebrate forage base and protective habitat provided by aquatic vegetation. As the forage base for piscivorous species shifted from shad to small sunfish during periods of heavy vegetation coverage, numbers of largemouth bass, an ambush predator, increased.

Other fish species declined in abundance as macrophytes increased. Most of them were open-water, benthic insectivores/omnivores whose feeding habitat in shallow, silted overbanks became colonized with vegetation. Species in this category are carp, smallmouth buffalo, spotted sucker, channel catfish, and freshwater drum. Decline of piscivorous adult white crappie has been attributed to several factors, most of which are directly related to the increase in macrophytes. Declining sauger populations, however, have been attributed to poor spawning success in the headwaters of Chickamauga Reservoir.

Based on preliminary analysis, milfoil appears more beneficial to several important gamefish species than spinyleaf naiad, possibly because of its different underwater growth form and structure.

The operation of SQN had no measurable effect on the coverage of macrophytes in Chickamauga Reservoir, and thus no indirect effects on resident fish populations.

INTRODUCTION

Macrophyte Effects on Chickamauga Reservoir Fish Populations

Monitoring studies of fish and aquatic macrophyte population trends in Chickamauga Reservoir, with respect to operation of SQN, found an overwhelming relationship of aquatic macrophytes and cove fish populations. This relationship developed over time, as aquatic macrophytes were relatively uncommon in the reservoir in the early years studied, became the purpose of this report. Temporal changes in the fish populations were evident in 1979 (TVA 1980), but were not attributed to aquatic vegetation until 1985 when significant ($P>0.05$) increases in abundance of certain species, particularly warmouth, redear sunfish, bluegill, and largemouth bass were detected (TVA 1985). At that time smallmouth buffalo, channel catfish, and freshwater drum showed significantly decreasing trends. A seven-fold increase in coverage of rooted aquatic macrophytes between 1976 and 1983 emerged as the overriding influence on the fish community of Chickamauga Reservoir (TVA 1985), and its alteration of the littoral zone habitat has continued to affect rotenone standing stock estimates of several fish species (McDonough and Buchanan 1991, Kerley 1989, 1990, and 1991). This report analyzes 21 consecutive years of fish sampling on Chickamauga Reservoir, spanning a broad range of aquatic macrophyte coverage.

Interpretations of fish community changes are more complex than simple correlations with amount of aquatic vegetation. Fish communities in reservoirs are not balanced (Noble 1986) and are subjected to highly variable water conditions (rate of spring warming, discharges, turbidity, water level fluctuation) which affect planktonic food chains, spawning

times and success, and early survival of different fish species and interspecific competition between early life stages of fish species. Year class strength of some species depends on high spring discharges following gradual warming of water temperatures. Dissolved oxygen in deeper levels of reservoir such as Chickamauga Reservoir (TVA 1990b) may become limiting for coolwater species during years of low discharges. Aquatic vegetation provides foraging and protective habitat for young of many fish species, according to the size of individual fish.

Influence of Sequoyah Nuclear Plant (SQN) on Aquatic Macrophytes

SQN commenced operation in 1981, the first of eight consecutive years during which Chickamauga Reservoir aquatic macrophyte coverages exceeded 2,000 ha. The existence of SQN as a readily visible factor during these years of macrophyte expansion prompted an examination for any evidence of a connection between SQN operation and macrophyte coverage patterns.

History of Aquatic Macrophytes in Chickamauga Reservoir

Chickamauga Reservoir was created in 1940 with the completion of Chickamauga Dam at Tennessee River mile (TRM) 471. Rooted submersed aquatic macrophytic vegetation was not abundant until the establishment of Eurasian watermilfoil (*Myriophyllum spicatum*) in 1961 (Smith et al. 1967). Milfoil is an exotic plant that was introduced from an aquarium into Watts Bar Reservoir, the next reservoir upstream, about 1953. From its establishment in Chickamauga Reservoir until the mid-1970s milfoil was the only abundant submersed aquatic macrophyte within the reservoir. While milfoil coverage expanded in most mainstream Tennessee River reservoirs between 1970 and 1985, spinyleaf naiad (*Najas minor*), another

exotic species, became the dominant species of vegetation in Chickamauga Reservoir in 1982 (Bates et al. 1985). It continued to be more abundant than milfoil until 1989 when there was a major decline in naiad coverage (Figure 1). Annual coverage of spinyleaf naiad (in combination with southern naiad, N. guadalupensis) and milfoil have fluctuated greatly over time. Hydrilla (Hydrilla verticillata) was found on Chickamauga Reservoir in 1988 (Burns et al. 1989), but has been rarely observed in recent years since treatment with herbicides (Lee Hill, TVA, personal communication).

As milfoil coverage expanded and colonized shallow water habitat along developed shorelines, the Tennessee Valley Authority (TVA) designated priority areas (Figure 2) for herbicide treatment. In addition to the application of herbicides such as 2,4-D to control milfoil and Aquathol K to control naiads, other management techniques currently in use include drawdowns and reservoir surcharge. Milfoil is vulnerable to winter drawdowns because it is a perennial, and its exposed root masses are subjected to lethal winter temperatures. The naiads, which are annuals have seeds which are less affected by dewatering. Winter drawdowns are particularly effective in controlling milfoil within the drawdown zone of Chickamauga Reservoir, relative to other TVA mainstream reservoirs, because the magnitude of the drawdown is greater, over 2.5 m, thereby exposing large areas with milfoil colonies.

Total macrophyte coverage (all species combined) in Chickamauga Reservoir has been dynamic over the past 15 years. Coverage increased from less than 20 ha in 1974 to about 300 ha in 1976. Between 1977 and

1983, total coverage of aquatic macrophytes increased seven fold (422 to 2,791 ha) and colonized 19 percent of the surface area of Chickamauga Reservoir. During this period, spinyleaf naiad became the dominant submersed species of aquatic vegetation. Submersed aquatic vegetation declined in 1984 (2,161 ha) due to record heavy rains in May, and high flows and increased turbidities, which suppressed growth of deep water colonies (TVA 1985). Aquatic macrophytes in Chickamauga Reservoir reached their greatest abundance during the drought years of 1985-88, averaging over 2,700 ha annually, as clearer water allowed naiads and other macrophytes to grow in deeper water. Peak abundance occurred in 1988, when over 3,000 ha or 21 percent of the total surface area of Chickamauga Reservoir, was colonized. As more normal rainfall patterns returned to the Tennessee Valley in 1989 and 1990, coupled with unusually high flows in June and July 1989, submersed aquatic vegetation dramatically decreased (Burns et al. 1991) to about 1,400 and 900 ha, respectively. High seasonal flows continued in 1991 and 1992, and submersed macrophytes declined to 275 ha in 1991 (Burns et al. 1992) and 155 ha in 1992 (Lee Hill, TVA, personal communication).

Macrophyte Management Plan for Chickamauga Reservoir

The TVA management plan for controlling aquatic macrophytes in Chickamauga Reservoir (Burns et al. 1992) does not attempt the total eradication of aquatic vegetation. Instead the intent is to control vegetation in priority areas: i.e., high-use recreation and public access areas, areas adjacent to residences, resorts, and marinas, small areas of exotic plant colonies in newly colonized reservoirs that could become major problems, and areas of dense vegetation that harbor mosquito

populations. Approximately 3 percent of the surface area of Chickamauga Reservoir is designated for herbicide treatment if vegetation is excessive. During recent drought years (1985-88), when vegetation coverages exceeded 3,000 ha, about 650 ha-treatments were were made with herbicides annually. Although some of these areas during good growth periods received 2 or 3 treatments during the growing season, the physical areas treated did not exceed 3 percent of the total reservoir surface. Treatment has been reduced along with a natural decline of vegetation in 1989 and 1990, and only 130 ha (cumulative) were treated in 1990 (Burns et al. 1991). The downward trend in vegetation continued in 1991 and 1992, and treatment was reduced to 26 ha in 1992 (David Webb, TVA, personal communication).

Role of Macrophytes in the Aquatic Ecosystem

The literature is rich with information regarding the role of aquatic macrophytes in aquatic ecosystems. To quote John Muir, "When one tugs at a single thing in nature, he finds it attached to everything else in the world." So it seems with aquatic macrophytes. The complex morphology of aquatic macrophytes creates a diversity of microhabitats for colonizing organisms (from epiphytic algae and invertebrates to zooplankton to benthic macroinvertebrates to young and/or small fishes, as well as adult fish of some species) and provides refuge from predators (Miller et al. 1989). Macrophytes also modify the physical environment by directly or indirectly affecting the chemical composition, nutrient cycles, and biological features of the ecosystem. Published literature reporting importance and impacts of macrophytes have been reviewed by Gregg and Rose (1982), McDermid and Naiman (1983), Pandit (1984), Engel (1985,

1988), and Carpenter and Lodge (1986).

Aquatic macrophytes alter the velocity of waves and currents, modify sedimentation patterns and substrates, stabilize habitats, reduce erosion, affect temperature regimes, and influence available light. Macrophytes store nutrients during spring and early summer, thereby delaying blooms of blue-green algae until the macrophytes senesce in midsummer (Engel 1985). Macrophyte beds, by intercepting runoff, storing nutrients, and retarding algal blooms, can improve water quality (Goulder 1969, Modlin 1970, according to Engel 1985).

Diel variation in photosynthetic and respiration rates within macrophyte beds can cause depletion of oxygen and dissolved inorganic carbon and change pH. Oxygen depletion may be severe in morning hours following night respiration (Losee and Wetzel 1988). During summer when aquatic macrophyte biomass is greatest, diel ranges of dissolved oxygen and pH in a Missouri reservoir were as wide as 14 mg/l and 3 pH units, respectively (Wiley and Jones 1987). Daytime DO concentrations were 230 percent greater near macrophyte beds than no-plant zones (Sculthorpe 1967, according to Miller et al. 1989). Submersed macrophytes are important in maintaining chemical equilibria of the carbon dioxide-bicarbonate buffering system of the surrounding water mass.

Sediment-water interactions of aquatic macrophytes greatly influence the hydrochemistry and nutrient cycles in aquatic ecosystems. Nutrients are absorbed from the sediments by rooted species of plants and released back into the water during senescence, providing a nutrient resource for

phytoplankton (Miller et al. 1989).

Aquatic macrophytes greatly increase habitat available to aquatic invertebrates. Submersed macrophytes provided nearly 10 times more surface area for invertebrate colonization than did the entire benthic area of Lawrence Lake, MI (Losee and Wetzel 1988). Macrophytes support complex interactions of invertebrate behavior, life cycles, and predator-prey relationships. The most common invertebrate organisms in macrophyte beds are crustaceans, chironomids, oligochaetes, and gastropods, with the majority being herbivores such as scrapers, shredders, filterers, and collectors. Less common are predators represented by Coleopterans (beetles), Odonates (dragonflies and damselflies), and Hemipterans (giant water bugs, backswimmers, water scorpions, and water boatmen) (Miller et al. 1989). Core samples indicated more benthic invertebrates below macrophytes than areas devoid of macrophytes.

Significant differences have been documented in the macroinvertebrate communities associated with Eurasian watermilfoil and open littoral habitats of the mainstream Tennessee River (Pardue and Webb 1985). Greater numbers of taxa and individual organisms occurred in dense beds of watermilfoil. Immature insects, amphipods, naidid worms, and leeches were more abundant in the milfoil than in open water areas. A non-burrowing mayfly, Caenis, an important fish food organism, was more abundant in the milfoil, probably due to the increased surface area provided by the highly dissected leaves of watermilfoil as well as the protection from predation afforded by the vegetation. However, a

burrowing mayfly, Hexagenia bilineata, a highly important fish food organism, preferred the open littoral zone, presumably because the milfoil root system interferes with the ability of the mayfly nymphs to establish burrows.

Larval fishes are typically more abundant in submersed aquatic macrophyte beds than open water areas (Paller 1987), using them as a refuge from predators and feeding on associated zooplankton (Healey 1984). In Orange Lake, Florida, the greatest number of larval fish species was captured in floating-emergent vegetation, which was also important as a nursery area for juveniles of many species (Conrow et al. 1990). In Spirit Lake, Iowa, 17 of 21 YOY species studied were more abundant along vegetated shorelines than adjacent areas devoid of vegetation (Bryan 1989).

Macrophyte beds support higher densities of fish than areas without macrophytes (Borawa et al. 1979, Killgore 1979, Savitz 1981). Largemouth bass and bluegill behavior differs in lakes with and without aquatic macrophytes (Savitz et al. 1983). Small fishes (less than 120 mm long) find shelter in macrophyte beds denser than 200 g dry weight/m^2, while movement of larger fish is restricted (Hall and Werner 1977, Engel 1985, Mittlebach 1988). Small bass and bluegills avoid no-plant zones along shore, while larger individuals inhabit lower density macrophyte beds offshore (Engel 1985). Juvenile bluegill and longear sunfish numbers were positively correlated with the height of vegetation, and largemouth bass and other game species were more abundant in beds of hydrilla in shallow water than open water areas (Killgore 1979).

METHODS

Aquatic macrophyte coverage has been quantified annually since 1978 using aerial photography. Overflights were conducted in September or October. Aquatic macrophyte colonies were identified to species or dominant species combinations, delineated during photointerpretation, and area of coverage determined by planimetry (TVA 1985). Macrophyte coverages before 1977 were estimated from herbicide treatment records and by visual inspection (Leon Bates and David Webb, TVA, Water Management, Muscle Shoals, Alabama).

Relationships of vegetation coverage with average daily discharge from Chickamauga Reservoir, mean water temperature, percentage of possible sunshine, and the previous year's vegetation coverage were analyzed by linear regression (SAS Institute, 1985) for the period 1971-92. Daily discharges at Chickamauga Dam, water temperatures (1.5 m depth) at the SQN intake (TRM 484.7), phytoplankton densities and secchi readings near SQN, and sunlight availability at the Chattanooga airport (National Oceanic and Atmospheric Administration, Climatic Data Center, Asheville, North Carolina) were averaged for each year during the first four months of the growing season (March - June), which is the critical period for growth of submersed aquatic vegetation (David Webb and Leon Bates, TVA, personal communication).

Aquatic macrophyte coverage for Chickamauga Reservoir and management units 1, 3, 5, and 8 (Figure 3) was used to evaluate impacts of SQN operation on submersed aquatic vegetation. Coverage data were obtained

from seasonal workplans of TVA's aquatic plant management program. Trends upstream of SQN were from units 5 and 8, and those downstream from units 1 and 3.

Fish community trend analysis was based on twenty-one consecutive years (1970-90) of cove rotenone surveys conducted in the lower and middle areas of Chickamauga Reservoir (Figure 2), following standardized methods (TVA 1980). The four coves sampled were Gold Point (TRM 476.2R), Chigger Point (TRM 478.0L), Sale Creek (TRM 495.0R/TRM 495.1R), and Gillespie Bend (TRM 508.0R). Log transformed standing stock estimates (number +1/ha) were analyzed by linear regression to determine correlations of submersed aquatic vegetation coverage with total and individual fish species abundances for three size groups. Significant trends, determined at the 0.05 alpha level, were discussed in the text. Trends in total fish biomass were also evaluated by regression analysis. Although the rotenone coves were sprayed with herbicides beginning in 1982 to facilitate the retrieval of fish, vegetation in areas adjacent to the coves was not treated.

Cove rotenone surveys are biased toward fish species inhabiting shallow shoreline areas. Common shoreline species in Chickamauga Reservoir (carp, golden shiner, several sunfish species, largemouth bass, yellow perch, brook silverside, and adult gizzard shad) are adequately sampled by cove rotenone surveys. However, during summer, when rotenone surveys are conducted, species such as black crappie, white crappie, sauger, freshwater drum, channel catfish, yellow bass, smallmouth buffalo, and spotted sucker prefer open-water and/or deeper, cooler water

than that usually found in coves. Although open-water and deepwater species are not collected in their true abundance by cove rotenone methods, trends in their abundance may reasonably be discerned in TVA's long-standing database.

The twenty-one year time span was divided into four periods according to amount and dominant species of submersed aquatic macrophyte coverage (Figure 4). Standing stocks of fish species significantly correlated with macrophyte abundance were discussed for each period. During Period I, 1970-75, aquatic vegetation was sparse, covering less than 100 ha annually (ranged from 4 to 77 ha), and was primarily milfoil. Macrophyte coverage increased from 293 to 2,188 ha during Period II, 1976-81, and milfoil continued to be dominant. In Period III, 1982-88, vegetation on Chickamauga Reservoir reached its greatest coverage, ranging between 2,161 and 3,175 ha. Spinyleaf naiad, and to a lesser extent southern naiad, were the dominant species of aquatic vegetation during this time period, which included several drought years, especially 1985-88. During Period IV, 1989-90, vegetation decreased to 1,388 and 861 ha, respectively, and was primarily milfoil. The recent trend in macrophyte coverage in Chickamauga Reservoir is similar to trends observed in three other Tennessee River mainstream reservoirs (Figure 5).

Annual reservior-wide estimates of bluegill and largemouth bass harvest, 1977-91, were provided by TWRA creel surveys (TWRA 1992). Because creel surveys span the entire reservoir and year, their results are not directly comparable to shallow cove rotenone surveys conducted in midsummer. Data collected in 1986 were disregarded due to questionable validity (Todd St. John, TWRA, Nashville, personal communication).

RESULTS AND DISCUSSION

Overall Fish Community

Total fish standing stocks of each size class showed significant positive correlations with aquatic macrophyte coverage in Chickamauga Reservoir (Figure 6A). The trend was most evident for young-of-year (YOY) fish, whose average abundance increased from 8,097/ha during Period I to 26,000/ha and 37,150/ha during Periods II and III, respectively. But when vegetation sharply declined in Period IV, average standing stock of young fish fell to 20,000 fish/ha. Biomass of young fish was also significantly related to aquatic vegetation, ranging from 10.7 kg/ha in 1970 to 112 kg/ha in 1985 (Figure 6B). Average densities of intermediate fish increased from 571 fish/ha in Period I, to 1,212 and 1,206 for the next two time periods. Unlike young fish, intermediate sizes increased when vegetation plummeted in Period IV, averaging nearly 2,000 fish/ha. Biomass of intermediate fish was not significantly correlated with vegetation, and ranged from 12.6 kg/ha in 1980 to 91.2 kg/ha in 1971. Standing stocks of adults averaged 962 individuals/ha in Period I, and grew to averages of 1,407 and 2,035/ha during Periods II and III, respectively. Adult abundance dropped slightly in Period IV. The expansion began with a low of 537 fish/ha in 1970, peaked at 2,818 in 1983 during Period III, after which there has been a gradual, general decline. Biomass of adults was also significantly related to the amount of vegetation coverage, and was greatest during Period III when the average biomass was 269 kg/ha.

A hydroacoustic survey of Chickamauga Reservoir embayments in August, 1990, indicated fish numbers and biomass were positively related to surface coverage of aquatic macrophytes (Meinert et al. 1992). That study agrees with findings of the present study described above.

Species Increasing with Aquatic Vegetation

Abundance of several fish species increased with macrophyte abundance, most notably golden shiner, warmouth, bluegill, redear sunfish, largemouth bass, black crappie, and brook silverside. Yellow bass and yellow perch, relatively new inhabitants of Chickamauga Reservoir, also increased in abundance along with vegetation. All of these species are midwater insectivores with the exception of largemouth bass, which is an ambush predator on many of the other species. Gizzard shad also appeared to increase with vegetation; however, quantification of their abundance in Chickamauga Reservoir based on cove rotenone data following the initiation of herbicide treatment of rotenone coves in 1982 is somewhat unreliable. Increased abundance of YOY bluegill, redear sunfish, and warmouth shifted the forage base from shad to small sunfish, as also observed at Guntersville Reservoir during heavy macrophyte infestations (TVA 1989).

Golden Shiner

Golden shiner (*Notemigonus crysoleucas*) abundance (all sizes combined as YOY) was positively correlated with the amount of aquatic macrophyte coverage (Table 1). Average standing stock during Period I was only 3 fish/ha, but increased over a hundred-fold to 369/ha during Period II

(Figure 7). The peak year of abundance during Period II, 1980, occurred at 794/ha. Stocks of golden shiners declined to an average of 270/ha during Period III. Golden shiners reached their greatest abundance to date in Chickamauga Reservoir during Period IV. The two-year average was 547/ha, and the all-time annual peak abundance was 1,000/ha in 1990. The decline in golden shiner abundance during Period III implies that milfoil provides more favorable habitat for this species than spinyleaf naiad.

Preferred golden shiner habitat is moderate to very dense vegetation. Golden shiners consume a wide variety of food organisms, including protozoans, copepods, cladocerans, aquatic insects, and often filamentous algae and higher aquatic plants (Becker 1983). Being an omnivorous, phytophilic species, golden shiners benefit from aquatic vegetation by deriving habitat, invertebrate food sources, and even macrophytic food sources, explaining their recent upward population trends in Chickamauga Reservoir.

Warmouth

Warmouth (*Lepomis gulosus*) YOY standing stocks appeared to be highly correlated with aquatic macrophyte abundance (Figure 8). Averaging only 14/ha in Period I, their abundance increased dramatically to 818/ha (maximum 3,235/ha in 1981) in Period II. Average stock density continued high, 1,303/ha, during Period III, but declined with declining vegetation in Period IV, averaging 237/ha.

Standing stocks of intermediate warmouth significantly increased with vegetation, and their average abundances rose steadily during the four

designated periods. Densities increased from 6/ha to 22/ha to 47/ha and 73/ha during Periods I-IV, respectively. Apparently intermediate warmouth were more able to survive; i.e., escape predation, in less vegetated cover than YOY because of their larger size.

Warmouth are considered food generalists due to the large variation in prey chosen by individual warmouth (Savitz 1981). They are in considerable competition for food with the other fish species present (bluegill, largemouth bass, and yellow perch). Due to their affinity for vegetation, warmouth are considered habitat specialists.

Bluegill

Standing stocks of young and intermediate bluegill (*Lepomis macrochirus*) significantly increased with aquatic macrophytes in Chickamauga Reservoir, 1970-90 (Table 1). In Period I standing stocks of young and intermediate bluegill averaged 1,484 and 261 fish/ha, respectively (Figure 9). Dramatic increases in abundance occurred during Period II when average standing stocks of young bluegill expanded over 10 times (to 16,620/ha), peaking in 1980 at nearly 27,000/ha, and numbers of intermediate sizes almost tripled (to 717/ha). The second-highest abundance of intermediate bluegill occurred in 1980 at 977/ha. But in Period III bluegill abundance fell. Young bluegill declined to about 70 percent (11,913/ha) of their density during Period II, while intermediate bluegill were less affected, dropping to 575/ha. During Period IV intermediate bluegill rebounded to an average of 973/ha, almost double their density during Period III. Peak abundance of intermediate bluegill, 1,096/ha, occurred in 1990. However, YOY bluegill continued to

decline in Period IV, dropping to 6,071/ha. As was the case for warmouth, intermediate size bluegill are better able to escape predation in less dense vegetation than the smaller sizes.

Adults followed the same trend as intermediate bluegills, although their abundance did not significantly increase ($P>0.05$) with total vegetation coverage during the 21-year timespan. During Period III numbers of adults declined in rotenone samples, but rebounded in Period IV following the demise of spinyleaf naiad. Adult bluegill abundance in 1990 was similar to that of Period II, when milfoil was the dominant form of aquatic vegetation.

Annual harvest of bluegill fluctuated between 15,000 and 80,000 (Figure 10A), according to creel surveys conducted 1977-91 (TWRA 1992). Over 50,000 were taken in 1979 (Period II), 1987 and 1988 (Period III), and 1990 and 1991 (Period IV). The drop in 1989 harvest may have resulted from the four year drought which lasted until 1989. Increasing harvest in 1990 agrees with cove rotenone data, and the 1991 harvest is the largest recorded in the 15 year period.

Usual catch rates ranged from 1-2 fish/hr, but were highest in 1979 (Period II) when nearly 5 fish/hr were caught (Figure 10B). Lowest catch rates were in 1984 (Period III). Catch rates improved in 1990 and 1991 following the demise of spinyleaf naiad.

Certain aspects of bluegill life history favor their success, measured in increased abundance, in the presence of aquatic vegetation.

Hatched from nests in littoral areas, bluegill larvae migrate into open-water habitat before returning to littoral zones at a length of 12 mm (Conrow et al. 1990). Higher larval densities are found in dense, floating-emergent vegetation than littoral zones devoid of vegetation. Young bluegills find both shelter from predation and an abundant food supply in vegetated areas. Food consists of small invertebrates, including chironomids, mayflies, water mites, amphipods, cladocerans, caddisflies, and odonate larvae, supplemented with bryozoans, snails, and vegetation (Savitz 1981, Engel 1985). Bluegills frequently consume filamentous algae, pondweed leaves, and sprouting macrophytes, presumably for clumps of attached invertebrates (Savitz 1981). Lack of invertebrate food due to depletion of Daphnia and the emergence of chironomid larvae force bluegill to consume vegetation in July and August (Engel 1985). As bluegill grow to approximately 180 mm, their diet changes from microcrustaceans to larger insects, and competition with young largemouth bass sometimes occurs (see discussion below). Bluegills less than 100 mm standard length restrict their habitat to vegetated areas for protection from predation at the expense of higher foraging return available in open waters. Larger bluegills switch to open-water zooplankton as their risk of predation diminishes (Mittelbach 1981).

Bluegill in Lake Conroe, Texas, declined following removal of submersed aquatic vegetation by introduced grass carp (Ctenopharyngodon idella) (Bettoli et al. in press). This is the mirror effect of observations made during Period II in Chickamauga Reservoir when bluegill abundance increased dramatically with increases in aquatic macrophytes.

Redear sunfish

Standing stocks of redear sunfish (*Lepomis microlophus*) have followed a trend similar to that of bluegill in relation to aquatic macrophyte coverage (Figure 11). YOY redear have shown the strongest relationship (Table 1). Average standing stocks of YOY redear of 84/ha in Period I increased fifty-fold in Period II to 4,435/ha, peaking in 1981 at nearly 22,000/ha. Average densities rose slightly during Period III to 4,623/ha, reaching almost 8,000/ha in 1988 which was roughly a third of the peak abundance of Period II. When macrophytes declined in Period IV, standing stocks of YOY redear fell to an average of only 130/ha.

Intermediate redear sunfish abundance also corresponded positively to increased macrophyte coverage. There was a two-fold increase in average standing stocks between Period I and Period II, 21/ha vs. 41/ha. During Period III, standing stocks averaged 128/ha, nearly triple the previous average. Still greater abundances occurred in spite of vegetation declines in Period IV, peaking at over 700/ha in 1989, and averaged 413/ha. Increasing abundances of intermediate redear sunfish during Periods III and IV, while YOY abundances were declining, indicated the advantage of a larger size in being more able to escape predation in sparse vegetation than YOY.

Although overall correlation of adult redear sunfish and aquatic vegetation was not significant at the 0.05 level, useful information in the average standing stocks during the four designated periods was found. Adults were more abundant during the periods when milfoil was the predominant form of aquatic vegetation (Periods II and IV). Standing

stocks averaged 74/ha and 101/ha, respectively for these periods, compared to averages of 42/ha during Period I and 54/ha during Period III. This is consistent with the pattern observed in adult bluegill standing stocks.

Largemouth Bass

Young and intermediate largemouth bass (*Micropterus salmoides*) standing stocks were significantly correlated with acreages of aquatic macrophytes (Table 1). Densities of young ranged from 18/ha in 1972 to 912 in 1980. Average densities in Period I, 66/ha, increased nearly nine-fold to 526/ha during Period II (Figure 12). In Period III average densities of young largemouth bass fell to 206/ha. Average abundance increased somewhat in Period IV to 285/ha.

Standing stocks of intermediate largemouth bass ranged between 3/ha in 1970 to 145/ha in 1981. Average densities were lowest, 28/ha, in Period I, and increased to 87 and 85/ha during Periods II and III, respectively. During Period IV average standing stocks of intermediate largemouth bass fell slightly to 58/ha.

Although the relationship between standing stocks of adult largemouth bass and aquatic vegetation was not statistically significant at the 0.05 level, their numbers generally increased over the 21-year period (Figure 12). The lowest abundance was 3/ha in 1970 (Period I), and the highest was 48/ha in 1985 (Period III). Cove populations of adult largemouth bass varied little since 1987 in spite of declining vegetation after 1988.

An increasing trend in largemouth bass abundance (all sizes combined) relative to aquatic macrophyte coverage is evident in Chickamauga Reservoir coves (Figure 12). The positive relationship between largemouth bass and aquatic vegetation was also evident in Lake Conroe, Texas, when numbers of age-1 and older bass declined after grass carp removed aquatic macrophytes (Bettoli et al. in press).

Fishing effort for largemouth bass in Chickamauga Reservoir increased tremendously between 1977 and 1991 (TWRA 1992). Creel surveys conducted by the State of Tennessee indicate black bass, predominantly largemouth bass, have been the most sought sportfish species in the reservoir since 1982. Estimated angler hours of fishermen seeking black bass increased from 35,000 in 1977 to nearly 600,000 in 1991 (Table 3). Expressed in trips, these figures represent about 8,250 in 1977 compared to nearly 190,000 in 1991. Harvest of largemouth bass increased nearly thirteen-fold between 1977 and 1991, as annual estimates increased from about 5,000 fish in 1977 to nearly 64,000 in 1991, peaking at over 125,000 fish in 1988 (Table 3, Figure 13A). Harvest estimates of largemouth bass numbers and weights were directly ($r=0.64$, $P=0.0100$ and $r=0.89$, $P=0.0001$, respectively) correlated to fishing pressure.

Annual catch rates for harvested fish over the past 16 years averaged about 0.20 fish/hr, ranging from 0.09 to 0.37 fish/hr (Figure 13B). Highest harvest rates occurred in 1983, 1984, and 1988, while lowest rates occurred in 1990 and 1991. Actual catch rates were higher than harvest rates, since many bass fishermen practiced catch and release fishing. Data from 1988 to 1991 indicate roughly 3 times more largemouth

bass were caught than harvested in Chickamauga Reservoir (TWRA 1992). Declining harvest rates in recent years may be partly explained by catch and release fishing.

Harvest of largemouth bass by number and weight and fishing pressure were not significantly correlated ($P>0.05$) with the amount of aquatic macrophyte coverage during the study period. However, there was a positive relationship between catch rates for harvested fish and aquatic macrophytes ($r=0.58$, $P=0.0248$). Largemouth bass were harvested at higher rates during years of heavy aquatic vegetation, perhaps because they were more vulnerable to capture around patches of vegetation. Fishing pressure ($r=0.86$, $P=0.0001$) and harvest of largemouth bass numbers ($r=0.61$, $P=0.0158$) and weights ($r=0.83$, $P=0.0001$) were significantly correlated with year, indicating that all three parameters increased over time. However, harvest rates and average size of largemouth bass did not show a significant trend relative to year.

Comparison of data from 1988 and 1991, years of highly contrasting vegetation coverage, illustrates the effect of aquatic macrophytes on a largemouth bass sport fishery. During 1988, when vegetation was heavy, the number of bass harvested was greatest of the study period, but mean size was smallest, 0.56 pounds (Table 3). Total weight harvested was about 70,000 pounds. Bass were larger when vegetation coverage was sparse in 1991, averaging 1.32 pounds each. Total weight harvested in 1991 was highest of the study period, nearly 85,000 pounds, although the total number harvested was only half that of 1988 (TWRA 1992). Other studies have shown that usually there is an inverse relationship between

mean size of largemouth bass and aquatic macrophyte coverage (Mike Maceina, Auburn University, personal communication).

From 1987 to 1991 over 50,000 pounds of largemouth bass were taken annually from Chickamauga Reservoir (TWRA 1992). The question arises as to the amount of fishing pressure and harvest Chickamauga Reservoir can sustain and still provide a quality sport fishery. Since 1987 the annual harvest rate averaged 1.71 pounds/acre. The greatest harvest rate, 2.39 pounds/acre, occurred in 1991, and was followed in 1992 by the lowest rate in recent years, 1.19 (Table 3). However, all harvest rates, are less than the national average of 2.67 pounds/acre (Jenkins 1982). At Guntersville Reservoir, another Tennessee River mainstem reservoir, 46 miles downstream, harvest rates were higher, but have decreased from 4.70 pounds/acre in 1990 to 3.66 and 1.59 in 1991 and 1992, respectively (Donny Lowery, TVA, personal communication). Fishing pressure and harvest at Chickamauga Reservoir declined in 1992 to 282,000 hours and 30,846 fish, respectively, but harvest rate, catch rate, and mean size improved from 1991 estimates (TWRA 1993).

Small bass and bluegill (39 to 119 mm) seek shelter in aquatic vegetation, but their access into extremely dense vegetation (greater than 300 g dry wt/m^2) is restricted. Medium-sized largemouth bass and bluegill (120 to 179 mm) select loose vegetation or disperse offshore. Bass larger than 180 mm stay offshore or in channels or open areas of the foliage, although during summer they may seek cooler water temperatures provided by overhanging plant canopies (Engel 1988). They frequently occupy small "holes" devoid of plants within dense vegetation, and become

ambush predators, whereas in sparse vegetation they actively pursue prey (Killgore et al. 1989).

Principal food items of small largemouth bass inhabiting vegetation are chironomids, odonates, mayflies, fishes, and cladocerans (Engel 1985). The onset of piscivory by young largemouth in Lake Conroe, Texas, was delayed by abundant aquatic vegetation, as largemouth bass smaller than 100 mm rarely consumed fish (Bettoli et al. 1992). Most did not become piscivorous until reaching lengths of 140 mm. But when vegetation was very sparse, piscivory of young largemouth bass was common at smaller lengths, down to about 60 mm. Earlier piscivory translates into faster growth rates of young largemouth. In Wisconsin fish in the diet outnumber insects when bass lengths exceed 240 mm. (Engel 1985). In Oklahoma crayfish are the dominant food of bass in dense vegetation, followed by bluegill and YOY bass. In heavier vegetation YOY bass are more vulnerable to predation than bluegill, until they grow large enough to escape predation, about October (Summers 1980).

Largemouth bass production is enhanced by the presence of aquatic macrophytes; however, there is a point where increasing aquatic vegetation leads to decreased bass production, presumably due to foraging inefficiencies brought about by excessive plant growth. That point appears to be above 20 percent coverage in studies of 30 Texas reservoirs (Durocher et al. 1984). Optimal largemouth bass production in Illinois ponds dominated by Potamogeton crispus and Najas flexilis occurs at an aquatic macrophyte standing crop of 52 grams dry weight/m^3 (Wiley et al. 1984). Bass growth is also reduced in waters having dense vegetation (Engel 1985).

In experiments of various densities of simulated vegetation, largemouth bass switch foraging behavior from active searching to ambush tactics as plant density increases. Fathead minnows and golden shiners are more vulnerable to predation than bluegills (Savino and Stein 1982a). As simulated vegetation becomes extremely dense, bass predatory activity declines in response to reduced visual contact with bluegills and the ability of the bluegills to "hide" (Savino and Stein 1982b). Other laboratory experiments indicate that in sparsely vegetated environs largemouth bass are food specialists, whereas in dense vegetation they are food generalists (Anderson 1984).

Largemouth bass and bluegill are commonly found together in aquatic macrophyte beds, and the initial relationship observed is that of predator-prey. However, this is a function of size; i.e., the larger bass is the predator and the bluegill is the prey. Given the differences in size, both species have been designated as food specialists since there is very little or no competition for food (Savitz 1981). But when size is taken into account, and both species are smaller than 120 mm, diet overlap can be as high as 70 percent (Engel 1988). Diet overlap decreases to only 11 percent as the two species grow beyond 180 mm with bass consuming insects and small fish while bluegills graze zooplankton. Young of year bass and YOY yellow perch (25-49 mm) have a slightly overlapping diet for invertebrates in West Point Lake, Alabama-Georgia until midsummer at which time bass switch to small fishes (Timmons 1984).

Black crappie

Although black crappie (*Pomoxis nigromaculatus*) were present in cove

rotenone samples as far back as 1972, they have only recently become common in Chickamauga Reservoir (Figure 14). Recent increases in YOY black crappie standing stocks were significantly correlated with increases in aquatic macrophyte coverages (Table 1). Increased water clarity during the drought years of 1985-88 may have favored black crappie over white crappie, which tend to do better in turbid water. Since increased water clarity also encourages aquatic macrophyte growth, it is not possible to say which had the larger effect on black crappie abundance. YOY black crappie were very rare in cove rotenone samples in Periods I and II, occurring in only three years and averaging only 1 fish/ha. During Period III average standing stocks improved greatly, to 16/ha, and the peak abundance occurred in 1988 when 102/ha were found. Following the decrease of naiads in Period IV, YOY black crappie abundance remained high, as standing stocks were 18 and 72/ha, respectively.

Increases in intermediate black crappie abundance were also correlated with aquatic macrophytes, but their numbers have not expanded greatly. None were found in rotenone surveys in Period I, and the average during Period II was only 1 fish/ha. Three fish/ha was the average density during Periods III and IV. Peak abundance of intermediate black crappie occurred in 1988 when standing stocks were 12/ha.

The shift in dominance to black crappie from white crappie in Chickamauga Reservoir has been recently attributed to increased aquatic macrophyte coverage (McDonough and Buchanan 1991). Young black crappie

are thought to benefit more from vegetated areas for invertebrate feeding and shelter than white crappie which prefer deeper, more open-water habitats. This is particularly important in Chickamauga Reservoir where juvenile crappie survival is critical to harvestable-size recruitment. At lengths less than 200 mm both crappie species are zooplanktivorous and insectivorous (Ellison 1984). Adults of both species are mainly piscivorous, but black crappie are somewhat slower to convert to a fish diet, and are less adapted to capturing prey in turbid water than white crappie.

In a natural Wisconsin lake, crappie (presumably black crappie) occupied the pelagic region adjacent to macrophyte beds during summer and were spatially segregated from largemouth bass and bluegill (Engel 1985). They ate mainly zooplankton (Daphnia, Mesocyclops, and Leptodora) and relatively few insects, making their diet more specialized than largemouth bass or bluegill, and remained zooplanktivorous until about 200 mm. Small crappie consumed food under 2 mm long, while large crappie food measured 5 mm or more in length. The diets of medium bluegills and crappies overlapped by 90 percent, as both species shared Daphnia and Leptodora. This interspecific competition intensified with the collapse of Daphnia in July. Diets diverged as they grew to larger sizes, with overlaps of only 25 percent (Engel 1985). Fish are of primary importance to adult black crappie on a volume basis, although invertebrates are numerically more important (Becker 1983).

Brook silverside

Brook silverside (Labidesthes sicculus) also have benefited by

increases in aquatic macrophytes (Table 1). Their average standing stocks (all sizes considered YOY) increased from 18/ha during Period I to 100/ha in Period II (Figure 15). Their greatest average abundance, 212/ha, occurred in Period III, peaking in 1986 at 490/ha. Average standing stocks of brook silverside fell to 92/ha in Period IV. Apparently this surface-dwelling species is more suited to abundant naiad growth than abundant milfoil growth.

Affinity of brook silverside for aquatic macrophytes was also reported from Lake Conroe, Texas (Bettoli et al. 1991, Bettoli et al. in press). Stocks of brook silverside collapsed following the removal of aquatic macrophytes by grass carp. However another atherinid species, the inland silverside (Menidia beryllina), increased in abundance, presumably because it was better adapted to open water conditions than brook silverside.

Young brook silverside are pelagic most of their first summer, feeding on cladocerans, copepods, and other small crustaceans. They migrate to shallow shoreline areas as summer ends, joining adult brook silverside. Diet shifts to aquatic and terrestrial insects along with move to shoreline habitat (Pflieger 1975). Their entire lifespan is 17 months (Becker 1983).

Yellow Bass

Standing stocks of all three sizes of yellow bass (Morone mississippiensis), a species not found in Chickamauga Reservoir before 1969 (Starnes et al. 1982), have shown significant positive correlations

with aquatic macrophyte coverage in Chickamauga Reservoir (Table 1). Average YOY abundances have steadily increased over the four periods, although there were marked declines in 1978 and 1979 (Figure 16). Standing stocks increased from an average of 10/ha in Period I to 16/ha in Period II. During Period III, YOY yellow bass abundance averaged 28/ha, but the greatest abundance occurred in Period IV when average stocks were 190/ha. The all-time peak abundance of YOY occurred in 1990 (372/ha).

Intermediate and adult yellow bass also rose in average abundance in the first three periods, but, in contrast to YOY, fell in Period IV. Standing stocks of intermediate yellow bass were 3, 13, 13, and 5/ha, respectively, while adult stocks averaged 1, 4, 5, and 3/ha, respectively, over the four periods.

Young yellow bass feed primarily on small crustaceans (copepods and cladocerans), switching to aquatic insects as they grow (Pfleiger 1975). Based on the positive correlation of YOY yellow bass and aquatic macrophytes in Chickamauga Reservoir, and the enlarged insect fauna associated with aquatic macrophytes, it appears the macrophyte beds provide a desirable invertebrate food supply for YOY yellow bass.

Larger yellow bass also benefited from increased macrophyte coverage, presumably due to invertebrate fauna inhabiting submersed vegetation (Starnes et al. 1982), although fish become more important in their diet as they grow. Adults are mostly piscivorous, feeding on small fish, even young of their own species (Pfleiger 1975).

Yellow Perch

The young of yellow perch (*Perca flavescens*), a non-native species that invaded the Tennessee River system following introductions into headwater reservoirs of the Hiwassee River in North Carolina in the 1950's (Etnier and Starnes, in press), have increased in abundance along with aquatic vegetation in Chickamauga Reservoir (Table 1). Average standing stocks were 1/ha in Period I, 21/ha during Period II, 12/ha during Period III, and finally 32/ha in Period IV. Relatively high abundances were found in three years of Period II (1978 [36/ha], 1980 [41/ha], and 1981 [39/ha]) and one year of Period IV (1990 [48/ha]), when milfoil was the dominant macrophyte (Figure 17). YOY yellow perch abundance was also high in one year of Period III, 1988 (48/ha), but was less than 10/ha during the other six years of Period III.

Although trends in intermediate and adult abundance were not significantly correlated with coverage of total aquatic macrophytes, annual standing stock estimates imply yellow perch abundance is related to the type of aquatic vegetation Chickamauga Reservoir. Stocks rose from averages of 8 and 4/ha for intermediate and adult sizes, respectively, during Period I to 54 and 20/ha during Period II. But in Period III, average intermediate and adult stocks fell to 28 and 14/ha, respectively. When naiads declined and milfoil was once again the dominant macrophyte in Period IV, average standing stocks of intermediate and adult yellow perch rebounded to all-time highs of 118 and 83/ha, respectively. Thus, standing stocks of yellow perch appear to be more related to the species of aquatic macrophyte present than the amount of aquatic macrophyte present; i.e., they are more numerous during years of

greater milfoil coverage than years when naiads are more abundant.

Yellow perch are termed food generalists due to large trophic diversity (Savitz 1981). They feed mostly on small invertebrates, along with some minnows and darters, putting them in competition with other fish species inhabiting littoral vegetation. They prefer habitats with cooler water than bluegill, warmouth, and largemouth bass (Timmons 1984), thus segregating them somewhat spatially.

Gizzard Shad

Standing stocks of YOY gizzard shad (*Dorosoma cepedianum*) have significantly increased with aquatic macrophytes in Chickamauga Reservoir (Table 1), but have been highly erratic over time, according to cove rotenone surveys (Figure 19). The average density in Period I was only 38 fish/ha, although they were considerably more abundant during 1970 and 1971. In Period II the average YOY gizzard shad density increased to 338/ha due to high densities of 1,905 and 115/ha during 1977 and 1978, respectively. Highest average standing stocks, 850/ha, occurred during Period III, and ranged from about 60/ha in 1984 to 2,800 in 1985. YOY gizzard shad dropped to about 8/ha but rebounded to 741/ha during Period IV.

There are several possible explanations for the variable abundance of gizzard shad in rotenone samples. YOY gizzard shad form pelagic, actively foraging schools in open-water areas during daylight hours, creating patchy distributions. When the block net is placed across the mouth of the rotenone cove late in the afternoon, schools of YOY shad may

or may not be trapped in the cove. Increasing milfoil colonies between 1978 and 1981 reduced feeding zones inside the rotenone coves, resulting in apparent declining stocks of YOY shad. Beginning in 1982, coves were treated with herbicides to remove vegetation and facilitate collection of fish during rotenone surveys. However, this activity created open areas in the vegetation and may have attracted YOY shad into the "new" feeding zones. Standing stocks jumped in 1982 and remained high during the years of naiad dominance, but this is not believed to be a result of the increased vegetation, rather an attraction to the open areas following herbicide treatment.

Another factor complicating conclusions about YOY gizzard shad abundance drawn from rotenone surveys is species interactions with YOY threadfin shad. Evidence of competition between the two shad species followed the severe winters of 1976-77 and 1977-78, which caused high mortalities of temperature-sensitive threadfin shad. Coincident with greatly reduced stocks of YOY threadfin shad in cove rotenone samples, the following summers were very high stocks of YOY gizzard shad (Figure 19). Both species have extended, overlapping spawning seasons of approximately three months in the spring and early summer (Wallus and Kay 1990), and resultant young shad may be in frequent competition for planktonic food organisms during their first summer. (Inability to identify larval shad prevents research on interspecific competition in areas where they coexist.)

An obvious shortcoming of cove rotenone surveys to measure YOY gizzard shad abundance is the fact that standing stocks of adults are

usually one or two orders of magnitude greater than the abundance of young (Figure 18). This amplifies the pelagic nature of YOY shad; i.e., the young are not sampled by cove rotenone in their "true" reservoir abundance. Hydroacoustic surveys provide better measurement of fish in the pelagic zone, which are primarily YOY shad during the summer.

Regression analysis indicated that adult gizzard shad standing stocks are significantly correlated to aquatic macrophyte coverage (Table 1). However, for the same reasons as YOY gizzard shad, adult shad should not be expected to increase in abundance with vegetation because their preferred habitat is open water (Wallus and Kay 1990). Declining abundance in 1979 and 1980 samples, before coves were treated with herbicides, may just indicate foraging habitat of adult shad was reduced by increased macrophyte coverage (Figure 18). There was little difference in average standing stocks between Periods I and II, 622 vs. 773 fish/ha, respectively. However, a major increase occurred during Period III, when average abundance doubled to 1,547 fish/ha. But since coves were treated with herbicides during this period, their observed abundance is not considered to be directly associated with the amount of aquatic vegetation, but instead due to the attraction of open-water foraging habitat within the macrophyte beds created by herbicide treatments. As the abundance of macrophytes plummeted in Period IV, gizzard shad abundance "fell" to an average of 933 fish/ha, which may be a more accurate measurement of their true abundance.

Aspects of gizzard shad early life history have a direct bearing on year classes of other species. Due to their sheer numbers and extended

period of occurrence, larval and juvenile gizzard shad have an enormous effect on the planktonic food supply necessary to support young fish of spatially and temporally coincident species. Gizzard shad measuring between 6-25 mm in length feed exclusively on zooplankton (Kissick 1988) and later switch to phytoplankton. Selective predation on zooplankton populations by young gizzard shad is substantial (Cramer and Marzolf 1970), and can lead to zooplankton depletion (Kissick 1988). In one study gizzard shad less than 20 mm in length ate zooplankton (Cyclops, Bosmina, and Daphnia), but gradually switched to phytoplankton when they grew beyond 22 mm (Cramer and Marzolf 1970). Another study showed shad zooplanktivory continued to 30 mm, with small shad larvae less than 25 mm selecting larger zooplankton (Cyclops and Calanoida) and larger larvae feeding on smaller zooplankton (Bosmina and Keratella), while a 35 mm specimen had fed exclusively on the phytoplankter Pediastrum (Barger and Kilambi 1980). Young gizzard shad virtually cease feeding at night (Kissick 1988). In pond experiments gizzard shad suppressed bluegill growth and recruitment by removing planktonic food needed by small bluegill which indirectly affected growth of largemouth bass that preyed upon bluegill (Kirk and Davies 1985). In Ohio reservoirs peak densities of larval gizzard shad can drive zooplankton to temporal extinction, thereby limiting recruitment of other fish species and controlling fish community composition (DeVries and Stein 1992). Competition for planktonic food during larval stages to the detriment of other species has also been demonstrated with threadfin shad (Ziebell, et al. 1986, DeVries et al. 1991).

The timing of shad spawning, determined by water temperature, is a

major factor in largemouth bass year class strength. Gradually rising temperatures in the spring delay shad spawning, separating them more temporally from the earlier-spawned largemouth bass. This favors YOY bass survival by allowing them to grow larger before the young shad become available as prey (Adams and DeAngeles 1987). If water temperature rises rapidly, young shad will grow too quickly to be utilized by YOY bass.

Species Decreasing with Aquatic Vegetation

Most of the fish species that have decreased over time are open-water benthic insectivores or omnivores, such as carp, smallmouth buffalo, spotted sucker, channel catfish, and freshwater drum. Their feeding habitat is predominantly broad mud flats. Piscivorous species that have declined, such as sauger and white crappie are also associated with open-water habitat.

Carp

Standing stocks of adult carp (*Cyprinus carpio*) have decreased relative to aquatic macrophyte abundance (Table 1). They were most numerous in Period I when average stocks were 10/ha (Figure 20). Peak abundance was measured in 1971 at 17/ha. As milfoil expanded during Period II average adult carp abundance dropped to 4/ha. During Period III average stocks were 2/ha, and remained at that level through Period IV.

A curious contrast to declining adult carp abundance relative to aquatic vegetation is increasing YOY abundance (Table 1). YOY carp were

virtually absent in cove rotenone samples during Period I, averaging 0.06/ha. As milfoil invaded, average densities jumped to 5/ha, peaking at 24/ha in 1981. Average density fell to 3/ha in Period III. No YOY carp were found in Period IV.

Carp is a highly adaptive species, and tolerates considerable pollution. They are omnivorous, and consume a wide variety of animal and plant material (Pflieger 1975). Aquatic insects are the most important food category. Their decline in abundance in Chickamauga Reservoir cannot be explained solely in terms of vegetation dynamics.

Smallmouth Buffalo

Intermediate and adult smallmouth buffalo (*Ictiobus bubalus*) standing stocks were inversely related to aquatic macrophyte abundance (Table 1). Intermediate smallmouth buffalo abundance averaged highest (7/ha) during Period I (Figure 21). Peak abundance was 36/ha in 1971. This size has been virtually absent from cove rotenone samples since 1975, appearing during only three years.

Adult smallmouth buffalo also were most abundant during Period I, averaging 10/ha during 1970-75. Peak abundance of 25/ha occurred in 1972. As milfoil proliferated in Period II, adult smallmouth buffalo stocks fell to average 2/ha, and remained at that level during Period III. Stocks fell to 1/ha during Period III, following the collapse of naiads.

Smallmouth buffalo are opportunistic bottom-feeders, consuming

aquatic insects, attached algae, crustaceans, and zooplankton (Tomelleri and Eberle 1990). Its feeding behavior is adapted for open, soft substrates, and is apparently hindered by rooted aquatic vegetation.

Spotted sucker

Another benthic invertivore significantly decreasing in abundance relative to aquatic macrophytes is spotted sucker (*Minytrema melanops*), specifically YOY and adults. Average YOY standing stocks were 19/ha in Period I (Figure 22). Peak YOY occurrence was in 1973 when 93/ha were observed. Average density fell to 4/ha during Period II, and further declined in Period III to 2/ha. Their abundance did not change in Period IV.

Standing stocks of adults averaged 13/ha in Period I, and increased slightly to 15/ha during Period II. Peak abundance was 31/ha in 1974. However, as total vegetation reached its greatest coverage in the 1980's, average abundance of adult spotted suckers dropped to 4/ha, and remained low (3/ha) in Period IV.

Food habits of spotted sucker have been little studied, but probable food organisms are molluscs and insect larvae (Forbes and Richardson 1920). A 150-mm specimen had ingested mostly ostracods and chironomid larvae, along with lesser amounts of mayfly larvae, amphipods, copepods, filamentous algae, and higher plant material (Becker 1983).

Channel Catfish

YOY and intermediate channel catfish (*Ictalurus punctatus*) abundance

in Chickamauga Reservoir has decreased in relation to aquatic macrophytes (Table 1). Although YOY have never been particularly abundant in cove rotenone surveys in Chickamauga (all-time peak annual abundance was 9/ha), average standing stocks fell from 3/ha to 2/ha between Period I and Period II (Figure 23). YOY abundance further declined during Period III to an average of 0.4/ha, as none were sampled in five of the seven years of that period. Their numbers remained below 1/ha in Period IV.

Stocks of intermediate channel catfish were highest in Period I, averaging 8/ha. Their greatest abundance, 12/ha, occurred in 1971 and 1972. When milfoil coverage increased in Period II, intermediate stocks decreased to an average of only 2/ha. During Period III this size of channel catfish continued to decline in abundance, falling to an average of 1/ha. No rebound in abundance occurred during Period IV, and the average density of intermediate channel catfish remained at 1/ha.

Standing stocks of adult channel catfish were not significantly correlated at the 0.05 alpha level to aquatic macrophyte abundance, but were highly erratic over time. The peak abundance, 50/ha, occurred in 1981 when milfoil was very abundant; and were it not for this unusual observation, a significant negative relationship would have been found. Average standing stocks were 14/ha and 17/ha during the first two periods, respectively, and dropped to 6/ha in Period III. In Period IV adult channel catfish abundance still averaged only 5/ha.

Channel catfish feed on the bottom and detect food by touch and smell. Food is highly varied, both living and non-living (Becker 1983).

Insects, freshwater clams, snails, fish, and algae are common food items, with fish becoming more important numerically for adult catfish (Tomelleri and Eberle 1990).

White Crappie

The recent decline of white crappie (*Pomoxis annularis*) in Chickamauga Reservoir has been of great concern (Buchanan and McDonough 1990, McDonough and Buchanan 1991). Declining adult stocks have been attributed at least in part to increased aquatic vegetation. Other factors were obviously involved because average density during Period I, 8/ha, increased to 11/ha in Period II (Figure 24). The all-time annual peak density, 30/ha, occurred in 1979 following three years of rapidly climbing milfoil coverage (from 293 to 802 ha). Major declines in adult stocks occurred during Period III, as average abundance fell to 1/ha. In 1987 and 1988 no adult white crappie at all were found in any of the four Chickamauga coves sampled. White crappie did not recover following the naiad decline in Period IV, as average density was less than 1/ha. The peak abundance of YOY in 1987, 135/ha, did not survive to intermediate and/or adult size in succeeding years.

Although spawning success and survival through the first summer were found in Chickamauga Reservoir, year class strength declined during the second summer when mortality was correlated with increased aquatic vegetation, YOY and yearling sunfish and largemouth bass, and adult largemouth bass and gizzard shad (Buchanan and McDonough 1990). Larval sunfish abundance greatly increased during the years of heaviest macrophyte colonization, and the resultant competition for planktonic

food may have reduced larval white crappie abundance in some years. Pelagic crappie also compete with preponderant numbers of larval gizzard and threadfin shad, which are capable of causing zooplankton depletion. Circumstantial evidence from Douglas Reservoir, Tennessee, indicates young, pelagic white crappie do very well in the absence of threadfin shad (Wilson 1991).

In recent years, white crappie have been replaced in dominance by black crappie in Chickamauga Reservoir due to differences in food habits and preferred habitats, especially during the drought period of 1985-88. YOY white crappie abundance was positively correlated with abundance of YOY gizzard shad, and inversely correlated with the abundance of adult threadfin shad. Adult white crappie abundance was positively correlated with dissolved oxygen, and negatively correlated with aquatic vegetation; fishing pressure; density of YOY black crappie, sunfish, gizzard shad, and threadfin shad; yearling stocks of sunfish; and adult density of gizzard shad (Buchanan and McDonough 1990).

Zooplankton food of young white crappie (11-100 mm) included Daphnia, Cyclops, Diaptomus, and Leptodora, with Cyclops being most strongly selected in crappie less than 30 mm. Bottom fauna organisms were unimportant food items. As the fish grew, the order of selection was Daphnia, Diaptomus, and Leptodora (Nelson et al. 1967). Small white crappie (8-17 cm) are pelagic in reservoirs (O'Brien et al. 1984). In Chickamauga Reservoir, juveniles of both crappie species (50-200 mm) had very similar feeding habits, consuming primarily copepods, with lesser amounts of cladocerans and chironomid larvae (Buchanan and McDonough

1990). As previously mentioned, competition with bluegills and other sunfish appears to have seriously impaired year class strengths of white crappie in Chickamauga Reservoir during the 1980's, coincident with heavy colonization of aquatic macrophytes.

In pond experiments the presence of gizzard and threadfin shad decreased the total number and biomass of YOY white crappie (Guest et al. 1990), due to overlapping zooplankton diets as larvae and juveniles. Threadfin shad continue to feed on zooplankton as adults by visual feeding, and suppressed densities of copepods and Daphnia. Adult threadfin shad compete with white crappie for zooplanktonic food, while adult gizzard shad do not. This is consistent with previous studies on Chickamauga Reservoir (Buchanan and McDonough 1990).

Sauger

All three sizes of sauger (Stizostedion canadense) declined coincident with increasing vegetation (Table 1). However the major factor for their decline is believed to be poor spawning success at Hunter Shoals (TRM 521) due to low discharges from Watts Bar Dam during April, especially during the drought years of the mid to late 1980s (Hickman et al. 1990).

YOY sauger abundance averaged 1.2/ha in Period I before aquatic macrophytes were common (Figure 25). Average abundance fell 0.6/ha during Period II, and sauger were only found one year of that 6-year period, 1977, which was also the all-time peak occurrence year, when 4/ha were measured. No YOY sauger were collected in cove rotenone surveys

during Period III, but small numbers reappeared in 1990. These could have been naturally reproduced in Chickamauga Reservoir, but it is more likely they were from 191,000 fingerlings released by the Tennessee Wildlife Resources Agency (TWRA) into Chickamauga Reservoir during 1990 (Hevel and Hickman 1991).

Intermediate sauger declined from 1.0/ha in Period I 0.8/ha in Period II. No intermediate sauger were collected in cove rotenone surveys after 1979. Adult sauger average stocks fell successively during the four designated periods from 1.2/ha to 1.0, 0.4, and finally 0.0/ha, respectively.

Food of young saugers in the 12-50 mm size range includes Daphnia, Cyclops, chironomids, and YOY of other fishes, such as white bass and freshwater drum (Priegel 1969). Fish become more important in sauger diet as the young grow, but microcrustaceans are eaten when smaller fish are unavailable. Juvenile and adult sauger are highly piscivorous in Tennessee River reservoirs, preying heavily upon gizzard and threadfin shad, although Hexagenia nymphs occasionally occur in the diet.

Due to preference for coolwater habitats, sauger are not commonly found in the relatively shallow coves chosen for rotenone samples. Furthermore they are not directly affected by aquatic macrophytes due to their cooler, deeper habitat. But even though rotenone surveys do not provide accurate estimates of sauger abundance, the virtual absence of all three sizes from 1980 to 1990 indicates the species suffered considerable decline in Chickamauga Reservoir during that time period.

Estimates of the sauger spawning population fell from 18,000+ in 1986 to approximately 2,000 in 1991 (Hevel and Hickman 1991)

Sauger larvae do not compete for zooplankton with larval shad and sunfish due to temporal separation; i.e., sauger larvae hatch earlier in the spring than most other species. Instead of competition for food during the larval period, their decline in recent years is attributed to unfavorable conditions for spawning and/or egg survival on the spawning grounds at Hunter Shoals (TRM 521), primarily due to low river flows during drought years (Hickman et al. 1990). Increasing flows since 1989 coupled with a newly-instituted April minimum discharge of 4000 cfs in "dry" years or 8000 cfs during "wet" years for a three year test period at Watts Bar Dam (Yeager and Shiao 1992) should combine with the fingerling stocks by TWRA to improve the sauger fishery in Chickamauga Reservoir in the near future.

Freshwater drum

Decreases in YOY and intermediate freshwater drum (*Aplodinotus grunniens*) were significantly correlated with increasing aquatic macrophytes (Table 1). YOY drum, whose annual standing stocks were as high as 200/ha and 224/ha in 1972 and 1973, respectively, averaged 116/ha during Period I (Figure 26). In Period II standing stocks of YOY drum sharply decreased to only 4/ha. Their average abundance remained at 4/ha during Period III. In Period IV, following the decline of naiads, average density of YOY climbed to 69/ha, mostly due to a large increase in 1990 when 135/ha were found.

Intermediate drum also declined relative to aquatic plant abundance, with average standing stocks dropping from 135/ha in Period I to 39/ha in Period II. Their peak abundance was 275/ha in 1974 while vegetation was still relatively sparse. During Period III average intermediate drum abundance (surprisingly) rose to 64/ha, roughly half the Period I average. In Period IV stocks of intermediate drum rose to an average of 103/ha, and like YOY stocks, had the greater abundance in 1990, 138/ha.

The pelagic young of freshwater drum consume cladocerans and copepods, as do other larval fishes. Aquatic insects, such as chironomids and Hexagenia, become more important as the young grow and become bottom feeders (Becker 1983). Fish, crayfish, and immature aquatic insects provide the bulk of adult drum diet (Pflieger 1975), although Asiatic clams (Corbicula spp.) are frequently consumed by Tennessee River drum.

Milfoil and Spinyleaf Naiad Growth Forms

Many fish species whose numbers increased with aquatic macrophytes reached their greatest abundances during the period when milfoil was the dominant form of aquatic vegetation, 1976-81. Their numbers declined as spinyleaf naiad replaced milfoil as the dominant macrophyte, 1982-88. Abundance of these phytophilic species was not just related to the total amount of vegetation present, but also to the dominant species of macrophyte present.

Differences in leaf morphology and underwater growth form of Eurasian watermilfoil and spinyleaf naiad provide different habitats for

invertebrates and fish. Broad, feathery leaves of milfoil provide abundant surface area for aquatic invertebrates and epiphytic algae (Figure 27A). Bunched stems of milfoil grow from the substrate to the water surface. Near the surface the stems branch to form dense canopies. From substrate level milfoil colonies have the appearance of a forest with distinct trunks (i.e. bunched stems) and an overhead canopy. Since the water column below the canopy remains somewhat open, movement of fish is not entirely restricted. Milfoil colonies usually are most abundant at depths between 1.5 and 3 m. Strands of milfoil persist into the winter, providing habitat for aquatic life well beyond the seasonal growth period.

In contrast, the growth form of the annual macrophyte spinyleaf naiad is dense, bushy, and brittle (Figure 27B). It usually grows in shallower areas than milfoil, often in backs of coves and along shorelines, and has a high density of slender, wire-like stems. During the drought years of the 1980s when the water was unusually clear, this plant expanded its coverage to deeper water (1-2 m) to areas once colonized by milfoil. In shallow water spinyleaf naiad may not form a distinct canopy near the surface. Instead its "Brillo pad" growth form may occupy a large portion of the water column. Fish are less able to move within this growth form than within milfoil. Although some foraging and protection benefit is afforded, spinyleaf naiad may actually decrease shoreline habitat for small fish due to its dense, bushy growth. Furthermore, spinyleaf naiad plants generally "break-up" by September, leaving shoreline areas devoid of vegetated cover for fish and aquatic invertebrates in the mid-fall, winter, and early spring months.

Factors Affecting Aquatic Macrophytes

Univariate regression analysis found that of the variables tested the amount of aquatic macrophyte coverage during the previous year had the greatest influence (r=0.90, P=0.0001) on coverage during the next year (Figure 28). In other words, propagules (milfoil root masses, fragments of milfoil stems, and seed banks of annual species) from the previous season are of prime importance to the magnitude of macrophyte coverage during the following season. Paucity of aquatic vegetation upstream from Chickamauga Reservoir also lessens the likelihood of recolonization by floating fragments. Favorable abiotic growing conditions alone will not produce abundant vegetation.

Sunlight availability was also highly correlated (r=0.68, P=0.0005) with aquatic macrophyte coverage (Figure 29). Sunlight availability in this model was the percentage of possible sunshine reaching the earth's surface. (Actual amounts of sunlight penetrating the reservoir's water surface in vegetated areas, measured with a secchi disc, would have been more appropriate, but were not available for the study period.) As with terrestrial plants, sunlight, the energy source for photosynthesis, has been documented as the most important environmental factor affecting submersed aquatic macrophyte abundance (Barko et al. 1986, Johnstone and Robinson 1987).

During the period 1971-92 aquatic macrophyte coverage was inversely related (r=0.54, P=0.0100) to discharges of the Tennessee River at Chickamauga Dam during the critical part of the growing season (March to June) (Figure 30). Factors associated with high discharges that

negatively affect growth of aquatic macrophytes are increased scouring, siltation, and turbidity caused by suspended solids. Scouring action during high flows may uproot plants or cause fragmentation that results in reduced abundance of aquatic vegetation. Siltation can smother root masses, small plants, and bury seed banks with sediment. Turbidities due to suspended solids absorb sunlight penetrating the water's surface, thereby depriving submersed macrophytes of their photosynthetic energy source. A recent study of Chickamuga embayments also found aquatic vegetation negatively correlated to turbidity (Meinert et al. 1992).

A biogenic source of turbidity that may be important during some years is excessive growth of phytoplankton. Phytoplankton absorb sunlight, and like suspended solids may limit the amount of sunlight available for macrophytes. Although insufficient chlorophyll a and secchi depth data precluded regression analysis, it would be expected that reduced light availability caused by phytoplankton blooms would negatively affect aquatic macrophyte growth and coverage. An unusually large phytoplankton bloom in Chickamauga Reservoir during spring 1990 (Wayne Poppe, TVA, personal communication) may have suppressed aquatic macrophyte growth that year. Excessive phytoplankton blooms and epiphyton growth, associated with eutrophication, have led to reductions of submersed aquatic macrophytes in Chesapeake Bay (Orth and Moore 1983) and Europe (De Nie 1987).

As in other biological processes, temperature affects the growth rate of aquatic vegetation. However, when mean March-June water temperatures for years 1975-92 were regressed against macrophyte coverage, the

relationship was not significant (P=0.4875). This was because two of the lowest mean water temperatures occurred during two of the highest vegetation years, 1983 and 1984 (Figure 31); and the effect of cooler water was overridden by the amount of previous years' vegetation coverage. Removing these two years from the regression yielded a significant relationship (r=0.55, P=0.0290).

Two multiple regression models explained large percentages of the variance in aquatic macrophyte coverage in Chickamauga Reservoir, 1975-92. The better model was:

Sumbersed aquatic macrophytes, hectares =

- 8347.71 + 0.67(Previous season's coverage, hectares)

+ 153.15(Sunlight availability, percentage)

where: R^2 = 0.85 F = 43.02 Prob>F = 0.0001; n = 18.

The second model was:

Sumbersed aquatic macrophytes, hectares =

2814.26 + 0.77(Previous season's coverage, hectares)

- 0.07(Average March-June daily discharge, cfs)

where: R^2 = 0.83 F = 36.6; Prob>F = 0.0001; n = 18.

Because sunlight and discharge were highly correlated (r = -0.84, P = 0.0001), it was inappropriate to include both in the same model.

Herbivorous animals, such as certain species of turtles, can affect the establishment and regrowth of some aquatic macrophytes. This may be especially important when vegetation is sparse. Turtles are trapped and removed from experimental vegetation plantings on Guntersville Reservoir to allow establishment of desirable plant species (Doug Murphy, TVA, personal communication).

Effects of SQN Operation on Aquatic Macrophytes

Because this report has identified populational levels of submersed aquatic macrophytes as having a dramatic effect on the resident fish community in Chickamauga Reservoir, a brief discussion and evaluation of the operational impacts of SQN on aquatic macrophyte communities is included to assess potential indirect impacts to the resident fish community. Macrophyte coverage data used in this analysis would detect only major changes rather than restricted or localized impacts associated with SQN operation.

Since initial operation in 1981, SQN has had no documented effect on growth or distribution of aquatic vegetation in Chickamauga Reservoir. After four years of operation, similarities in trends of vegetation coverage in littoral habitat along mainchannel areas upstream and downstream of SQN showed no significant effect on aquatic macrophyte communities (TVA 1985). During most years between 1977 and 1992, vegetation coverage fluctuated similarly in mainchannel habitat downstream of SQN and upstream of SQN, regardless of SQN operational status (Figure 32). During drought years from 1984 to 1988 aquatic macrophyte coverage remained relatively stable or increased in mainchannel habitat both upstream and downstream of SQN. Beginning in 1989 aquatic macrophyte coverage has declined dramatically on Chickamauga Reservoir (Figure 4) in mainchannel areas both upstream and downstream of SQN. In 1992 there was only about 155 ha of aquatic macrophytes in Chickamauga Reservoir (Table 2).

Significant changes that have occurred in aquatic macrophyte populations on Chickamauga Reservoir are considered to be primarily related to environmental factors associated with natural climatic events such as sunlight availability, water clarity, and flow and not the operational status of SQN. The increase in aquatic macrophyte coverage during the drought years from 1984 to 1988, followed by a dramatic decline in 1989 and 1990 is similar to that of other mainstream reservoirs such as Kentucky, Wheeler, and Guntersville (Figure 5). Because changes in aquatic macrophyte communities are related to factors other than the operational status of SQN, indirect effects of SQN to fish populations are minimal.

CONCLUSIONS

Aquatic macrophytes in the littoral zones of Chickamauga Reservoir have a profound effect on the fish community. Total numbers and biomass of all fish species combined increased with submersed aquatic vegetation coverage. Certain species (golden shiner, yellow bass, warmouth, bluegill, redbreast sunfish, largemouth bass, black crappie, yellow perch, and brook silverside) are favored by increasing vegetation, while others (carp, smallmouth buffalo, spotted sucker, channel catfish, white crappie, and freshwater drum) are hindered. The forage base for piscivorous predators is primarily shad when aquatic vegetation is sparse and small sunfish when vegetation is dense.

The dominant species of vegetation, i.e., milfoil and naiads, differ in leaf morphology and growth form and provide different habitats for

invertebrates and fish. This is believed to affect the abundance of many fish species in Chickamauga Reservoir. Based on preliminary analysis, milfoil appears more beneficial to most of the important gamefish species than spinyleaf naiad because of its growth form.

Black crappie and white crappie abundances are oppositely affected by dense growth of aquatic macrophytes. Young black crappie benefit from an increased invertebrate food source and protective habitat within macrophyte colonies, while white crappie prefer deeper, open-water habitats and do not benefit from shoreline vegetation. Both species are in competition for zooplanktonic food with enormous numbers of young gizzard and threadfin shad and, in seasons of abundant aquatic macrophytes, young of three sunfish species. Clear water in Chickamauga Reservoir during the drought years of the 1980s also contributed to the shift in dominance from white crappie to black crappie.

Decreases in aquatic macrophyte coverage since 1989 should result in a restructuring of the fish community that would reverse some of the trends presented in this report. Species that increased with heavy infestations of aquatic macrophytes are expected to decrease in abundance, while open-water species should increase. White crappie are expected to return as the dominant crappie species in Chickamauga Reservoir.

Factors identified as affecting submersed aquatic macrophyte coverage were macrophyte coverages from the previous year, sunlight availability, and discharges of the Tennessee River. Water temperature

was an important factor in most years. Two factors affecting water clarity, suspended solids and phytoplankton, could not be identified as important factors given the limited amount of available data.

There is no evidence that SQN operation affected the coverage of submersed aquatic macrophytes in Chickamauga Reservoir; thus, there were no indirect effects to the resident fish community.

RECOMMENDATIONS

Further studies of fish communities within milfoil and spinyleaf naiad colonies are needed to verify that differences in community structure of fishes are related to the growth forms of the dominant vegetation species. The present study compared fish densities on an annual basis, and in many years the habitat of the coves was altered by herbicide treatment to facilitate rotenone sampling. Recommended future studies would involve taking rotenone samples in two milfoil-dominated coves and in two similar coves where spinyleaf naiad is the dominant macrophyte. Herbicides would not be used in any of the four coves. All four coves would be sampled during the same summer, and would not be the coves routinely sampled for SQN monitoring.

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Table 1. Fish species showing significant correlation in numerical abundance (numbers/hectare) or weight (kg/hectare) and aquatic macrophyte coverage in Chickamauga Reservoir, 1970-90 by size group*.

Species	Size Group	Slope	F-Value	PR > F
Increasing species				
Total species	YNG_NO	0.00009	52.953	0.0001
Total species	YNG_WT	0.00005	16.842	0.0001
Total species	INT_NO	0.00004	12.612	0.0006
Total species	ADT_NO	0.00004	9.701	0.0025
Total species	ADT_WT	0.00002	5.533	0.0211
Gizzard shad	YNG_NO	0.00021	15.052	0.0002
Gizzard shad	ADT_NO	0.00005	5.495	0.0215
Golden shiner	YNG_NO	0.00020	31.766	0.0001
Carp	YNG_NO	0.00007	17.213	0.0001
Brook silverside	YNG_NO	0.00003	18.379	0.0001
Yellow bass	YNG_NO	0.00008	5.608	0.0203
Yellow bass	INT_NO	0.00010	15.958	0.0001
Yellow bass	ADT_NO	0.00007	17.929	0.0001
Warmouth	YNG_NO	0.00029	101.323	0.0001
Warmouth	INT_NO	0.00012	43.691	0.0001
Warmouth	ADT_NO	0.00008	16.719	0.0001
Bluegill	YNG_NO	0.00011	28.029	0.0001
Bluegill	INT_NO	0.00004	8.434	0.0047
Redear sunfish	YNG_NO	0.00029	90.765	0.0001
Redear sunfish	INT_NO	0.00009	16.591	0.0001
Largemouth bass	YNG_NO	0.00008	13.553	0.0004
Largemouth bass	INT_NO	0.00007	16.721	0.0001
Black crappie	YNG_NO	0.00007	7.933	0.0061
Black crappie	INT_NO	0.00005	12.125	0.0008
Yellow perch	YNG_NO	0.00011	10.140	0.0021
Decreasing species				
Carp	ADT_NO	-0.00007	13.856	0.0004
Smallmouth buffalo	INT_NO	-0.00004	8.922	0.0037
Smallmouth buffalo	ADT_NO	-0.00005	6.777	0.0110
Spotted sucker	YNG_NO	-0.00009	10.875	0.0014
Spotted sucker	ADT_NO	-0.00008	13.301	0.0005
Channel catfish	YNG_NO	-0.00004	8.474	0.0047
Channel catfish	INT_NO	-0.00009	28.297	0.0001
White crappie	ADT_NO	-0.00011	30.338	0.0001
Sauger	YNG_NO	-0.00003	8.439	0.0047
Sauger	INT_NO	-0.00002	6.717	0.0113
Sauger	ADT_NO	-0.00002	5.928	0.0171
Freshwater drum	YNG_NO	-0.00017	26.305	0.0001
Freshwater drum	INT_NO	-0.00005	5.398	0.0227

* YNG_NO = YOY/ha, INT_NO = intermediates/ha, ADT_NO = adults/ha, YNG_WT + YOY kg/ha, ADT_WT = adult kg/ha.

Table 2. Aquatic macrophytes (hectares) in Chickamauga Reservoir, 1970-92.*

Year	Total	Milfoil	Naiads	Pondweeds	Mixed	Algae
1970	11	-	-	-	-	-
1971	13	-	-	-	-	-
1972	20	-	-	-	-	-
1973	4	-	-	-	-	-
1974	13	-	-	-	-	-
1975	77	-	-	-	-	-
1976	293	-	-	-	-	-
1977	422	-	-	-	-	-
1978	802	190	612	0	tr	0
1979	635	-	-	-	-	-
1980	1,328	482	844	1	0	0
1981	2,188	1,225	879	79	4	0
1982	2,626	701	1,827	85	13	0
1983	2,791	759	1,921	2	48	60
1984	2,161	292	1,788	0	116	3
1985	2,275	341	1,799	13	114	8
1986	2,778	477	1,853	3	438	7
1987	2,770	465	1,994	23	267	21
1988	3,017	849	1,901	8	251	8
1989	1,388	869	312	11	221	tr
1990	861	638	69	17	134	4
1991	275	100	8	11	149	tr
1992	155	71	27	9	24	6

tr--less than 0.5
* Coverages for 1970-77 and 1979 are estimates from surveys and herbicide treatment records; coverages for 1978 and 1980-92 were determined by aerial photography.

Table 3. Angling summary for black bass in Chickamauga Reservoir, 1977-92.*

Year	Estimated Hours	Estimated Trips	Estimated Number Harvested	Estimated Weight Harvested	Harvest Rate (No./Hr)	Mean Weight (Lbs.)	Estimated Weight Per Acre
1977	35,331	8,251	5,014	6,736	0.141	1.34	0.19
1978	28,418	6,675	5,931	6,792	0.208	1.15	0.19
1979	44,171	9,830	11,930	14,010	0.270	1.17	0.39
1980	123,020	28,829	17,760	25,989	0.144	1.46	0.73
1981	123,304	26,909	22,730	28,027	0.184	1.23	0.79
1982	163,736	36,088	31,332	41,000	0.191	1.31	1.15
1983	132,551	27,022	39,983	48,765	0.301	1.22	1.37
1984	113,106	23,310	36,654	41,720	0.324	1.14	1.17
1985	135,017	29,840	23,006	27,943	0.170	1.21	0.78
1986	-	-	-	-	-	-	-
1987	291,517	58,733	46,355	57,996	0.159	1.25	1.63
1988	336,764	114,336	125,686	70,233	0.373	0.56	1.98
1989	273,732	53,399	43,477	54,795	0.158	1.26	1.54
1990	449,698	86,198	42,030	54,314	0.093	1.29	1.53
1991	598,039	189,486	63,971	84,542	0.106	1.32	2.39
1992	281,895	104,793	30,846	41,951	0.120	1.36	1.19

* TWRA 1992, 1993.

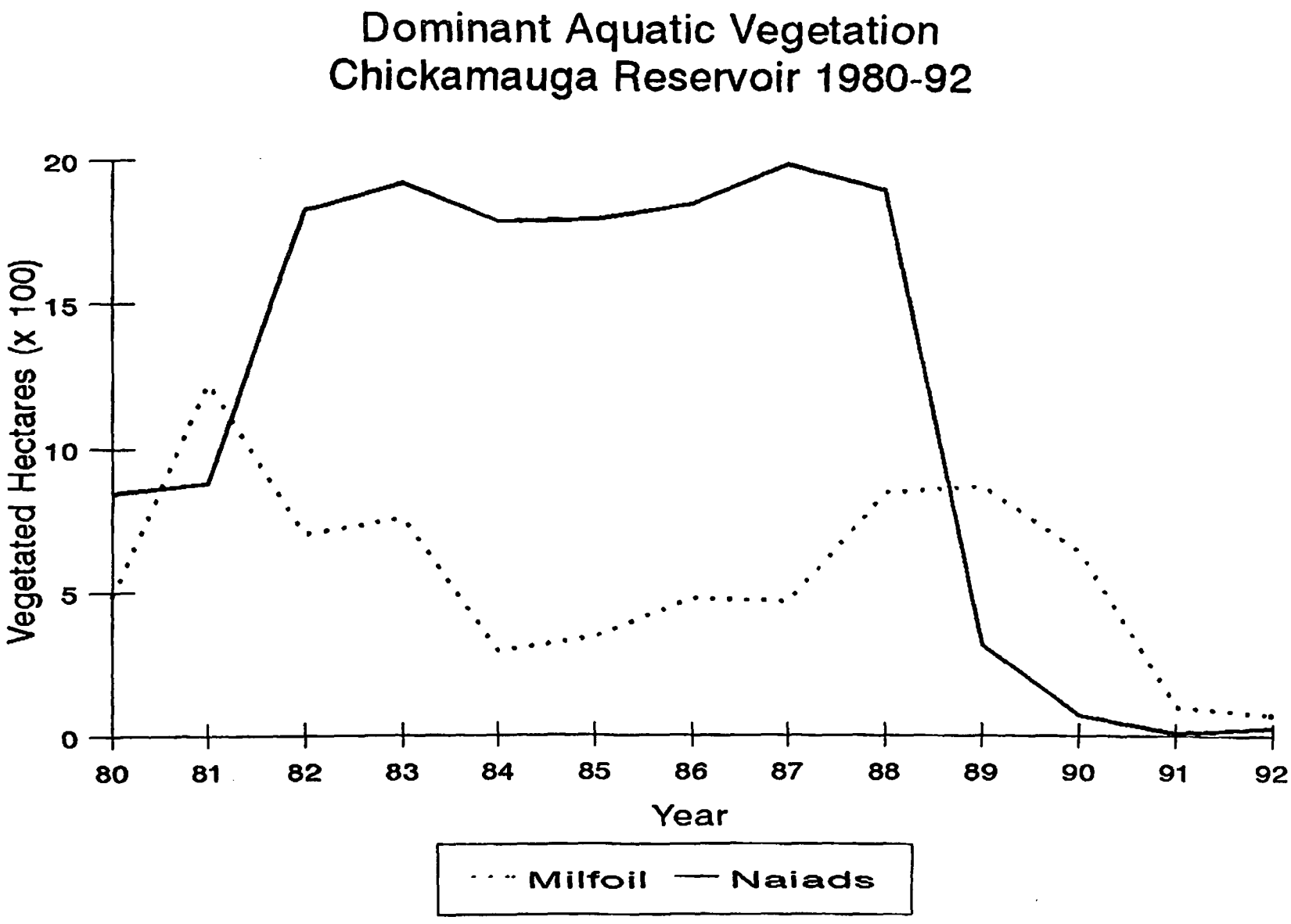

Figure 1. Coverages (hectares) of Eurasian watermilfoil and spinyleaf naiad in Chickamauga Reservoir, 1980-92.

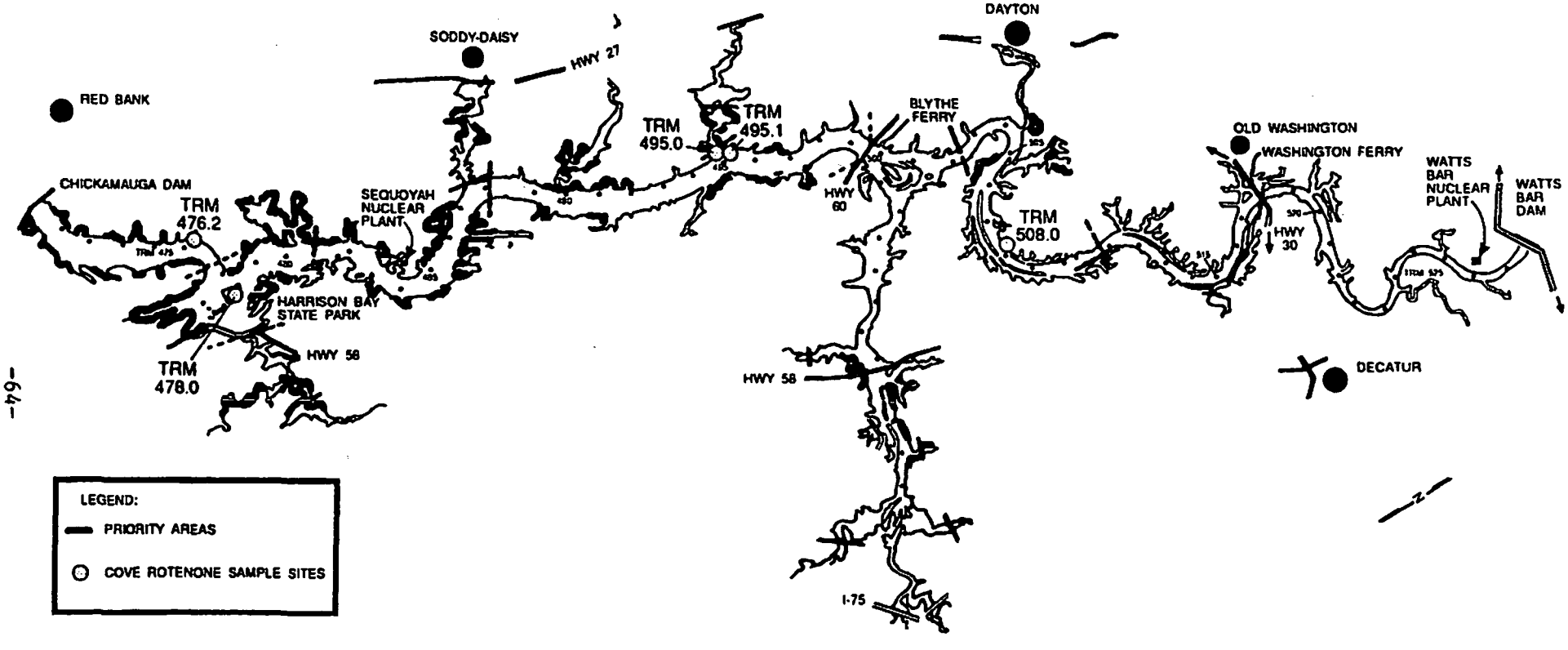

Figure 2. Locations of cove rotenone sample sites and priority areas treated with herbicides in Chickamauga Reservoir, 1970-90.

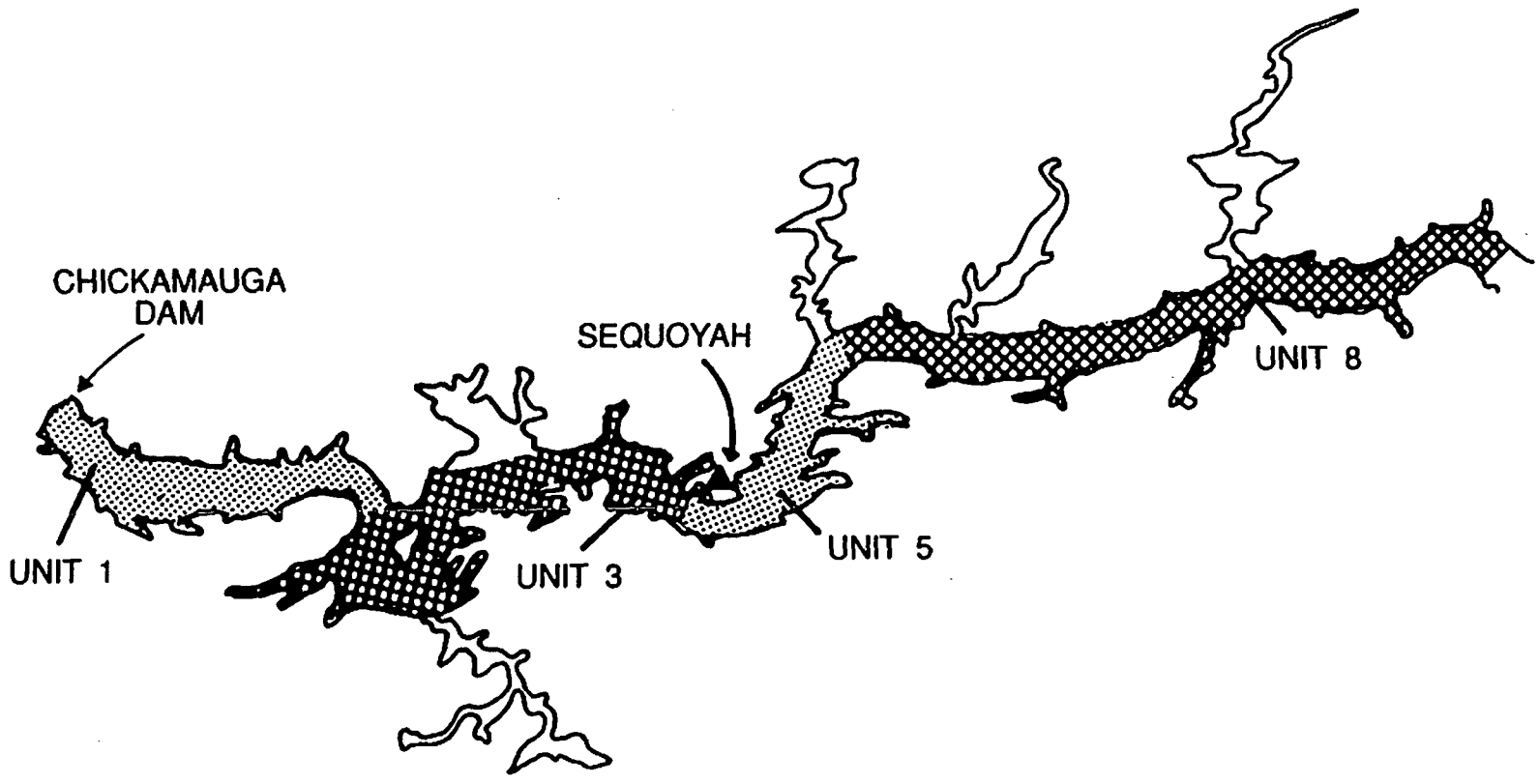

Figure 3. Mainchannel aquatic plant management units on Chickamauga Reservoir in the vicinity of SQN.

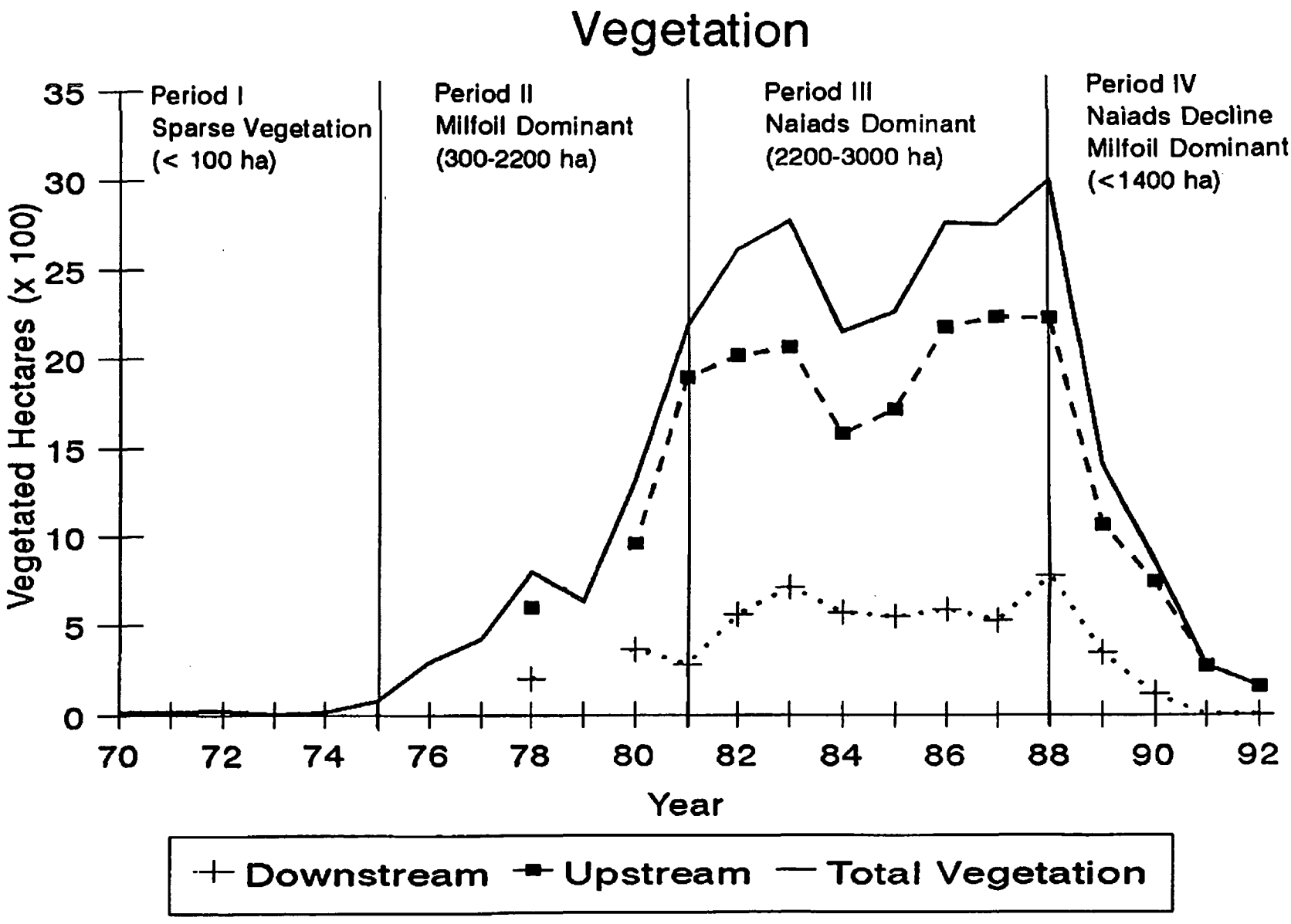

Figure 4. Total coverage of aquatic macrophytes in Chickamauga Reservoir (solid line), upstream and downstream from SQN (dashed lines), and four time periods based on extent of macrophyte coverage and dominant species present, 1970-92.

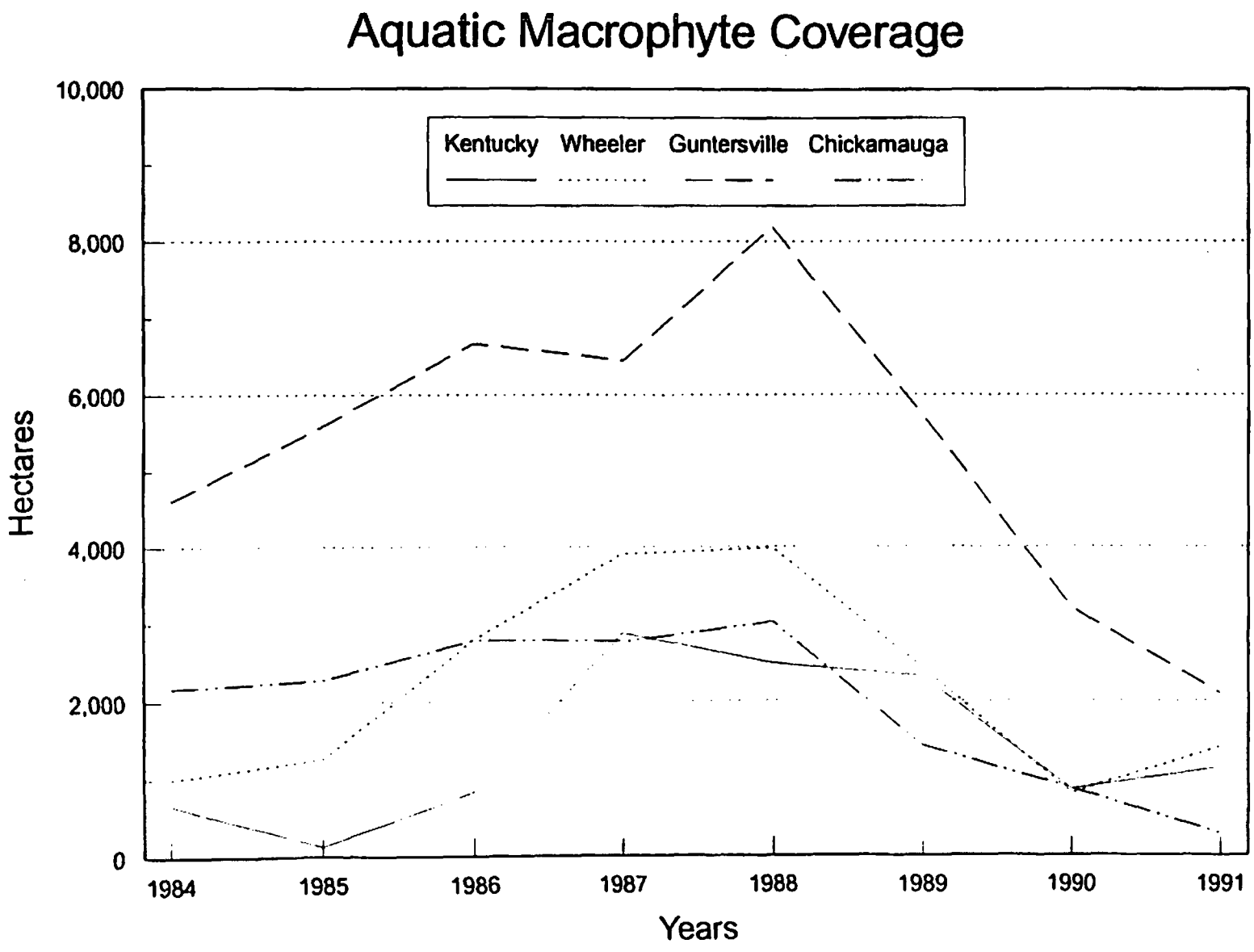

Figure 5. Total macrophyte coverages of four TVA mainstream reservoirs, 1984-91.

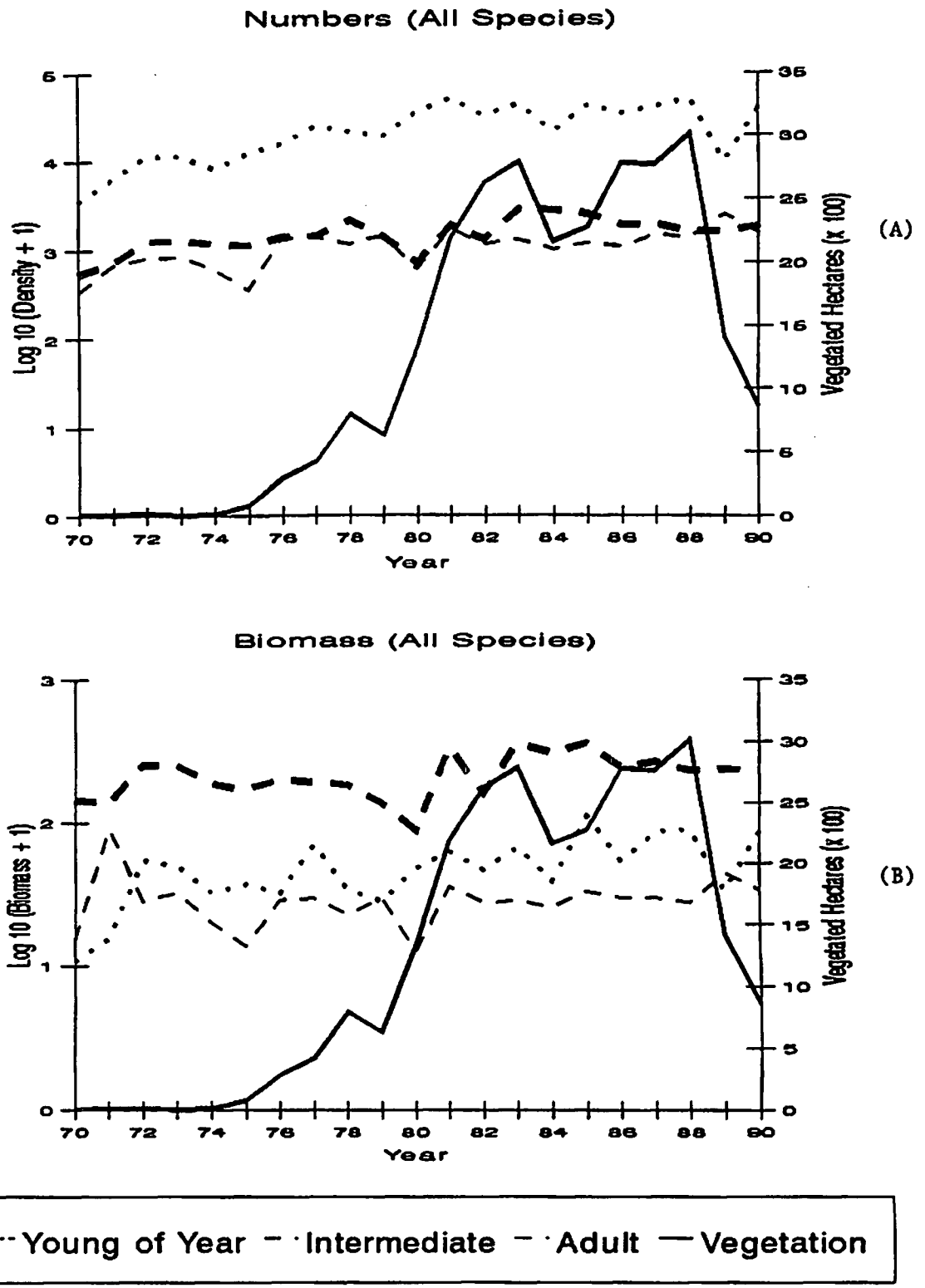

Figure 6. Annual standing stock densities (A, numbers/hectare) of all species combined and biomass (B, kg/hectare) as determined by cove rotenone sampling, 1970-90.

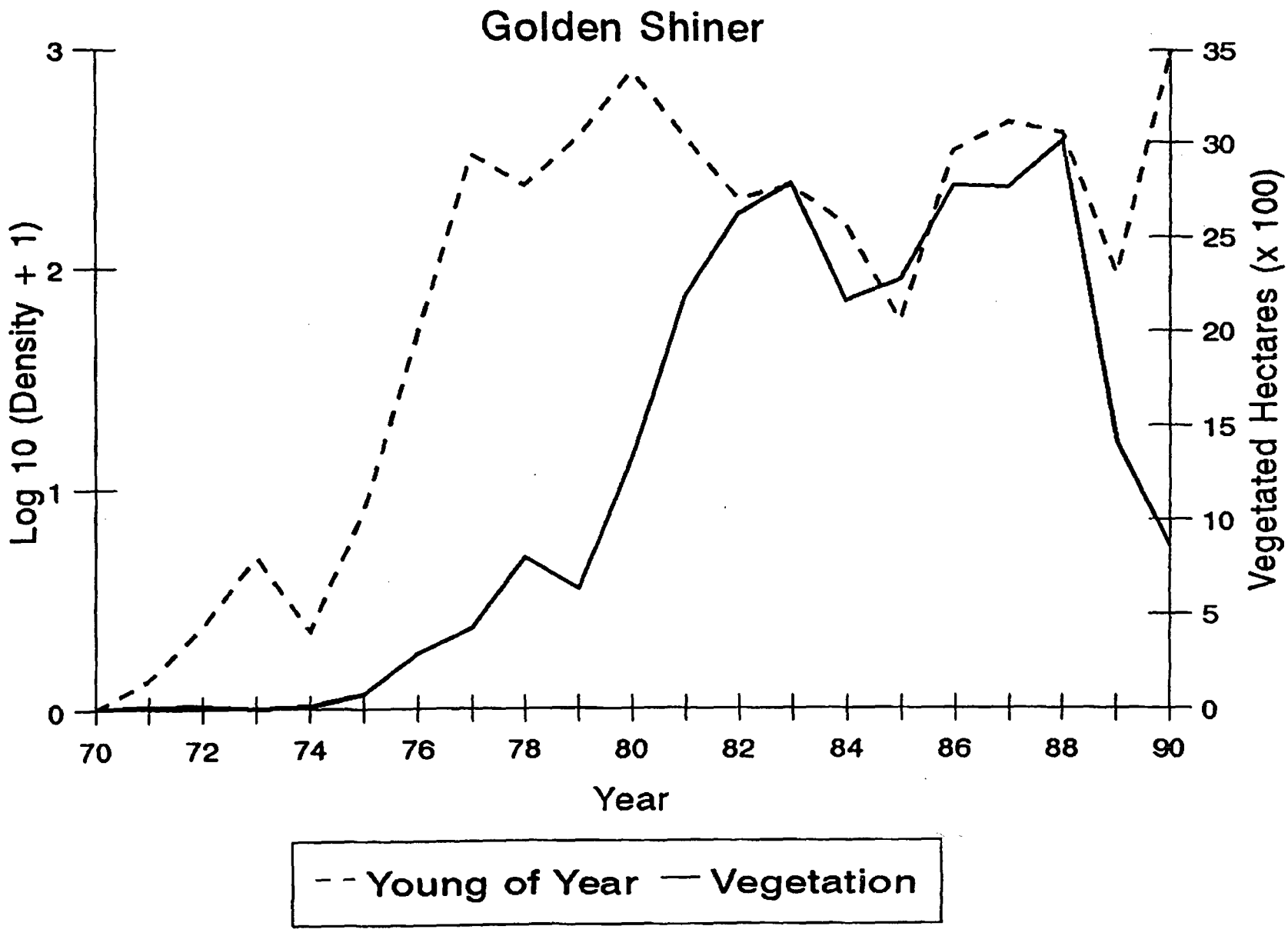

Figure 7. Annual standing stock densities (numbers/hectare) of golden shiner, as determined by cove rotenone sampling, 1970-90.

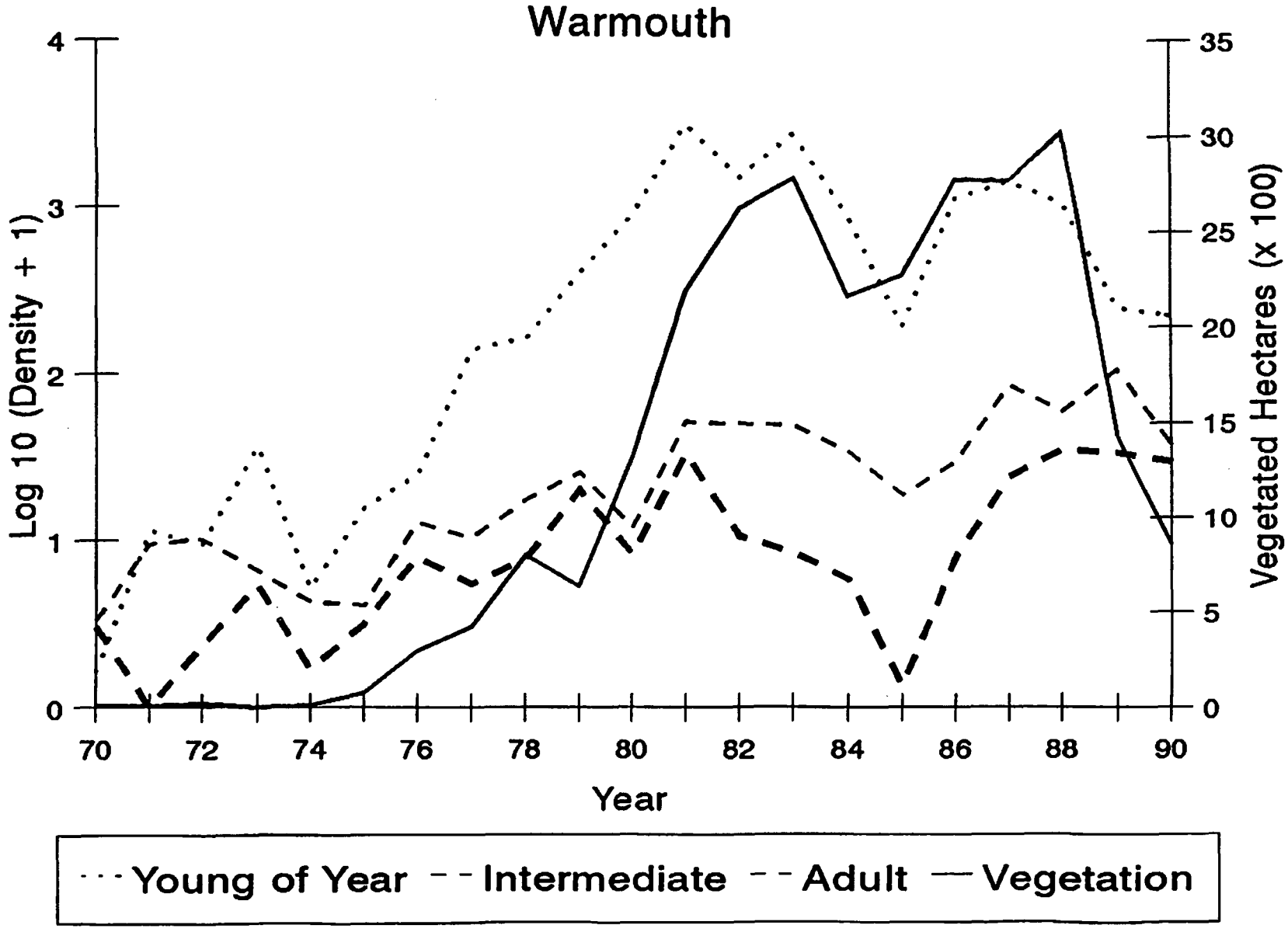

Figure 8. Annual standing stock densities (numbers/hectare) of warmouth, as determined by cove rotenone sampling, 1970-90.

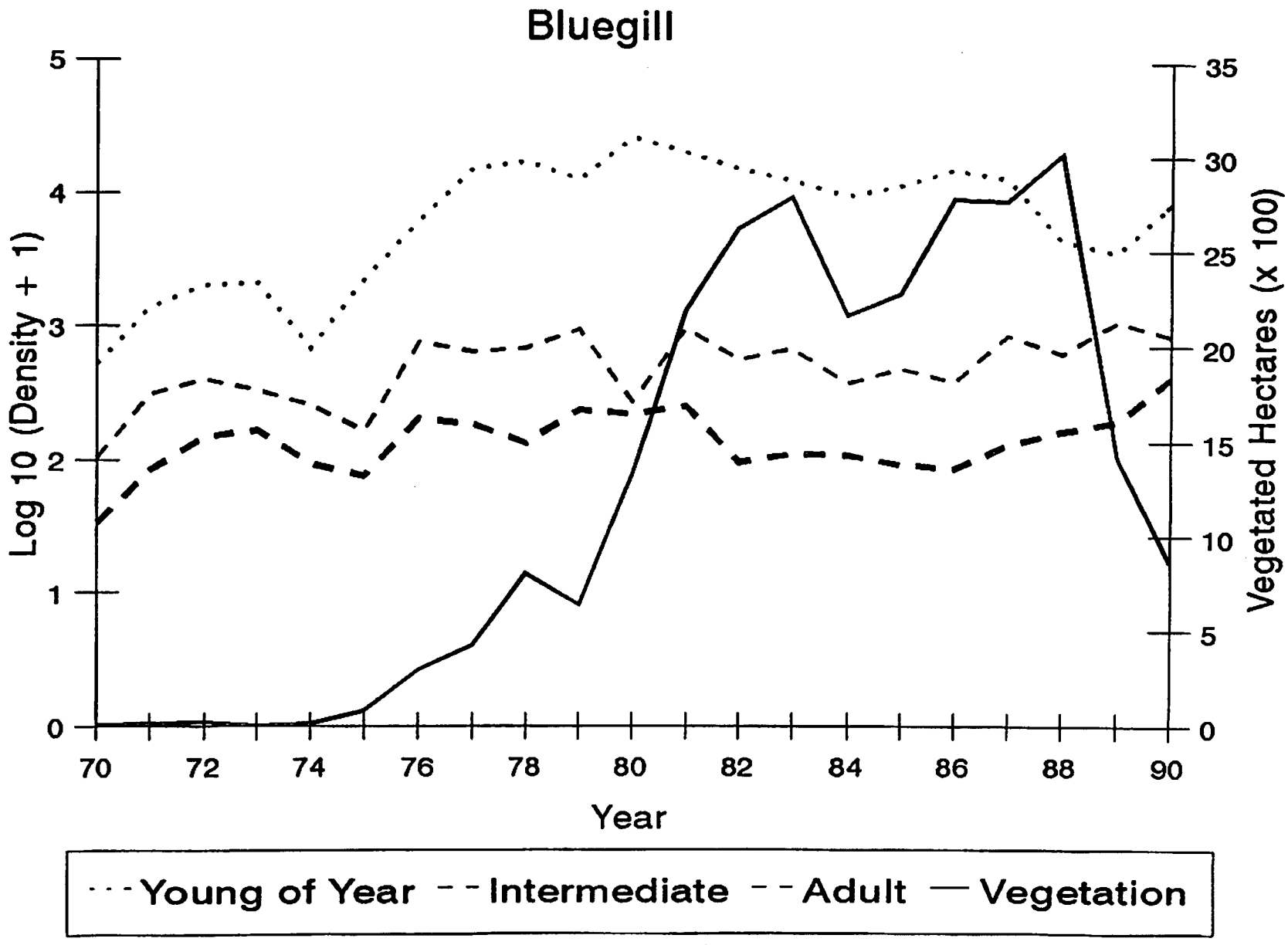

Figure 9. Annual standing stock densities (numbers/hectare) of bluegill, as determined by cove rotenone sampling, 1970-90.

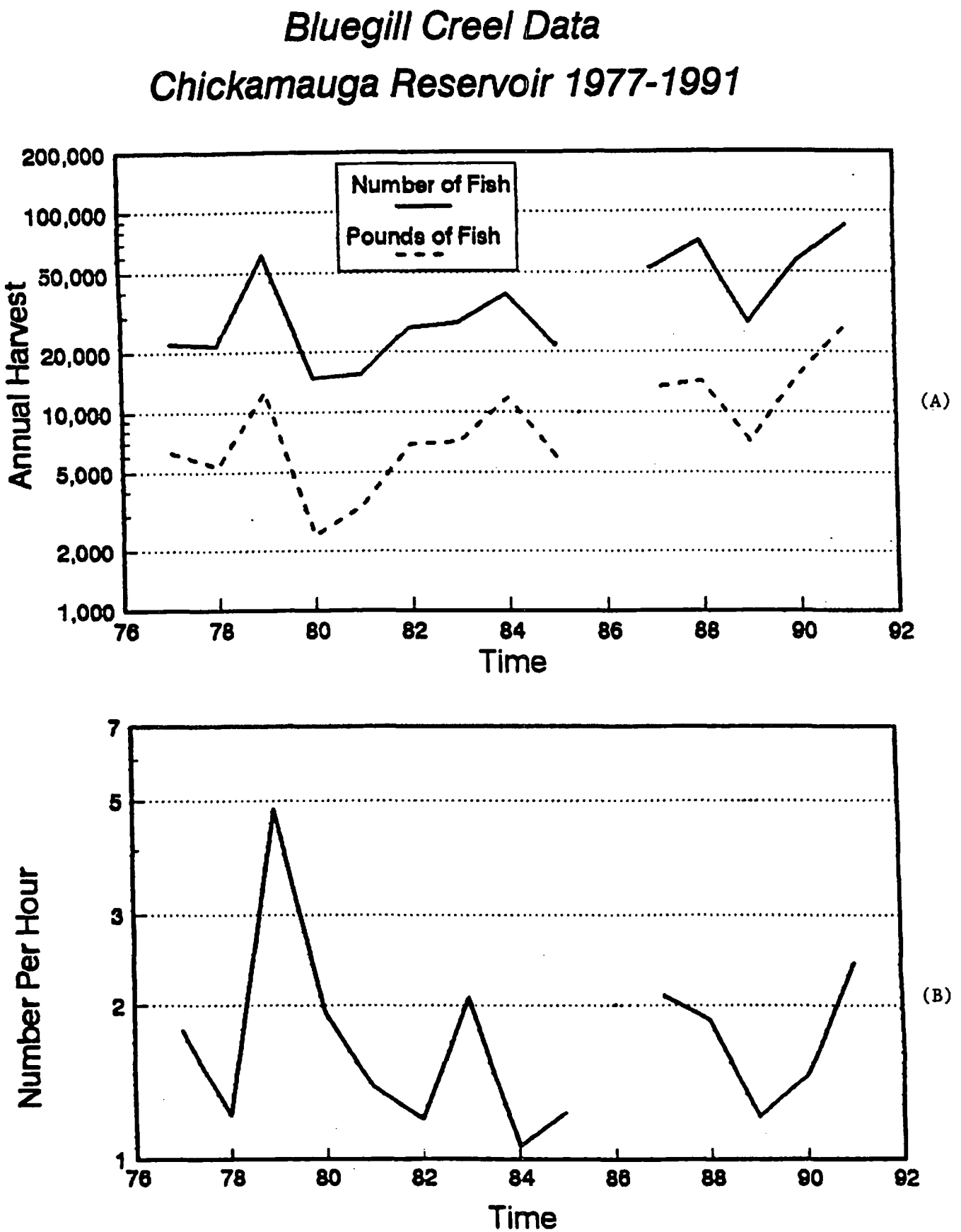

Figure 10. Estimates of creel harvest (numbers and pounds) of bluegill (A) and catch per hour, (B) 1977-91 (TWRA data).

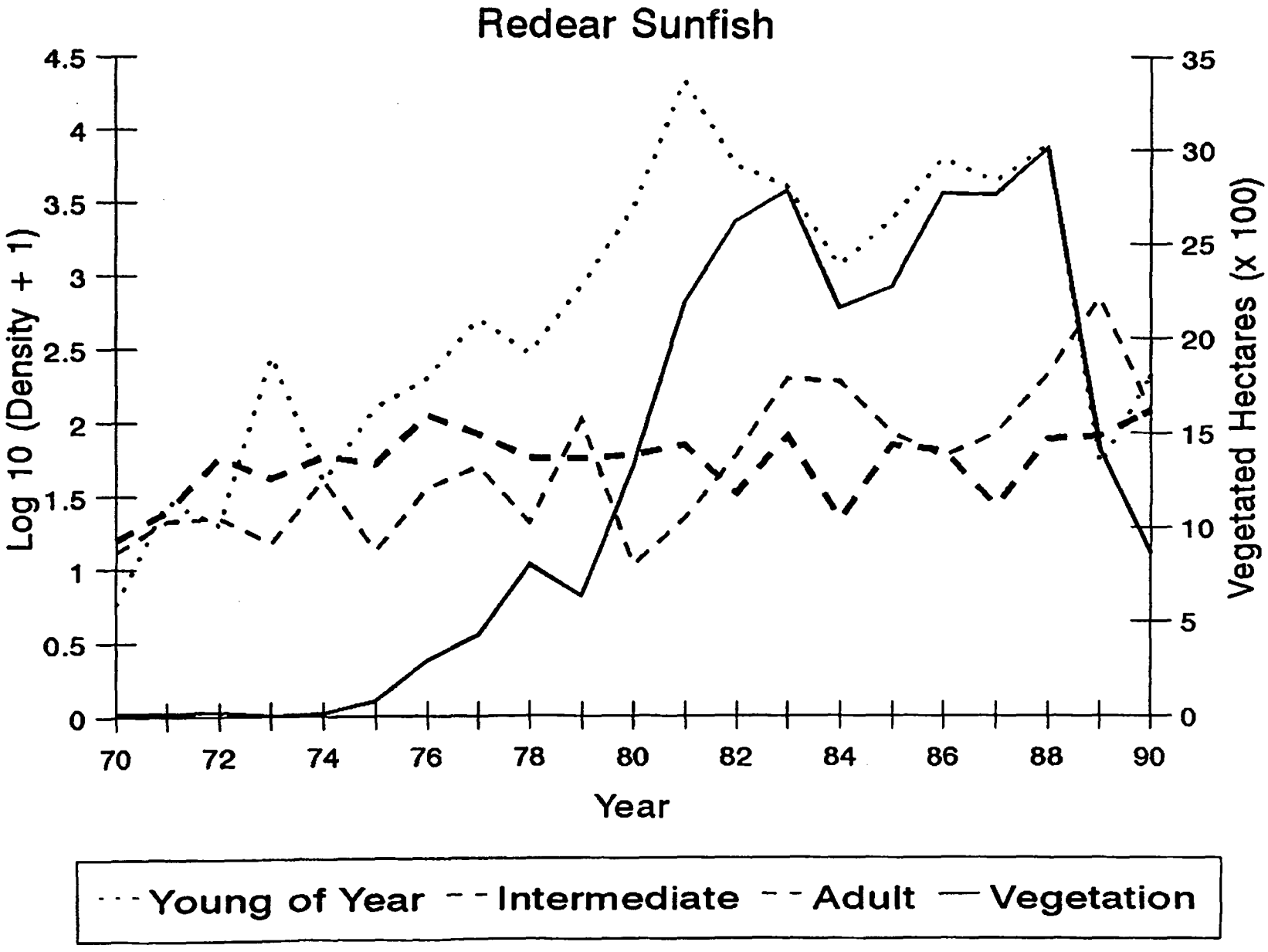

Figure 11. Annual standing stock densities (numbers/hectare) of redear sunfish, as determined by cove rotenone sampling, 1970-90.

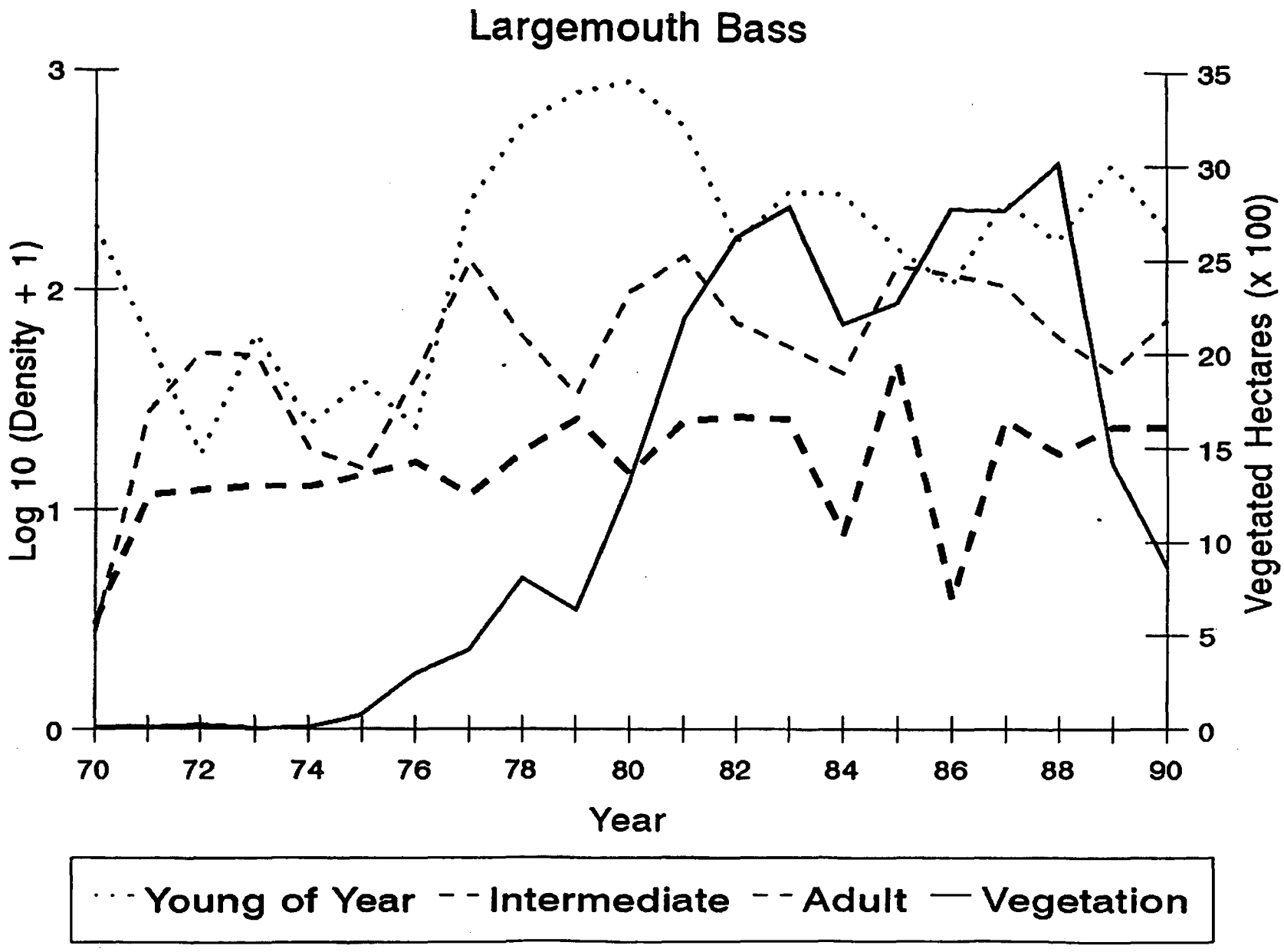

Figure 12. Annual standing stock densities (numbers/hectare) of largemouth bass, as determined by cove rotenone sampling, 1970-90.

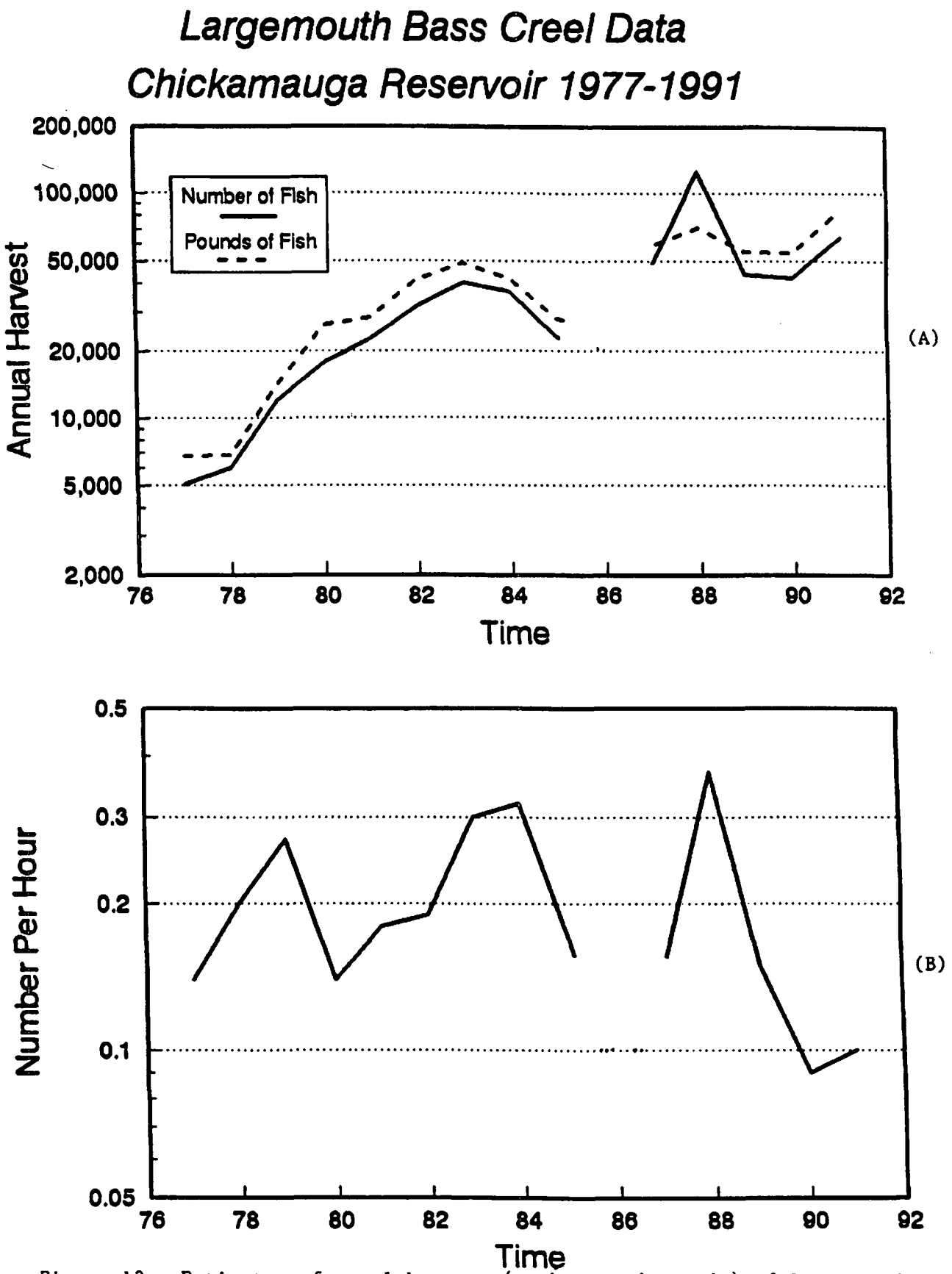

Figure 13. Estimates of creel harvest (numbers and pounds) of largemouth bass (A) and catch per hour, (B) 1977-91 (TWRA data).

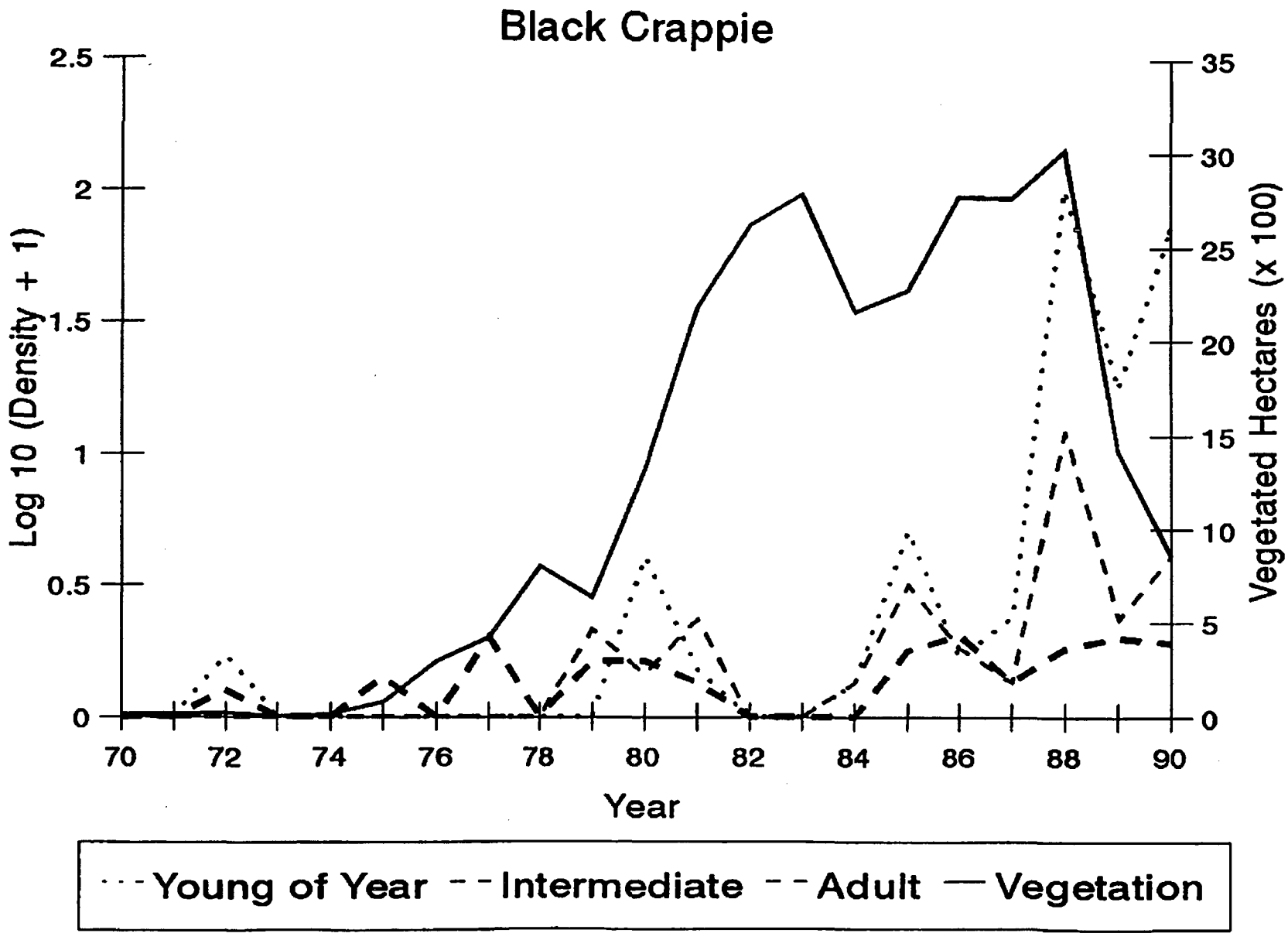

Figure 14. Annual standing stock densities (numbers/hectare) of black crappie, as determined by cove rotenone sampling, 1970-90.

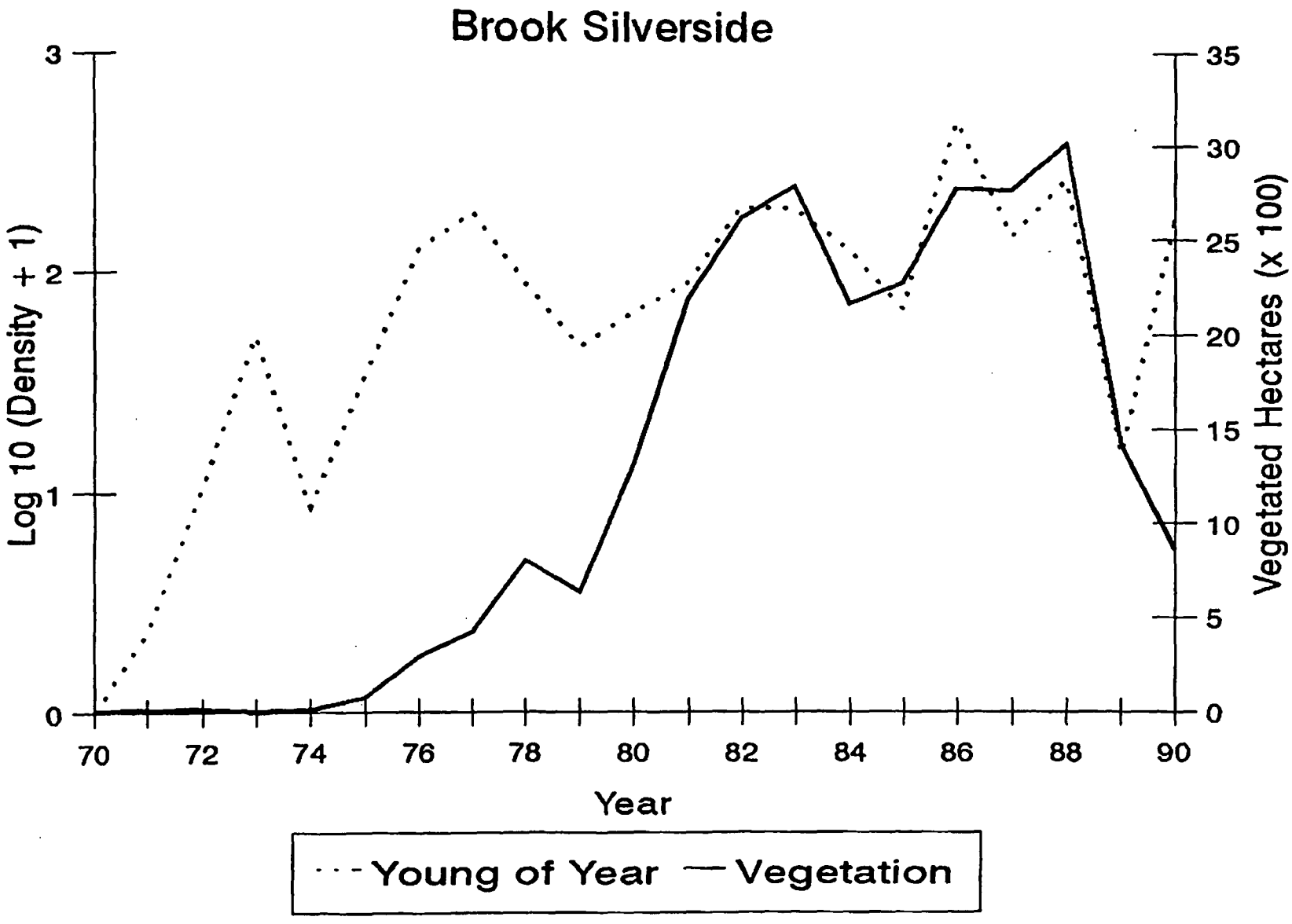

Figure 15. Annual standing stock densities (numbers/hectare) of black crappie, as determined by cove rotenone sampling, 1970-90.

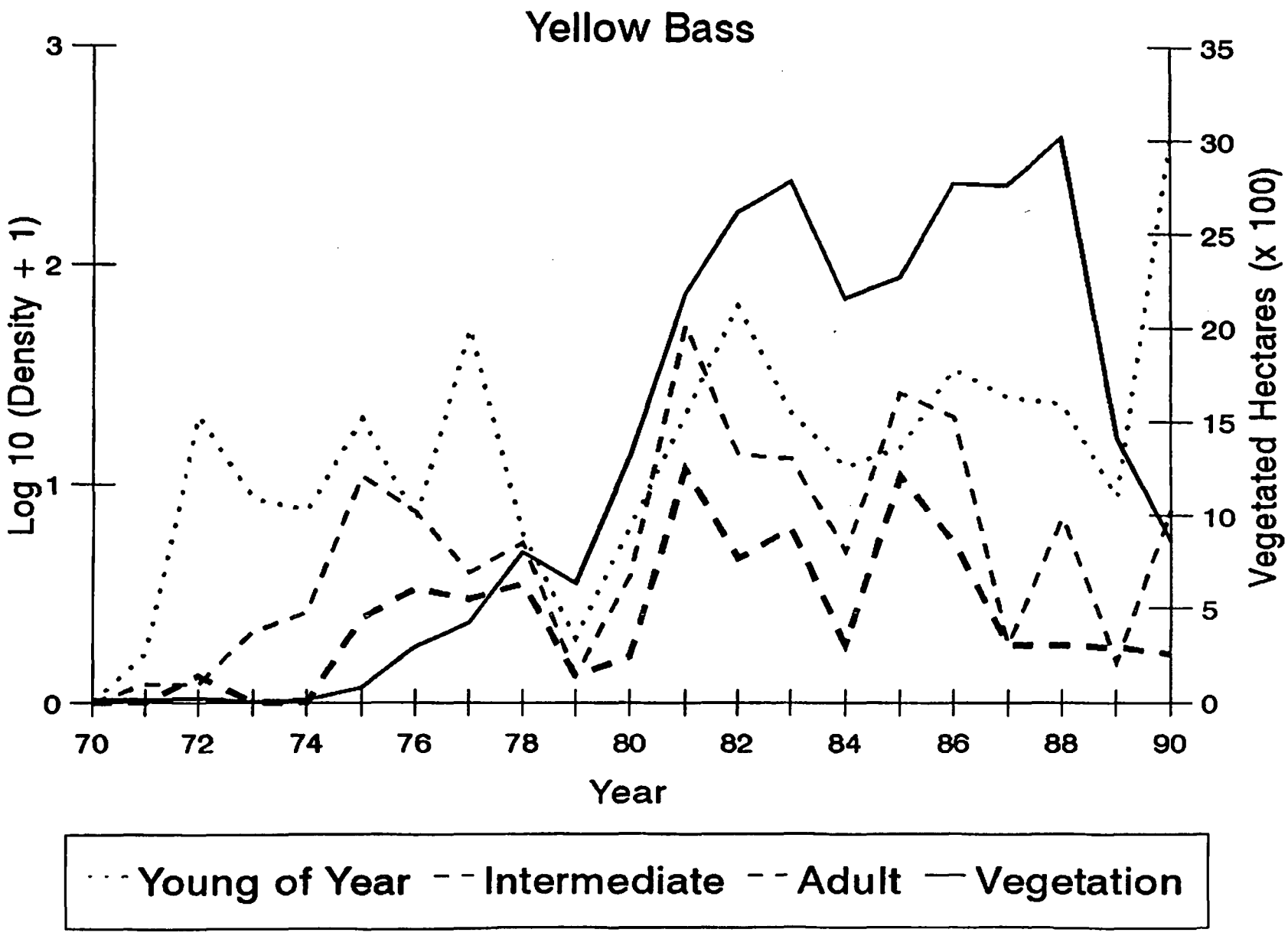

Figure 16. Annual standing stock densities (numbers/hectare) of yellow bass, as determined by cove rotenone sampling, 1970-90.

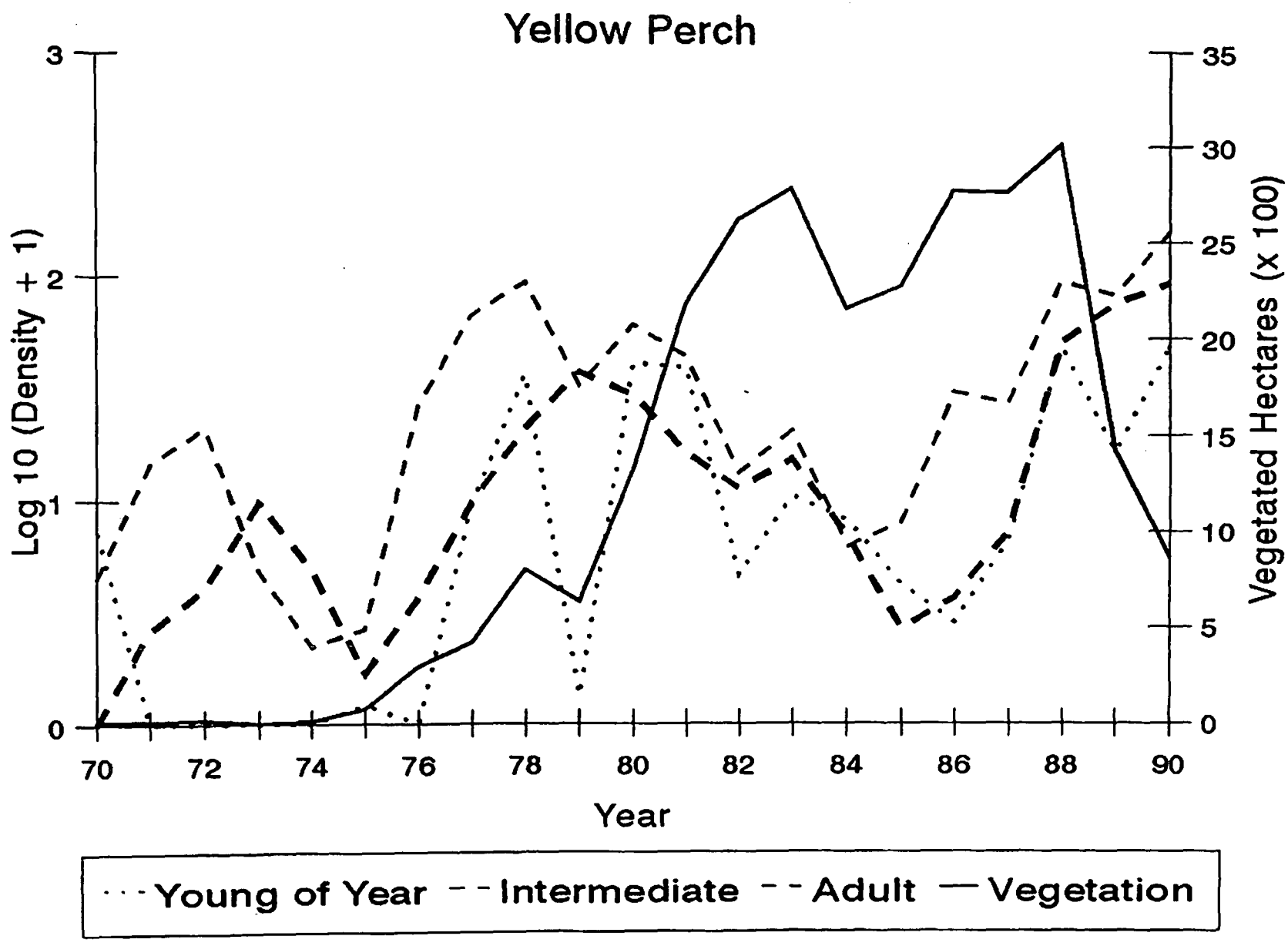

Figure 17. Annual standing stock densities (numbers/hectare) of yellow perch, as determined by cove rotenone sampling, 1970-90.

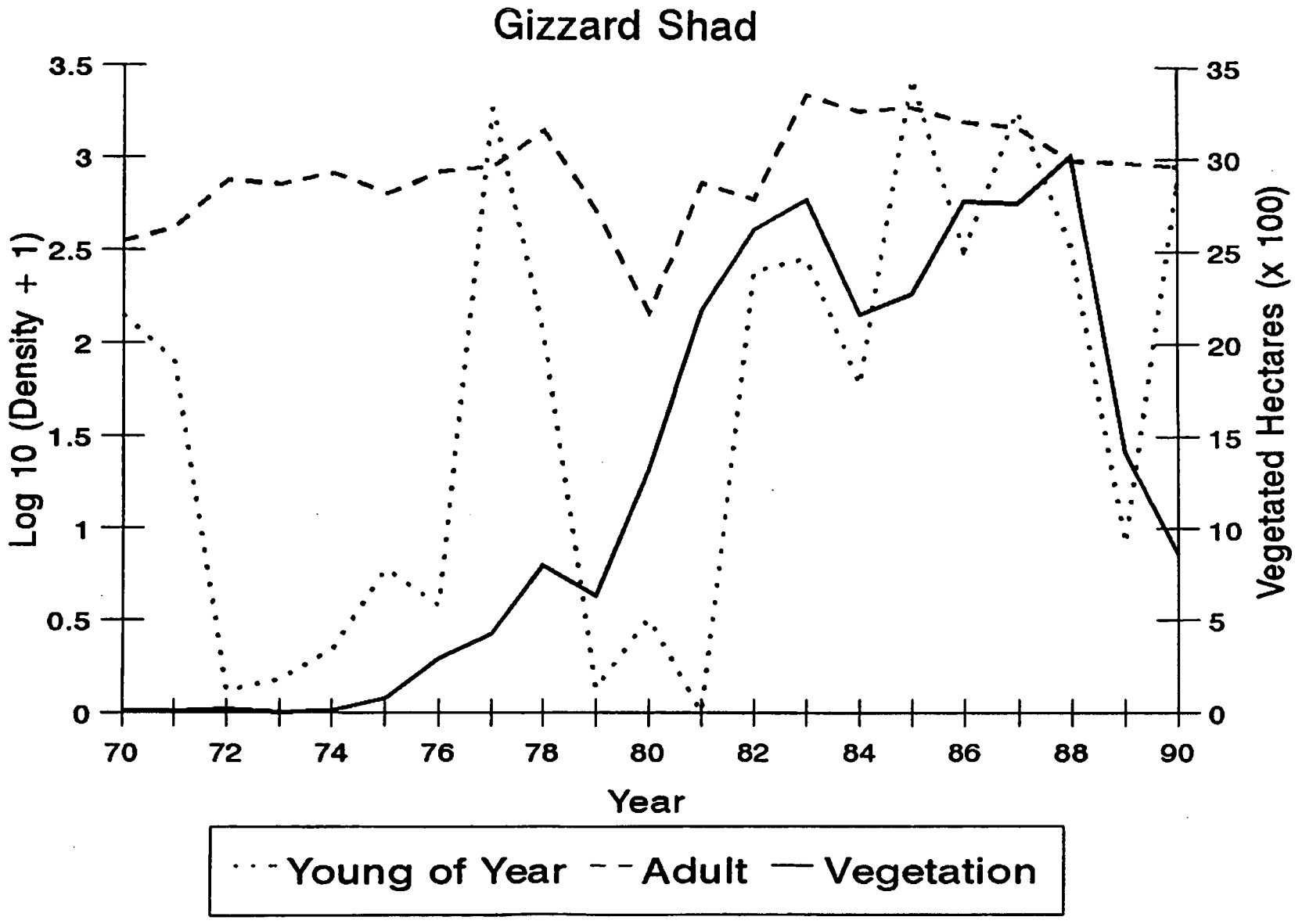

Figure 18. Annual standing stock densities (numbers/hectare) of gizzard shad, as determined by cove rotenone sampling, 1970-90.

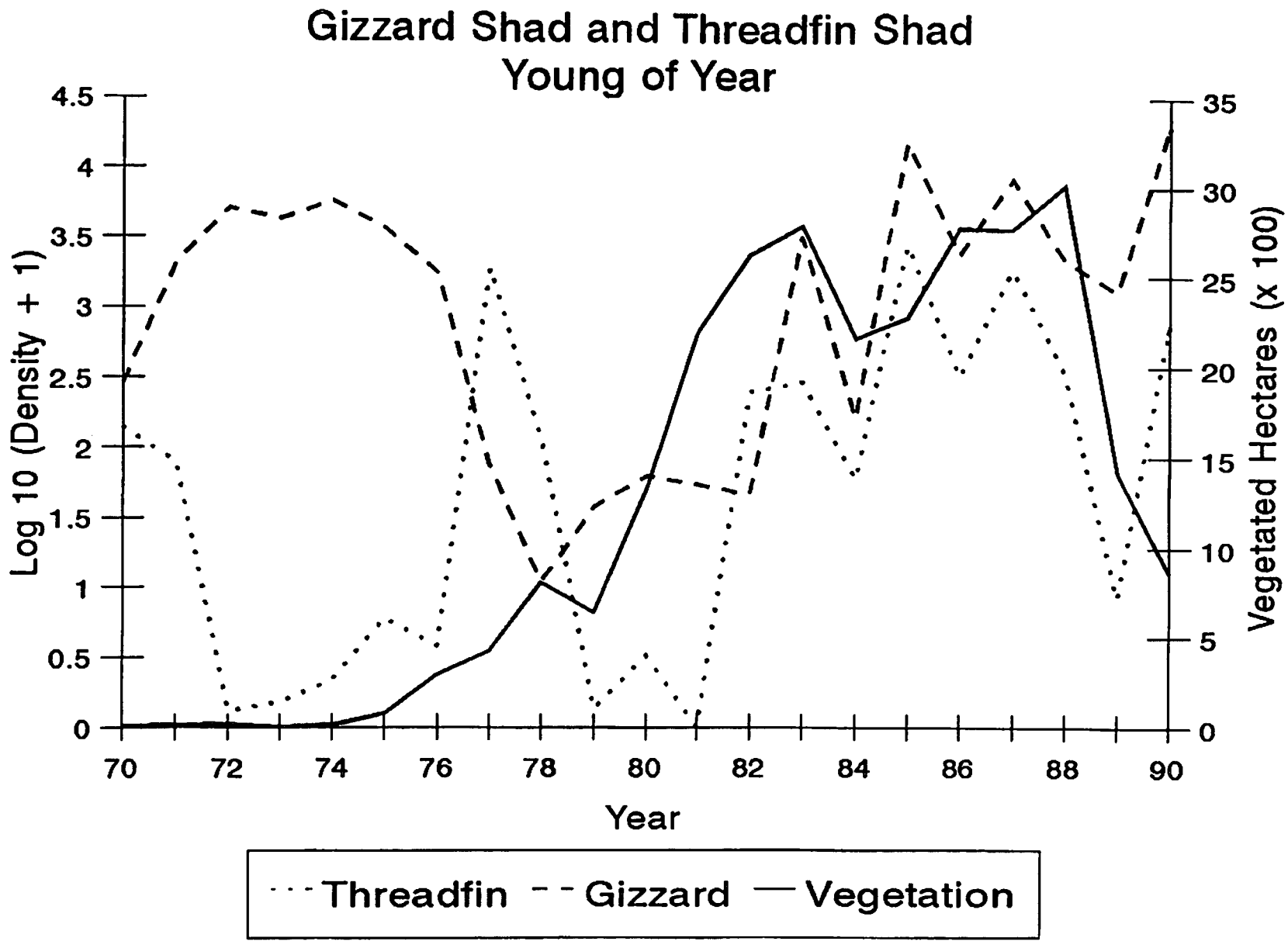

Figure 19. Annual standing stock densities (numbers/hectare) of YOY gizzard shad and threadfin shad, as determined by cove rotenone sampling, 1970-90.

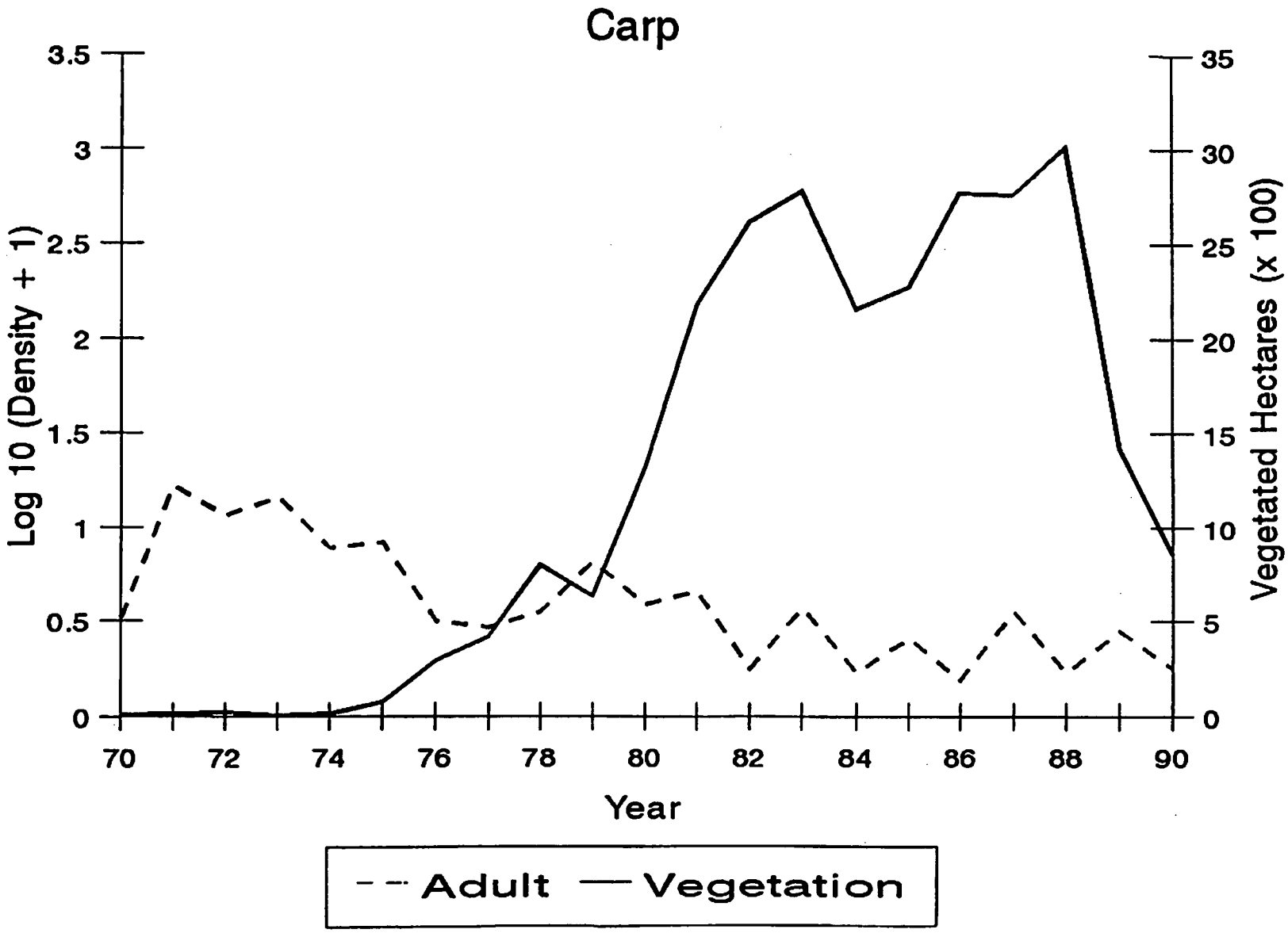

Figure 20. Annual standing stock densities (numbers/hectare) of carp, as determined by cove rotenone sampling, 1970-90.

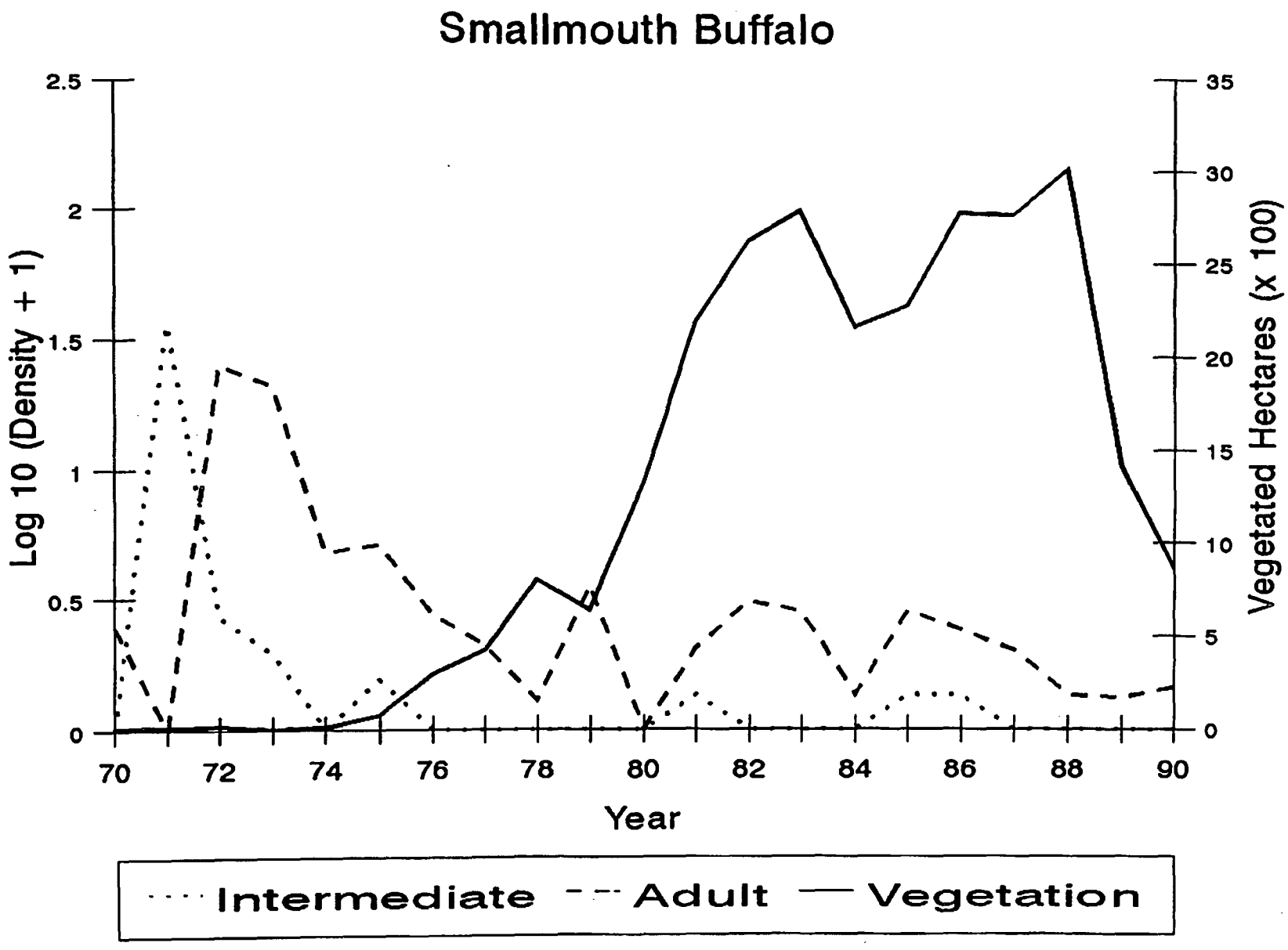

Figure 21. Annual standing stock densities (numbers/hectare) of smallmouth buffalo, as determined by cove rotenone sampling, 1970-90.

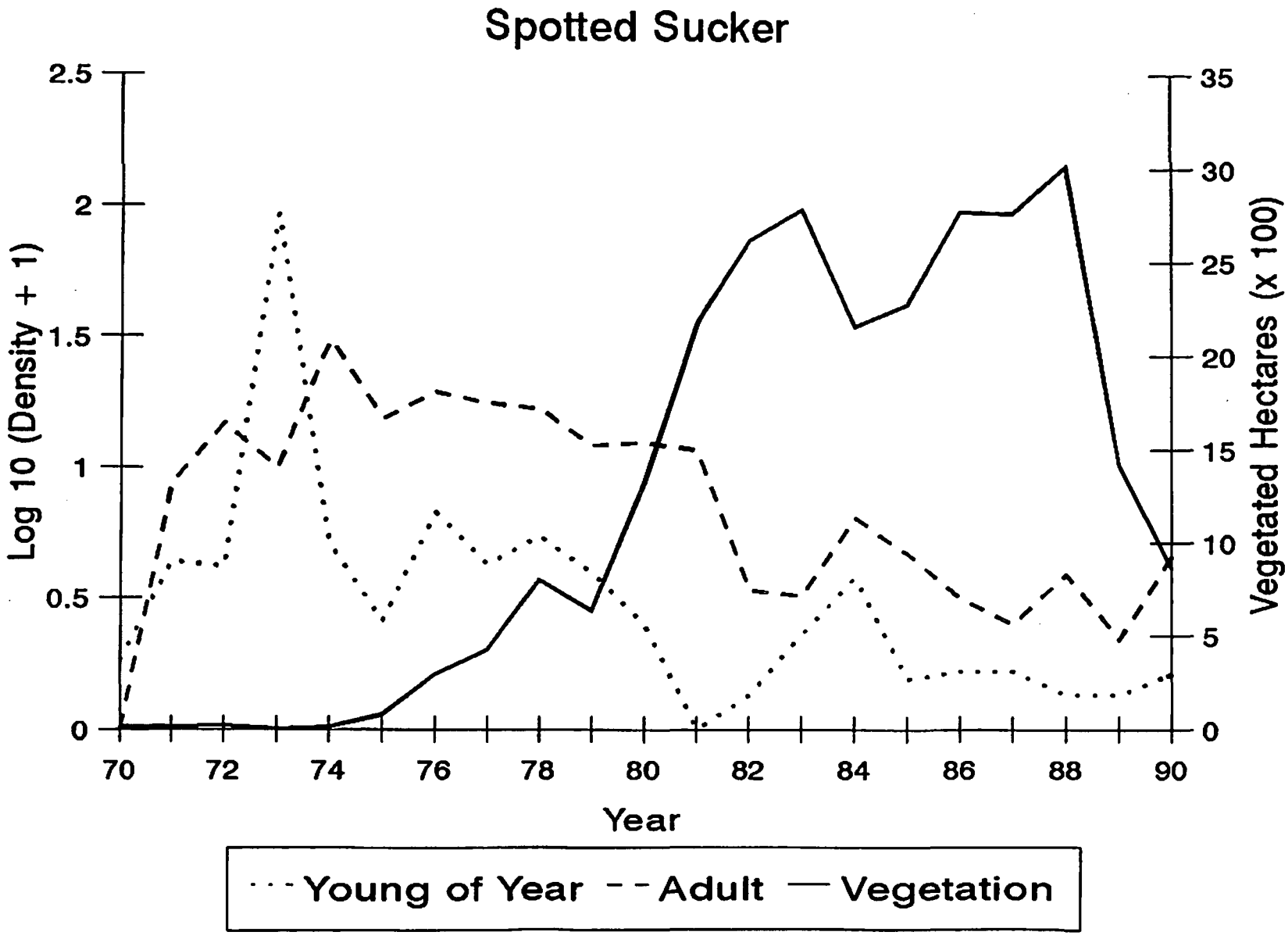

Figure 22. Annual standing stock densities (numbers/hectare) of spotted sucker, as determined by cove rotenone sampling, 1970-90.

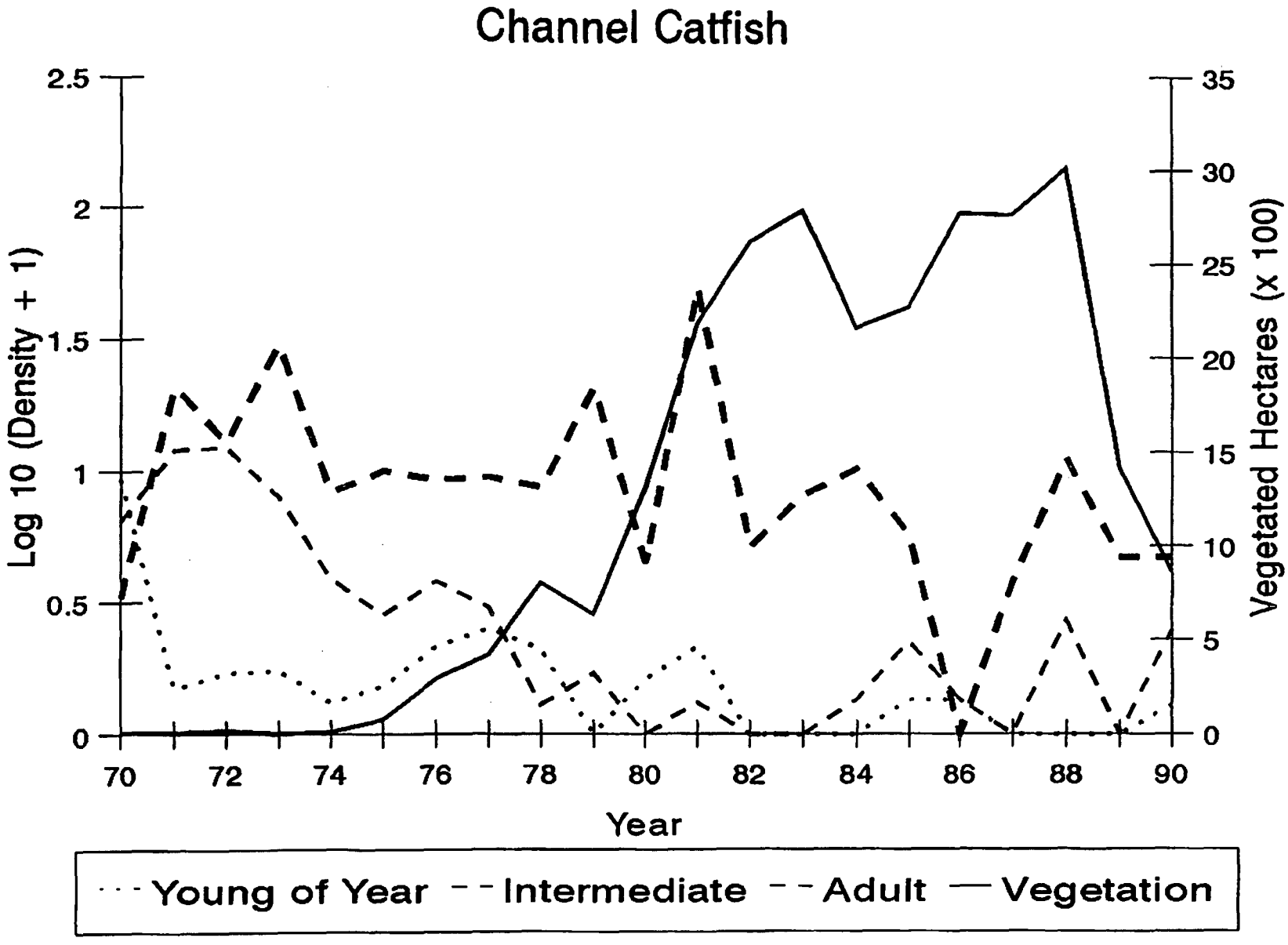

Figure 23. Annual standing stock densities (numbers/hectare) of channel catfish, as determined by cove rotenone sampling, 1970-90.

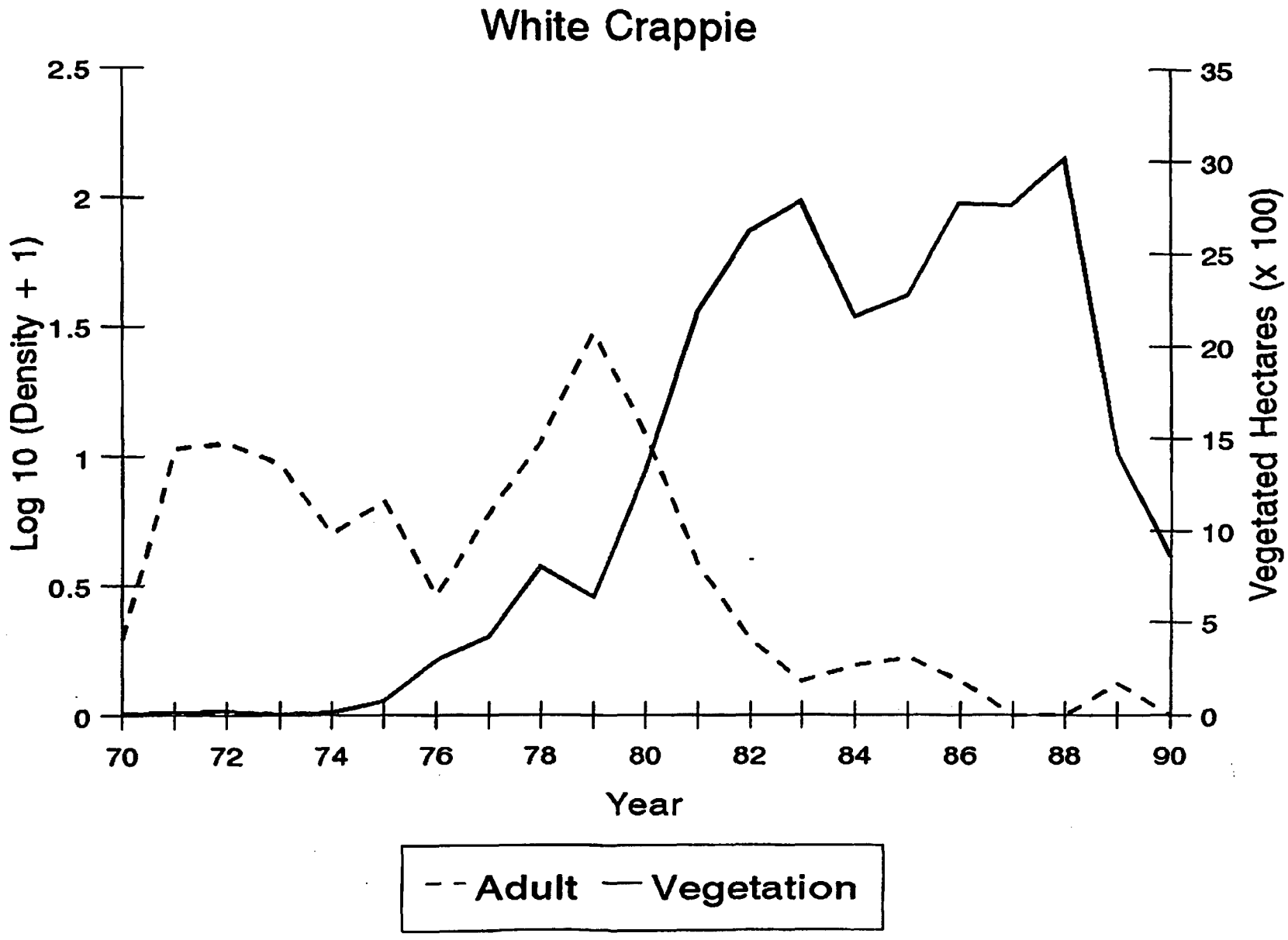

Figure 24. Annual standing stock densities (numbers/hectare) of white crappie, as determined by cove rotenone sampling, 1970-90.

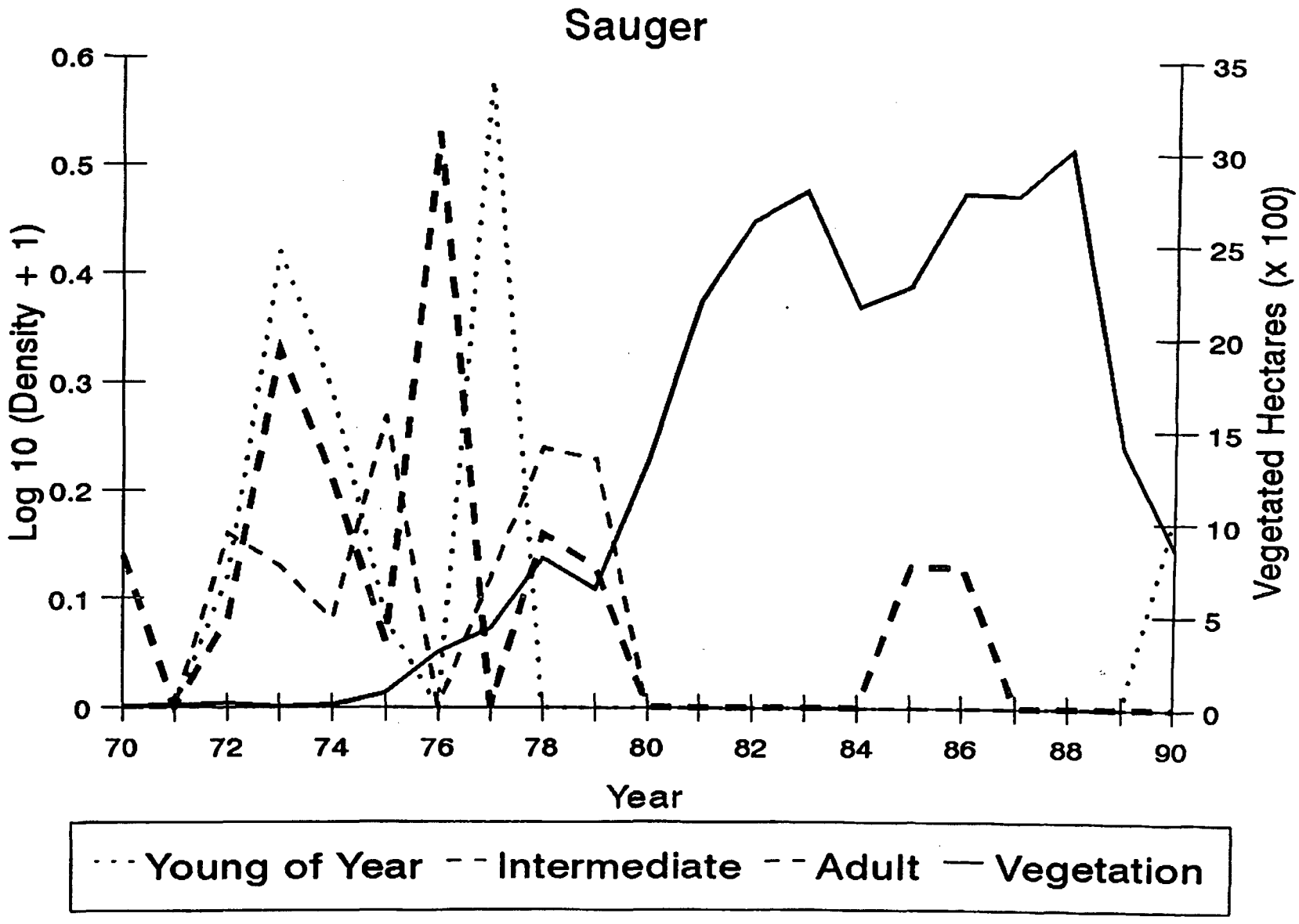

Figure 25. Annual standing stock densities (numbers/hectare) of sauger, as determined by cove rotenone sampling, 1970-90.

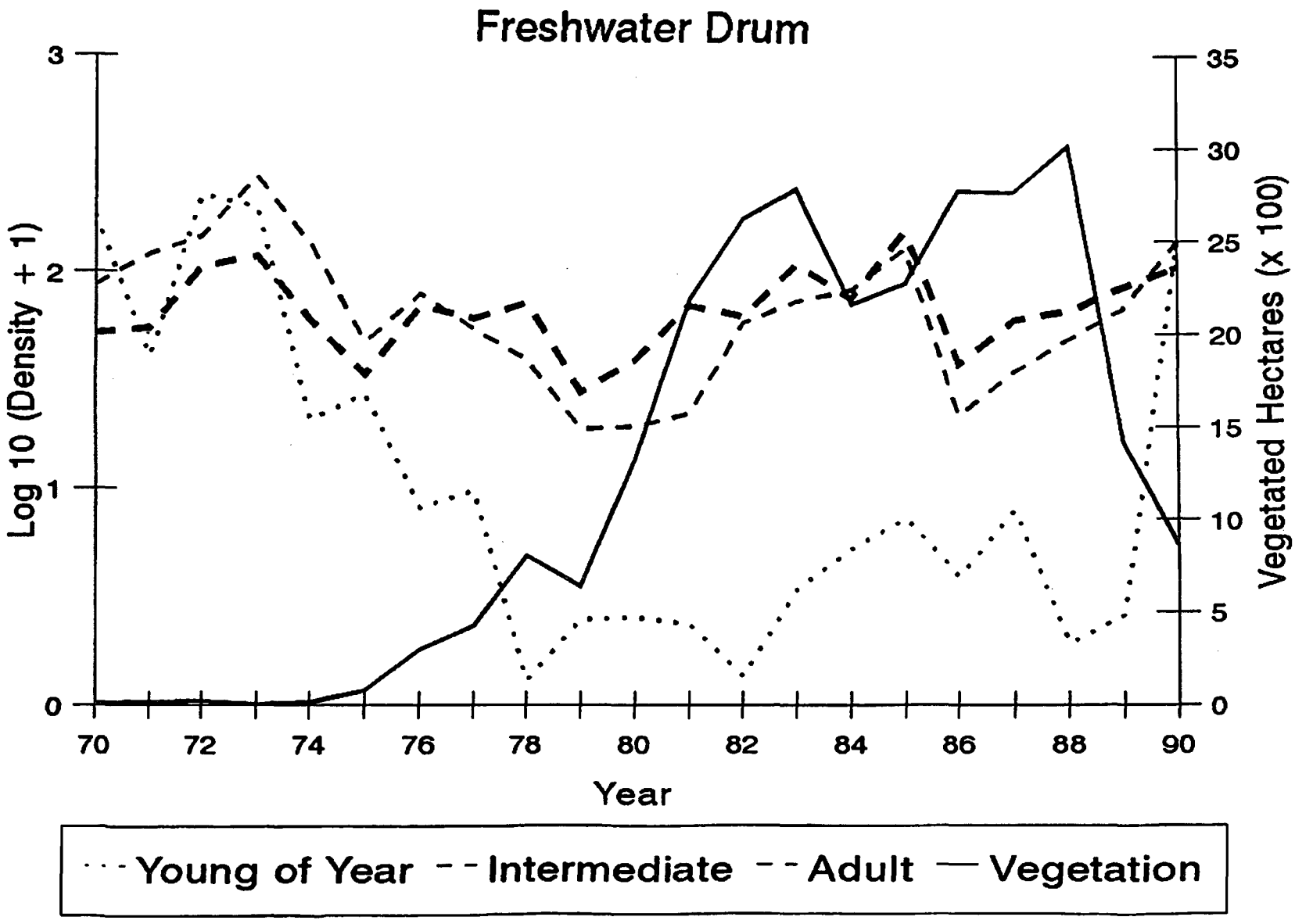

Figure 26. Annual standing stock densities (numbers/hectare) of freshwater drum, as determined by cove rotenone sampling, 1970-90.

A

B

Figure 27. Underwater photographs of Eurasian watermilfoil (A) and spinyleaf naiad (B) illustrating differences in growth forms.

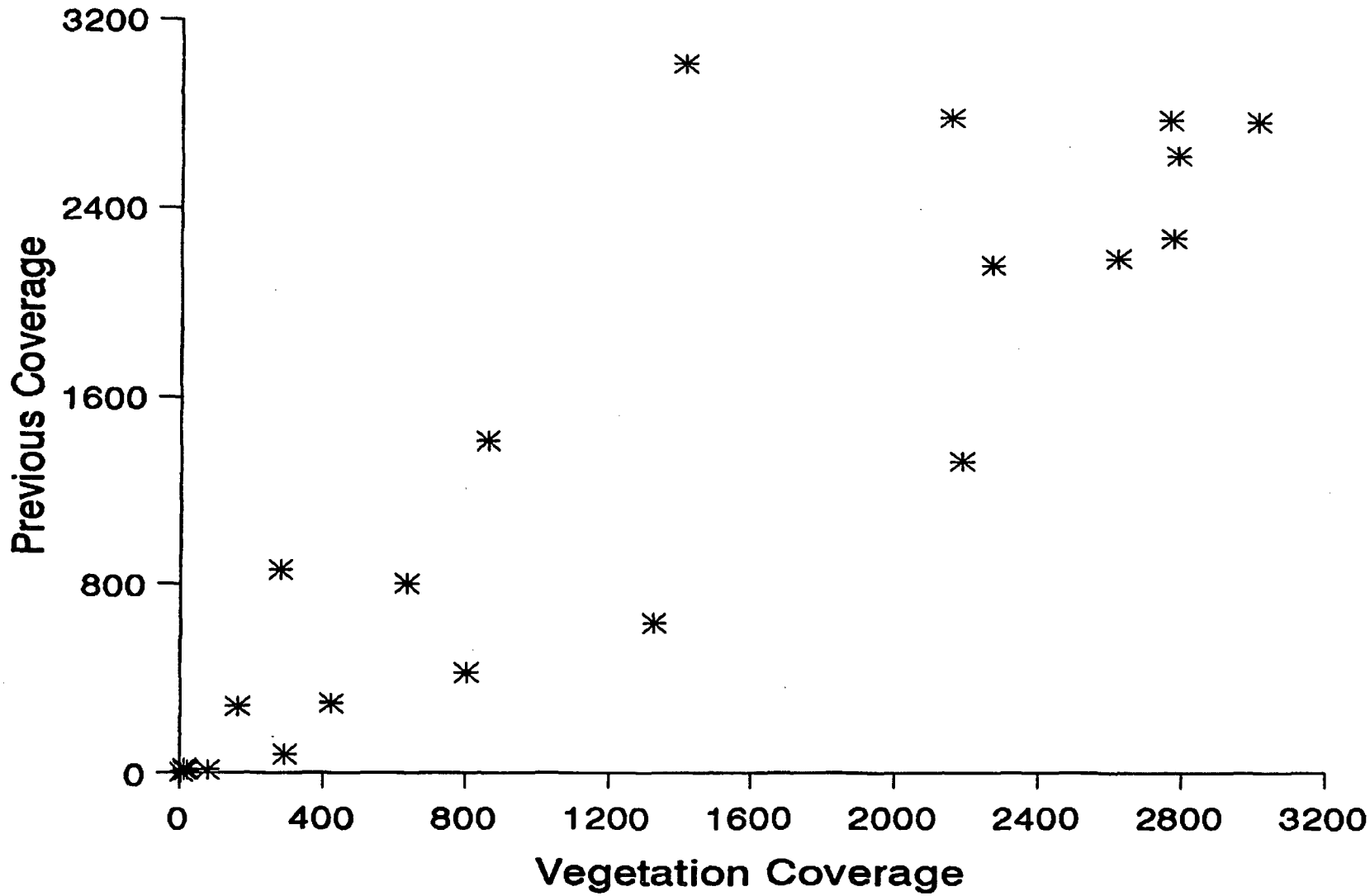

Figure 28. Previous year's aquatic macrophyte coverage (hectares) versus current year's coverage in Chickamauga Reservoir, 1971-92.

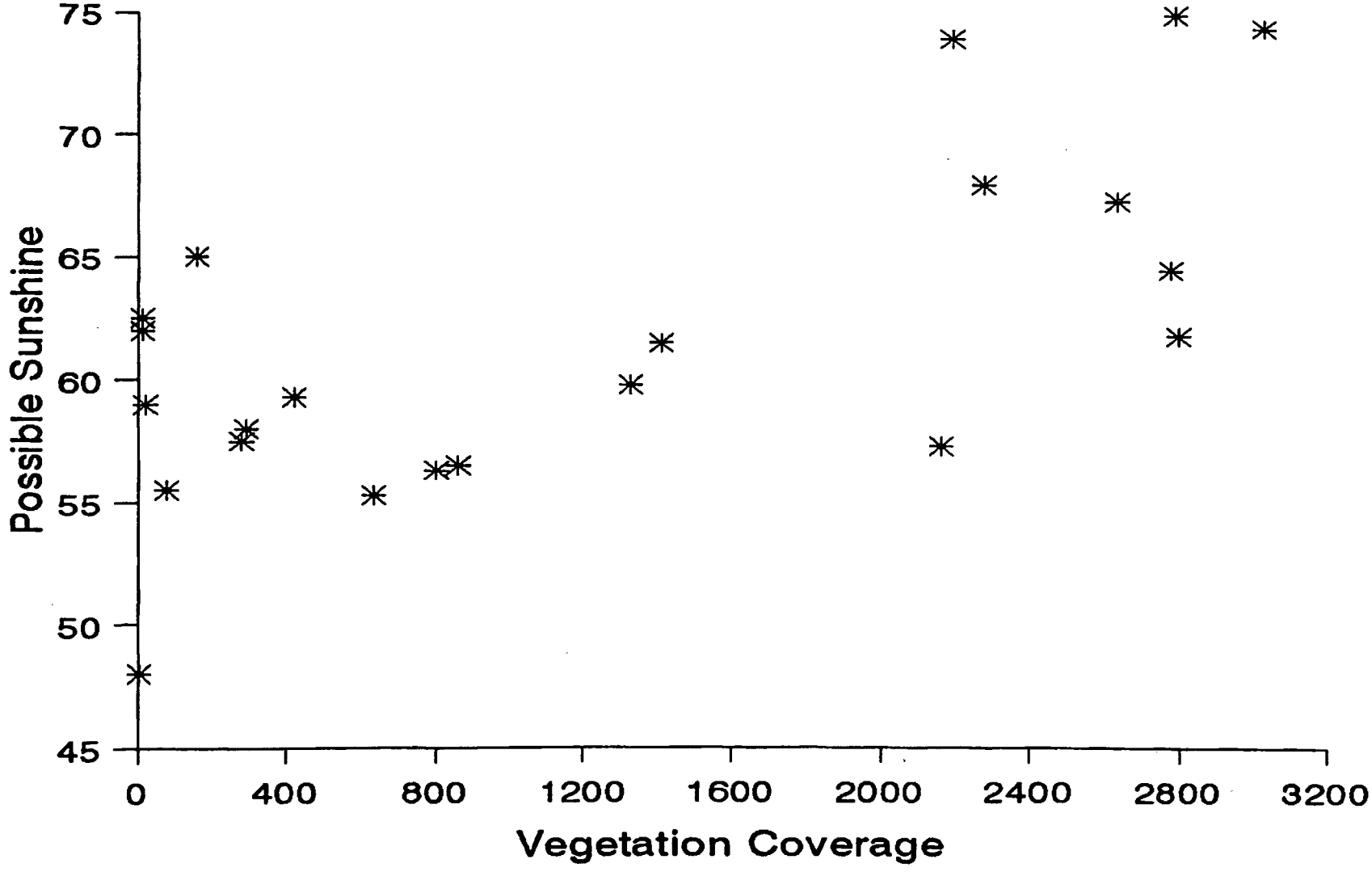

Figure 29. Average March-June sunshine (percent of possible) at Chattanooga, TN, versus aquatic macrophyte coverage (hectares) in Chickamauga Reservoir, 1971-92.

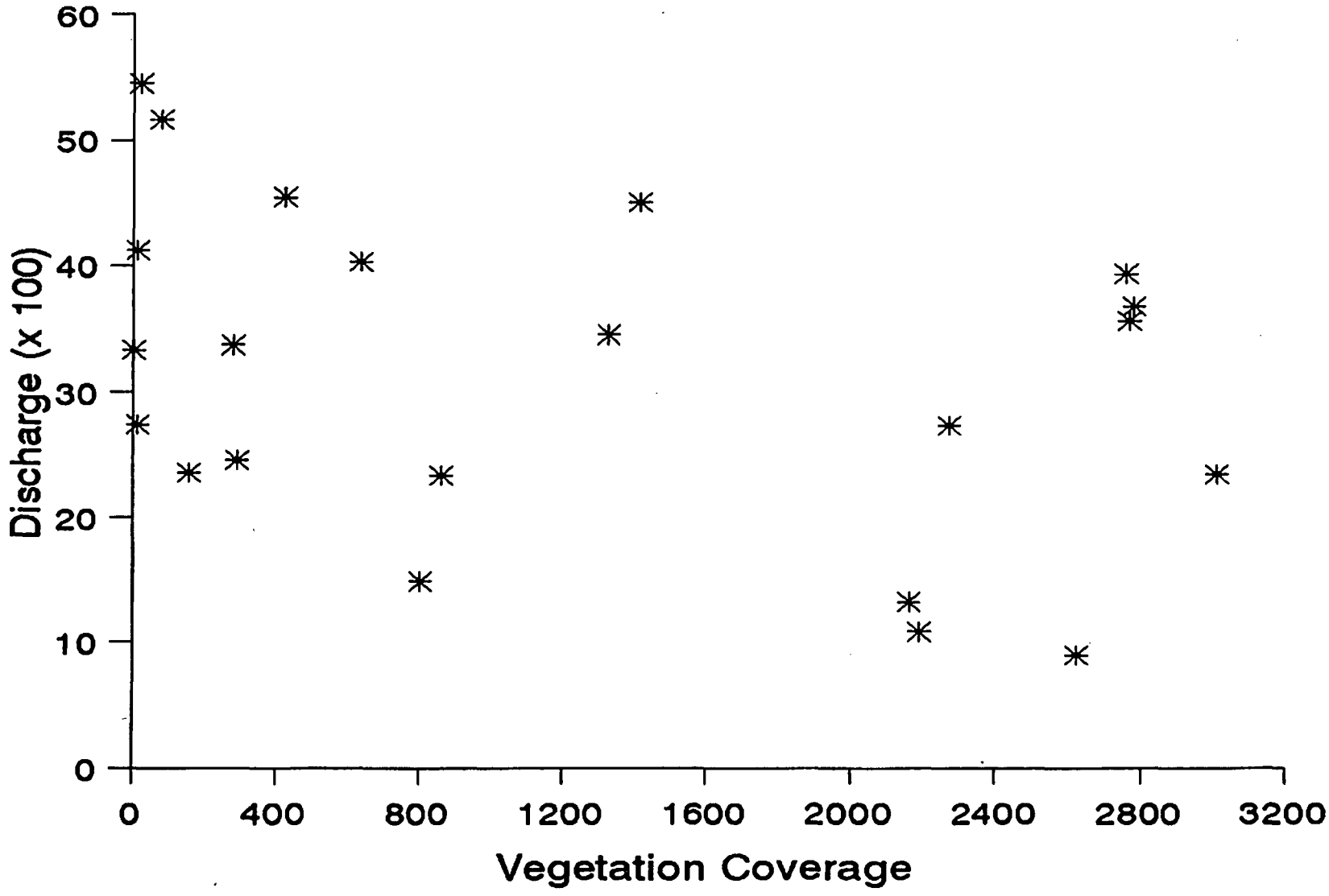

Figure 30. Average March-June daily discharge (cfs) at Chickamauga Dam versus current year's aquatic macrophyte coverage in Chickamauga Reservoir, 1971-92.

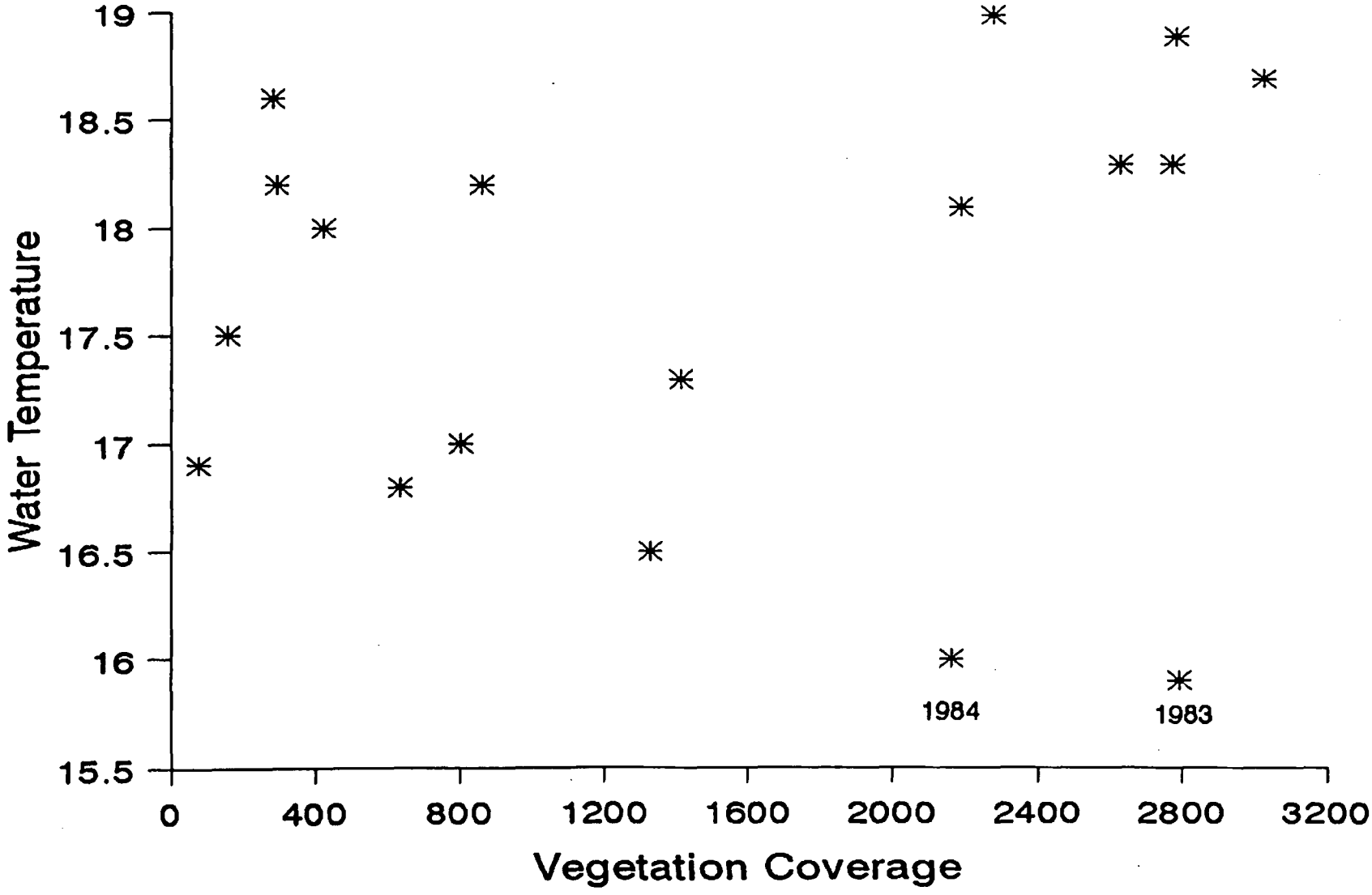

Figure 31. Average March-June water temperatures (°C, 1.5 m depth) at TRM 484.7 versus aquatic macrophyte coverage (hectares) in Chickamauga Reservoir, 1975-92.

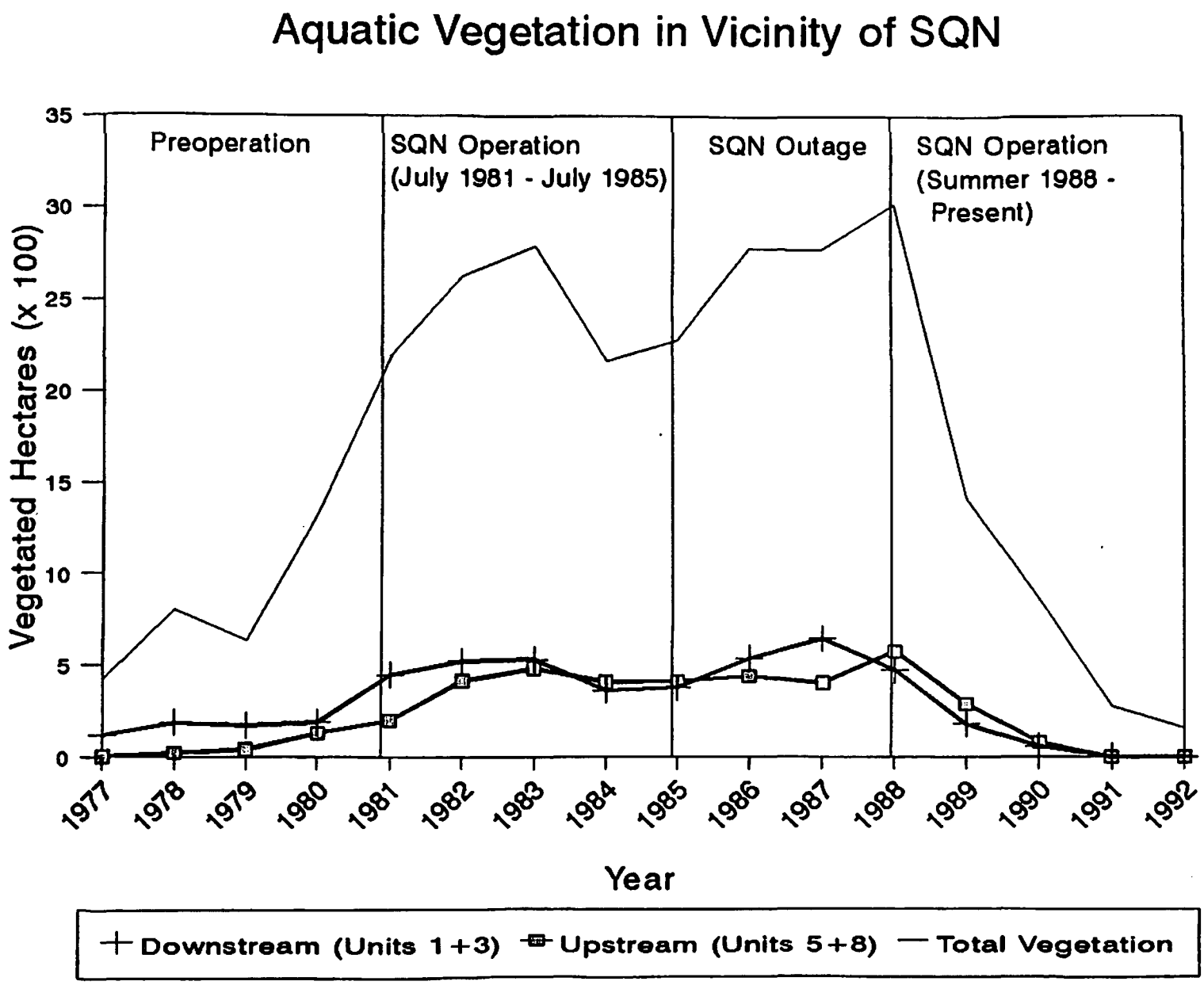

Figure 32. Aquatic macrophyte coverage (hectares) in mainchannel areas downstream and upstream from SQN and total coverage in Chickamauga Reservoir, 1977-92.

10052

TENNESSEE VALLEY AUTHORITY

Water Resources
Aquatic Biology Department

1990 PREOPERATIONAL MONITORING OF THE MUSSEL FAUNA IN UPPER CHICKAMAUGA RESERVOIR IN THE VICINITY OF THE WATTS BAR NUCLEAR PLANT

Prepared by
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Norris, Tennessee
March 1991

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INTRODUCTION

The freshwater mussel fauna at three sites in the Tennessee River near the Watts Bar Nuclear Power Plant (WBN) was monitored annually from 1983 through 1986, with biennial sampling from 1986 to the present. These studies have provided long-term baseline information on the occurrence, relative abundance, distribution, and condition of mussels in upper Chickamauga Reservoir, as part of the WBN preoperational aquatic monitoring program (Ahlstedt 1989). The objectives of the present study were to update the status of these mussel populations and identify trends or changes which may have occurred since the last survey in July 1988. Approximately one month after the July 1988 survey, extremely low dissolved oxygen levels brought about by drought conditions caused a mussel kill in this reach of the river.

SITE DESCRIPTION

The most upstream of the three mussel beds sampled (TRMs 528-529L) is located on the opposite side of the river (left descending bank) and upstream from WBN (Figure 1). The middle bed (TRMs 526-5278) is on the same side of the river as WBN (right descending bank), just downstream from the mouth of Yellow Creek and the WBN diffuser. The lowermost bed (TRMs 520-521L) is located six river miles downstream from WBN on the left descending side of the river. All three mussel beds were sampled near the overbank along the inside edge of the navigation channel. Substrates generally consist of gravel, cobble, sand, and relic shells of

the Asian clam (Corbicula fluminea). Four sampling stations were established on each of the three mussel beds. Each sampling station was located using river mile markers, navigation buoys, and bankside landmarks.

METHODS

All live freshwater mussels (excluding the Asian clam) were collected by four scuba divers during 11 minutes of bottom time. Four sites were sampled in each of the three mussel beds for a total of 12 timed dives. Mussel specimens found were placed in mesh bags and brought to the surface dive boat for sorting and identification. At each sampling site, up to 50 specimens of each species from each of the three mussel beds were measured in millimeters using a dial caliper. Shell measurements included length, height, and thickness. All specimens were returned to the substrate at the station from which they were collected.

RESULTS AND DISCUSSION

Twenty-two mussel species were reported during the 1988 and 1990 surveys (Table 1). Freshwater mussel species found during both surveys were identical, except for Pleurobema rubrum, which was reported only in 1988, and Ptychobranchus fasciolaris, which was found only in 1990. Both of these species are uncommon in the Tennessee River.

The total number of mussel specimens found in 1990 (991 mussels) was 62 percent less than the number found in 1988 (1610 mussels) (Table 1).

Most of this difference reflects reductions in the most abundant mussel species, Elliptio crassidens. However, E. crassidens continued to dominate the samples accounting for 53 percent of the total number of specimens in 1990, compared to 60 percent in 1988.

During the 1990 survey, divers observed a large number of dead mussels throughout the study area, which accounted for this reduction. At least 14 other mussel species were reported in lower numbers as well. A prolonged drought resulted in low dissolved oxygen levels which probably was responsible for the mussel die-offs. Because of severe drought conditions in 1988, hourly low dissolved oxygen levels of 2.0 ppm were reported from mid-June through August, with 0 ppm from mid-July through mid-August. On August 11, 1988, a limited mussel survey was conducted in upper Chickamauga Reservoir to determine if mussels were stressed or dying. Twenty-two percent of the 86 specimens collected were either dead or weak (could not close), including one Federally listed endangered species Lampsilis abrupta.

Mussel species composition and densities on the three beds remained similar between the two surveys (Tables 2 and 3). The highest numbers of mussels were found at TRM 528, with lowest densities at TRM 526. The high concentration of freshwater mussels at TRM 528 is probably the result of large numbers of mussels culled at the launch ramp in this area by commercial mussel fishermen before this reach of the Tennessee River became a state protected mussel sanctuary.

Population Age Structure

Age class data could not be determined during the 1988 or 1990 surveys because most specimens were eroded so that annual growth rests could not be distinguished. Shell measurement data allowed some indication of growth levels between 1988 and 1990 (Tables 2 and 3). Mean shell size of most mussel species increased since 1988. Seven species had lower mean sizes in 1990 than reported in 1988, but, due partly to small sample size, differences were not significant (P=0.05). No juvenile or young mussels have been sampled since monitoring began in 1983. The fauna is characterized by old individuals in poor health (i.e., emaciated soft parts and extreme shell erosion).

Within Mussel Bed Comparisons

Analysis of variance (ANOVA) of relative abundance within each bed revealed significant differences (Table 4), indicating that the distribution of a few species is not uniform on each bed. These same differences were reported in previous surveys (Ahlstedt 1989), and probably reflect habitat variations along the length of each bed and/or sampling variability. These differences were not substantial enough to affect comparisons among the full beds. Between year comparisons revealed no significant changes.

CONCLUSIONS

The absence of juvenile freshwater mussels and the overall poor condition of mussels found support previous conclusions that the mussel fauna in the upper Tennessee River near WBN site is very old and has probably had

limited reproduction since the closure of Watts Bar Dam in 1942. The severe drought in 1988 and resultant low dissolved oxygen levels downstream from Watts Bar Dam probably affected individual mussels which were already in poor condition or old. Continued preoperational monitoring of the mussel fauna in this reach of the Tennessee River is expected to show gradual declines in species diversity and abundance.

LITERATURE CITED

Ahlstedt, Steven A. 1989. Update of the Watts Bar Nuclear Plant preoperational monitoring of the mussel fauna in upper Chickamauga Reservoir. Tennessee Valley Authority, Water Resources, Aquatic Biology Department, Technical Report Series, TVA/WR/AB-89/9, Norris, Tennessee 37828-2017. 26 p.

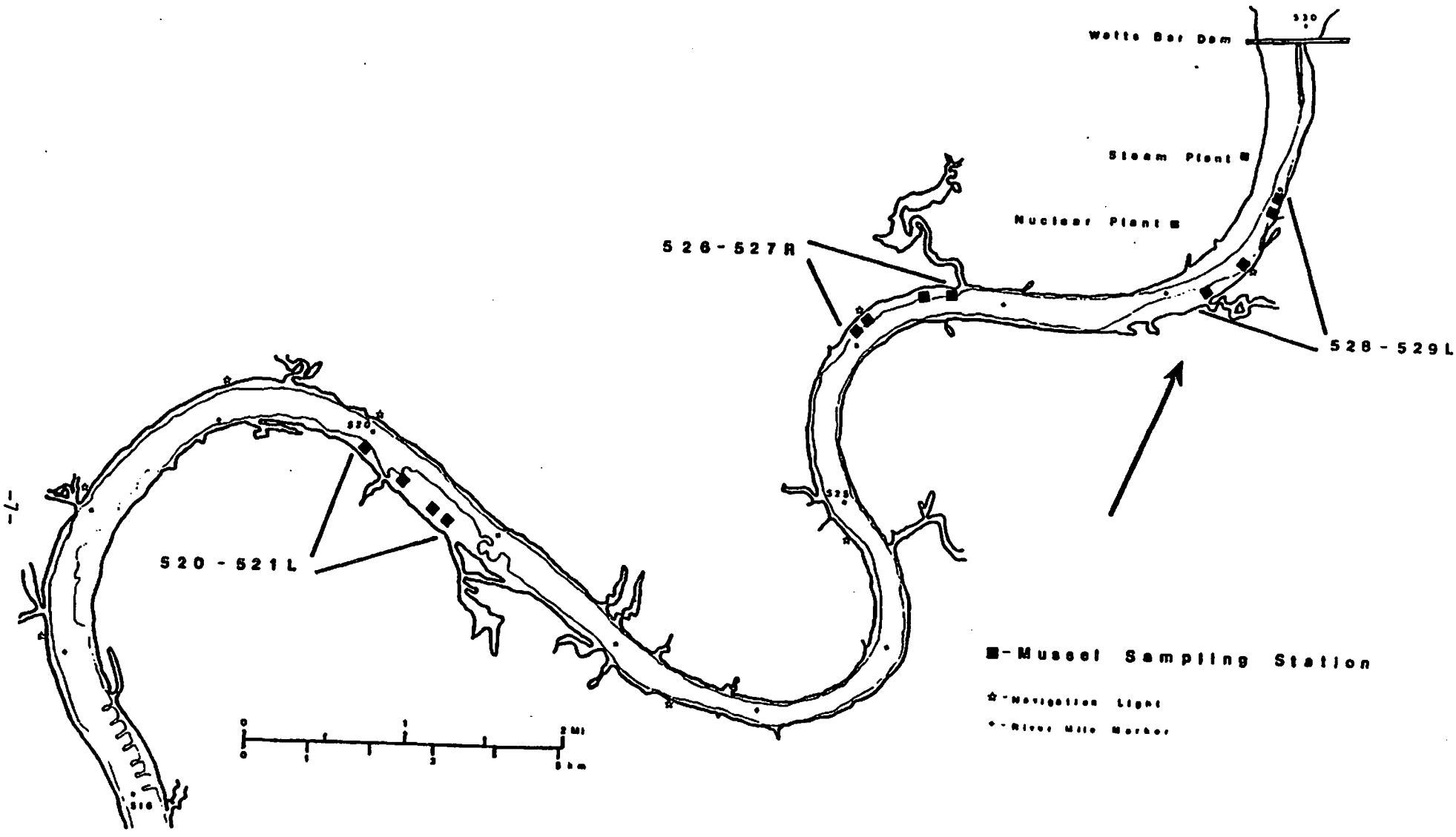

Figure 1. Tennessee River downstream from Watts Bar Dam showing the locations of the three mussel beds and the three sampling stations examined in 1988 and 1990.

Table 1. Total numbers and percent composition of mussel samples at three sites (TRMs 520-521L, TRMs 526-5278, and TRMs 528-529L) in upper Chickamauga Reservoir in the vicinity of Watts Bar Nuclear Plant during 1988 and 1990.

Species	1988 (percent)	1990 (percent)
Actinonaias ligamentina	3	5 (1)
Amblema plicata	49 (3)	10 (1)
Anodonta grandis	29 (2)	20 (2)
Anodonta imbecillis	1	1
Anodonta suborbiculata	1	1
Cyclonaias tuberculata	93 (6)	90 (9)
Ellipsaria lineolata	23 (1)	28 (3)
Elliptio crassidens	970 (60)	524 (53)
Elliptio dilatata	3	1
Lampsilis abrupta E	12 (1)	4
Lampsilis ovata	3	1
Leptodea fragilis	12 (1)	8 (1)
Ligumia recta	7	2
Menalonaias nervosa	9 (1)	3
Obliquaria reflexa	7	11 (1)
Pleurobema cordatum	224 (14)	139 (14)
Pleurobema oviforme C	2	1
Pleurobema rubrum	1	0
Potamilus alatus	55 (3)	45 (5)
Ptychobranchus fasciolaris	0	1
Quadrula metanevra	8	8 (1)
Quadrula pustulosa	80 (5)	79 (8)
Tritogonia verrucosa	18 (1)	9 (1)
Total Specimens	1610	991
Total Species	22	22

C - Cumberlandian Species
E - Endangered Species

Table 2. Summary of measurements taken of freshwater mussel specimens on three beds during sampling in 1988 and 1990. Measurements are reported in millimeters.

REACH=TRM 520 YEAR=1988

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	2	93.00	90.90	95.10	71.65	71.30	72.00	49.35	47.60	51.10
Amblema plicata	12	97.95	73.20	115.30	72.45	53.00	86.10	43.01	33.30	52.10
Anodonta grandis	3	101.60	81.70	119.90	59.83	53.60	65.30	44.00	34.50	50.40
Cyclonaias tuberculata	50	75.88	64.30	88.60	64.96	55.20	75.20	38.08	32.20	44.90
Elliptio crassidens	51	104.08	92.40	124.50	66.17	60.10	84.90	42.50	34.10	50.70
Elliptio dilatata	1	96.80	96.80	96.80	45.40	45.40	45.40	26.90	26.90	26.90
Lampsilis ovata	1	110.70	110.70	110.70	76.90	76.90	76.90	61.80	61.80	61.80
Ligumia recta	2	156.05	144.40	167.70	57.45	54.20	60.70	48.65	44.40	52.90
Megalonaias nervosa	4	155.25	144.20	170.20	109.25	100.80	117.20	59.87	53.30	65.60
Ellipsaria lineolata	9	79.49	65.10	100.00	59.98	47.50	70.60	37.53	32.70	50.30
Pleurobema cordatum	52	91.03	68.50	110.10	73.16	54.90	83.60	46.47	38.20	54.80
Potamilus alatus	10	132.07	114.90	151.00	96.46	76.30	113.40	39.75	34.40	48.30
ula metanevra	6	80.70	66.70	92.10	63.15	54.20	70.10	43.43	38.40	47.30
Quadrula pustulosa	5	57.08	52.20	68.80	52.20	46.90	61.30	34.66	31.30	37.30
Tritogonia verrucosa	3	101.07	91.80	109.40	55.10	50.50	57.40	27.93	23.20	34.00

Table 2. (continued)

REACH=TRM 526 YEAR=1988

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	1	107.60	107.60	107.60	76.80	76.80	76.80	55.40	55.40	55.40
Amblema plicata	22	105.73	64.80	117.60	77.38	51.10	89.30	49.21	34.80	56.90
Anodonta grandis	19	131.44	101.00	155.10	72.65	56.10	89.90	55.26	43.50	71.20
Anodonta imbecillis	1	54.00	54.00	54.00	24.10	24.10	24.10	16.20	16.20	16.20
ona tuberculata	8	82.56	63.40	94.70	71.49	60.70	78.10	41.26	31.30	45.00
Elliptio crassidens	50	113.30	100.10	129.20	70.47	44.20	79.30	45.82	39.90	55.30
Lampsilis abrupta	2	96.10	93.40	98.80	69.75	69.50	70.00	57.50	51.40	63.60
Lampsilis ovata	1	139.90	139.90	139.90	90.40	90.40	90.40	77.30	77.30	77.30
Leptodea fragilis	9	98.76	70.40	126.30	61.44	44.90	76.00	32.27	23.80	39.80
Obliquaria reflexa	7	54.84	44.20	62.70	43.20	36.20	49.60	32.27	24.40	36.00
Ellipsaria lineolata	4	88.22	81.70	94.30	68.20	61.50	72.80	40.80	38.40	42.30
Pleurobema cordatum	31	100.33	83.40	113.90	79.15	70.30	89.20	49.45	43.10	54.50
Pleurobema rubrum	1	88.30	88.30	88.30	69.50	69.50	69.50	46.70	46.70	46.70
Potamilus alatus	29	147.89	110.30	187.70	109.59	86.70	131.20	41.57	31.00	50.30
Quadrula pus	21	58.90	52.60	64.00	55.89	46.60	64.10	36.14	30.00	40.60
Tritogonia verrucosa	13	114.88	96.30	140.80	64.74	50.10	76.30	41.53	29.70	50.70

Table 2. (Continued)

REACH=528 YEAR=1988

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Amblema plicata	14	101.22	82.30	119.80	74.19	63.50	89.80	44.59	32.10	52.00
Anodonta grandis	7	125.20	109.70	136.10	66.87	57.60	81.30	52.64	48.40	58.70
Anodonta suborbiculata	1	107.80	107.80	107.80	79.20	79.20	79.20	38.70	38.70	38.70
Cyclonaias tuberculata	29	83.77	67.20	97.50	69.95	58.90	97.70	41.00	36.10	49.30
Elliptio crassidens	50	112.93	99.60	136.40	69.48	61.30	76.20	44.49	36.30	54.60
Elliptio dilatata	2	103.25	95.60	110.90	45.45	40.80	50.10	29.15	27.50	30.80
Lampsilis abrupta	10	101.72	86.80	119.80	72.11	62.70	79.80	57.43	51.90	60.90
Lampsilis ovata	1	140.50	140.50	140.50	87.70	87.70	87.70	58.00	58.00	58.00
Leptodea fragilis	3	102.97	98.20	106.40	60.70	56.70	63.00	31.67	28.80	34.00
Ligumia recta	5	161.96	146.60	175.10	64.36	62.00	68.70	53.08	50.20	55.10
Megalonaias nervosa	5	164.90	155.10	170.80	118.14	110.40	126.60	61.18	53.60	68.70
Ellipsaria lineolata	10	93.77	83.50	102.80	69.20	62.10	77.40	41.00	36.10	44.50
Pleurobema cordatum	50	99.99	86.10	119.10	78.51	69.20	87.50	48.33	39.40	58.60
Pleurobema oviforme	2	72.20	70.20	74.20	55.00	54.00	56.00	40.70	40.70	40.70
Potamilus alatus	15	139.96	118.60	155.20	107.58	90.10	120.90	40.10	34.80	49.30
Quadrula metanevra	2	91.25	90.70	91.80	67.40	67.20	67.60	52.10	50.60	53.60
Quadrula pustulosa	51	57.85	12.40	81.10	55.00	40.70	98.40	35.02	26.20	43.10
Tritogonia verrucosa	2	115.75	98.30	133.20	56.80	51.40	62.20	43.55	26.70	60.40

Table 2. (Continued)

COMBINED TOTALS YEAR=1988

'SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	3	97.87	90.90	107.60	73.37	71.30	76.80	51.37	47.60	55.40
Amblema plicata	48	102.47	64.80	119.80	75.22	51.10	89.80	46.31	32.10	56.90
Anodonta grandis	29	126.85	81.70	155.10	69.93	53.60	89.90	53.46	34.50	71.20
Anodonta imbecillis	1	54.00	54.00	54.00	24.10	24.10	24.10	16.20	16.20	16.20
Anodonta suborbiculata	1	107.80	107.80	107.80	79.20	79.20	79.20	38.70	38.70	38.70
Cyclonaias tuberculata	87	79.12	63.40	97.50	76.22	55.20	97.70	39.34	31.30	49.30
Elliptio crassidens	151	110.06	92.40	136.40	68.69	44.20	84.90	44.26	34.10	55.30
Elliptio dilatata	3	101.10	95.60	110.90	45.43	40.80	50.10	28.40	26.90	30.80
Lampsilis abrupta	12	100.78	86.80	119.80	71.72	62.70	79.80	57.44	51.40	63.60
Lampsilis ovata	3	130.37	110.70	140.50	85.00	76.90	90.40	65.70	58.00	77.30
Leptodea fragilis	12	99.81	70.40	126.30	61.26	44.90	76.00	32.12	23.80	39.80
Ligumia recta	7	160.27	144.40	175.10	62.39	54.20	68.70	51.81	44.40	55.10
Megalonaias nervosa	9	160.61	144.20	170.80	114.19	100.80	126.60	60.60	53.30	68.70
Obliquaria reflexa	7	54.84	44.20	62.70	43.20	36.20	49.60	32.27	24.40	36.00
Ellipsaria lineolata	23	87.22	65.10	102.80	65.42	47.50	77.40	39.61	32.70	50.30
Pleurobema cordatum	133	96.57	68.50	119.10	76.57	54.90	89.20	47.87	38.20	58.60
l r oviforme	2	72.20	70.20	74.20	55.00	54.00	56.00	40.70	40.70	40.70
le : rubrum	1	88.30	88.30	88.30	69.50	69.50	69.50	46.70	46.70	46.70
Potamilus alatus	54	142.76	110.30	187.70	106.60	76.30	131.20	40.82	31.00	50.30
Quadrula a	8	83.34	66.70	92.10	64.21	54.20	70.10	45.60	38.40	53.60
Quadrula pustulosa	77	58.08	12.40	81.10	55.06	40.70	98.40	35.31	26.20	43.10
Tritogonia verrucosa	18	112.68	91.80	140.80	62.25	50.10	76.30	39.49	23.20	60.40

Table 2. (Continued)

REACH=520 YEAR=1990

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	2	97.35	96.00	98.70	72.15	71.40	72.90	49.60	47.60	51.60
Amblema plicata	5	100.30	76.60	120.10	71.08	54.50	87.20	41.74	33.60	47.20
Anodonta grandis	1	136.30	136.30	136.30	76.70	76.70	76.70	51.00	51.00	51.00
Anodonta imbecillis	1	52.00	52.00	52.00	24.80	24.80	24.80	14.30	14.30	14.30
Cyclonaias tuberculata	50	77.43	62.00	111.00	65.32	52.10	92.10	37.12	28.00	46.50
Ellipsaria lineolata	16	85.20	64.20	94.80	63.94	51.60	71.30	37.67	32.10	44.60
Elliptio crassidens	50	109.49	87.50	130.10	68.71	62.40	79.90	42.94	36.30	50.20
Leptodea fragilis	2	100.15	89.90	110.40	67.65	62.70	72.60	37.85	36.50	39.20
Megalonaias nervosa	2	164.85	155.60	174.10	115.65	110.70	120.60	56.20	56.20	56.20
Obliquaria reflexa	2	45.40	44.50	46.30	36.80	36.70	36.90	26.60	25.40	27.80
Pleurobema cordatum	34	91.89	75.60	110.10	71.37	59.50	82.40	42.27	32.90	52.00
Potamilus alatus	13	141.24	131.60	152.90	105.18	83.30	120.90	55.30	37.20	139.80
Quadrula metanevra	2	73.35	65.20	81.50	53.60	48.10	59.10	39.40	35.50	43.30
Quadrula pustulosa	17	52.47	45.70	64.10	49.12	42.80	55.70	31.34	25.30	37.50
Tritogonia verrucosa	1	94.00	94.00	94.00	52.20	52.20	52.20	32.50	32.50	32.50

Table 2. (Continued)

REACH=526 YEAR=1990

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	1	115.40	115.40	115.40	82.60	82.60	82.60	58.30	58.30	58.30
Amblema plicata	4	102.47	87.20	112.40	73.67	66.70	80.70	48.67	43.40	50.90
Anodonta grandis	17	136.27	108.70	159.10	76.23	61.50	99.90	56.54	44.40	68.80
Anodonta suborbiculata	1	126.20	126.20	126.20	96.40	96.40	96.40	48.30	48.30	48.30
Cyclonaias tuberculata	5	80.92	73.50	86.70	69.12	64.20	72.20	39.28	35.80	43.20
Ellipsaria lineolata	3	87.13	64.70	101.60	67.33	53.10	76.90	41.37	39.50	42.30
Elliptio crassidens	50	115.95	104.00	149.30	71.21	61.40	82.10	45.56	38.30	51.00
Lampsilis abrupta	1	98.10	98.10	98.10	83.70	83.70	83.70	62.10	62.10	62.10
Leptodea fragilis	5	111.74	101.80	130.10	69.30	61.00	89.50	36.24	32.80	40.00
Ligumia recta	1	173.10	173.10	173.10	73.50	73.50	73.50	59.90	59.90	59.90
Obliquaria reflexa	6	57.62	48.50	64.60	45.73	39.60	49.90	36.08	29.90	45.10
Pleurobema cordatum	24	102.52	90.20	120.70	78.21	69.00	90.60	48.51	41.70	52.80
Potamilus alatus	28	146.09	120.10	169.10	108.90	88.40	126.30	40.99	33.10	47.70
Quadrula metanevra	2	84.35	77.90	90.80	66.20	62.30	70.10	50.65	49.90	51.40
Quadrula pustulosa	26	60.05	50.10	74.40	55.38	44.90	66.90	35.37	28.00	42.10
Tritogonia verrucosa	7	105.43	78.10	130.10	56.16	43.40	65.90	35.67	26.60	42.50

Table 2. (Continued)

REACH=528 YEAR=1990

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
Actinonaias ligamentina	2	120.90	120.80	121.00	81.30	80.10	82.50	60.95	60.10	61.80
Amblema plicata	1	110.20	110.20	110.20	75.70	75.70	75.70	38.50	38.50	38.50
Anodonta grandis	2	127.75	126.40	129.10	74.10	69.20	79.00	52.95	46.80	59.10
Cyclonaias tuberculata	14	87.13	76.30	94.90	73.68	66.80	83.30	40.56	34.10	49.60
Ellipsaria lineolata	9	85.23	72.70	102.30	64.28	53.20	74.60	41.13	36.20	47.40
Elliptio crassidens	60	119.35	104.60	134.70	72.48	61.10	82.70	46.00	38.20	51.60
Elliptio dilatata	1	94.60	94.60	94.60	46.90	46.90	46.90	28.60	28.60	28.60
Lampsilis abrupta	3	108.57	101.00	120.60	83.23	81.80	86.00	62.17	55.70	67.70
Lampsilis ovata	1	121.70	121.70	121.70	78.10	78.10	78.10	68.30	68.30	68.30
Leptodea fragilis	1	141.70	124.70	124.70	69.60	69.60	69.60	39.70	39.70	39.70
Ligumia recta	1	172.10	172.10	172.10	68.30	68.30	68.30	58.70	58.70	58.70
Megalonaias nervosa	1	170.10	170.10	170.10	118.40	118.40	118.40	57.10	57.10	57.10
Obliquaria reflexa	3	56.40	54.80	58.00	42.90	40.30	46.40	30.37	28.50	31.70
Pleurobema cordatum	74	98.21	85.40	116.80	76.30	67.20	90.10	47.50	39.60	56.90
Pleurobema oviforme	1	72.80	72.80	72.80	56.00	56.00	56.00	41.70	41.70	41.70
Potamilus alatus	4	124.70	83.20	147.60	101.20	72.60	116.90	36.65	21.50	43.50
Ptychobranchus fasciolaris	1	116.80	116.80	116.80	61.40	61.40	61.40	44.70	44.70	44.70
Quadrula metanevra	4	89.70	85.30	100.70	66.97	60.20	71.50	48.42	46.30	51.80
Quadrula pustulosa	35	58.17	44.10	82.80	54.31	43.30	67.40	34.77	25.20	45.40
Tritogonia verrucosa	1	136.30	136.30	136.30	70.90	70.90	70.90	34.70	34.70	34.70

Table 2. (Continued)

SPECIES	N	LENGTH MEAN	LENGTH MIN	LENGTH MAX	WIDTH MEAN	WIDTH MIN	WIDTH MAX	THICKNESS MEAN	THICKNESS MIN	THICKNESS MAX
COMBINED TOTALS YEAR=1990										
Actinonaias ligamentina	5	110.38	96.00	121.00	77.90	71.40	82.60	55.88	47.60	61.80
Amblema plicata	10	102.16	76.60	120.10	72.58	54.50	87.20	44.19	33.60	50.90
Anodonta grandis	20	135.42	108.70	159.10	76.04	61.50	99.90	55.90	44.40	68.80
Anodonta imbecillis	1	52.00	52.00	52.00	24.80	24.80	24.80	14.30	14.30	14.30
Anodonta suborbiculata	1	126.20	126.20	126.20	96.40	96.40	96.40	48.30	48.30	48.30
Cyclonaias tuberculata	69	79.65	62.00	111.00	67.29	52.10	92.10	37.97	28.00	49.60
Ellipsaria lineolata	28	85.42	64.20	102.30	64.41	51.60	76.90	39.18	32.10	47.40
Elliptio crassidens	160	115.21	87.50	149.30	70.91	61.10	82.70	44.91	36.30	51.60
Elliptio dilatata	1	94.60	94.60	94.60	46.90	46.90	46.90	28.60	28.60	28.60
Lampsilis abrupta	4	105.95	98.10	120.60	83.35	81.80	86.00	62.15	55.70	67.70
Lampsilis ovata	I	121.70	121.70	121.70	78.10	78.10	78.10	68.30	68.30	68.30
Leptodea fragilis	8	110.46	89.90	130.10	68.92	61.00	89.50	37.07	32.80	40.00
Ligumia recta	2	172.60	172.10	173.10	70.90	68.30	73.50	59.30	58.70	59.90
Megalonaias nervosa	3	166.60	155.60	174.10	116.57	110.70	120.60	56.50	56.20	57.10
Obliquaria reflexa	11	55.06	44.50	64.60	43.34	36.70	49.90	32.80	25.40	45.10
Pleurobema cordatum	132	97.37	75.60	120.70	75.38	59.50	90.60	46.34	32.90	56.90
Pleuroberna oviforme	1	72.80	72.80	72.80	56.00	56.00	56.00	41.70	41.70	41.70
Potamilus alatus	45	142.78	83.20	169.10	107.14	72.60	126.30	44.74	21.50	139.80
Ptychobranchus fasciolaris	1	116.80	116.80	116.80	61.40	61.40	61.40	44.70	44.70	44.70
Quadrula metanevra	8	84.27	65.20	100.70	63.44	48.10	71.50	46.72	35.50	51.80
Quadrula pustulosa	78	57.56	44.10	82.80	53.53	42.80	67.40	34.22	25.20	45.40
Tritogonia verrucosa	9	107.59	78.10	136.30	57.36	43.40	70.90	35.21	26.60	42.50

Table 2. (Continued)

SPECIES	N	GRAND TOTAL YEAR 1988 and 1990								
		LENGTH			WIDTH			THICKNESS		
		MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
Actinonaias ligamentina	8	105.69	90.90	121.00	76.20	71.30	82.60	54.19	47.60	61.80
Amblema plicata	58	102.42	64.80	120.10	74.76	51.10	89.80	45.95	32.10	56.90
Anodonta grandis	49	130.35	81.70	159.10	72.42	53.60	99.90	54.46	34.50	71.20
Anodonta imbecillis	2	53.00	52.00	54.00	24.45	24.10	24.80	15.25	14.30	16.20
Anodonta suborbiculata	2	117.00	107.80	126.20	87.80	79.20	96.40	43.50	38.70	48.30
Cyclonaias tuberculata	156	79.35	62.00	111.00	67.25	52.10	97.70	38.74	28.00	49.60
Ellipsaria lineolata	51	86.23	64.20	102.80	64.86	47.50	77.40	39.37	32.10	50.30
Elliptio crassidens	311	112.71	87.50	149.30	69.83	44.20	84.90	44.59	34.10	55.30
Elliptio dilatata	4	99.47	94.60	110.90	45.80	40.80	50.10	28.45	26.90	30.80
Lampsilis abrupta	16	102.07	86.80	120.60	74.62	62.70	86.00	58.62	51.40	67.70
Lampsilis ovata	4	128.20	110.70	140.50	83.27	76.90	90.40	66.35	58.00	77.30
Leptodea fragilis	20	104.07	70.40	130.10	64.32	44.90	89.50	34.10	23.80	40.00
Ligumia recta	9	163.01	144.40	175.10	64.28	54.20	73.50	53.48	44.40	59.90
Megalonaias nervosa	12	162.11	144.20	174.10	114.78	100.80	126.60	59.57	53.30	68.70
Obliquaria reflexa	18	54.98	44.20	64.60	43.28	36.20	49.90	32.59	24.40	45.10
Pleurobema cordatum	265	96.96	68.50	120.70	75.98	54.90	90.60	47.11	32.90	58.60
Pleurobema oviforme	3	72.40	70.20	74.20	55.33	54.00	56.00	41.03	40.70	41.70
ob rubrum	1	88.30	88.30	88.30	69.50	69.50	69.50	46.70	46.70	46.70
Potamilus alatus	99	142.77	83.20	187.70	106.84	72.60	131.20	42.60	21.50	139.80
Ptychobranchus fasciolaris	1	116.80	116.80	116.80	61.40	61.40	61.40	44.70	44.70	44.70
Quadrula metanevra	16	83.81	65.20	100.70	63.82	48.10	71.50	46.16	35.50	53.60
Quadrula pustulosa	155	57.82	12.40	82.80	54.29	40.70	98.40	34.76	25.20	45.40
Tritogonia err	27	110.98	78.10	140.80	60.62	43.40	76.30	38.06	23.20	60.40

Table 3. Mean shell lengths (mm) of measured freshwater mussel species obtained during the 1988 and 1990 surveys from the Tennessee River near the Watts Bar Nuclear Plant site.

Species	1988 Number	1988 Mean	1990 Number	1990 Mean
Actinonaias ligamentina	3	97.87	5	110.38
Amblema plicata	48	102.47	10	102.16
Anodonta **grandis**	29	126.85	20	135.42
Anodonta **imbecillis**	1	54.00	1	52.00
Anodonta suborbiculata	1	107.80	1	126.20
Cyclonaias tuberculata	87	79.12	69	79.65
Ellipsaria **lineolata**	23	87.22	28	85.42
Elliptio crassidens	151	110.06	160	115.21
Elliptio dilatata	3	101.10	1	94.60
Lampsilis abrupta	12	100.78	4	105.95
Lampsilis ovata	3	130.37	1	121.70
Leptodea **fragilis**	12	99.81	8	110.46
Ligumia recta	7	160.27	2	172.60
Megalonaias nervosa	9	160.61	3	166.60
Obliquaria reflexa	7	54.84	11	55.06
Pleurobema **cordatum**	133	96.57	132	97.37
Pleurobema oviforme	2	72.20	1	72.80
Pleurobema **rubrum**	1	88.30		
Potamilus alatus	54	142.76	45	142.78
Ptychobranchus **fasciolaris**			1	116.80
Quadrula metanevra	8	83.34	8	84.27
Quadrula pustulosa	77	58.08	78	57.56
Tritogonia verrucosa	18	112.68	9	107.59
Measured Specimens	689		598	
Average Mean Lengths		99.52		99.26
Species Total	22		22	

Table 4. Station-by-station comparisons of the total number of mussels found in 1988 and 1990 on each of the three beds in the Tennessee River near the Watts Bar Nuclear Plant site using analysis of variance, ANOVA (significance level < 0.05).

Mussel Bed and Species	P > F	Station Differences Duncan's Relationships*
TRM 520-521L		
Elliptio crassidens	0.0536	.0 .8 .6 .3
Potamilus alatus	0.0305	.6 .8 .3 .0
TRM 526-527R		
Obliquaria reflexa	0.0655	.8 .5 .3 .0
Pleurobema cordatum	0.1096	.3 .5 .0 .8
Potamilus alatus	0.0602	.8 .5 .0 .3
Quadrula pustulosa	0.0985	.5 .8 .3 .0
Tritogonia verrucosa	0.0354	.3 .0 .8 .5
TRM 528-529L		
Ellipsaria lineolata	0.0277	.2 .5 .8 .9
Elliptio dilatata	0.0520	.8 .2 .5 .9
Quadrula metanevra	0.0219	.8 .5 .2 .9
Quadrula pustulosa	0.1390	.8 .2 .5 .9

*Decimal numbers are 1/10 mile identifiers of station locations, in each case listed in descending order for the abundance of the species being evaluated.
Station identifiers sharing a common underline are not significantly different from each other

10159

TENNESSEE VALLEY AUTHORITY

River Basin Operations
Water Resources

POPULATION SURVEY OF SAUGER IN CHICKAMAUGA RESERVOIR 1990-1991

Prepared by
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August 1991

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INTRODUCTION

In 1986 the Tennessee Valley Authority (TVA), in cooperation with the Tennessee Wildlife Resources Agency (TWRA), initiated an intensive program to determine the status of the sauger population in upper Chickamauga Reservoir and to identify potential impacts of operation of Watts Bar (WBN) and Sequoyah (SQN) Nuclear Plants on this important sport fish. Results of this program from 1986 through 1989 documented annual population densities, spawning location, spawning habitat characteristics, pre- and post-spawn movement patterns, year class strengths, and growth rates (Hevel 1988, Hickman et al. 1989 and Hickman et al. 1990). These studies indicated an extreme decline of sauger numbers, and as a result TWRA stocked 191,000 sauger fingerlings into Chickamauga Reservoir during summer 1990 to bolster the population.

Heavy rainfall during late winter and early spring 1990 resulted in ineffective sampling conditions for migrating sauger in upper Chickamauga Reservoir. Sauger have been successfully sampled in the spilling basin of Watts Bar Dam from February through March; however, during these months in 1990, Watts Bar Dam spill gates were open for much of this period and the generators were operated constantly. To avoid the turbulent water, sampling was restricted to the normally unproductive lock approach channel resulting in low capture efficiencies.

Because of the low capture rates in 1990, the limited data collected that year are addressed in this report along with 1991 results. Objectives

during the final two years (1990 and 1991) of the project were to: (1) continue monitoring adult sauger population density and (2) evaluate impacts of SQN operation and potential impacts of WBN operation on the sauger spawning migration.

DESCRIPTION OF STUDY AREA

The study area in 1990 and 1991 was generally restricted to two major sites: immediately downstream of Watts Bar Dam and the previously identified Hunter Shoals spawning area (Hevel 1988 and Hickman et al. 1989) at Tennessee River mile (TRM) 520-521 (Figure 1). Flows in upper Chickamauga are controlled by hydroelectric turbine discharges and generally infrequent spillway releases from Watts Bar Dam. Water temperatures fluctuate in response to discharges from the dam and environmental influences such as cold fronts and solar heating. The SQN diffuser is located 38 river miles below Hunter Shoals at TRM 483.4 (TVA 1985). WBN is located in upper Chickamauga Reservoir two river miles downstream of Watts Bar Dam with a diffuser located at TRM 527.8 (TVA 1986). Operational characteristics of both plants were detailed by Hickman et al. (1989). SQN units 1 and 2 operated at essentially full load throughout the 1990 and 1991 sampling periods. WBN did not operate during the 1990 or 1991 sample periods but did pump water through the cooling system even though there was no thermal load.

METHODS

From mid-January to mid-April 1990 and from December 1990 to mid-April

1991 Watts Bar tailwater areas were sampled with experimental gill nets. Procedures were the same as used during 1986-89 sampling in upper Chickamauga Reservoir (Hickman et al. 1990).

Sampling in 1990 was restricted to the lock approach channel until March 7. From that point, both the spilling basin and the sauger spawning area (Hunter Shoals) were sampled until mid-April. Sampling in 1991 was also restricted to the lock channel from February 19 to March 11, with the spilling basin sampled at other times during the period from December 1990 to April 15, 1991. Hunter Shoals could not be sampled until mid-April in 1991 due to continual high discharges through Watts Bar Dam generators before that time. During both years set times were typically limited to two hours to reduce catch mortality.

Hickman et al. (1989) suggested that a potential impact of nuclear plant operation on success of the sauger spawn in upper Chickamauga Reservoir would be attraction of fish to the warmer diffuser area instead of suitable spawning sites. Additionally, the altered temperature regime in the discharge plume could upset the synchrony of female sauger gonadal development during the migration to the spawning site. To test these potential impacts experimental gill nets were set in the vicinity of the SQN plant and SQN diffuser during late January 1990 and 1991 and during peak spawning in mid-April 1991. Observations on the spawning readiness of female sauger were only used to address potential impacts to gonadal development. Individuals were considered spawning ready when they reached a free flowing state (i.e., when eggs could be observed after applying slight pressure to the ventral surface anterior to the vent).

Data recorded on each net from all sample areas included: date, location, length of time net was fished, and total number of each fish species collected. For each sauger captured, additional data were taken on total length (mm), weight (g), and sex (when available). Prior to release, adult sauger were tagged with numbered disc reward tags below the posterior insertion of the dorsal fin as described by Hickman et al. (1989). Numbered spaghetti tags were used on most yearling sauger to reduce tissue damage caused by disc tags as a result of the rapid growth of juvenile fish. Tag numbers were recorded and the fish released into the same area in which they had been captured.

DATA ANALYSIS

Gill netting data from 1990 and 1991 were summarized as catch per unit effort (number/hour) for all species and length-frequency percentages for sauger. Year classes were separated using lenght-frequency information and knowledge from scale analysis of previous samples of sauger from upper Chickamauga Reservoir. Sauger population size was estimated using the Thompson and Juday mark and recapture census method (Lackey 1974). Although some assumptions required for this method were violated (i.e., a closed system), this estimate of number of spawning adult sauger provided the best available measure of abundance. This multiple census method of estimation is based on the formula:

$$N = \frac{\Sigma C_t m_t}{\Sigma r_t}$$

where N = estimated population size,
C_t = total fish captured on day t,
m_t = total number of marked fish at the start of day t, and
r_t = number of recaptures in the sample C_t.

Relative weights (W_r) were calculated as a measure of fish condition. Relative weight is based on a percentage comparison of the observed weight per unit length with an accepted standard weight per unit length. It is calculated using the formula:

$$W_r = \frac{W}{W_s} \times 100$$

where W is the observed weight and W_s is the standard weight for a given length. Standard weights of sauger for comparison with Chickamauga Reservoir fish were generated from the sauger standard weight equation proposal by Guy et al. (1990).

RESULTS AND DISCUSSION

A total of 2,350 fish representing 29 species and two hybrids were captured during 527 hours of gill netting in spring 1990 in Chickamauga Reservoir (Table 1). Channel catfish (1.10 caught/hr), gizzard shad (0.90), yellow bass (0.70), and blue catfish (0.50) were the most abundant species captured. A total of only 41 sauger were collected (including recaptures) with 34 being tagged.

The 574 hours of experimental gill netting conducted in late-winter and early spring 1991 yielded 3,094 fish representing 28 species and 2 hybrids (Table 1). Sauger and channel catfish were the most abundant species with catches per net hour of 1.07 and 0.92, respectively. Next in abundance were yellow bass (0.69), white bass (0.51), Cherokee bass (0.46) and skipjack herring (0.44). Catch rates of all other

species were less than 0.40 individuals per hour. A total of 614 yearling and adult sauger were collected in 1991 of which 521 were tagged.

Inspection of length frequency percentages between 1990 and 1991 sample years indicates that the 1990 year class was much stronger (Figure 2). Age 1 sauger made up over 71 percent of the population in 1991, compared to only 15 percent of the population in 1990. However, the apparent strength of the 1990 year class may be deceiving as most naturally produced age 1 sauger do not typically participate in the spawning migration (Hickman et al. 1989). George Peck (personal communication) stated walleye and saugeye fingerlings released in Cherokee Reservoir annually from 1982 to 1990 tended to remain near the release area for one year before dispersal. TWRA released approximately 116,000 fingerling sauger (age 0) during May 1990 in upper Chickamauga Reservoir at Washington Ferry (TRM 518), 12 river miles below Watts Bar Dam. It is probable the capture of large numbers of age 1 fish in spring 1991 was a result of this release, and due to unnatural "clumping" in the study area the numbers may not reflect the actual strength of the 1990 year class. An additional 75,000 fingerling sauger were released in May 1990 by TWRA into Sugar Creek, a small tributary to the Hiwassee River embayment of Chickamauga Reservoir. Gill netting and electrofishing sampling in 15 embayments in Chickamauga Reservoir in an unrelated study during May 1991 (Al Brown, personal communication) resulted in the collection of 27 yearling sauger, 25 of which were from Hiwassee River embayments, again suggesting unnatural clumping of stocked fingerlings. Therefore, it is possible that 1991 sample results may be deceiving in that the abundance of the 1990 year class may appear artifically high.

None stocked in 1991

per Anders 8/31/92

A total of only 9 recaptures ~~were~~ WAS obtained during 1990 sampling at both the Watts Bar Dam and Hunter Shoals areas resulting in a population estimate of only 78 (confidence interval of 42 to 515) sauger migrating to the headwaters of Chickamauga Reservoir. This indication of an extremely depressed population was alarming; however, the abnormally high flow conditions which lasted through much of the sauger spawn in 1990 reduced sauger sampling efficiency and possibly altered typical distribution of migrating sauger. While adult sauger numbers probably continued to decline during 1989, it is unlikely our results are an accurate depiction of the extent of the decrease.

The population estimate of sauger in upper Chickamauga during the spring 1991 spawning migration of 7,024 fish revealed a dramatic increase over 1990 sauger abundance. However, most of the estimated population consisted of age 1 fish, probably resulting from TWRA stocking activities. A total of 2,037 (with a confidence interval of 1,411 to 3,660) were age 2 or greater revealing that the adult sauger population has increased over the previous lowest estimate (disregarding the low 1990 estimate) of 1,124 in 1989.

The relative condition of sauger in upper Chickamauga Reservoir in both 1990 and 1991 was above average to average. Anderson (1980) suggested W_r values in the range of 95 - 105 be considered average. The mean W_r of sauger in 1990 was 109 with sauger in 1991 exhibiting a W_r of 104.

A total of only 2 sauger have been collected in 448 net hours between the two sample years in the vicinity of the SQN diffuser. This sampling was done during both peak migration and peak spawning periods. It is apparent sauger do not congregate at the SQN diffuser during the spawning season. Neither of the 2 sauger collected in the vicinity of the SQN diffuser were free-flowing females. All female sauger captured in free-flowing condition were obtained on or near the historical spawning area during the April spawning period suggesting synchrony of gonadal development was not upset by heated effluent from SQN.

CONCLUSIONS

During the six year history of this project, sauger exhibited definite movement patterns, demonstrated a propensity to a certain spawning location, and their population declined. Adult sauger population estimates dropped from an estimated 18,000+ in 1986 to approximately 2,000 in 1991 (final year of study). Primary reasons for the declining abundance were found to be poor reproductive success as a result of low flows and unstable water temperatures during sauger spawning. Conditions during spring 1990 and 1991 appear to have met both major criteria for successful sauger spawns; however, natural reproductive success cannot be determined due to the stocking of 175,000 age 0 sauger by TWRA. These stockings were apparently successful as numerous age 1 sauger were captured in the vicinity of the stocking area in 1991.

A satellite project was developed based on the results of these investigations which addresses flow levels necessary to enhance sauger

reproductive success. It is anticipated that sauger densities in Chickamauga Reservoir can be increased through timing of appropriate minimum flow releases (4,000 cfs) from Watts Bar Dam with the historical sauger spawning period in the reservoir. Testing of this hypothesis is proposed for April during 1992 - 1994 under a separate project.

Impacts of SQN operation on the sauger spawn could not be investigated in 1990 due to late-winter spilling at Watts Bar Dam. However, sampling in the vicinity of SQN diffuser was conducted during plant operation in the 1991 sauger spawning period. Results revealed that SQN operation does not appear to impact either the migration of sauger to their traditional spawning grounds (only 2 captured at SQN diffuser during 140 hours of effort in 1991) or the syncrony of their gonadal development.

WBN has the greatest potential for adverse impacts because the plant is located only 7 river miles upstream of the only known sauger spawning area in Chickamauga Reservoir. However, discharges from WBN are expected to be only 3 feet per second (maximum of 0.6 percent of the flow past the plant). Water temperature fluctuations caused by plant operation will not influence conditions at Hunter Shoals due to the rapid dilution of the discharge water (only 0.8 C above ambient in mixing zone of diffuser). The potential to influence sauger movement patterns at WBN is similar to concerns at SQN, mainly diverting adult fish from the spawning site and/or altering the rate of sauger maturation due to increased water temperature in the immediate vicinity of the diffuser. However, due to the limited change in ambient water temperature as a result of WBN operation, no adverse impacts on the Chickamauga Reservoir sauger population are anticipated.

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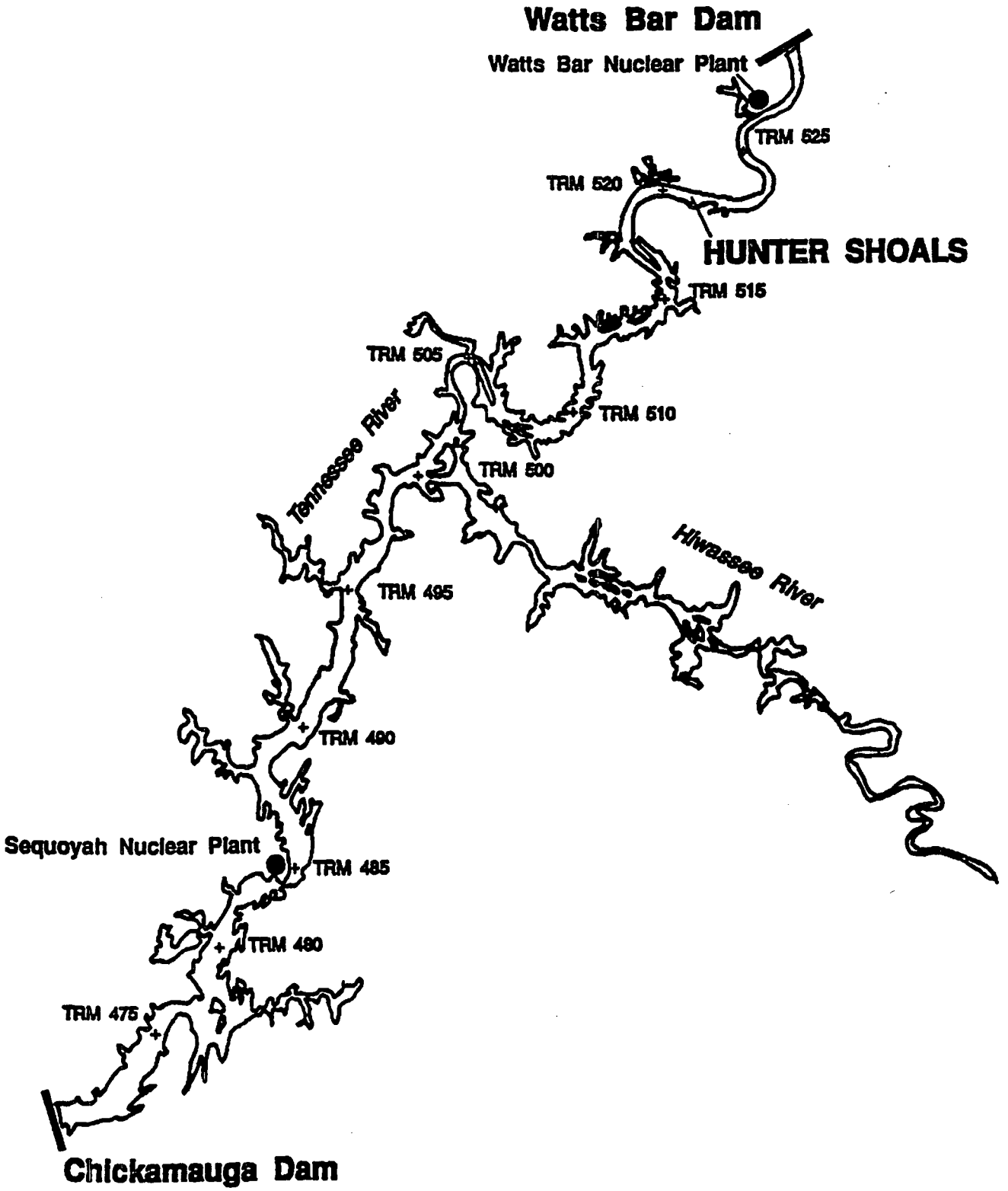

Figure 1. Location of nuclear plants and the sauger spawning area (Hunter Shoals) on Chickamauga Reservoir.

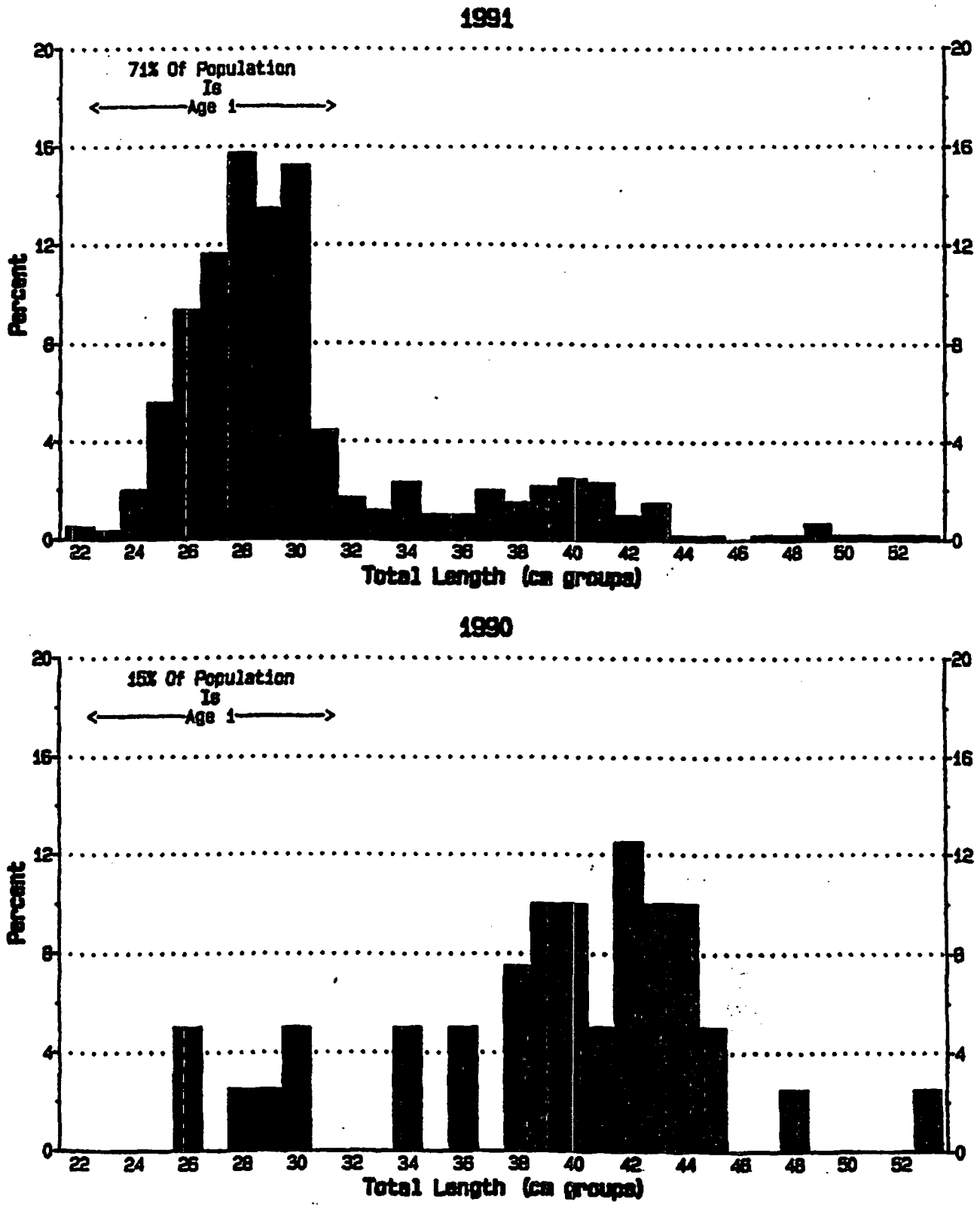

Figure 2. Annual percent length frequency and approximate age 1 group of sauger captured with gill nets in Chickamauga Reservoir during winter and spring 1990 and 1991.

Table 1. Species list, number collected, and catch per hour during winter - spring gill netting at Chickamauga Reservoir, 1990 (total effort of 527.4 hours) and 1991 (total effort of 574.4 hours).

Common Name	1990 Numbers Collected	1990 Catch Per Hour	1991 Numbers Collected	1991 Catch Per Hour
Paddlefish	3	0.01	-	-
Longnose Gar	30	0.06	7	0.01
Skipjack Herring	172	0.33	251	0.44
Alewife	15	0.03	-	-
Gizzard Shad	462	0.88	217	0.38
Hybrid Shad	6	0.01	11	0.02
Rainbow Trout	1	0.00	-	-
Mooneye	5	0.01	6	0.01
Carp	4	0.01	6	0.01
Golden Shiner	2	0.00	-	-
Quillback	-	-	4	0.01
Northern Hogsucker	1	0.00	-	-
Smallmouth Buffalo	2	0.00	21	0.04
Spotted Sucker	24	0.05	14	0.02
Black Redhorse	-	-	1	0.00
Golden Redhorse	-	-	4	0.01
Blue Catfish	281	0.53	206	0.36
Yellow Bullhead	1	0.00	1	0.00
Channel Catfish	590	1.12	531	0.92
Flathead Catfish	28	0.05	45	0.08
White Bass	123	0.23	295	0.51
Yellow Bass	379	0.72	399	0.69
Striped Bass	54	0.10	52	0.09
Cherokee Bass	29	0.05	263	0.46
Warmouth	1	0.00	-	-
Bluegill	7	0.01	7	0.01
Redear Sunfish	7	0.01	9	0.02
Smallmouth Bass	3	0.01	5	0.01
Largemouth Bass	7	0.01	6	0.01
White Crappie	9	0.02	9	0.02
Black Crappie	-	-	10	0.02
Yellow Perch	2	0.00	6	0.01
Sauger	41	0.08	614	1.07
Walleye	4	0.01	53	0.09
Freshwater Drum	57	0.11	29	0.05
Totals	2350	4.46	3094	5.39

TVAN CALCULATION COVERSHEET

Title	Plant WBN	Page 1
Annual Routine Radioactive Airborne Releases from the Operation of One Unit	Unit 1/2	

Preparing Organization	Key Nouns (For EDM)
Mechanical Design	Routine, Rad Release, FSAR, Airborne Rad, STP

Calculation Identifier	Each time these calculations are issued, preparer must ensure that the original (R0) RIMS/EDM accession number is filled in.		
TI-534	Rev	(for EDM use)	EDM Accession Number
Applicable Design Document(s)	R0	810908C0004	NEB 810824 236
NA	R6		
UNID System(s) : NA			

	R0	R7	R8	R9			
					Quality Related?	Yes ■	No ☐
DCN, EDC, NA	NA	EDC E50629A			Safety related? If yes, mark Quality Related yes	Yes ☐	No ■
Prepared	R.B. Tubb						
Checked	J.R. Marshall				These calculations contain unverified assumption(s) that must be verified later?	Yes ☐	No ■
Design Verified	L.W. Lau				These calculations contain special requirements and/or limiting conditions?	Yes ■	No ☐
Approved	G.E. German				These calculations contain a design output attachment?	Yes ☐	No ■
Approval Date	5/28/76				Calculation Classification	Essential	
SAR Affected?	Yes ☐ No ■	Yes ☐ No ■	Yes ☐ No ☐	Yes ☐ No ☐	Microfiche generated	Yes ■	No ☐
Revision applicability	Entire calc ■	Entire calc ■ Selected pgs ☐	Entire calc ☐ Selected pgs ☐	Entire calc ☐ Selected pgs ☐	Number TVA-F-C00324		

Statement of Problem: Calculate the total expected annual routine gaseous releases due to operation of one unit.

Abstract: This calculation determines the total annual routine gaseous releases due to the operation of one reactor unit. The sources of gaseous effluents included : building ventilation, condenser vacuum exhausts, waste gas decay tank releases, steam generator flash tank venting, refueling area releases, containment purges (through the purge filters) and containment venting (to the annulus through filters as installed by DCN D-50165-A, and without filters as determined in revision 4 which were kept for historical purposes.) NUREG-0017 R1 was used as the basis for the source term and release parameters used in the calculation. Midpoint values were used where appropriate. WBN System Description documents were used to obtain system design parameters. Releases were calculated taking no credit for effluent treatment or holdup, with the exception of containment building purge/vent releases (purge every 2 weeks with HEPA and charcoal filtration, vent continuously through filters or in batch mode with no filters), and the WGDT releases (60-day holdup and HEPA/charcoal filtration). This calculation assumes a maximum average of 100 cfm continuous vent flow from containment to the annulus. The actual flow may be less, however a larger flow will result in higher releases than that analyzed. **Therefore the long term average of 100 cfm continuous venting to the annulus is a limiting condition in this calculation.**

The results of this calculation were provided to Plant Chemistry (Betsy Eiford-Lee), who performed a preliminary 10CFR50, App.I offsite dose calculation in accordance with the WBN ODCM. Chemistry's evaluation indicates that the annual routine gaseous releases determined in this calculation with containment purge (through the purge filters) or the continuous venting through filters will result in routine offsite dose impacts that are within the Appendix I dose criteria. However, the results for the gaseous releases with containment venting to the annulus and then released to the atmosphere via the Auxiliary Building vent with no filtration will exceed the ODCM limits for thyroid and bone. It can therefore be concluded that unfiltered flow should not be used in a routine manner. This calculation assumes design basis NUREG-0017 release levels which are in excess of actual plant historical experience. An unfiltered venting operation may be performed if Chemistry determines **prior** to the venting that the inventory to be released will not cause the Appendix I limits to be exceeded. This is determined on an annual basis (taking into account the prior within year actual releases and the future within year expected releases) which cannot be determined by design analysis. Results can be seen in Tables 4a-c.

■ Microfilm and return calculation to Calculation Library:	Address : EQB 1M-WBN	☐ Microfilm and destroy.
☐ Microfilm and return calculation to:		

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER TI-534

Title: Annual Routine Radioactive Airborne Releases from the Operation of One Unit

Revision No.	DESCRIPTION OF REVISION
0	initial issue
1	Revision 1 was performed to utilize the most recent references and to remove the weak bases of the original calculation. pages added: all pages deleted: all
2	Revision 2 was performed to add C-14, add a filter to the WGS exhaust and correct minor deficiencies. pages changed: 1-6, 8, 9, 11, 16-21 pages added: none pages deleted: none
3	Revision 3 was performed to take into account holdup for Noble Gasses and Iodines in containment to decrease the conservatism of the calculation. pages changed: 1-10, 15, 18-21 pages added: 6.1, 9.1 pages deleted: none
4	Revision 4 was performed to add an alternate form of operation of containment venting to the annulus instead of purging containment. Pages changed: 1.1 (old cover), 2-6, 6.1, 7, 8, 9, 9.1, 10, 11, 15, 17-21 Pages added: 1(new cover), 2.1, 6.2, 18.1, 19.1 Pages deleted: none R4: 28 total pages
5	Revision 5 was performed as part of DCN D-50165-A. This DCN adds a HEPA and charcoal filter in the containment vent line. Therefore, all containment releases via the vent will now be filtered. The release analyzed is a continuous release (as opposed to batch releases analyzed before). The revision 4 unfiltered annulus vent releases are retained for historical purposes. Pageschanged: 1, 2.1, 3-6, 6.1, 6.2, 7, 8, 9.1, 10, 11, 18.1, 19.1, 20, 21 Pages added: 2.2, 9.2, 18.2, 19.2, Attachment A Pages deleted: none R5: 59 total pages
6	Revision 6 was performed in support of EDC E50629-A, which incorporates the use of a Tritium Production Core (TPC). This calculation was redone in the new format and the tritium release calculation was changed, instead of using 3425 MWt, 102% of 3411 was used. Pages were renumbered. Numbered pages in attachment in sequence with the rest of the calculation. Footnotes in table 1 were deleted, but are still in WBNNAL3-003. Asterisks were deleted in table 2 as they did not correspond to any footnotes. STP runs were done for the purge, and filtered vent case since the flow rate between the upper and lower containment had changed because of PER 00-013317-000 Pages changed: 1.2-25 Pages added: 1 (cover sheet) Pages deleted : Classification forms (5 and 6), 2.0,2.1,2.2, 9.1,9.2,18.1,18.2,19.19.2 R6 : total pages 53
7	Revision 7 provides additional results associated with EDC E50629A along with R6. This revision determines the potential releases associated with 1 or 2 rod failure of a TPBAR and is changed for revision to TI-535. Concentrations and activities are reported in this situation. Pages changed : 2,3,7,9,10,17,24,25 Pages added: none Pages deleted: none R7 : total pages 53

TVAN CALCULATION RECORD OF REVISION	
CALCULATION IDENTIFIER TI-534	
Title: Annual Routine Radioactive Airborne Releases from the Operation of One Unit	
Revision No.	DESCRIPTION OF REVISION

TVAN CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

Calculation Identifier TI-534 Revision 7

Method of design verification (independent review) used:

1. Design Review ☐
2. Alternate Calculation ☐
3. Qualification Test ☐

Comments:

Design Verifier

Date

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: TI-534	Revision:7	

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TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document TI-534	Rev. 7	Plant: WBN	

Subject:
Annual Routine Radioactive Airborne Releases from the Operation of One Unit

☐ Electronic storage of the input files for this calculation is not required. Comments:

■ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The computer input for R3 and R4 are permanently stored in FILEKEEPER file # 301819

The computer input for R5 is permanently stored in FILEKEEPER file # 301914

The computer input for R6 is permanently stored in FILEKEEPER file # 303338

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document TI-534	Rev. 7	Plant: WBN	

Subject:
Annual Routine Radioactive Airborne Releases from the Operation of One Unit

Microfiche Number	Description		
R3:	Name	Code	Description
TVA-F-COO0047	TI534S	STP	Noble Gas and Iodine Containment Purge Release
R4:	Name	Code	Description
TVA-F-C000287	TI534S4	STP	Noble Gas and Iodine Containment Vent Release
R5:	Name	Code	Description
TVA-F-C000288	TI534S5	STP	Noble Gas and Iodine Filtered Vent Release
R6:			
TVA-F-C000323	TI534S	STP	Noble Gas and Iodine Containment Purge Release
TVA-F-COO0324	TI534FV	STP	Noble Gas and Iodine Filtered Vent Release

Purpose

This calculation was performed to quantify the total radioactive releases that are expected due to the operation of one unit. Revision 1 utilizes the most recent references for source term parameters and bases. The calculated routine releases are those due to the normal operation of one reactor unit. These results will ultimately be used to update the WBN FSAR chapter 11.3 and to demonstrate compliance with offsite dose objectives of 10CFR50, Appendix I (performed by Chemistry). R3 was performed to account for noble gas and iodine holdup in containment between purges. Revision 4 was performed to account for the alternate operational process of venting to the annulus (then releasing effluents via the auxiliary building vent) instead of utilizing the purge system. Revision 5 is performed because DCN D-50165 (ref.19) is adding a filter in the vent line. The unfiltered vent releases determined in revision 4 are retained for information purposes.

Introduction

A simplified schematic of the gaseous effluent sources and release pathways is given in Figure 1. The details of this schematic were determined from references 2 through 8, except for the containment vent flow rates which were based on actual release methods employed by the plant. The containment vent flow is an assumed value in this analysis and hence a limiting condition. Revision 4 of this analysis determines the impact of using containment venting to the annulus instead of containment purge. This release is unfiltered. Revision 5 evaluates the effect of placing a filter in the vent line and having a continuous vent release.

NUREG-0017, revision 1 (ref.1) was used as the basis for the generation of the gaseous effluent source terms and release parameters. WBN System Description documents were used to obtain system design parameters. The sources of gaseous effluents considered in this calculation are consistent with that document and include:

1. Containment Purge
2. Aux. Bldg ventilation
3. Turbine Bldg ventilation
4. Waste Gas Decay Tank (WGDT) releases
5. Refueling Area releases
6. Condenser Vacuum Exhaust (CVE)
7. Steam Generator Blowdown (SGBD) flash tank venting
8. Containment Vent (as an alternate to Containment Purge)

Revision 6 supports EDC 50629-A, which incorporates the use of a Tritium Production Core (TPC). The only quantity affected by this change will be the additional amount of tritium produced. Reference 23 gives a design guideline of 1 Ci/rod/yr which amounts to a maximum of 2304 Ci/yr. The gaseous release amounts to 10% of 2304 Ci/yr. Therefore an additional 230.4 Ci/yr will be seen using a TPC. The calculation for tritium is also changed for the non-TPC using a different power rating, 102% of 3411 MWt, which is the nominal value given in ref.9.

Revision 7 is in addition to R6 which evaluates the unlikely failure of a TPBAR and addresses the change in exchange flow between the upper and lower containment in R3 of TI535.

Input Data and Bases

1. All gaseous effluent pathways are based on those identified in Fig.1 (references 2 through 8),except for containment unfiltered vent as performed in revision 4, which is based on an unfiltered release. The revision
   5 containment vent release rate is an assumed value bounding measured plant vent flow rates.

2. Primary and secondary side coolant and steam activities (Table 1) for noble gasses, halogens, tritium are taken from ref. 9. See Input Data #17 below for particulates .

3. RCS water parameter (ref.11):
   Volume = 11375 ft^3

Pressure = 2250 psia
Temperature = 588.2 °F
Specific Volume = 0.02265 ft^3/lb (ref.10)

Input and Data Bases (Cont'd)

4. a. Containment (CTM) purge and vent releases are filtered through a HEPA and charcoal filter (ref.7, 19) with filtration efficiencies of 99% and 70% respectively. These are the minimum efficiencies allowed by ref.1 and will result in higher releases (as compared to those that would be obtained using greater treatment efficiencies).
   b. The containment vent releases travel to the annulus. The annulus vacuum control subsytem takes suction
   from the annulus and vents the gasses out of the Auxiliary Building Vent (ref.17). This path (venting to annulus) has a filter placed in the vent line (incorporated in revision 5, DCN D-50165). The revision 4 results did not have any filtration. The unfiltered condition is retained in this calculation for historical purposes.

5. CTM gaseous Source terms are based on a 3%day (noble gas) and 8E-4% /day (iodines) release of RCS coolant into the CTM airborne atmosphere (ref.1 and ref.5).

6. WGDT releases are based on a 173 ft^3/day (@STP) input of RCS coolant offgas to the waste gas disposal system and a WGDT holdup time of 60 days (ref.1).

7. Auxiliary Building ventilation noble gas source terms are based on a 160 lb/day release of RCS coolant activity into the AB atmosphere (ref.1).

8. Auxiliary Building ventilation iodine releases are based on 1.85 Ci/yr per μCi/g of RCS for 300 days and 6.8 Ci/yr per μCi/g for 65 days (ref.1).

9. Refueling Area iodine releases are based on 0.16 Cilyr per μCi/g of RCS for 300 days and 0.3 Ci/yr per μCi/g for 65 days (ref.1).

10. TB ventilation noble gas source terms are based on a 1700 lb/hr release of secondary steam into the TB atmosphere (ref.1).

11. TB ventilation iodine source terms are based on 8500 Cilyr per μCi/g of secondary steam for 300 days and 1400 Ci/yr per μCi/g for 65 days (ref.1). Reference 1 uses BWR values as a basis for these PWR source terms based on the similarity of turbine building leakage rates resulting from similarity of basic design and operation of PWR and BWR generation equipment housed in the Turbine Building.

12. CVE noble gas source terms are based on a steam flowrate to the condenser of 8.5E6 lb/hr (ref.3) at secondary steam activities.

13. CVE iodine source terms are based on a 3500 Ci/yr per μCi/g of secondary steam releases to the CVE (ref.1).

14. SGBD flash tank source terms are based on a maximum SGBD flow of 12.5 gpm/steam generator (ref.2) ~~and a .33 flashing fraction of secondary coolant (ref.1)~~. Iodines are ~~further~~ reduced in the offgases by applying a 0.05 partition factor (ref.1). There are no noble gas releases from this path as there are no noble gas source terms in the secondary coolant (ref.9).

15. Ar-41 releases are 34 Ci/yr (ref.1).

16. a. Total tritium releases are based on .4 Cilyr per MWt (ref.1), with 10% of that available for release via gaseous pathways (ref.1, for non-TPC) and a power level of 3480 MWt, 102% of the nominal value 3411 MWt. This results in 139.2 Cilyr.
    b. With the operation a TPC, an additional total activity of 2304 Cilyr is given, ref.23. With 10% of this available for release via gaseous pathways ref.1. This results in an additional 230.4 Cilyr.
    c. 1 or 2 TPBAR failures with TPC operation have potential tritium release of a maximum of 11600 Ci/TPBAR ref. 25. 10% is available for release via gaseous pathways ref. 1. Failure of a TPBAR is considered an abnormal event.

1. Total particulate releases (Table 2) are taken directly from Table 2-17 of ref.1. Since these values are prior to treatment, the releases from the CTM Bldg. Purge and WGDT are reduced by applying a HEPA filtration factor of 0.01 (99% efficiency (ref.1)). Revision 5 added a filter for containment venting, there is no treatment for releases from other areas.

2. C-14 releases are 1.6 Cilyr from containment, 4.5 Ci/yr from Auxiliary Building, and 1.2 Ci/yr from the WGS for a total of 7.3 Cilyr (ref.1).

3. The WGS discharge is filtered with a HEPA (efficiency of 99%, ref.1) and charcoal (efficiency 70%, ref.1) filter prior to release (ref.14)

4. NUREG-0017 suggests 22 containment purges a year during power operation, and 2 purges during refueling. Therefore, this calculation uses one purge every two weeks. The computer code STP (ref.16) is used to model the purge releases. The flows (from TI-535, ref.15) are:

Continuous leakage of noble gasses into containment: 3%/day = 2.85E5 g k r
Continuous leakage of iodine into containment: 8E-4%/day = 7.6E1 g/hr
Continuous leakage of particulates (information only, since particulates handled by #17 above): 14.77 g/hr
Continuous leakage of tritium (information only, since tritium handled by #16 above): 2.85E4 g/hr
Exchange Flow between Lower Containment and Instrument Room: 20 cfm = 3.437 cc/hr
Exchange Flow between Lower and Upper Containment: 1194 cfm = 2.0286E9 c c k r

Purge Flow from Upper Containment: 14958 cfm = 2.5414310 cc/hr
Purge Flow from Lower Containment: 7500 cfm = 1.2743E10 cc/hr
Purge Flow from Instrument Room: 540 cfm = 9.1747E8 cc/hr
Purge Flow from Instrument Room to Lower Containment: 110 cfm = 1.8689E8 ccihr

The volumes are (from TI-535):
Lower Containment: 1.0848310 cc
Upper Containment: 1.8321310 cc
Instrument Room: 5.502638 cc

The purge model is taken from TI-535 (ref.15) and modified by adding a "purge environment" component which does not allow decay (an accumulator volume). The model assumes 60 days without purge to maximize inventory in containment (TI-535), then purge for 10 hours (into a dummy volume) in order to baseline the minimum concentrations in containment (TI-535), then 2 weeks without purge, then 12 hours purge flow into the "purge environment". A 12 hour purge was chosen because this results in a more conservative release since an 8 hour purge yields the equilibrium concentrations in containment (TI-535). To take into account a year of operation, the purge flows are multiplied (by use of the "X" card) by the following factors:

Noble Gasses: X=26 (based on 52 weeks/year divided by 2 weeks/purge)
Iodines: X=7.8 (based on 26 purges/year times 0.3=(1-0.7) for filters)

21. One alternate mode of operation is to vent containment to the annulus instead of purging. This revision 4 case (retained for historical purposes, but no longer applies because of the filters installed due to DCN D-50165-A) assumes 4 unfiltered ventslday at 36 minlvent at a flow rate of 1000 cfm. This is based on actual release methods employed by the plant. The flows between components are the same as #20 above except that there is no purge flow, and the following vent flows and volume cards are added:

Annulus Volume = 5.30939 cc (=28317 cc/cuft*0.5*3.75E5 cuft, ref.18)

Containment Vent Flow to annulus = 1.69939 cclhr (=28317 cc/cuft*60min/hr*1000 cfm) starting at 144 hours (in order to allow buildup of radionuclides in lower containment), lasts 0.6 hours, and resumes every 6 hours.

Flow from annulus to dummy = 1.699E9 cc/hr (=1000 cfm, this continuous flow maximizes releases and represents the annulus vacuum control subsystem).

The above flow pattern occurs in the model until equilibrium (the activity in the annulus and containment at the beginning of each of the 6 hour cycling period is essentially the same) is achieved (312 hours, determined by trial and error), at which time the annulus flow is to the environment with no filtration. The flow is multiplied by 365 (= daylyear). The venting pattern (36 min vent every 6 hr) and continuous annulus vacuum control continuous flow occurs for 24 hours. This will give the annual release for the venting operation.

22. DCN D-50165 installed a filter on the vent path to the annulus. Revision 5 evaluates this path using the same flows between components as in #20 above except that there is no purge flow, and the following continuous filtered vent flows and volume cards are added:

Annulus Volume = 5.30939 cc (=28317 cc/cuft*0.5*3.75E5 cuft, ref.18)

CVACU (containment ventilation air cleanup unit) volume = 1.0 (arbitrary, small for minimal holdup)

Containment Vent Flow to annulus = 1.69938 cc/hr (=100 cfm*60 min/hr*28317 cc/cuft). This flow is modeled as a continuous flow through a filter (utilizing the "U" card in STP) with filter efficiencies of 70% for iodines (ref.19, 21, 22, for a 2" charcoal filter bed, ref.19,22) and 99% for particulates (ref. 19, 21, 22,, for a HEPA).

Flow From annulus to dummy = 1.69938 cc/hr for time = 0 to time = 6 months. This allows for some time to reach equilibrium in containment.

Flow From annulus to environment = 1.69938 cc/hr for time = 6 months to time = 18 months. This gives a years release utilizing an 18 month operational cycle.

Assumptions

1. WGDT releases are assumed to be at RCS coolant concentrations, after correcting for standard temperature and pressure. Thus, no credit is taken for treatment, holdup, or decay prior to entering the waste gas decay tank.

Technical Justification: Since no credit is being taken for treatment, holdup, or decay, the resultant releases are maximized.

2. Secondary coolant input to the SGBD flash tank is assumed to have a density of 1 gm/cc.

Technical Justification: Actual coolant density will be less than 1 gm/cc due to actual secondary coolant temperature and pressure parameters as compared to STP. A lower coolant density would result in a lower activity input (and release). Therefore, use of 1 gm/cc is conservative.

3. Releases of noble gases and iodines from the Containment Building are assumed to be due to a purge every two weeks.

Technical Justification: The basis is from NUREG-0017 and small intervals between purges maximizes releases due to less time for decay.

4. For the unfiltered venting of containment, a rate of 1000 cfm is used, with a frequency of 4 times a day for a duration of 36 min (0.6 hr).

Technical Justification: These values were established through discussions with system engineers at WBN. These assumed values are anticipated to bound the actual venting of containment in batch mode.

5. For the filtered continuous venting of containment (as established by installation of a filter in the vent line, DCN D-50165-A, ref.19), it is assumed that the flow is a maximum average of 100 cfm.

Technical Justification: The measured continuous flow varied, however is bounded by 100 cfm (ref.20). The use of 100 cfm as an average flow should bound a future increase. A higher average flow than measured will reduce any holdup time, and hence give larger releases. The 100 cfm is a limiting condition for this calculation. It is realized that if venting does not occur for a period of time, at the start of any new venting that the flow may exceed 100 cfm for short periods. This assumption is for the long term average flow being limited to 100 cfm.

Limiting Conditions/Special Requirements

This calculation assumes a maximum average of 100 cfm continuous vent flow from containment to the annulus. The actual flow may be less, however a larger average flow will result in higher releases than that analyzed. **Therefore the long term average of 100 cfm continuous venting to the annulus is a limiting condition in this calculation.**

Figure 1

WBN Gaseous Effluent Pathways

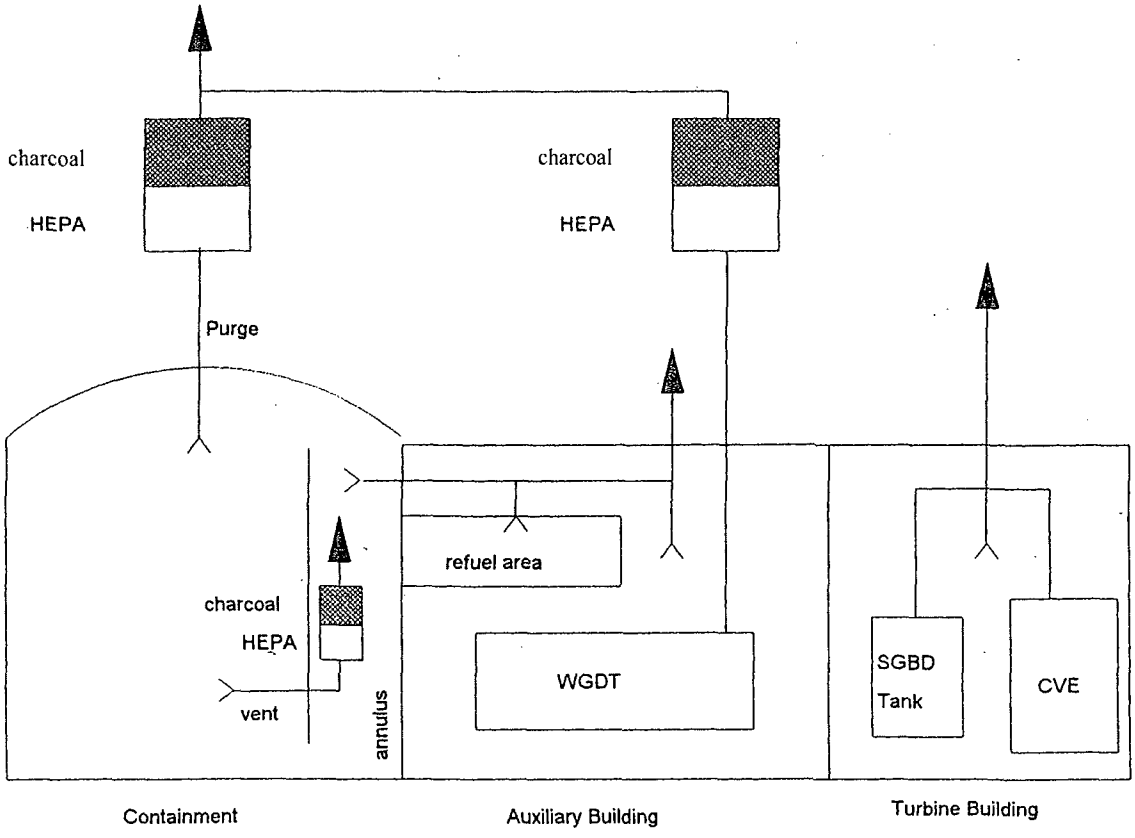

Table 1

(Reference 9)

Nuclide	Reactor Coolant WBN µCi/g	Secondary Water WBN µCi/g	Secondary Steam WBN µCi/g
Class 1			
Kr85m	1.71E-01	0.00E+00	3.63E-08
Kr85	2.66E-01	0.00E+00	5.51E-08
Kr87	1.61E-01	0.00E+00	3.22E-08
Kr88	3.00E-01	0.00E+00	6.31E-08
Xe131m	6.54E-01	0.00E+00	1.34E-07
Xe133m	7.17E-02	0.00E+00	1.54E-08
Xe133	2.53E+00	0.00E+00	5.25E-07
Xe135m	1.39E-01	0.00E+00	2.90E-08
Xe135	9.04E-01	0.00E+00	1.91E-07
Xe137	3.65E-02	0.00E+00	7.62E-09
Xe138	1.29E-01	0.00E+00	2.68E-08
Class 2			
Br84	1.72E-02	9.56E-08	9.56E-10
I131	4.77E-02	1.41E-06	1.41E-08
I132	2.25E-01	3.37E-06	3.37E-08
I133	1.49E-01	4.03E-06	4.03E-08
I134	3.64E-01	2.93E-06	2.93E-08
I135	2.78E-01	6.19E-06	6.19E-08
Class 3			
Rb88	2.04E-01	7.36E-07	3.61E-09
Cs134	7.39E-03	4.58E-07	2.36E-09
Cs136	9.08E-04	5.56E-08	2.78E-10
Cs137	9.79E-03	6.11E-07	3.05E-09
Class 4			
N16	4.00E+01	1.29E-06	1.29E-07
Class 5			
H3	1.00E+00	1.00E-03	1.00E-03
H3(TPC)	3.70E+00	3.70E-03	3.70E-03

Table 1 (Cont'd)

Nuclide	Reactor Coolant WBN µCi/g	Secondary Water WBN µCi/g	Secondary Steam WBN µCi/g
Class 6			
Na24	4.99E-02	1.86E-06	9.30E-09
Cr51	3.26E-03	1.56E-07	7.56E-10
Mn54	1.68E-03	7.80E-08	3.96E-10
Fe55	1.26E-03	5.88E-08	3.00E-10
Fe59	3.16E-04	1.44E-08	7.32E-11
Co58	4.84E-03	2.28E-07	1.13E-09
Co60	5.58E-04	2.64E-08	1.32E-10
Zn65	5.37E-04	2.52E-08	1.20E-10
Sr89	1.47E-04	6.84E-09	3.48E-11
Sr90	1.26E-05	5.88E-10	3.00E-12
Sr91	1.02E-03	3.52E-08	1.76E-10
Y90	1.26E-05	5.88E-10	3.00E-12
Y91m	4.93E-04	4.34E-09	2.17E-11
Y91	5.47E-06	2.52E-10	1.32E-12
'9 3	4.46E-03	1.50E-07	7.65E-10
Zr95	4.10E-04	1.92E-08	9.48E-11
Nb95	2.95E-04	1.32E-08	6.84E-11
Mo99	6.75E-03	3.03E-07	1.45E-09
Tc99m	5.01E-03	1.40E-07	7.27E-10
Ru103	7.89E-03	3.72E-07	1.92E-09
Ru106	9.47E-02	4.44E-06	2.16E-08
Rh103m	7.89E-03	3.72E-07	1.92E-09
Rh106	9.47E-02	4.44E-06	2.16E-08
Ag110m	1.37E-03	6.36E-08	3.24E-10
Te129m	2.00E-04	9.36E-09	4.68E-11
Te129	2.57E-02	2.96E-07	1.48E-09
Te131m	1.59E-03	6.60E-08	3.30E-10
Te131	8.26E-03	3.97E-08	2.05E-10
Te132	1.79E-03	7.98E-08	3.99E-10
Ba137m	9.79E-03	6.11E-07	3.05E-09
Ba140	1.37E-02	6.25E-07	3.12E-09
La140	2.64E-02	1.13E-06	5.60E-09
Ce141	1.58E-04	7.32E-09	3.72E-11
Ce143	2.96E-03	1.22E-07	6.23E-10
Ce144	4.21E-03	1.92E-07	9.83E-10
Pr143	2.96E-03	1.22E-07	6.23E-10
Pr144	4.21E-03	1.92E-07	9.83E-10
W187	2.65E-03	1.07E-07	5.40E-10
Np239	2.32E-03	1.02E-07	5.09E-10

Table 2 (from ref.1)

Particulate Release Rate for Gaseous Effluents *
(Ci/yr)/unit

Nuclide	Containment	Auxiliary Building	Fuel Pool Area	Waste Gas System
Cr51	9.2(-3)	3.2(-4)	1.8(-4)	1.4(-5)
Mn54	5.3(-3)	7.8(-5)	3.0(-4)	2.1(-6)
Co57	8.2(-4)	NA	NA	NA
Co58	2.5(-2)	1.9(-3)	2.1(-2)	8.7(-6)
Co60	2.6(-3)	5.1(-4)	8.2(-3)	1.4(-5)
Fe59	2.7(-3)	5.0(-5)	NA	1.8(-6)
Sr89	1.3(-2)	7.5(-4)	2.1(-3)	4.4(-5)
Sr90	5.2(-3)	2.9(-4)	8.0(-4)	1.7(-5)
Zr95	NA	1.0(-3)	3.6(-6)	4.8(-6)
Nb95	1.8(-3)	3.0(-5)	2.4(-3)	3.7(-6)
Ru103	1.6(-3)	2.3(-5)	3.8(-5)	3.0(-6)
Ru106	NA	6.0(-6)	6.9(-5)	2.7(-6)
Sb125	NA	3.9(-6)	5.7(-5)	NA
Cs134	2.5(-3)	5.4(-4)	1.7(-3)	3.3(-5)
Cs136	3.2(-3)	4.8(-5)	NA	5.3(-6)
Cs137	5.5(-3)	7.2(-4)	2.7(-3)	7.7(-5)
Ba140	NA	4.0(-4)	NA	2.3(-5)
Ce141	1.3(-3)	2.6(-5)	4.4(-7)	2.2(-6)

* Particulate release rates are prior to filtration

Calculations

Note: RC, SW, and SS refer to the concentrations of Reactor Coolant, Secondary Water, and Secondary Steam given in Table 1.

1. CTM BLDG RELEASES (noble gases and iodines)

A.1 Containment Ventilation (Purge)

The results for this are taken from the STP output. The STP model is described in Input and Bases section.

A.2 Containment Ventilation (Vent)

The activities released during this operation are taken directly from the STP output. The STP model is described in Input and Bases section.

B. Waste Gas Decay Tanks

Noble Gas and Iodines

The input to the waste gas system is 173 ft^3/day (ref.1) at STP (14.7 psia, 273.2°K). To determine the amount of reactor coolant gases that this corresponds to, we can use the ideal gas law relation of V=kT/P with the temperature and pressure conditions of reactor coolant (588.2°F, 2250 psia, ref.11) as follows:

(588.2-32)5/9 + 273.2 = 582 °K

Input of RCS gas into WGDT (ft^3/day) = (173 ft^3/day)(14.7/2250)(582/273.2) = 2.41 ft^3/day

Converting this into a mass flow yields:

(gmlyr) = (2.41 ft^3/day)(365 day/yr)(1/0.02265 lb/ft^3)(453.6 gm/lb = 1.76E7 gmlyr

The quantity of activity releases from the WGDTs can now be estimated as:
(Ci/yr) = (1.76E7 g/yr)(1E-6Ci/μCi)(RC μCi/g)(exp(-.693*60days*1440min/day*60s/min/T (sec)))
where T is the radiological halflife from ref.12

2. Auxiliary Building Releases

A. AB Ventilation

Noble Gases

(Ci/yr) = (160 lb/day)(453.6 g/lb)(365 day/yr)(1E-6 Ci/μCi)(RC μCi/g) = 26.5 * RC (μCi/g)

Iodines

(Ci/yr) = (1.85 Ci/yr per μCi/g_{RC})(300/365)(RC μCi/g) + (6.8Ci/yr per μCi/g)(65/365)(RC μCi/g) = 2.73*RC (μCi/g)

B. Refuel Area

Iodines

(Ci/yr) = (0.16 Ci/yr per μCi/g_{RC})(300/365)(RC μCi/g) + (0.3Ci/yr per μCi/g)(65/365)(RC μCi/g) = 0.185*RC (μCi/g)

3. Turbine Building Releases
   A. TB Ventilation
      Noble gases
   (Cilyr) = (1700 lb/hr)(453.6 g/lb)(8760hr/yr)(1E-6 Ci/μCi)(SSμCi/g) = 6760 * SS (μCi/g)

      Iodines
   (Cilyr) = (8500 Ci/yr per μCi/gss)(300/365)(SS μCi/g) + (1400Ci/yr per μCi/g)(65/365)(SS μCi/g)
   = 7236 * SS (μCi/g)

   B. Condenser Vacuum Exhaust
      Noble gases
   (Ci/yr) = (8.536 lb/hr)(453.6 g/lb)(8760hr/yr)(1E-6 Ci/μCi)(SSμCi/g) = 3.38E7* SS (μCi/g)

      Iodines
   (Ci/yr) = (3500 Ci/yr per μCi/gss)

   C. SGBD Flash Tank
      Iodines
   (Ci/yr) = (12.5gal/min per SG)(4SG)(1g/cc)(0.05)(3785cc/gal)(SW μCi/g)(1440 min/day)(1E-6 Ci/μCi)(365 day/yr)
   = 4973 * SW (μCi/g)

4. Total Tritium
   a. Non-TPC core configuration
   (Ci/.yr) = (0.4 Ci/yr per MWt)(1.02)(3411 MWt)(0.1) = 139.2 Ci/yr

   b. TPC
   (Ci/yr) = (.1)(2304Ci/yr) + 139.2 Ci/yr = 369.6 Ci/yr

   *c. TPC - Failure of one TPBAR
   (Ci/yr) = (.1)(11600 Ci) + 139.2 Ci/yr + 230.4 Ci/yr= 1529.6 Ci/yr

   *d. TPC - failure of two TPBARs
   (Ci/yr) = (.1)(2 rods)(11600 Ci) + 139.2 Ci/yr + 230.4 Cilyr = 2689.6 Ci/yr

5. Total Particulate
   (Ci/yr) = (Ci/yr from Table 2)(1-.99) - for containment purge and WGDT, otherwise Cilyr from Table 2 without
   modification.

Tables 3a and 3b contain the calculation of the above routine gaseous releases.

Revision 6 redid the containment purge and filtered vent case scenarios because of the change in exchange flow in between the upper and lower containment. The unfiltered vent case was not ran as it does not represent current configuration of the plant.

Revision 7 included the potential tritium release values for one or two TPBAR failures for the TPC. Failure of a TPBAR is considered an abnormal event and thus is not a routine release. Evaluation against Appendix I limits is not addressed for TPBAR failures Failure of a TPBAR would only affect the tritium release to the RCS. An additional 1160 or 2320 Ci would be added to the RCS as calculated in item 4 above.
* 11600 Ci is an instantaneous maximum release of the TPBAR's entire inventory ref. 25

Table 3a

WBN Annual Routine Releases (Ci/yr), Using Containment Purge

	WDS (CTM Bldg)	CTM Purge (CTM Bldg)	Refuel Floor Exh. (Aux Bldg)	Aux Bld Exhaust (Aux Bldg)	TB Vent (TurbBldg)	Condenser CVE (TurbBldg)	SGBD Flashtank (TurbBldg)
Kr-85m	3.73E-97	2.00E+01	0.00E+00	4.53E+00	2.45E-04	1.23E+00	0.00E+00
Kr-85	4.63E+00	6.85E+02	0.00E+00	7.05E+00	3.72E-04	1.86E+00	0.00E+00
Kr-87	0.00E+00	1.09E+01	0.00E+00	4.27E+00	2.18E-04	1.09E+00	0.00E+00
Kr-88	0.00E+00	2.84E+01	0.00E+00	7.95E+00	4.27E-04	2.13E+00	0.00E+00
Xe-131m	3.52E-01	1.17E+03	0.00E+00	1.73E+01	9.06E-04	4.53E+00	0.00E+00
Xe-133m	1.14E-08	4.63E+01	0.00E+00	1.90E+00	1.04E-04	5.21E-01	0.00E+00
Xe-133	1.72E-02	3.12E+03	0.00E+00	6.70E+01	3.55E-03	1.77E+01	0.00E+00
Xe-135m	0.00E+00	3.86E+00	0.00E+00	3.68E+00	1.96E-04	9.80E-01	0.00E+00
Xe-135	6.01E-47	1.55E+02	0.00E+00	2.40E+01	1.29E-03	6.46E+00	0.00E+00
Xe-137	0.00E+00	3.18E-01	0.00E+00	9.67E-01	5.15E-05	2.58E-01	0.00E+00
Xe-138	0.00E+00	3.33E+00	0.00E+00	3.42E+00	1.81E-04	9.06E-01	0.00E+00
Ar-41	0.00E+00	3.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	6.02E-05	3.18E-03	4.70E-02	6.92E-06	3.35E-06	4.71E-04
I-131	1.44E-03	5.84E-03	8.82E-03	1.30E-01	1.02E-04	4.94E-05	6.93E-03
I-132	0.00E+00	1.61E-03	4.16E-02	6.14E-01	2.44E-04	1.18E-04	1.66E-02
I-133	1.16E-21	3.55E-03	2.76E-02	4.07E-01	2.92E-04	1.41E-04	1.98E-02
I-134	0.00E+00	1.66E-03	6.73E-02	9.94E-01	2.12E-04	1.03E-04	1.44E-02
I-135	4.08E-66	3.16E-03	5.14E-02	7.59E-01	4.48E-04	2.17E-04	3.06E-02
H-3	0.00E+00	1.39E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3(TPC)	0.00E+00	3.70E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr-51	1.40E-07	9.20E-05	1.80E-04	3.20E-04	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.10E-08	5.30E-05	3.00E-04	7.80E-05	0.00E+00	0.00E+00	0.00E+00
Co-57	0.00E+00	8.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58	8.70E-08	2.50E-05	2.10E-02	1.90E-03	0.00E+00	0.00E+00	0.00E+00
Co-60	1.40E-07	2.60E-05	8.20E-03	5.10E-04	0.00E+00	0.00E+00	0.00E+00
Fe-59	1.80E-08	2.70E-05	0.00E+00	5.00E-05	0.00E+00	0.00E+00	0.00E+00
Sr-89	4.40E-07	1.30E-04	2.10E-03	7.50E-04	0.00E+00	0.00E+00	0.00E+00
Sr-90	1.70E-07	5.20E-05	8.00E-04	2.90E-04	0.00E+00	0.00E+00	0.00E+00
Zr-95	4.80E-08	0.00E+00	3.60E-06	1.00E-03	0.00E+00	0.00E+00	0.00E+00
Nb-95	3.70E-08	1.80E-05	2.40E-03	3.00E-05	0.00E+00	0.00E+00	0.00E+00
Ru-103	3.20E-08	1.60E-05	3.80E-05	2.30E-05	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.70E-08	0.00E+00	6.90E-05	6,OOE-06	0.00E+00	0.00E+00	0.00E+00
Sb-125	0.00E+00	0.00E+00	5.70E-05	3.90E-06	0.00E+00	0.00E+00	0.00E+00
Cs-134	3.30E-07	2.50E-05	1.70E-03	5.40E-04	0.00E+00	0.00E+00	0.00E+00
Cs-136	5.30E-08	3.20E-05	0.00E+00	4.80E-05	0.00E+00	0.00E+00	0.00E+00
Cs-137	7.70E-07	5.50E-05	2.70E-03	7.20E-04	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.30E-07	0.00E+00	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00
Ce-141	2.20E-08	1.30E-05	4.40E-07	2.60E-05	0.00E+00	0.00E+00	0.00E+00
C-14	1.20E+00	1.60E+00	0.00E+00	4.50E+00	0.00E+00	0.00E+00	0.00E+00

'Note that in running this case for R6 the particulate flow in the STP input deck was given as 29.53, which is a 2 unit value, the one unit value is 14.77. The use in STP of the higher particulate flow rate does not impact the results as the particulates are addressed by Inputs and Data Bases #17. The flow rate between the upper and lower containment was determined to be 3.0525E9 cc/hr , but a value of 3.0526E9 cc/hr was inadvertently used. Since the difference is relatively small, less than .01%, the calculation was considered to be acceptable. This conclusion is further supported by the nearly insignificant change that occurred in this revision from the previous value of 2.0286E9 cc/hr. In revision 3 of TI-535, the 2.0286E9 cc/hr was documented to be correct, but since the change to the results in this calculation was insignificant and conservative, the results of this calculation using the higher flow rate for exchange flow between upper and lower containment are not being changed.

Table 3b
WBN Annual Routine Releases (Ci/yr), Unfiltered Containment Vent

	WDS (CTM Bldg)	CTM Vent (CTM Bldg)	Refuel Floor Exh. (Aux Bldg)	Aux Bld Exhaust (Aux Bldg)	TB Vent (TurbBldg)	Condenser CVE (TurbBldg)	SGBD Flashtank (TurbBldg)
Kr-85m	3.73E-97	1.58E+01	0.00E+00	4.53E+00	2.45E-04	1.23E+00	0.00E+00
Kr-85	4.63E+00	6.13E+02	0.00E+00	7.05E+00	3.72E-04	1.86E+00	0.00E+00
Kr-87	0.00E+00	3.17E+00	0.00E+00	4.27E+00	2.18E-04	1.09E+00	0.00E+00
Kr-88	0.00E+00	1.65E+01	0.00E+00	7.95E+00	4.27E-04	2.13E+00	0.00E+00
Xe-131m	3.52E-01	1.13E+03	0.00E+00	1.73E+01	9.06E-04	4.53E+00	0.00E+00
Xe-133m	1.14E-08	5.57E+01	0.00E+00	1.90E+00	1.04E-04	5.21E-01	0.00E+00
Xe-133	1.72E-02	3.29E+03	0.00E+00	6.70E+01	3.55E-03	1.77E+01	0.00E+00
Xe-135m	0.00E+00	2.02E-01	0.00E+00	3.68E+00	1.96E-04	9.80E-01	0.00E+00
Xe-135	6.01E-47	1.68E+02	0.00E+00	2.40E+01	1.29E-03	6.46E+00	0.00E+00
Xe-137	0.00E+00	3.65E-03	0.00E+00	9.67E-01	5.15E-05	2.58E-01	0.00E+00
Xe-138	0.00E+00	1.55E-01	0.00E+00	3.42E+00	1.81E-04	9.06E-01	0.00E+00
Ar-41	0.00E+00	3.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	2.29E-05	3.18E-03	4.70E-02	6.92E-06	3.35E-06	4.71E-04
I-131	1.44E-03	1.95E-02	8.82E-03	1.30E-01	1.02E-04	4.94E-05	6.93E-03
I-132	0.00E+00	2.76E-03	4.16E-02	6.14E-01	2.44E-04	1.18E-04	1.66E-02
I-133	1.16E-21	1.50E-02	2.76E-02	4.07E-01	2.92E-04	1.41E-04	1.98E-02
I-134	0.00E+00	1.10E-03	6.73E-02	9.94E-01	2.12E-04	1.03E-04	1.44E-02
I-135	4.08E-66	1.01E-02	5.14E-02	7.59E-01	4.48E-04	2.17E-04	3.06E-02
H-3	0.00E+00	1.39E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3 (TPC)	0.00E+00	3.70E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr-51	1.40E-07	9.20E-03	1.80E-04	3.20E-04	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.10E-08	5.30E-03	3.00E-04	7.80E-05	0.00E+00	0.00E+00	0.00E+00
Co-57	0.00E+00	8.20E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58	8.70E-08	2.50E-02	2.10E-02	1.90E-03	0.00E+00	0.00E+00	0.00E+00
Co-60	1.40E-07	2.60E-03	8.20E-03	5.10E-04	0.00E+00	0.00E+00	0.00E+00
Fe-59	1.80E-08	2.70E-03	0.00E+00	5.00E-05	0.00E+00	0.00E+00	0.00E+00
Sr-89	4.40E-07	1.30E-02	2.10E-03	7.50E-04	0.00E+00	0.00E+00	0.00E+00
Sr-90	1.70E-07	5.20E-03	8.00E-04	2.90E-04	0.00E+00	0.00E+00	0.00E+00
Zr-95	4.80E-08	0.00E+00	3.60E-06	1.00E-03	0.00E+00	0.00E+00	0.00E+00
Nb-95	3.70E-08	1.80E-03	2.40E-03	3.00E-05	0.00E+00	0.00E+00	0.00E+00
Ru-103	3.20E-08	1.60E-03	3.80E-05	2.30E-05	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.70E-08	0.00E+00	6.90E-05	6.00E-06	0.00E+00	0.00E+00	0.00E+00
Sb-125	0.00E+00	0.00E+00	5.70E-05	3.90E-06	0.00E+00	0.00E+00	0.00E+00
Cs-134	3.30E-07	2.50E-03	1.70E-03	5.40E-04	0.00E+00	0.00E+00	0.00E+00
Cs-136	5.30E-08	3.20E-03	0.00E+00	4.80E-05	0.00E+00	0.00E+00	0.00E+00
Cs-137	7.70E-07	5.50E-03	2.70E-03	7.20E-04	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.30E-07	0.00E+00	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00
Ce-141	2.20E-08	1.30E-03	4.40E-07	2.60E-05	0.00E+00	0.00E+00	0.00E+00
C-14	1.20E+00	1.60E+00	0.00E+00	4.50E+00	0.00E+00	0.00E+00	0.00E+00

Table 3c

WBN Annual Routine Releases (Ci/yr), Filtered Continuous Containment Vent

	WDS (CTM Bldg)	CTM Vent (CTM Bldg)	Refuel Floor Exh. (Aux Bldg)	Aux Bld Exhaust (Aux Bldg)	TB Vent (TurbBldg)	Condenser CVE (TurbBldg)	SGBD Flashtank (TurbBldg)
Kr-85m	3.73E-97	3.72E+00	0.00E+00	4.53E+00	2.45E-04	1.23E+00	0.00E+00
Kr-85	4.63E+00	6.64E+02	0.00E+00	7.05E+00	3.72E-04	1.86E+00	0.00E+00
Kr-87	0.00E+00	4.48E-01	0.00E+00	4.27E+00	2.18E-04	1.09E+00	0.00E+00
Kr-88	0.00E+00	3.10E+00	0.00E+00	7.95E+00	4.27E-04	2.13E+00	0.00E+00
Xe-131m	3.52E-01	1.07E+03	0.00E+00	1.73E+01	9.06E-04	4.53E+00	0.00E+00
Xe-133m	1.14E-08	4.07E+01	0.00E+00	1.90E+00	1.04E-04	5.21E-01	0.00E+00
Xe-133	1.72E-02	2.82E+03	0.00E+00	6.70E+01	3.55E-03	1.77E+01	0.00E+00
Xe-135m	0.00E+00	2.26E-02	0.00E+00	3.68E+00	1.96E-04	9.80E-01	0.00E+00
Xe-135	6.01E-47	5.83E+01	0.00E+00	2.40E+01	1.29E-03	6.46E+00	0.00E+00
Xe-137	0.00E+00	3.76E-04	0.00E+00	9.67E-01	5.15E-05	2.58E-01	0.00E+00
Xe-138	0.00E+00	1.69E-02	0.00E+00	3.42E+00	1.81E-04	9.06E-01	0.00E+00
Ar-41	0.00E+00	3.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	0.00E+00	8.16E-07	3.18E-03	4.70E-02	6.92E-06	3.35E-06	4.71E-04
I-131	1.44E-03	5.30E-03	8.82E-03	1.30E-01	1.02E-04	4.94E-05	6.93E-03
I-132	0.00E+00	1.36E-04	4.16E-02	6.14E-01	2.44E-04	1.18E-04	1.66E-02
I-133	1.16E-21	2.36E-03	2.76E-02	4.07E-01	2.92E-04	1.41E-04	1.98E-02
I-134	0.00E+00	4.26E-05	6.73E-02	9.94E-01	2.12E-04	1.03E-04	1.44E-02
I-135	4.08E-66	8.80E-04	5.14E-02	7.59E-01	4.48E-04	2.17E-04	3.06E-02
H-3	0.00E+00	1.39E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3(TPC)	0.00E+00	3.70E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr-51	1.40E-07	9.20E-05	1.80E-04	3.20E-04	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.10E-08	5.30E-05	3.00E-04	7.80E-05	0.00E+00	0.00E+00	0.00E+00
Co-57	0.00E+00	8.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58	8.70E-08	2.50E-04	2.10E-02	1.90E-03	0.00E+00	0.00E+00	0.00E+00
Co-60	1.40E-07	2.60E-05	8.20E-03	5.10E-04	0.00E+00	0.00E+00	0.00E+00
Fe-59	1.80E-08	2.70E-05	0.00E+00	5.00E-05	0.00E+00	0.00E+00	0.00E+00
Sr-89	4.40E-07	1.30E-04	2.10E-03	7.50E-04	0.00E+00	0.00E+00	0.00E+00
Sr-90	1.70E-07	5.20E-05	8.00E-04	2.90E-04	0.00E+00	0.00E+00	0.00E+00
Zr-95	4.80E-08	0.00E+00	3.60E-06	1.00E-03	0.00E+00	0.00E+00	0.00E+00
Nb-95	3.70E-08	1.80E-05	2.40E-03	3.00E-05	0.00E+00	0.00E+00	0.00E+00
Ru-103	3.20E-08	1.60E-05	3.80E-05	2.30E-05	0.00E+00	0.00E+00	0.00E+00
Ru-106	2.70E-08	0.00E+00	6.90E-05	6.00E-06	0.00E+00	0.00E+00	0.00E+00
Sb-125	0.00E+00	0.00E+00	5.70E-05	3.90E-06	0.00E+00	0.00E+00	0.00E+00
Cs-134	3.30E-07	2.50E-05	1.70E-03	5.40E-04	0.00E+00	0.00E+00	0.00E+00
Cs-136	5.30E-08	3.20E-05	0.00E+00	4.80E-05	0.00E+00	0.00E+00	0.00E+00
Cs-137	7.70E-07	5.50E-05	2.70E-03	7.20E-04	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.30E-07	0.00E+00	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00
Ce-141	2.20E-08	1.30E-05	4.40E-07	2.60E-05	0.00E+00	0.00E+00	0.00E+00
C-14	1.20E+00	1.60E+00	0.00E+00	4.50E+00	0.00E+00	0.00E+00	0.00E+00

Results

Below is a summary of the annual routine releases from WBN due to the operation of one reactor unit.

Table 4a

Total Releases (Ci/yr), with Containment Purge

Nuclide	Contain. Building	Aux. Building	Turbine Building	Total
Kr-85m	2.00E+01	4.53E+00	1.23E+00	2.58E+01
Kr-85	6.90E+02	7.05E+00	1.86E+00	6.99E+02
Kr-87	1.09E+01	4.27E+00	1.09E+00	1.62E+01
Kr-88	2.84E+01	7.95E+00	2.13E+00	3.85E+01
Xe-131m	1.17E+03	1.73E+01	4.53E+00	1.19E+03
Xe-133m	4.63E+01	1.90E+00	5.21E-01	4.88E+01
Xe-133	3.12E+03	6.70E+01	1.77E+01	3.20E+03
Xe-135m	3.86E+00	3.68E+00	9.80E-01	8.52E+00
Xe-135	1.55E+02	2.40E+01	6.46E+00	1.85E+02
Xe-137	3.18E-01	9.67E-01	2.58E-01	1.54E+00
Xe-138	3.33E+00	3.42E+00	9.06E-01	7.66E+00
Ar-41	3.40E+01	0.00E+00	0.00E+00	3.40E+01
Br-84	6.02E-05	5.02E-02	4.81E-04	5.07E-02
I-131	7.29E-03	1.39E-01	7.08E-03	1.53E-01
I-132	1.61E-03	6.56E-01	1.70E-02	6.75E-01
I-133	3.55E-03	4.35E-01	2.03E-02	4.58E-01
I-134	1.66E-03	1.06E+00	1.47E-02	1.08E+00
I-135	3.16E-03	8.10E-01	3.13E-02	8.45E-01
H-3	1.39E+02	0.00E+00	0.00E+00	1.39E+02
H-3(TPC)	3.70E+02	0.00E+00	0.00E+00	3.70E+02
Cr-51	9.21E-05	5.00E-04	0.00E+00	5.92E-04
Mn-54	5.30E-05	3.78E-04	0.00E+00	4.31E-04
Co-57	8.20E-06	0.00E+00	0.00E+00	8.20E-06
Co-58	2.50E-04	2.29E-02	0.00E+00	2.32E-02
Co-60	2.61E-05	8.71E-03	0.00E+00	8.74E-03
Fe-59	2.70E-05	5.00E-05	0.00E+00	7.70E-05
Sr-89	1.30E-04	2.85E-03	0.00E+00	2.98E-03
Sr-90	5.22E-05	1.09E-03	0.00E+00	1.14E-03
Zr-95	4.80E-08	1.00E-03	0.00E+00	1.00E-03
Nb-95	1.80E-05	2.43E-03	0.00E+00	2.45E-03
Ru-103	1.60E-05	6.10E-05	0.00E+00	7.70E-05
Ru-106	2.70E-08	7.50E-05	0.00E+00	7.50E-05
Sb-125	0.00E+00	6.09E-05	0.00E+00	6.09E-05
Cs-134	2.53E-05	2.24E-03	0.00E+00	2.27E-03
Cs-136	3.21E-05	4.80E-05	0.00E+00	8.01E-05
Cs-137	5.58E-05	3.42E-03	0.00E+00	3.483-03
Ba-140	2.30E-07	4.00E-04	0.00E+00	4.00E-04
Ce-141	1.30E-05	2.64E-05	0.00E+00	3.95E-05
C-14	2.80E+00	4.50E+00	0.00E+00	7.30E+00

Table 4b

Total Releases (Ci/yr), with Unfiltered Containment Vent

Nuclide	contain. Building	Aux. Building	Turbine Building	Total
Kr-85m	1.58E+01	4.53E+00	1.23E+00	2.16E+01
Kr-85	6.18E+02	7.05E+00	1.86E+00	6.27E+02
Kr-87	3.17E+00	4.27E+00	1.09E+00	8.53E+00
Kr-88	1.65E+01	7.95E+00	2.13E+00	2.66E+01
Xe-131m	1.13E+03	1.73E+01	4.53E+00	1.15E+03
Xe-133m	5.57E+01	1.90E+00	5.21E-01	5.81E+01
Xe-133	3.29E+03	6.70E+01	1.77E+01	3.37E+03
Xe-135m	2.02E-01	3.68E+00	9.80E-01	4.86E+00
Xe-135	1.68E+02	2.40E+01	6.46E+00	1.99E+02
Xe-137	3.65E-03	9.67E-01	2.58E-01	1.23E+00
Xe-138	1.55E-01	3.42E+00	9.06E-01	4.48E+00
Ar-41	3.40E+01	0.00E+00	0.00E+00	3.40E+01
Br-84	2.29E-05	5.02E-02	4.81E-04	5.07E-02
I-131	2.10E-02	1.39E-01	7.08E-03	1.67E-01
I-132	2.76E-03	6.56E-01	1.70E-02	6.75E-01
I-133	1.50E-02	4.35E-01	2.03E-02	4.70E-01
I-134	1.10E-03	1.06E+00	1.47E-02	1.08E+00
I-135	1.01E-02	8.10E-01	3.13E-02	8.52E-01
H-3	1.39E+02	0.00E+00	0.00E+00	1.39E+02
H-3(TPC)	3.70E+02	0.00E+00	0.00E+00	3.70E+02
Cr-51	9.20E-03	5.00E-04	0.00E+00	9.70E-03
Mn-54	5.30E-03	3.78E-04	0.00E+00	5.68E-03
Co-57	8.20E-04	0.00E+00	0.00E+00	8.20E-04
Co-58	2.50E-02	2.29E-02	0.00E+00	4.79E-02
Co-60	2.60E-03	8.71E-03	0.00E+00	1.13E-02
Fe-59	2.70E-03	5.00E-05	0.00E+00	2.75E-03
Sr-89	1.30E-02	2.85E-03	0.00E+00	1.59E-02
Sr-90	5.20E-03	1.09E-03	0.00E+00	6.29E-03
Zr-95	4.80E-08	1.00E-03	0.00E+00	1.00E-03
Nb-95	1.80E-03	2.43E-03	0.00E+00	4.23E-03
Ru-103	1.60E-03	6.10E-05	0.00E+00	1.66E-03
Ru-106	2.70E-08	7.50E-05	0.00E+00	7.50E-05
Sb-125	0.00E+00	6.09E-05	0.00E+00	6.09E-05
Cs-134	2.50E-03	2.24E-03	0.00E+00	4.74E-03
Cs-136	3.20E-03	4.80E-05	0.00E+00	3.25E-03
Cs-137	5.50E-03	3.42E-03	0.00E+00	8.92E-03
Ba-140	2.30E-07	4.00E-04	0.00E+00	4.00E-04
Ce-141	1.30E-03	2.64E-05	0.00E+00	1.33E-03
C-14	2.80E+00	4.50E+00	0.00E+00	7.30E+00

Table 4c
Total Releases (Ci/yr), with Continuous Filtered Containment Vent

Nuclide	Contain. Building	Aux. Building	Turbine Building	Total
Kr85m	3.72E+00	4.53E+00	1.23E+00	9.48E+00
Kr85	6.69E+02	7.05E+00	1.86E+00	6.78E+02
Kr87	4.48E-01	4.27E+00	1.09E+00	5.81E+00
Kr88	3.10E+00	7.95E+00	2.13E+00	1.32E+01
Xe131m	1.07E+03	1.73E+01	4.53E+00	1.09E+03
Xe133m	4.07E+01	1.90E+00	5.21E-01	4.31E+01
Xe133	2.82E+03	6.70E+01	1.77E+01	2.90E+03
Xe135m	2.26E-02	3.68E+00	9.80E-01	4.68E+00
Xe135	5.83E+01	2.40E+01	6.46E+00	8.88E+01
Xe137	3.76E-04	9.67E-01	2.58E-01	1.23E+00
Xe138	1.69E-02	3.42E+00	9.06E-01	4.34E+00
Ar41	3.40E+01	0.00E+00	0.00E+00	3.40E+01
Br84	8.16E-07	5.02E-02	4.81E-04	5.07E-02
I131	6.74E-03	1.39E-01	7.08E-03	1.53E-01
I132	1.36E-04	6.56E-01	1.70E-02	6.73E-01
I133	2.36E-03	4.35E-01	2.03E-02	4.57E-01
I134	4.26E-05	1.06E+00	1.47E-02	1.07E+00
I135	8.80E-04	8.10E-01	3.13E-02	8.42E-01
H3	1.39E+02	0.00E+00	0.00E+00	1.39E+02
H3(TPC)	3.70E+02	0.00E+00	0.00E+00	3.70E+02
Cr51	9.21E-05	5.00E-04	0.00E+00	5.92E-04
Mn54	5.30E-05	3.78E-04	0.00E+00	4.31E-04
Co57	8.20E-06	0.00E+00	0.00E+00	8.20E-06
Co58	2.50E-04	2.29E-02	0.00E+00	2.32E-02
Co60	2.61E-05	8.71E-03	0.00E+00	8.74E-03
Fe59	2.70E-05	5.00E-05	0.00E+00	7.70E-05
Sr89	1.30E-04	2.85E-03	0.00E+00	2.98E-03
Sr90	5.22E-05	1.09E-03	0.00E+00	1.14E-03
Zr95	4.80E-08	1.00E-03	0.00E+00	1.00E-03
Nb95	1.80E-05	2.43E-03	0.00E+00	2.45E-03
Ru103	1.60E-05	6.10E-05	0.00E+00	7.70E-05
Ru106	2.70E-08	7.50E-05	0.00E+00	7.50E-05
Sb125	0.00E+00	6.09E-05	0.00E+00	6.09E-05
Cs134	2.53E-05	2.24E-03	0.00E+00	2.27E-03
Cs136	3.21E-05	4.80E-05	0.00E+00	8.01E-05
Cs137	5.58E-05	3.42E-03	0.00E+00	3.48E-03
Ba140	2.30E-07	4.00E-04	0.00E+00	4.00E-04
e141	1.30E-05	2.64E-05	0.00E+00	3.95E-05
C14	2.80E+00	4.50E+00	0.00E+00	7.30E+00

Conclusion

Based on the results presented in Table 4a, 4b, and4c, the following conclusions can be made:

1. The total expected routine gaseous effluents are calculated to be:

With Containment Purge:

Total	5.60E+03 Curies/year
Total (TPC)	5.83E+03 Curies/year
Noble Gas (Xe,Kr)	5.42E+03 Curies/year
Particulates	4.70E-02 Curies/year
Tritium	1.39E+02 Curieslyear
Tritium(TPC)	3.70E+02 Curies/year
Carbon 14	7.30E+00 Curies/year
Iodines/Bromine	3.26E+00 Curieslyear

With Unfiltered Containment Vent:

Total	5.75E+03 Curies/year
Total (TPC)	5.98E+03 Curies/year
Noble Gas (Xe,Kr)	5.47E+03 Curies/year
Particulates	1.26E-01 Curies/year
Tritium	1.39E+02 Curieslyear
Tritium(TPC)	3.70E+02 Curies/year
Carbon 14	7.30E+00 Curies/year
Iodines/Bromine	3.29E+00 Curies/year

With Continuous Filtered Containment Vent:

Total	5.02E+03 Curieslyear
Total (TPC)	5.25E+03 Curies/year
Noble Gas (Xe,Kr)	4.84E+03 Curies/year
Particulates	4.70E-02 Curies/year
Tritium	1.39E+02 Curies/year
Tritium(TPC)	3. 70E+02 Curieslyear
Carbon 14	7.30E+00 Curies/year
Iodines/Bromine	3.25E+00 Curies/year

2. The results of this calculation were provided to Plant Chemistry (Betsy Eiford-Lee), who performed a preliminary 10CFR50, App.I offsite dose calculation in accordance with the WBN ODCM. Chemistry's evaluation indicates that the annual routine gaseous releases determined in this calculation with containment purge (through the purge filters), or continuous filtered vent, will result in routine offsite dose impacts that are within the Appendix I dose criteria. However, the results for the gaseous releases with containment venting to the annulus and then released to the atmosphere via the Auxiliary Building vent with no filtration will exceed the ODCM limits for thyroid and bone.

This calculation assumes design basis NUREG-0017 release levels which are in excess of actual plant historical experience. An unfiltered venting operation may be performed if Chemistry determines **prior** to the venting that the inventory to be released will not cause the Appendix I limits to be exceeded. This is determined on an annual basis (taking into account the prior within year actual releases and the future within year expected releases) which cannot be determined by design analysis.

Revision 7 includes the evaluation of 1 or 2 TPBAR failures for a TPC with the results following :

	1 rod		2 rod	
TPC	Purge	Filtered Vent	Purge	Filtered Vent
Total (Cilyr)	6.99E+03	6.41E+03	8.15E+03	7.57E+03
Tritium (Cilyr)	1.53E+03	1.53E+03	2.69E+03	2.69E+03

References

1. NUREG-0017 R1 "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents From Pressurized Water Reactors" April 1985

2. System Description N3-15-4002 R2 "Steam Generator Blowdown System"

3. System Description N3-2-4002 R2 "Condensate System"

4. System Description N3-30RB-4002 R5 "Reactor Building Ventilation System"

5. System Description N3-77A-4001 R2 "Gaseous Waste Disposal System"

6. WBN drawing 47W866-10 R30

7. WBN drawing 47W866-1 R35

8. WBN drawing 47W830-4 R23

9. WBNNAL3-003 R3 "Reactor Coolant and Secondary Side Activities in Accordance with ANSI/ANS-18.1-1984"

10. ASME Steam Table, Fifth Edition, 1983

11. WBNNAL2-001 R2 "Analysis of Watts Bar Nuclear Plant Anticipated Transients Without SCRAM"

12. Computer Code STPISOTP R1, code I.D. 262342, controlled user's manual # I

13. System Description N3-68-4001 R3

14. WBN drawing 1-47W830-4 R7

15. TI-535 R3 "Max. Expected Airborne Concentration in Primary Containment, Turbine Building, Auxiliary Building, and Instrument Room During Normal Operation"

16. Computer Code STP R6, code I.D. 262165, controlled user's manual #2

17. System Description N3-65-4001 R3 "Emergency Gas Treatment System"

18. TI-RPS-197 R14 "Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident"

19. DCN D-50165-A

20. Work order 990211900, -Attachment A

21 Regulatory Guide 1.140 R1 "Design, Testing, and Maintenance Criteria For Normal Ventilation Exhaust System Air Filtration And Adsorption Units of Light-Water-cooled Nuclear Power Plants.

22a. IONEX drawing 6928 RA

22b. IONEX drawing 6110

22c. IONEX drawing 6930

23.NDP-98-181 " Tritium Production Core (TPC) Topical Report", Westinghouse Electric Company, February 8 1999, RIMS# B44 000929 001

24. EDC-E50629-A

25. WAT-D-10890, Westinghouse document NDP-00-0326, " Transmittal of Waste Management Evaluation for the Watt's Bar Tritium Production Core", RIMS# T71 001204 807

7322

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SUSCEPTIBILITY OF THREADFIN SHAD TO IMPINGEMENT[1]

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ABSTRACT

Threadfin shad impingement at 13 Tennessee Valley Authority electric generating plants from August 1974 through July 1975 was analyzed to assess mortality resulting from low water temperature. Concurrent laboratory experiments were conducted to evaluate the ability of cold-stressed threadfin shad to avoid impingement. Temperatures of 12°C stressed fish in the laboratory, while those below 8°C caused high impingement mortality. At 5 of 12 fossil-fuel plants, 90 percent or more of the annual threadfin impingement occurred when water temperatures were below 10°C. At four plants, impingement was not related to low temperatures. Impingement at the Browns Ferry Nuclear Plant generally coincided with low water temperatures, but individual impingement peaks were not consistently associated with cold shocks.

INTRODUCTION

The collection of fish on cooling water intake screens (impingement) at electric generating facilities is currently receiving attention throughout the country, owing primarily to licensing requirements for nuclear plants and enactment of the Federal Water Pollution Control Act, Section 316(b). In the southeast United States threadfin shad, *Dorosoma petenense* (Günther), comprise a large proportion of the fish which are impinged at inland generating facilities, occasionally accumulating in large enough numbers to cause physical damage to the intake screens.

Often the greatest threadfin shad impingement occurs during the colder winter and spring months. Threadfin shad are known to be sensitive to low water temperatures and are frequently observed in an apparent moribund condition throughout many reservoirs during this cold period. Laboratory studies have suggested that exposure of threadfin shad to temperatures below approximately 7-9°C causes high mortality, especially when associated with rapid decreases in temperatures (cold shocks) (Parsons and Kimsey 1954; Strawn 1965).

The Tennessee Valley Authority (TVA) has been conducting studies at its 12 fossil-fuel and one nuclear electric generating plants to assess the magnitude of fish impingement and its effect on the reservoir fish populations. Because of high impingement during the colder months of the year at several TVA power plants, it was hypothesized that much of the impingement represented a collection of threadfin shad that were dead or dying because of cold stress. To evaluate this hypothesis a cooperative study was undertaken between TVA and Oak Ridge National Laboratory in 1975. The purpose of this report is to present preliminary results of that study. Specific objectives are:

1. To describe the behavior and swimming ability of threadfin shad exposed to laboratory-induced cold temperatures.
2. To evaluate the susceptibility of cold-stressed threadfin shad to, and ability to recover from, impingement under experimental conditions.
3. To examine the quantitative seasonal aspects of threadfin shad impingement at each TVA electric generating station.
4. To assess the amount of impingement that may be attributed to cold stress.

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MATERIALS AND METHODS

Experimental Cold Stress and Impingement

Approximately 650 threadfin shad 9-14 cm in length were dip netted during the periods May 8-12 and June 2-6, 1975, from a tributary of the Clinch River in Roane County, Tennessee. Fish were transported with negligible mortality 12 km to the Oak Ridge National Laboratory, where they were held in circular 770-l and 1700-l fiberglass tanks for 4-8 days before testing. An inflow of 8 l/min circulated from the outer edge to the central stand pipe of each tank at a velocity of approximately 6 cm/sec. Shad were fed brine shrimp *(Artemia salina)* nauplii at 0900 hr. daily during acclimation and experimentation.

Since threadfin shad continuously circled the tanks against the flow, measurements of this cruising speed were made on groups being cold acclimated at 1° C per day or less. Time to complete one circle, circumference of that circle, and water velocity were recorded for 20 individual fish at each of 13 temperatures over a range of 5.5 to 25° C. Cruising speed was calculated for each fish by dividing the circumference by the travel time and adding water velocity; individual values were averaged for fish at each temperature.

Impingement testing was conducted in an indoor 30 cm-wide x 30 cm-deep x 6.5 m-long concrete flume. Water depth was 17 cm. A variable-speed pump of 2000 l/min capacity was capable of circulating water from 10 to 30 cm/sec through three 1 m-long sections, each enclosed by sections of 12 mm-mesh intake screens used at TVA power plants. A set of baffles below the inflow from the pump reduced turbulence. Water temperature was maintained ± 0.2° C by adjusting the temperature of the 8-20 l/min of water being added at the head of the flume. Excess water flowed over stop-logs at the tail of the flume. To decrease water temperatures below 8° C, two Blue M model PCC-2 portable cooling units were used to compensate for room and pump heating. A minimum temperature of 6.5° C could be maintained. Water velocities were set at 23 cm/sec with a Marsh-McBirney model 722 electromagnetic current meter. Velocities in each section ranged from a minimum of 19.5 cm/sec along the sidewalls to 24 cm/sec. Dissolved oxygen ranged from 92 to 95 percent saturation throughout the tests.

The effect of temperature on the ability of threadfin shad (mean fork length 11.8 cm, range 10.1-13.3 cm) to swim without impingement in a current similar to that found at the intake of TVA power plants was assessed. To simulate fluctuating winter temperatures, fish were exposed to a gradual temperature decrease of 1, 2, 3, or 4° C during the four hours preceding testing. Two series of impingement tests were conducted at temperatures ranging from 6.5 to 20° C. In Series A, each of 12 groups of 8 threadfin shad was exposed to a drop of 1, 2, or 4° C before testing at 20, 16, 12 or 8° C. A total of 200 threadfin shad were placed in a 1700-l circular tank at 24° C. After four days, 15 fish were transferred to each of two 770-l circular tanks. Temperature in one of these tanks was held at 4° C above the test temperature (e.g., 24° C before the initial test at 20° C). Temperature was lowered 1° C per day in the other until a temperature 2° C above the test temperature was reached (e.g., 22° C before the initial test). Temperature in the 1700-l tank was decreased 1° C each day. After four days this group reached the test temperature.

At 0900 hr. on the day of testing, temperatures in the small tanks were dropped 4° C and 2° C over a 4-hour period, at which time eight fish were randomly removed from each tank and placed in separate sections of the flume. Eight fish were also removed from the 1700-l tank and placed in the third flume section. Groups were randomly assigned to flume sections. Fish were held in the flume for one minute at a water velocity of 10 cm/sec, after which velocity was increased to 23 cm/sec for two hours. The number of fish impinged, or immobilized on the downstream screen, and the number of body contacts made with the downstream screen was recorded every five minutes. The position of fish in the flume was monitored and occasionally filmed with an 8-mm movie camera. After two hours, velocity was returned to zero. Fish were retained in each section for 17 hours at the test temperature (± 1° C) to assess latent mortality. Length and sex of all fish were then recorded. Fish remaining in each of the three circular tanks were periodically observed for mortality or signs of stress. Those in the two small tanks were removed 17 hours after conclusion of the flume test, and three new groups of fish were immediately introduced to repeat the procedure at a new (colder) test temperature.

Series B was conducted similarly at test temperatures of 18, 14, 12, 10, 8, and 6.5° C. The upstream section of the flume was not used; the two groups of fish in each trial were exposed to 1 or 3° C decreases during the four hours preceding testing in the same manner described above. In contrast to Series A in which impinged fish were not removed from screens, in Series B fish were transferred to a holding tank after 10 minutes of impingement to assess their survival.

Table 1. Physical characteristics, number of impingement samples and threadfin shad composition of impinged fish at TVA's fossil-fueled and nuclear power plants.

Plants[1]	*Number of screens*	*Maximum cooling water required* (m^3/sec)	*Average water velocity (cm/sec) in front of trashracks (range)*	*Number of 24-hr. impingement samples*	*Percent threadfin by number of all species impinged*
Tennessee River System					
John Sevier	8	28.6	13.8 (5.4-19.8)	44	24.1
Bull Run	3	25.1	34.4 (19.8-54.9)	44	87.2
Kingston	18	61.0	13.6 (3.0-27.4)	50	97.2
Watts Bar	6	17.7	Not available	42	58.7
Widows Creek:		68.9		48	87.0
Units 1-6	12		29.2 (8.5-47.2)		
Units 7-8	6		42.8 (25.2-67.7)		
Browns Ferry	18[2]	113.5	Not available	181	70.9
Colbert	12	54.6	21.3 (13.7-25.9)	51	83.9
Johnsonville	20	64.9	Not available	50	67.0
Cumberland River					
Gallatin	8	37.4	23.7 (19.8-27.4)	52	70.0
Cumberland	16	101.9	Not available	42	93.9
Green River					
Paradise	6	48.8	Not available	42	52.1
Ohio River					
Shawnee	20	67.9	Not available	38	30.9
Mississippi River					
Allen	9	21.7	8.2 (4.6-15.2)	52	10.5

[1] Fossil-Fuel except for Browns Ferry (nuclear).
[2] Only 12 screens of Units 1 and 2 in operation during the study period.

In separate experiments, the ability of threadfin shad to survive impingement for 0, 2, and 5 minutes at 10 and 20° C was briefly examined. At each of the two temperatures, 20 fish were placed in each of the three flume sections and held at 23 cm/sec until approximately 50 percent of each group was impinged. Fish were removed immediately after immobilization on the upper section screen, after two minutes on the middle section screen, and after five minutes on the lower section screen and held in tanks at the test temperature to assess mortality.

Impingement Monitoring at TVA Plants

At the 12 TVA fossil-fuel steam plants, all of which utilize vertical traveling screens, weekly fish impingement samples were collected from August 1974 through July 1975 (Table 1). At the beginning of the sample period all the vertical traveling screens in the intake pumping structure were rotated and washed clean, then stopped for 24 hours. All screens which had water passing through them during the sample period were then washed again, either individually or by unit. Impinged fish were collected in a catch basket installed in the screen wash sluice trench. All fish were separated by species into 25-mm total length increments and enumerated. Intake water temperatures were recorded during the sample periods at most plants.

Sampling at Browns Ferry Nuclear Plant differed somewhat from that at the fossil-fuel plants because of requirements established in the Environmental Technical Specifications for the plant. Thrice weekly 24-hour samples were collected from one screen designated the test screen. When this screen was not in operation, an alternate was used. Hourly surface river temperatures 2 km upstream of the Browns Ferry intake were compared with impingement counts.

RESULTS

Experimental Cold Stress

No mortality was observed above 12° C in test fish exposed to temperature drops of 1-4° C in four hours. Below 12° C, mortality rates increased with the magnitude of drop, but data were insufficient to make statistical comparisons. All moribund shad displayed a characteristic set of behavior patterns. In chronological order these were:

1. Movement to the surface of the water by an entire school. Dorsal fins of some fish broke the surface. (This pattern was displayed by most, but not all, groups of shad.)
2. Erratic, jerky swimming by a few fish. Group moved back to mid-depth in tank, schooling began to disintegrate.
3. Loss of equilibrium by individuals, with periods of inverted swimming.
4. Fish sank to bottom, or less frequently, floated to the surface remaining motionless except for occasional tail flickers and shallow opercular movement.
5. Death.

Cruising speed of threadfin shad varied directly with water temperature over the range studied (Figure 1) and can be characterised by the linear regression equation:

$$Y = 0.8597\ X + 4.4463$$

where Y is cruising speed in cm/sec and X is temperature in degrees C; the correlation coefficient, r, is 0.968. No differences in cruising speed were noted among fish held in tanks of different sizes.

Experimental Impingement

Threadfin shad exhibited a series of relatively consistent behavior patterns in the test flume. All fish swam actively against currents of 10 and 23 cm/sec. At 23 cm/sec shad normally formed a school and explored boundaries of the test section for several minutes. During this period individuals occasionally brushed against the lower screen but quickly moved away. At warmer temperatures shad moved to the head of each section after the exploratory period and often attempted to continue upstream by pushing their heads into the openings of the upstream screen. Healthy fish remained upstream throughout the remainder of the two-hour test period, occasionally reexploring the downstream area and contacting the lower screen.

Fish not capable of swimming against the current displayed two patterns of behavior before they invariably became impinged. Some attempted to maintain position at the head or along the edge of the flume as long as possible, then drifted downstream sideways or headfirst. As they approached the lower screen they attempted to turn back into the current, and usually struck the posterior half of the body or the tail on the screen. Other individuals swam immediately in front of the screen for periods exceeding 10 minutes. They occasionally drifted back against the screen and pushed off from it with the caudal fin.

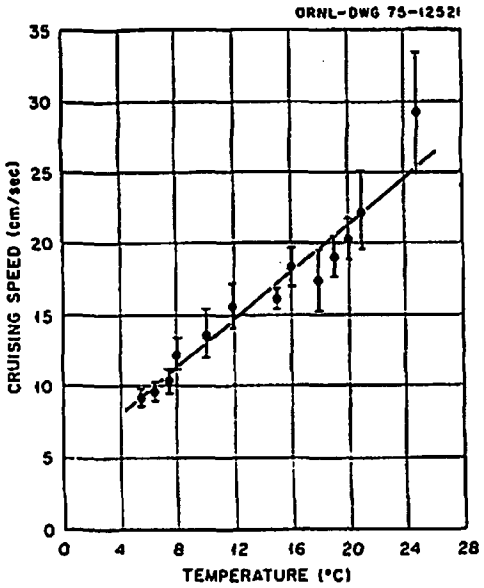

Figure 1. Effect of water temperature on cruising speed of 10-13 cm-long threadfin shad in circular 770 l tanks. Mean values given as points, standard deviation as vertical bars.

Table 2. Impingement test results for 20 groups of 8 threadfin shad, 10-13 cm, tested for 2 hours at 23 cm/sec.

Test Series	*Test Temp., C*	*ΔT, C*	*Percent Impinged*	*Percent Mortality*[1]	*Average Screen Contacts Per Fish*[2]	*Length of Critical Period, min*[3]
A[4]	8	2	12	37	45.9	70
		4	12	100	123.7	95
	12	1	12	37	53.0	80
		4	12	37	55.2	70
	16	2	0	0	1.3	0
		4	12	25	39.0	85
	20	1	0	0	14.3	90
		2	0	12	26.1	95
B	6.5	1	75	88	109.6	60
		3	75	100	63.7	65
	8	1	12	25	2.9	10
		3	25	63	26.9	35
	10	1	25	37	23.5	30
		3	25	37	11.2	25
	12	1	12	37	19.1	60
		3	25	50	37.1	50
	14	1	0	12	20.8	30
		3	0	12	29.5	55
	18	1	0	25	20.4	95
		3	12	12	27.8	90

[1] At end of 17 hrs. after test.
[2] Calculated by dividing number of contacts per 5 min. period by number of fish present and summing results.
[3] Period during which contacts/fish/period ≥ 1.
[4] Data from upstream flume section not presented because of presence of high turbulence.

In the final stage preceding impingement many individuals struck and broke away from the screen 50 times or more before becoming immobile (Table 2). Threadfin shad that had remained on the screen for up to five minutes commonly broke away to swim briefly before becoming reimpinged.

Most impingement occurred during the first hour of the test. The duration of this critical period was defined as the time during which the calculated mean number of screen contacts per fish in a five minute period was ≥ 1. All but one of the 20 groups tested displayed such a critical period lasting 95 minutes or less (Table 2). After this time, remaining fish appeared to be swimming strongly and seldom contacted the downstream screen. Despite their healthy appearance, an average of 23 percent of the survivors of each two-hour test died within the following 17 hours. Several groups were held an additional 48 hours with no additional mortality.

Impingement increased at lower test temperatures (Figure 2). Some mortality (impingement and latent) occurred at the warmer test temperatures. Below 14° C mortality increased, reaching 100 percent for two groups tested at 8 and 6.5° C. Threadfin shad exposed to larger temperature drops showed poorer survival below 12° C, but more data are required to precisely define the effect of each of the rapid temperature decreases. Data from the upstream flume section have not been presented since high mortality occurred for all groups tested there and analysis of movie films of fish movement suggested the presence of increased turbulence.

No threadfin shad survived even brief impingement. All fish removed from screens after either a few seconds or after 2, 5, and 10 minutes of impingement were alive but died within 2-4 hours. No difference in survival of male and female shad was observed in impingement tests.

Impingement Monitoring at TVA Steam Plants

The relative composition by number of threadfin shad to all species impinged over the year averaged 72 percent for all plants and ranged from 10.5 percent (Allen) to 97.2 percent (Kingston, Table 1). Estimated total annual impingement of threadfin shad at TVA's plants ranged from approximately 13,000 to 4,990,000.

The number of threadfin shad impinged at TVA steam plants varied greatly among seasons (Table 3). Comparison of impingement during sample periods when minimum intake water temperatures were below 10° C (cold period) and above 10° C (warm period) showed that 90.5-99.9 percent of threadfin shad impingement occurred during the colder period at five plants (John Sevier, Kingston,

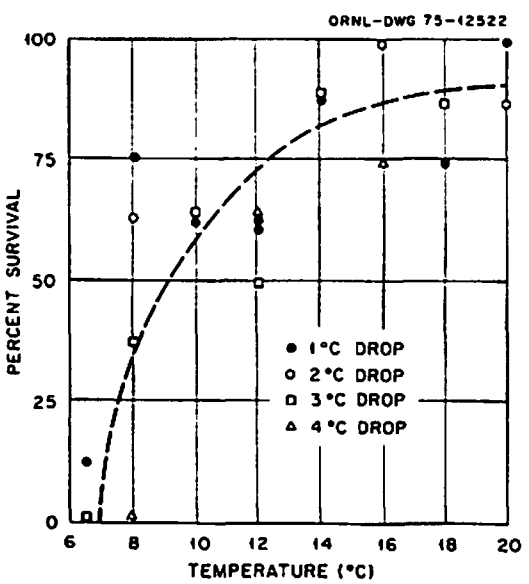

Figure 2. Effect of test temperature on threadfin shad survival 17 hrs. after swimming in water of 23 cm/sec velocity for 2 hrs. in a test flume. The 8 fish in each group subjected to temperature drops of 1-4° C before testing. Curve drawn by eye.

Table 3. Impingement of threadfin shad at TVA's Fossil-Fuel Steam Plants between August 1974—July 1975, given as percent by month.

Steam Plant	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Percent impinged at water temp. <10 C*[4]
Tennessee River													
John Sevier	0.0	0.0	0.0	0.0	3.3	0.04	81.4	15.2	0.1	0.0	0.0	0.0	99.9
Bull Run	0.3	2.2	5.2	52.5	8.0	12.8	4.8	6.5	2.2	2.1	1.6	1.8	50.0
Kingston	0.8	2.8	1.7	4.9	84.8	0.1	0.3	1.1	3.2	0.04	0.04	0.08	91.3
Watts Bar	1.1	7.9	0.2	0.8	4.2	6.1	27.9	21.2	16.2	11.3	0.8	2.2	48.9
Widows Creek	0.9	4.8	1.3	0.03	0.5	0.4	0.6	12.6	76.0	0.1	0.2	2.4	3.6
Colbert	5.4	1.4	0.1	0.1	2.0	1.2	13.6	20.2	53.1	0.0	0.1	2.8	—[3]
Johnsonville	1.3	0.3	0.3	0.4	22.3	32.0	24.9	15.5	2.6	0.01	0.0	0.4	96.5
Cumberland River													
Gallatin	4.5	61.4	10.8	10.4	6.8	0.8	3.1	1.4	0.6	0.2	0.02	0.01	12.8
Cumberland	31.8	42.1	14.5	7.6	0.6	1.6	1.7	—[2]	0.03	0.01	0.0	0.0	3.9
Green River													
Paradise	0.1	0.1	0.3	3.7	88.5	6.8	0.4	0.0	0.0	0.0	0.0	0.0	98.8
Ohio River													
Shawnee	—[1]	6.8	0.4	4.1	7.7	10.1	11.5	13.9	45.3	0.1	0.04	0.04	61.3
Mississippi River													
Allen	0.0	0.6	0.1	2.0	2.6	37.5	25.6	16.2	11.3	4.0	0.1	0.0	90.5

[1] Not sampled.
[2] Not in operation.
[3] Intake temperatures not available. 95.5% impinged between February 6 and April 17.
[4] Computed from average number impinged per 24-hour sample.

Table 4. Monthly impingement of threadfin shad at Browns Ferry Nuclear Plant between June 1974 and May 1975 and average daily maximum and minimum surface water temperatures in Wheeler Reservoir 2-km upstream of the intake channel.

	Jun.	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*
Mean number impinged per sample on test screen	102	706	1968	1545	328	824	413	1964	6618	6245	851	13
Range	5-1023	258-1569	147-8496	131-6683	108-620	92-3097	70-1714	202-5717	441-26,749	322-12,087	93-2018	2-47
Percent impinged on test screen	0.5	3.3	9.1	7.2	1.5	3.8	1.9	9.1	30.7	28.9	3.9	0.1
Mean of daily minimum temperatures (°C)	24.3	27.1	26.9	22.7	17.6	12.9	7.2	7.9	8.7	9.8	14.8	22.9
Mean of daily maximum temperatures (°C)	25.7	29.6	28.3	24.3	19.3	14.3	8.4	9.0	10.2	10.9	16.5	24.7

Table 5. Size distribution of threadfin shad impinged at Browns Ferry Nuclear Plant, June 1974—June 1975.

Total length (mm)	Percent in month												
	Jun.	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*
0- 25													
26- 50	96.0		0.3										11.0
51- 75	2.8	99.0	99.7	99.0	67.0	16.0	19.0	4.0	0.3				42.0
76-100	1.0	0.5		0.3	33.0	84.0	77.0	87.0	75.0	70.0	33.0	3.0	
101-125	0.1			0.5			3.0	8.0	23.0	28.0	62.0	39.0	11.5
126-150	0.1	0.5		0.3			0.8	0.5	1.5	1.5	4.0	45.0	24.0
151-175							0.3	0.3	0.3	0.3	0.8	13.0	11.0
176-200								0.3			0.3		0.5

Johnsonville, Paradise, and Allen, Table 3). At several of these plants most of the total impingement from all samples throughout the year occurred on one or a few sampling dates. At Kingston, 71.5 percent of all threadfin shad were impinged on December 11, 1974; at Paradise, 88.0 percent on December 21 and 27, 1974; at John Sevier, 71.6 percent on February 26, 1975.

At Bull Run, Watts Bar, and Shawnee Steam Plants approximately half of the impingement occurred during the cold period and about half either immediately preceded or followed it. Four plants (Widows Creek, Gallatin, Cumberland, Colbert) displayed high impingement (87.2-96.4 percent) during the warm period. Most threadfin shad were impinged at Widows Creek and Colbert just after the cold temperature period. Water temperature was not monitored at the Colbert plant, and the thermal regime near the plant was assumed to approximate that near the Browns Ferry plant located upstream. Cumberland and Gallatin steam plants showed highest impingement of threadfin shad during late summer and early fall when minimum intake temperatures exceeded 20° C.

Threadfin shad impingement at the Browns Ferry Nuclear Plant was also highly variable throughout the year. The average number impinged on the test screen per 24-hour sample ranged from one to three orders of magnitude within months (Table 4). Approximately 60 percent of the annual threadfin shad impingement occurred in February and March, during the end of the coldest period of the year. Between June and November, surface temperature (Table 4) remained well above 10° C, dropping to 10° C on November 29. During the subsequent 111-day period from November 30, 1974, to March 20, 1975, surface water temperature ranged from 5-10° C with occasional rises slightly above 10° C for short periods (Figure 3). Despite occasional periods of several days with water temperatures less than 8° C during December and January, impingement remained low (1.9 and 9.1 percent respectively of total annual numbers impinged). Several peaks during the highest impingement period (February 22 to mid-March) were immediately preceded by instances of cold shocks, while others were preceded by rising temperatures (Figure 4). After March 20, surface water temperature rapidly rose above 10° C while numbers of impinged fish sharply declined.

Threadfin shad less than 26mm total length were not impinged on the 10-mm mesh intake screens. At Browns Ferry Nuclear Plant, they first attained impingeable size in June at a total length between 26-50mm (Table 5). Few individuals greater than 125mm became impinged.

DISCUSSION

Laboratory studies indicated that water temperatures below approximately 12° C induced stress in adult threadfin shad, leading to increased impingement and mortality rates. The ability of threadfin shad to resist impingement in a test flume was severely impaired below 8° C. Further studies are needed to more clearly define the effects of rapid temperature decreases of various magnitudes.

It is clear that most unstressed adult threadfin shad are capable of swimming against the intake velocities encountered at most TVA power plants during warm periods of the year. At 22° C their cruising speed, as determined in the laboratory, approximates or exceeds the average intake velocities of five of eight TVA plants. The sustained swimming speed, or speed which they could maintain for several minutes, is expected to be twice the cruising speed at a given temperature (Bainbridge, 1958).

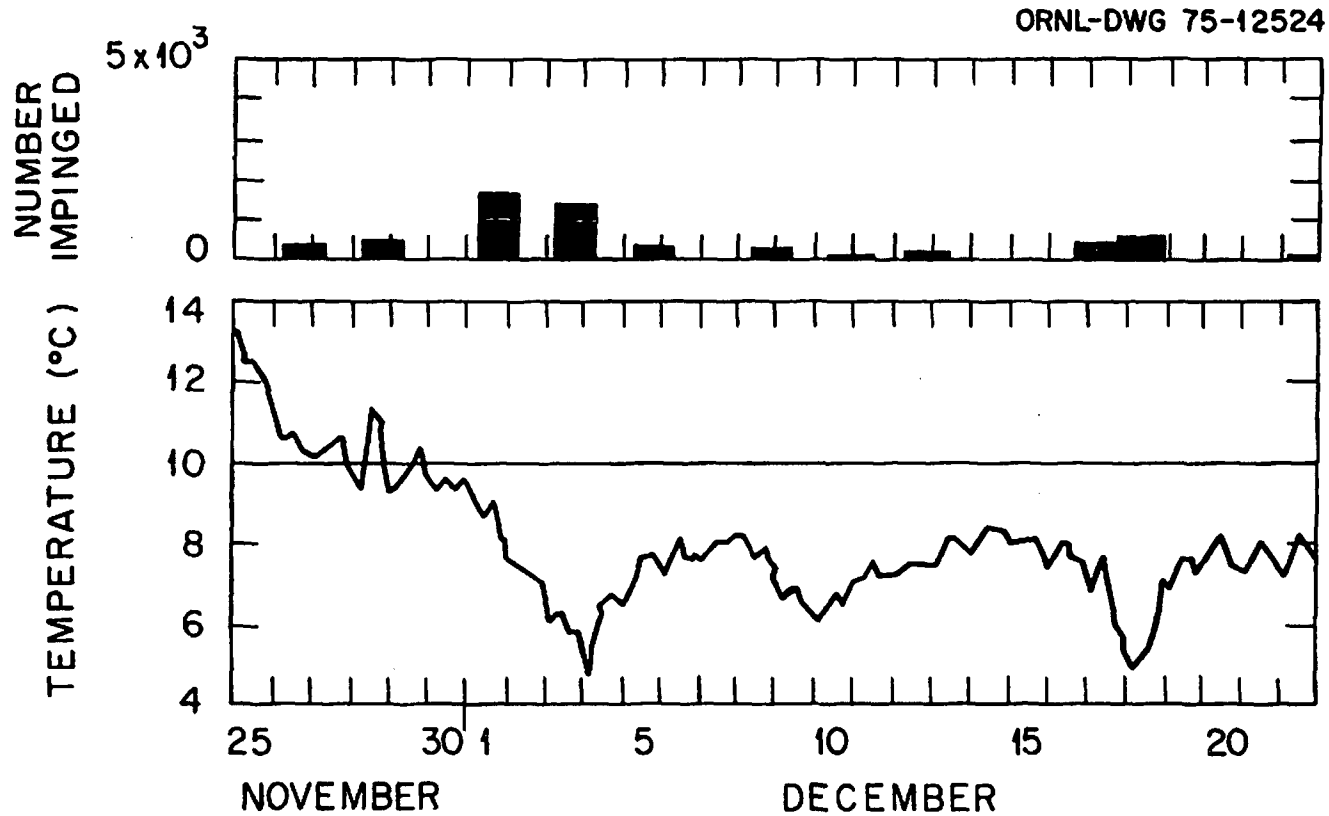

Figure 3. Numbers of threadfin shad impinged during 24-hr. sampling periods at Browns Ferry nuclear plant compared with surface water temperatures plotted at 6-hr. intervals during November-December 1974.

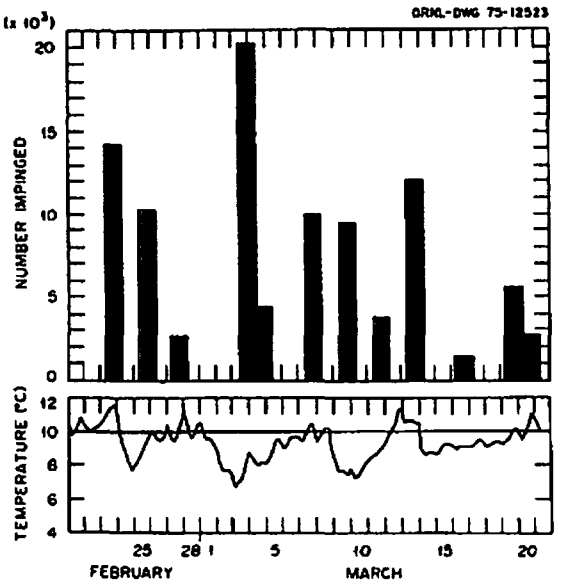

Figure 4. Numbers of threadfin shad impinged during 24-hr. sampling periods at Browns Ferry nuclear plant compared with surface water temperatures plotted at 6-hr. intervals during February-March 1975.

In the laboratory flume, unstressed shad explored the intake screen area and then attempted to swim upstream and leave the vicinity of the screen. This suggests that impingement of such fish may occur only if they are trapped by physical features of the intake structure or its associated environment (such as turbulence or turbidity) and cannot find a means of escape. In the laboratory, threadfin shad usually became impinged only after striking the screen repeatedly and becoming completely exhausted. In contrast to the ability of juveniles of some percichthyid and salmonid species to survive impingement for several minutes or more at velocities of 70 cm/sec or greater (Skinner, 1974; Bibko *et al.*, 1974), threadfin shad did not survive even momentary impingement.

Shad that were severely cold-stressed under laboratory conditions displayed a symptomatic, uncoordinated swimming behavior lasting several hours or more. This behavior closely paralleled that observed under natural conditions in reservoir populations of threadfin shad during the coldest period of the year. The extent of the population affected by cold shock as well as the mortality rate for the affected individuals is unknown and presumably varies considerably from reservoir to reservoir and year to year. Furthermore, it is not known to what extent cold-stressed fish would recover were they not pulled into the intake structure. Further laboratory and field study is needed to assess their ability to recover from varying degrees of cold stress.

Data collected at five TVA fossil-fuel plants indicated the existence of a strong relationship between threadfin shad rate of impingement and low ambient water temperature. These findings agree closely with those derived from studies at three Duke Power Company steam plants in North and South Carolina, in which greatest impingement of threadfin shad occurred during the colder winter period (T. J. Edwards, Duke Power Company, personal communication). Threadfin shad impingement at the remaining seven TVA fossil-fuel plants appeared to be only partially related, or completely unrelated, to low temperature.

The results of the more intensive sampling at the Browns Ferry Nuclear Plant, when combined with laboratory studies, suggest a hypothetical annual threadfin shad impingement cycle for that plant which is largely dependent on the size of the fish and the yearly temperature pattern.

During May, total impingement of threadfin shad consists of a few yearlings. In June, young-of-the-year threadfin, which previously had been susceptible to entrainment only, first attain impingeable size. For the next several months, impingement increases as this group becomes fully recruited into the impingeable population. Water temperature during this time is high, but due to their small

size and/or behavior patterns, the young shad are incapable of avoiding impingement. Despite decreasing temperature in October and November, low impingement of threadfin shad may be attributed to their increasing size and swimming ability.

Although water temperatures in late November reach the levels which laboratory studies suggest stress threadfin shad, no elevation is noted in impingement. Similarly, water temperatures reach an annual minimum during December and January with little or no resultant increase in impingement. In February and March, temperatures increase only slightly above the cold December-January period, while numbers of impinged fish increase greatly and frequently include several mass mortalities throughout this period. The two-month lag between the onset of the cold period and the beginning of high impingement suggests that threadfin shad may tolerate prolonged exposure to sustained low temperature for several weeks, after which they become highly susceptible to low temperature and/or cold shock, or that the fish are able to seek out areas of warmer temperature.

During April and May, water temperatures increase rapidly accompanied by a sharp decline in impingement. Factors such as large size and improved condition of fish, warm water, spawning movements, and/or a reduced population due to spawning mortality (Berry, *et al.*, 1956) or over-winter mortality may contribute to the reduced impingement. In June this impingement cycle is renewed when young-of-the-year reach impingeable size.

Future studies will attempt to resolve the discrepancy found between laboratory and Browns Ferry field findings and may facilitate a more accurate predictability of sudden mass mortalities and resulting increased impingement of threadfin shad due to cold stress.

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STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
Division of Solid Waste Management
Fifth Floor, L & C Tower
401 Church Street
Nashville, Tennessee 37243 - 1535

August 18, 1999

Mr. George Vickery
TVA
P.O. Box 2000
Spring City, Tennessee 37381-2000

Re: Watt's Bar Nuclear Plant

Dear Mr. Vickery:

The Division has received and reviewed correspondence dated June 22, 1999 from Ms. T. Marguerine Wilson, Environmental Restoration Specialist with TVA, regarding the above referenced site wherein she requested confirmation from the Division that all relevant issues regarding reclaiming the site's evaporation /percolation pond have been satisfactorily addressed. After review of the current analytical data and historic background information relevant to the evaporation/percolation pond, the Division concur; with the opinion of Ms. Wilson that use of the pond by Watts Bar Nuclear Plant did not adversely impact the environment and agrees that no further action should be taken with regard to this matter.

Should you have any questions concerning the above, please feel free to contact me at 615-532-0869.

Sincerely,

Ashley A. Holt

Ashley A. Holt, P.G.
State Remediation Program
Division of Solid Waste Management

Cc: SRP files

2

Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

June 24, 1999

Mr. Phil Stewart, Manager
Division of Water Pollution Control
Tennessee Department of Environment and Conservation
Chattanooga Field Office
Suite 550, 540 McCallie Avenue
Chattanooga, Tennessee 37402-2013

Dear Sir:

WATTS BAR NUCLEAR PLANT (WBN) - ANALYTICAL DATA FROM DISCHARGE SERIAL NUMBER (DSN)103 DURING DEWATERING OF THE EVAPORATION/ PERCOLATION (EP) POND

WBN has transferred the water from the EP pond to the Low Volume Waste Holding Pond (LVWHP). Rainwater that collected prior to covering the EP pond sediment was also transferred to the LVWHP. WBN, in consultation with your office, identified pH, Total Iron, and Total Phosphorus as key indicators for water quality concerns at DSN 103 while dewatering the EP pond. Per the request in your December 7, 1998 letter WBN is supplying a summary of this analytical data collected from DSN 103 during the dewatering of the EP pond for your records.

While compiling the data for this report, it was discovered that two samples collected on December 31, 1998, were not subsequently analyzed and reported. One sample was for Total Iron and was never found. The other sample was collected for Total Phosphorus.. The Total Phosphorus sample was located and analyzed for both Total Phosphorus and Total Iron. The sample had exceeded the holding time for Phosphorus and was not preserved with the acid specified by EPA protocol for Iron analyses. Hence, neither value is reportable on the Discharge Monitoring Report. The iron result was 0.130 mg/L. The phosphorus result was 0.06 mg/L. While not reportable, these values are consistent with results reported from days immediately before and after December 31, 1998 and indicate no problems with water quality during release of the EP pond water.

Please contact Robert Crawford of my staff at 423-365-8005 for any additional information.

Sincerely,

Odis E. Hickman Jr.

Odis E. Hickman Jr.
Radwaste/Environmental Control Superintendent

Attachment

Printed on recycled paper

Mailed 6/25/99 - DT 3

Tennessee Valley *Authority. Post* Office Box 2000, Spring City, Tennessee 37381-2000

June 22, 1999

Mr. Ronnie Bowers, Manager
Division of Site Remediation
Tennessee Department of Environment and Conservation
Fifth Floor, L & C Tower
Nashville, Tennessee 37243

Dear Mr. Bowers:

WATTS BAR NUCLEAR PLANT - RECLAIMING THE WATTS BAR NUCLEAR PLANT (WBN) EVAPORATION/PERCOLATION (EP) POND

WBN requests confirmation from your office that WBN has addressed all relevant issues with regard to reclaiming the site's EP pond. A general description of the pond, its history and WBN's intentions were included in the letter sent to your office on November 16, 1998. We have coordinated minor modifications to that original proposal with your office and will include them in the summary below. WBN has found your approach to compliance thorough and efficient. The additional sampling and documentation you have requested should make it clear to all concerned that WBN's use of this pond has not resulted in an adverse impact to the environment. Key elements of the process used to reclaim the pond follow:

1. Release of the water in the pond was coordinated with the Division of Water Pollution Control. This organization temporarily placed additional sampling requirements for constituents of concern on the effluent of the pond receiving water from the EP pond. No excursions of the site's National Pollutant Discharge and Elimination System permit limits occurred.
2. Prior to covering the sediments you requested additional analyses of the sediment samples. These results were faxed to you and are again summarized as an attachment to this letter. You also requested that groundwater samples be collected and analyzed and any anomalies addressed. A copy of the groundwater report submitted to WBN by TVA geologists is attached. There were no issues to address.
3. The banks of the EP pond were pushed in to cover the sediment in situ. Soil was added to ensure good drainage. Upon WBN's request, your office agreed that soil free of stones greater than 3 inches in diameter, stumps and other organic debris was acceptable to use as till. You confirmed the soil was acceptable for use in this application when you inspected the site a few days later.

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4. The EP pond area is now covered with soil suitable for vegetation and has been seeded, fertilized, and mulched. If the weather does not cooperate to promote good ground cover, the area will be re-seeded in the fall.
5. The four corners of the pond have been identified with aluminum monuments by surveyors. The corners correspond to the corners of the fence that originally surrounded the pond.
6. A sign has been hung from the inlet pipe to the pond which will be left standing to further mark the area. The sign warns that no excavation of the material inside the aluminum marker boundaries may take place without approval from WBN's Environmental Control Section.

Please identify any questions on this issue to Mr. Robert Crawford of my staff at (423) 565-5005.

Sincerely,

Odis E. Hickman Jr.

Odis E. Hickman, Jr.
Radwaste/Environmental Control Superintendent

Attachments (2)

March 29, 1999

Ms. Ashley Holt, P.G.
Division of Solid Waste Management
Tennessee Department of Environment and Conservation
401 Church Street
5th Floor L&C Tower
Nashville, Tennessee 37243

Dear Ms. Holt:

WATTS BAR NUCLEAR PLANT - RECLAIMING THE EVAPORATION1 PERCOLATION POND - GROUNDWATER SAMPLE LOCATIONS

Per our earlier conversations concerning the Evaporation Percolation (EP) Pond located at Watts Bar Nuclear Plant, it is proposed that groundwater samples be collected in the vicinity of the EP Pond with the Geoprobe Screen Point Groundwater Sampling System. As requested. groundwater samples will be collected from three locations down gradient the EP Pond in an effort to capture representative samples of groundwater from the Pond area. The following constituents will be analyzed: barium, cadmium, chromium, copper, lead and phosphorous; and when possible. filtered and unfiltered analyses will be performed. As we discussed, if no significant concentrations of these analyses are present in the groundwater, most likely no additional groundwater wells will need to be installed to monitor the EP Pond area. Enclosed is a site map showing the proposed groundwater sampling locations.

Sampling activities are scheduled to begin on Tuesday, March 30.

If you have any questions, please contact me at (423) 673-2305

Sincerely,

T. Margueritte Wilson

T. Margueritte Wilson, P.G.
Environmental Restoration Specialist
Environmental Engineering Services-East
River System Operations & Environment

TMW:ELD
Enclosure
cc (Enclosure):
Rob J. Crawford, MOB IT-WBN
W. Joseph Burke, GRN 2F-K
James A. Overton, GRN 2F-K
Files, ER&S, CEB 1B-M

23

ENVIRONMENTAL ASSISTANCE CENTER
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
540 McCALLIE AVE., SUITE 550
CHATTANOOGA, TENNESSEE 37402-
PHONE (423) 634-8745 STATEWIDE 1-888-891-8332 FAX (423) 634-6389

December 7, 1998

Mr. Odis E. Hickman, Jr.
Radwaste/Environmental Superintendent
Tennessee Valley Authority
Watts Bar Nuclear Plant
P.O. Box 2000
Spring City, TN 37381-2000

Re: Approval to Dewater the WBN Evaporation/Percolation Pond
NPDES Permit No. TN0020168
Tennessee River, Rhea County

Dear Mr. Hickman:

We received your request to dewater the Evaporation/Percolation Pond (Perc Pond) via facsimile on December 3, 1998. Upon reviewing the historical and current analytical data, and the planned procedures for the dewatering process, we hereby grant approval to dewater the Perc Pond through the Low Volume Waste Holding Pond. It is our understanding that the dewatering process is the initial step for closure of the Perc Pond. This closure will be authorized and supervised by the Division of Solid Waste Management through the State Remediation Section. Provisions must be made to prevent storm water from collecting in the Perc Pond area, both during and after the closure of the pond. Notification should be made to this office ASAP for any permit noncompliance or anomalous condition resulting from the dewatering operation. To complete our file, we would appreciate a copy of the analytical data at the conclusion of the dewatering process. If you should have any questions, please call Cynthia Anderson at (423)634-5712.

Sincerely,

Philip L. Stewart, P.E.
Manager
Division of Water Pollution Control

pls\cma\permti\tva\wbn\ppl1198

cc: DWPC, Nashville. Permit Section, c/o Larry Bunting
cc: DSWM, Chattanooga. c/o Guy Moose

November 16,1998

Mr. Ronnie Bowers, Manager
Division of Site Remediation
Tennessee Department of Environment and Conservatron
Fifth Floor L&C Tower
Nashville. Tennessee 37243

Dear Sir:

WATTS BAR NUCLEAR PLANT (WBN) - RECLAIMING THE EVAPORATIONIPERCOLATION(EP) POND

WBN requests concurrence that the actions proposed in this letter are appropriate and sufficient for reclaiming the site's EP pond. Formal closure under Tennessee's solid waste regulations does not apply to this pond. This pond is unique in that it was intentionally designed without a liner. Wastewater constituents were to be evaporated or tied-up in the soil mass below the pond as the water percolated through to the groundwater. Hence, the pond was not designed to "hold" an accumulation of liquid wastes and, therefore, does not meet the Solid Waste definition of a surface impoundment.

The pond was approved and constructed in 1979 and last used in 1986. After its last use, the inlet was flanged shut, the pond fenced, and the gate locked to ensure no other material would be added. The surface area is approximately 2 acres. The pond was created by excavating the land an average of 18 inches deep. The excavated material became the pond banks.

Solutions of boric acid. ammonium chloride, and sodium triphosphate used to clean plant piping systems and dilute solutions of spent hydrazine were the principle wastewaters sent to this pond. No Resource Conservation and Recovery Act (RCRA) hazardous wastes were ever discharged to this pond. Any ammonia or other volatile constituents have long since evaporated. All other constituents of potential concern have slowly percolated through to groundwater or been tied-up in the soil mass below the pond.

WBN proposes to take the following actions to reclaim this land:

1. Push the banks in over the sediment as the pond drains (burying the sediment in situ).
2. There is no need to add additional clay capping (though some may be added to ensure good contour and drainage). The pond was designed to leach as a method of treatment and this will allow WBN to return the land to its original contours as much as possible.
3. Additional top soil will be added as necessary to ensure adequate vegetation and prevent subsequent ponding.
4. The area will be seeded and mulched to ensure a good vegetative cover is obtained and maintained.

I have attached appropriate maps, pictures, diagrams, and analytical results from sediment and groundwater analyses which I feel justify the above actions. The pond's use, knowledge of the processes generating the wastewater, and the supporting analytical data indicate the sediment is not hazardous under RCRA regulations. Nor do the sediments contain significant levels of any wastewater constituents other than iron. Analytical results from a down gradient groundwater monitoring well are also provided. The ground well data indicates a sodium plume with an average sodium concentration of 2000 mg/l. N A has determined that no adverse environmental impacts are expected from this plume due to the relatively innocuous nature of sodium as an environmental pollutant, the extremely slow migration of the plume and the relatively small quantities involved. Also, there is little likelihood of intercepting a residential well as the plume continues its slow migration to the Tennessee River. Groundwater data does not indicate a cause for concern with regard to any of the parameters sampled.

I believe it is appropriate to reclaim this land in this manner. If you have any questions or require additional documentation, please contact Rob Crawford of my staff at (423) 365-8005.

Sincerely,

Odis E. Hickman Jr.

Odis E. Hickman, Jr.
Radwaste/Environmental Superintendent

RJC:JPT
cc: EDMS, WT 3B-K (Attachments)

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR PLANT
NPDES PERMIT NO. TN0026450
316(b) MONITORING PROGRAM

FISH IMPINGEMENT AT SEQUOYAH NUCLEAR PLANT DURING 2005 THROUGH 2007

ENVIRONMENTAL STEWARDSHIP AND POLICY

2007

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LIST OF ACRONYMS

AM&M	Aquatic Monitoring and Management
CCW	Condenser Cooling Water
CWA	Clean Water Act
EA	Equivalent Adult
EPA	Environmental Protection Agency
EPRI	Formerly known as the Electric Power Research Institute
MW	Megawatt
PIC	Proposal for Information Collection
PF	Production Foregone
RFAI	Reservoir Fish Assemblage Index
SQN	Sequoyah Nuclear Plant
TDEC	Tennessee Department of Environment and Conservation
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority

Introduction

Sequoyah Nuclear Plant (SQN) withdraws condenser cooling water (CCW) from the Tennessee River and is subject to compliance with the Tennessee Water Quality Act and the federal Clean Water Act (CWA). Section 316(b) of the CWA requires the location, design, construction, and capacity of cooling water intake structures to reflect the best technology available for minimizing adverse environmental impact. Impingement mortality is a potential mechanism for adverse impacts and is defined as the condition in which fish and/or shellfish are trapped or impinged against an intake screen and often killed in the process. In response to the Environmental Protection Agency (EPA) issuance of a 2004 rule for implementing Section 316(b), a rule subsequently suspended in 2007, and in accordance with a Proposal for Information Collection submitted to Tennessee Department of Environment and Conservation (TDEC) in 2005, Tennessee Valley Authority (TVA) conducted impingement monitoring at SQN to update the impingement database for potential intake effects. This report presents impingement mortality data collected from the CCW intake screens from January 2005 through January 2007 with comparisons to historical impingement data. Historical impingement mortality data from 1980-1985 assessed effects on the aquatic community of Chickamauga Reservoir for operational monitoring discharge permit requirements. An additional impingement study was conducted during December 2001 through February 2002, to compare peak numbers of fish impinged to historical impingement monitoring. No significant impacts were observed to the aquatic community in either of these studies and both datasets were similar in the numbers and species impinged.

Per an agreement reached in September 2001 with TDEC, Division of Water Pollution Control, TVA performs Reservoir Fish Assemblage Index (RFAI) (Hickman and Brown 2002) sampling annually to demonstrate that SQN operation is not impacting the balanced indigenous population in Chickamauga Reservoir. The primary reason for gathering these data is to support the continuation of a Section 316(a) thermal variance for SQN. However, the RFAI monitoring also gives an indication of the overall adverse environmental impact of plant operations to the reservoir fish assemblage and benthic community, including impacts from the plant's cooling water intake.

Plant Description

SQN is located on the west shore of Chickamauga Reservoir at Tennessee River Kilometer (TRK) 779.7 (TRM 484.5) (Figure 1). Construction began in 1970 and commercial operation for Unit 1 began in 1981 and Unit 2 in 1982. The two units (pressurized water reactors) have a total nameplate rating of 2,441 megawatts (MW). Natural draft cooling towers enable SQN to operate in an open or helper mode. In open mode operation, with both units at maximum power, total water demand is 72.45 m^3/s (2,558 cfs). CCW is drawn from Chickamauga Reservoir into the intake channel through an opening approximately 165 m (541 ft) long and 3 m (9.8 ft) high near the bottom of a skimmer wall situated near the river channel. This allows SQN to withdraw cooler water from the lower portion of the water column. From the intake channel, water passes through six, 3 m wide traveling screens to the intake pumps. Mesh openings on screens are 0.95 cm^2 (3/8 in^2). Both units were near full load during January 2005 through January 2007 (Figure 2). Average daily generation for the two combined was 2,373 MW; Unit 1 averaged 1,186 MW and Unit 2 averaged 1,187 MW. Six intake pumps were usually in operation, resulting in an average daily intake flow of 71.8 m^3/s (2,536 cfs). Velocity at the traveling screens averaged 37 cm/sec (1.2 fps).

Methods

Impingement sampling began on January 25, 2005, and weekly samples were collected through January 15, 2007. To simplify comparisons in this report, data from January 25, 2005 through January 23, 2006 will be referred to as Year-One, and from January 30, 2006 through January 15, 2007, as Year-Two. To collect each sample, intake screens were rotated and washed on a prearranged schedule by the plant assistant unit operator to remove all fish and debris. After 24 hours, screens were again rotated and washed with Aquatic Monitoring and Management (AM&M) crew on site. Fish and debris were collected in a catch basket constructed of 9.5 mm (3/8 in) mesh located at the end of the sluice pipe where the monitoring crew removed and processed the sample. Fish were sorted from debris, identified, separated into 25 mm (1 in) length classes, enumerated, and weighed. Data were recorded by one member of the AM&M crew and checked and verified (signed) by the other for quality control. Quality Assurance/Quality Control procedures for impingement sampling (TVA 2004) were followed to ensure samples were comparable with historical impingement mortality data.

Moribund/Dead Fish

Fish collected from a 24-hour screen wash were usually all dead when processed. Incidental numbers of fish which appeared to have been dead for more than 24 hours (i.e., exhibiting pale gills, cloudy eyes, fungus, or partial decomposition) were not included in the sample. Also, during winter, threadfin shad occasionally suffer die-offs or stress from cold-shock and are impinged after death or in a moribund state (Griffith and Tomljanovich 1975, Griffith 1978). If these die-off incidents were observed, they were documented to specify that either all, or a portion of impinged threadfin shad collected during the sample period were impinged due to cold-shock and may not have been impinged otherwise. Any fish collected alive were returned to the reservoir after processing.

Data Analysis

Impingement data from weekly 24-hour impingement samples were extrapolated to provide estimates of total fish impinged by week and total for each year of study. In rare situations when less than a 24-hour sample was possible, data were normalized to 24 hours. Historical data collected during 1981-1984 were averaged over a 52- week period, while data collected during 1985 were from January through July only. During 2001-2002, impingement data were collected from December through February and therefore represent only the winter period.

To facilitate the implementation of and compliance with the EPA regulations for Section 316(b) of the CWA (Federal Register Vol. 69, No. 131; July 9, 2004), prior to its suspension by EPA, fish lost to impingement were evaluated by extrapolating the losses to equivalent reductions of adult fish, or of biomass production available to predators in the case of forage species. In conformance with methods utilized by EPA in its Technical Development Documents in support of the Phase II Rule (EPA 2004), EPRI (Formerly known as the Electric Power Research Institute) has identified two models for extrapolating losses of fish eggs, larvae, and juveniles at intake structures to numbers or production of older fish (Barnthouse 2004). The Equivalent Adult (EA) model quantifies entrainment and impingement losses in terms of the number of fish that would have survived to a given future age. The Production Foregone (PF) model applies to forage fish species to quantify the loss from entrainment and impingement in terms of potential forage available for consumption by predators. These models require site-specific data

on the distribution and abundance of fish populations vulnerable to entrainment and impingement. TVA also used these models to determine the "biological liability" of the CCW intake structure based on the EPA guidance developed under the suspended rule.

Results and Discussion

Impingement sampling at SQN from January 2005 to January 2007 resulted in collection of 2,889 fish (22 species) during Year-One and 5,766 fish (21 species) during Year-Two (Table 1). Threadfin shad were predominate (91%) in the samples, followed by bluegill (3%), freshwater drum (2%), and channel and blue catfish (1% each) (Table 2). All other species contributed less than 1% of the total number collected. Annual estimates of number impinged and corresponding biomass are compared by species and year in Table 2. Rate of impingement was highest during November and December during Year-One (2005-2006), while peak impingement occurred during August, October, and November during Year-Two (2006-2007) (Table 3, Figure 3). Estimated annual impingement was calculated by extrapolating impingement rates from weekly samples. An estimated 20,223 fish were impinged during Year-One and 40,362 during Year-Two; of these, the majority was threadfin shad (Table 2). Estimated impingement during Year-Two was more than double the impingement estimate during Year-One due to collection of greater than two times more threadfin shad during Year-Two.

With the exception of samples collected during 1980-1982, annual historical impingement estimates for SQN were similar to those calculated during this study (Table 4, Figure 4). Although estimated impingement was much higher from 1980-1982, threadfin shad accounted for the majority of fish impinged in these samples as well as in samples collected during 1983-1985. The 2001-2002 data represented samples collected only in the winter when peak numbers are typically impinged at SQN (Kay and Baxter 2002). Impingement estimates for all species, except threadfin shad, were low and consistent with the 1980-1985 historical data and with data collected during the current study. Threadfin shad was the dominant species collected during 2001-2002, comprising 97% of the total number collected and 74% of the total weight (Table 5). Gizzard shad, freshwater drum, and sunfish comprised a notable proportion of historic impingement samples following threadfin shad (Tables 5 and 6). This was similar to the dominant species collected during this study.

Threadfin and/or gizzard shad typically comprise over 90% of fish impinged on cooling-water intake screens of thermal power stations in the Southeastern U. S. (EPRI 2005). They also comprise an average of 35%-56% of total fish biomass where they occur (Jenkins 1967). Threadfin shad have a high fecundity rate, move in large schools, and are intolerant to cold temperatures, often resulting in high mortality rates in winter. These traits are probably major contributing factors to the annual and seasonal fluctuation in numbers of fish impinged at SQN. A recent study by Fost (2006) indicated that cold-stressed threadfin and gizzard shad can be classified as either <u>impaired</u> or <u>moribund</u>. Impaired shad could recover if environmental conditions improved and would therefore not die if not impinged. Moribund fish on the other hand, are assumed to not be able to recover and die regardless of impingement. Fost's data indicated that threadfin shad began to exhibit reduced or impaired swimming performance at 7.5°C (45.5°F).

Plotted weekly ambient water temperatures for SQN (Figure 5) appear to be negatively correlated with peak shad impingement as previously reported by numerous studies

(EPRI 2005, Griffith and Tomljanovich 1975, Griffith 1978; McLean et al., 1980). No die-offs of threadfin shad were observed at SQN during the two years of monitoring by AMM crews or were reported by power plant personnel.

Application of the EA and PF models to the total numbers estimated impinged resulted in reduced numbers of fish which would have been expected to survive to either harvestable (EA) size/age or to provide forage (PF) (Table 4). This reduced number is considered the "biological liability" resulting from plant CCW impingement mortality based on the guidance developed for the now suspended 316(b) regulations. The numbers of fish representing SQN's biological liability for Year-One and Year-Two were 1,868 and 821, respectively.

As part of TVA's Vital Signs Monitoring Program resident fish communities were sampled in Chickamauga Reservoir upstream TRK 789.4 (TRM 490.5) and downstream TRK 775.7 (TRM 482.0) of SQN since 1999 (Baxter and Simmons 2007). Resulting data were analyzed using a multi-metric RFAI to rate the overall health and condition of the fish community at these sampling locations. Fish communities at both sites upstream and downstream from SQN have averaged a rating of "Good" during 1999-2006, indicating that SQN is not adversely impacting the resident fish community (Baxter and Simmons 2007).

Summary and Conclusions

Fish impingement rates at SQN during 2005-2007 were much lower than during 1980-1981, but were similar to historical data collected from 1982-1985. Threadfin shad has been the dominant species impinged during all years sampled and comprised 91% of fish impinged during this study. Biological liability after EA and PF reduction was low. Low impingement rates at SQN and "Good" RFAI scores for sites just upstream and downstream of SQN indicated that the SQN CCW intake is not adversely impacting the Chickamauga Reservoir fish community.

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McLean, R. B., P. T. Singley, J. S. Griffith, and M. V. McGee. 1980. Threadfin shad impingement: Effect of cold stress. NUREG/CR-1044, ORNL/NUREG/TM-340, Environmental Sciences Division, Publication No. 1495, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, 89 pp.

Tennessee Valley Authority. 2004. Impingement Counts. Quality Assurance Procedure No. RSO&E-BR-23.11, Rev 1. TVA River Systems Operation and Environment, Aquatic Monitoring and Management Knoxville TN. 11 pgs.

Table 1. List of Fish Species by Family, Scientific, and Common Name Including Numbers Collected in Impingement Samples During 2005-2007 at TVA's Sequoyah Nuclear Plant.

Family	Scientific Name	Common Name	Total Number Impinged	
			Year-One	Year-Two
Clupeidae	*Alosa pseudoharengus*	Alewife	10	4
	Dorosoma cepedianum	Gizzard shad	17	25
	Alosa chrysochloris	Skipjack herring	10	10
	Dorosoma petenense	Threadfin shad	2,529	5,373
Cyprinidae	*Pimephales notatus*	Bluntnose minnow	0	2
	Pimephales vigilax	Bullhead minnow	1	3
	Moxostoma spp.	Unidentified redhorse	0	1
	Notropis atherinoides	Emerald shiner	1	0
Ictaluridae	*Ictalurus furcatus*	Blue catfish	25	40
	Ictalurus punctatus	Channel catfish	50	32
	Pylodictis olivaris	Flathead catfish	3	11
	Ameiurus natalis	Yellow bullhead	1	0
Atherinidae	*Labidesthes spp.*	Unidentified silverside	0	1
Moronidae	*Morone saxatilis*	Striped bass	4	0
	Morone chrysops	White bass	2	4
	Morone mississippiensis	Yellow bass	24	10
Centrarchidae	*Lepomis spp.*	Unidentified sunfish	0	1
	Lepomis macrochirus	Bluegill	122	120
	Lepomis auritus	Redbreast sunfish	2	1
	Lepomis microlophus	Redear sunfish	1	0
	Micropterus salmoides	Largemouth bass	5	5
	Micropterus punctulatus	Spotted bass	1	13
	Pomoxis nigromaculatus	Black crappie	0	47
	Pomoxis annularis	White crappie	3	3
Poeciliidae	*Gambusia affinis*	Western mosquitofish	1	0
Percidae	*Sander canadense*	Sauger	1	0
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum	76	60
		Total Number of Fish	**2,889**	**5,766**
		Total Number of Species	**22**	**21**

Table 2. Estimated Annual Numbers, Biomass, and Percent Composition of Fish Impinged by Species at Sequoyah Nuclear Plant During 2005-2007.

	Estimated Number			Estimated Biomass (g)			
Species	**Year-One**	**Year-Two**	**Average**	**Year-One**	**Year-Two**	**Average**	**Percent Composition by Number**
Threadfin shad	17,703	37,611	**27,657**	59,612	70,539	**65,076**	91
Bluegill	854	840	**847**	6,636	5,054	**5,845**	3
Freshwater drum	532	420	**476**	63,686	28,385	**46,036**	2
Channel catfish	350	224	**287**	78,309	25,683	**51,996**	1
Blue catfish	175	280	**228**	67,998	70,021	**69,010**	1
Black crappie	0	329	**165**	0	385	**193**	1
Gizzard shad	119	175	**147**	6,902	2,506	**4,704**	**T**
Yellow bass	168	70	**119**	6,545	2,779	**4,662**	**T**
Skipjack herring	70	70	**70**	9,982	14,770	**12,376**	**T**
Alewife	70	28	**49**	560	791	**676**	**T**
Flathead catfish	21	77	**49**	6,391	67,326	**36,859**	**T**
Spotted bass	7	91	**49**	700	217	**459**	**T**
Largemouth bass	35	35	**35**	231	91	**161**	**T**
White bass	14	28	**21**	3,857	5,117	**4,487**	**T**
White crappie	21	21	**21**	91	42	**67**	**T**
Bullhead minnow	7	21	**14**	35	49	**42**	**T**
Striped bass	28	0	**14**	140	0	**70**	**T**
Redbreast sunfish	14	7	**11**	2,065	987	**1,526**	**T**
Bluntnose minnow	0	14	**7**	0	14	**7**	**T**
Unidentified redhorse	0	7	**4**	0	3,605	**1,803**	**T**
Emerald shiner	7	0	**4**	7	0	**4**	**T**
Yellow bullhead	7	0	**4**	35	0	**18**	**T**
Unidentified silverside	0	7	**4**	0	21	**11**	**T**
Redear sunfish	7	0	**4**	70	0	**35**	**T**
Unidentified sunfish	0	7	**4**	0	28	**14**	**T**
Western mosquitofish	7	0	**4**	7	0	**4**	**T**
Sauger	7	0	**4**	3,010	0	**1,505**	**T**
TOTAL	**20,223**	**40,362**	**30,293**	**316,869**	**298,410**	**307,640**	

Table 3. Numbers of Fish Impinged at Sequoyah Nuclear Plant by Month and Percent of Annual Total During Year-One, Year-Two, and for Both Years Combined.

Month	Total Number of Fish Impinged Year-One	Percent of Annual Total	Total Number of Fish Impinged Year-Two	Percent of Annual Total	Years One and Two Combined	Percent of Two-Year Total
Jan	295	10	570	10	865	10
Feb	9	0	179	3	188	2
Mar	46	2	86	1	132	2
Apr	68	2	30	1	98	1
May	4	0	13	0	17	0
Jun	5	0	5	0	10	0
Jul	41	1	173	3	214	2
Aug	62	2	751	13	813	9
Sep	193	7	242	4	435	5
Oct	262	9	1,515	26	1,777	21
Nov	358	12	1920	33	2,278	26
Dec	1,546	54	282	5	1,828	21
Total	**2,889**		**5,766**		**8,655**	

Table 4. Total Numbers of Fish Estimated Impinged by Year at Sequoyah Nuclear Plant and Numbers Following Application of Equivalent Adult and Production Foregone Models During 2005-2007.

	1980-1981	1981-1982	1982-1983	1983-1984	1984-1985	2005-2006	2006-2007
Extrapolated Annual Number Impinged	94,528	81,158	20,685	41,076	27,195	20,223	40,362
Number after EA and PF Reduction	4,851	5,843	2,256	4,162	2,761	1,868	821

Table 5. Percent Composition (By Number and Weight and After EA and PF Models Applied) of Major Species of Fish Impinged at Sequoyah Nuclear Plant Between December 18, 2001 and February 25, 2002.

Species Composition	Percent by Number	Percent by Weight
Threadfin shad	96.98	74.09
Bluegill	0.80	0.64
Freshwater drum	0.77	14.68
Gizzard shad	0.43	1.33
Alewife	0.23	0.82
Channel catfish	0.28	1.33
Striped bass	0.24	0.46
Mosquitofish	0.13	0.01
Logperch	0.03	0.08
Flathead catfish	0.02	4.68
Bluntnose minnow	0.02	0.03
Redear sunfish	0.02	0.02
Redbreast sunfish	0.01	0.73
Largemouth bass	0.01	0.27
White crappie	0.01	0.83

Table 6. Percent Composition (By Number and After EA and PF Models Applied) of Major Species of Fish Impinged at TVA's Sequoyah Nuclear Plant During 1980-1985 and 2005-2007.

	1980-1981		1981-1982		1982-1983		1983-1984		1984-1985		2005-2006		2006-2007	
Species Composition	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**	**% by Number**	**% after PA and EF**
Threadfin shad	83	63	72	46	49	25	70	44	65	42	87	59	93	77
Lepomis	8	16	4	7	8	12	9	14	6	12	4	9	2	5
Gizzard shad	4	3	9	6	22	11	2	1	8	5	1	0	0	0
Skipjack herring	0	0	0	0	1	1	3	2	4	3	0	0	0	0
Ictalurids	0	0	0	0	2	7	1	5	1	4	3	15	2	10
Freshwater drum	2	3	8	14	12	19	9	15	6	9	3	6	1	2
Spotted bass	0	0	1	2	0	0	0	0	0	0	0	0	-	1
White crappie	-	3	0	0	1	2	0	0	0	0	0	0	1	2
Yellow perch	-	3	-	6	1	6	-	4	-	3	0	0	0	0
Yellow/White bass	-	3	3	11	2	6	-	4	-	3	1	6	-	2
Bullhead minnow	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Total	**97**	**94**	**97**	**92**	**98**	**91**	**95**	**94**	**93**	**96**	**99**	**95**	**99**	**99**

Dash denotes not a major species during that year.

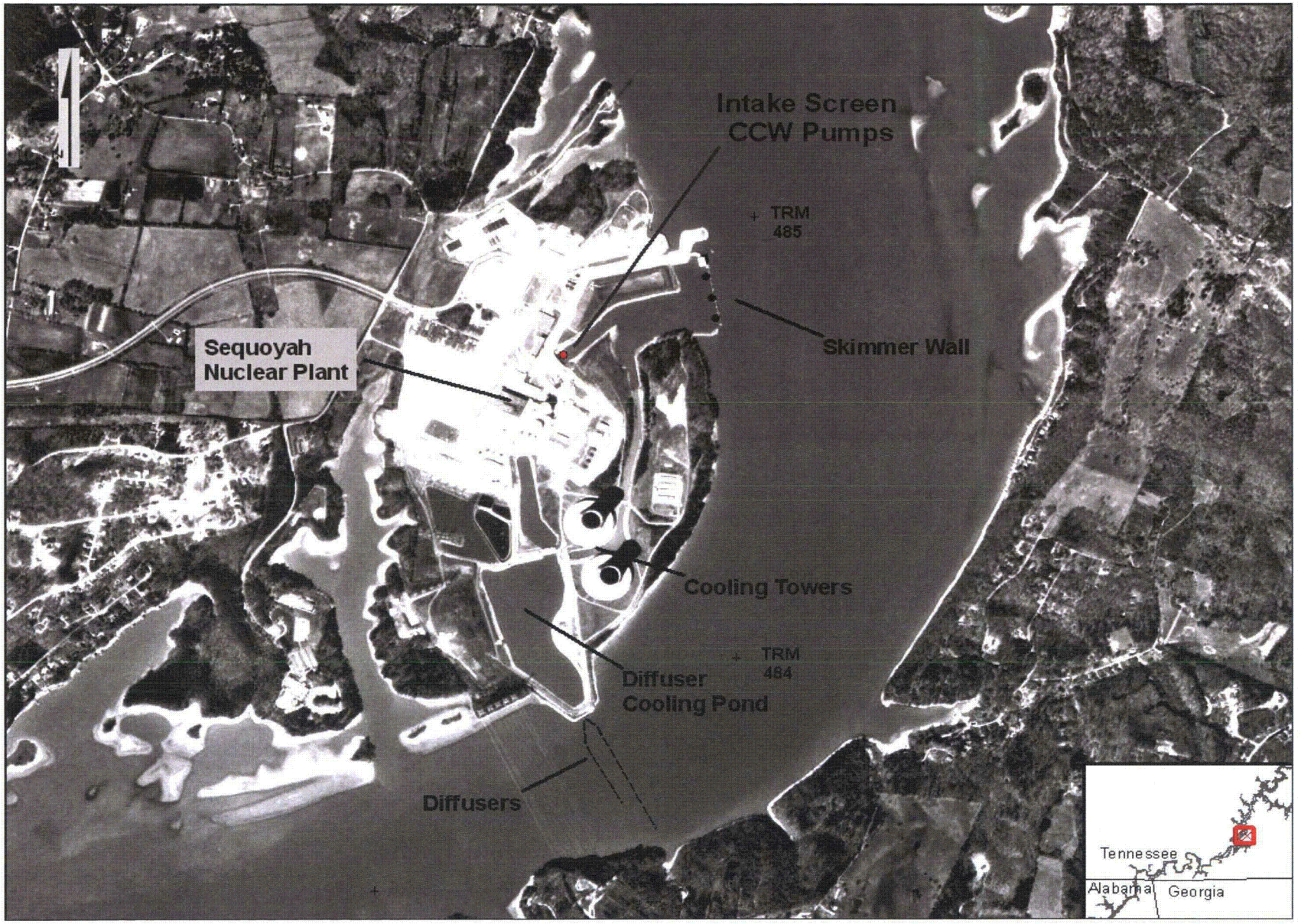

Figure 1. Aerial photograph of Sequoyah Nuclear Plant including CCW intake structure, skimmer wall, intake basin, and diffuser cooling pond.

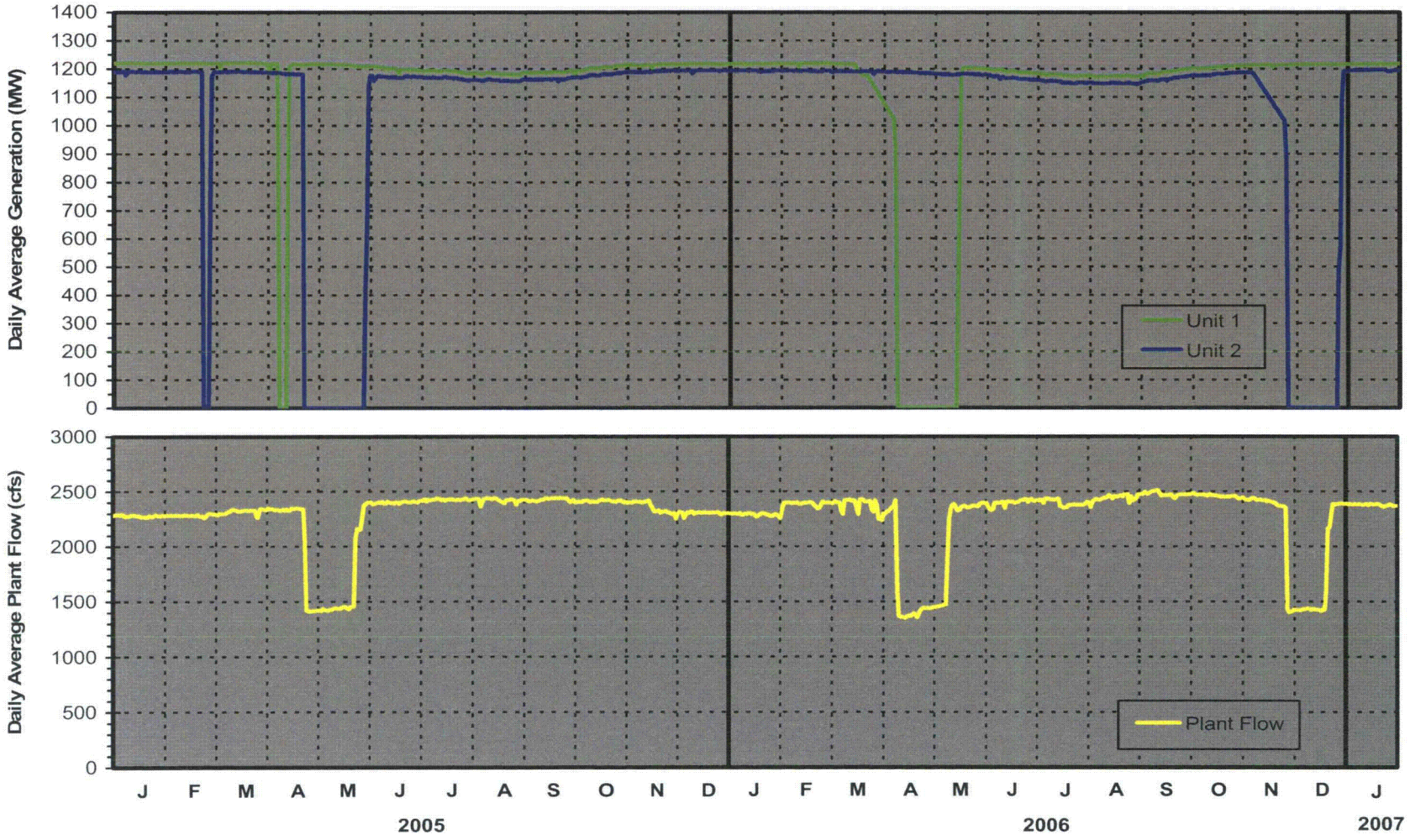

Figure 2. Average daily generation (MW) and intake flow (cfs) at Sequoyah Nuclear Plant during January 2005 through January 2007.

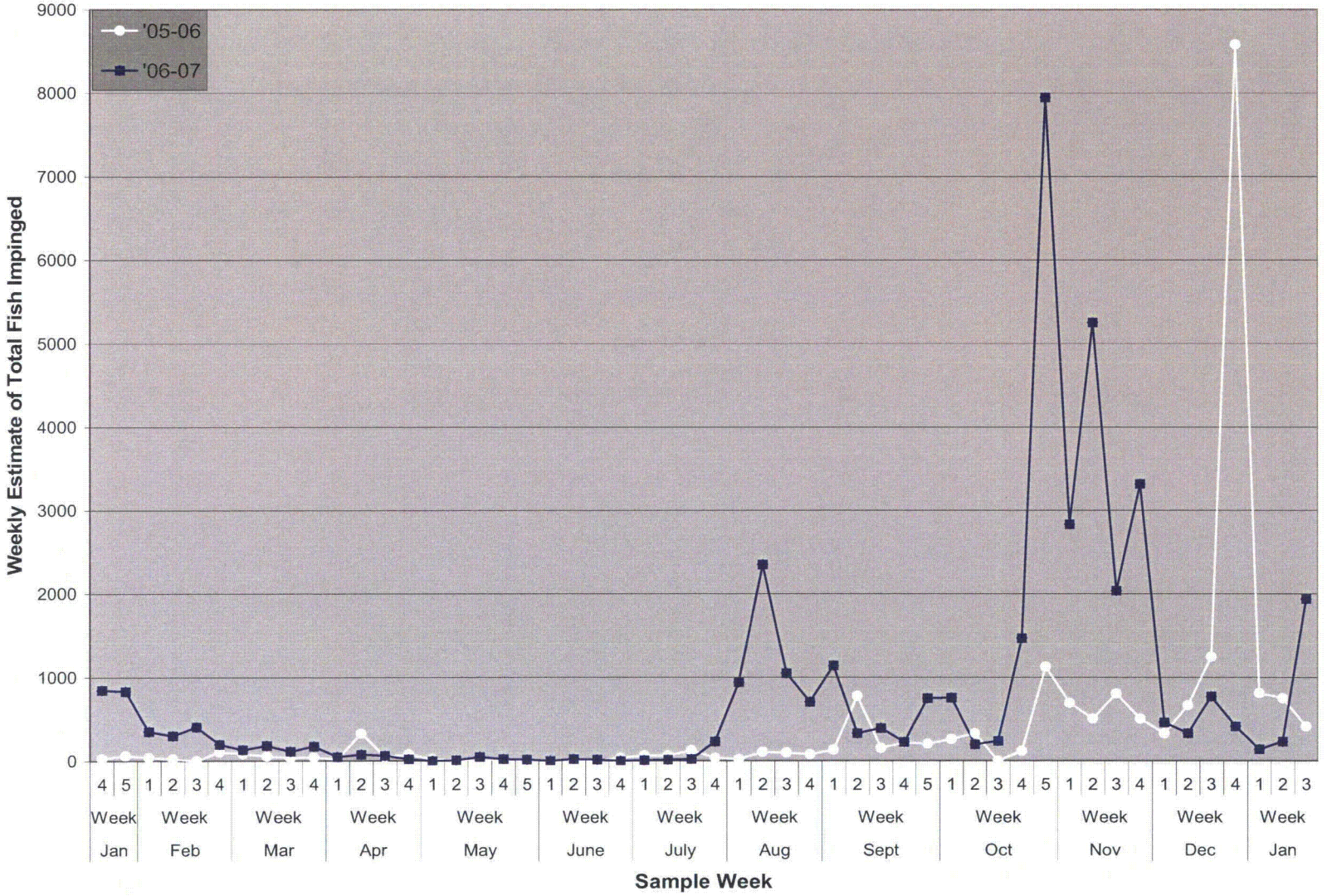

Figure 3. Estimated weekly fish impingement at Sequoyah Nuclear Plant during 2005-2007.

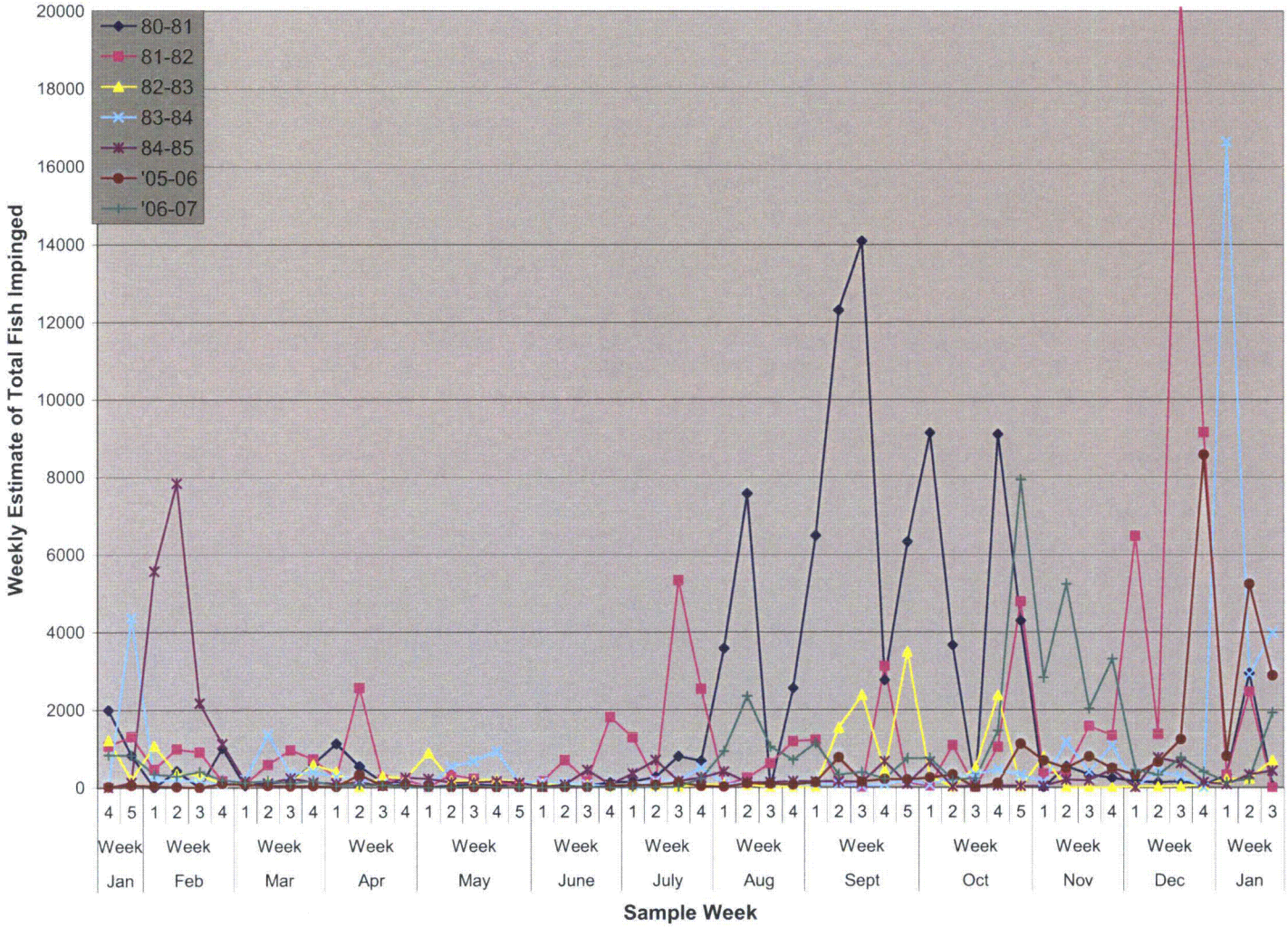

Figure 4. Comparison of estimated weekly fish impingement at Sequoyah Nuclear Plant during historical and recent monitoring periods.

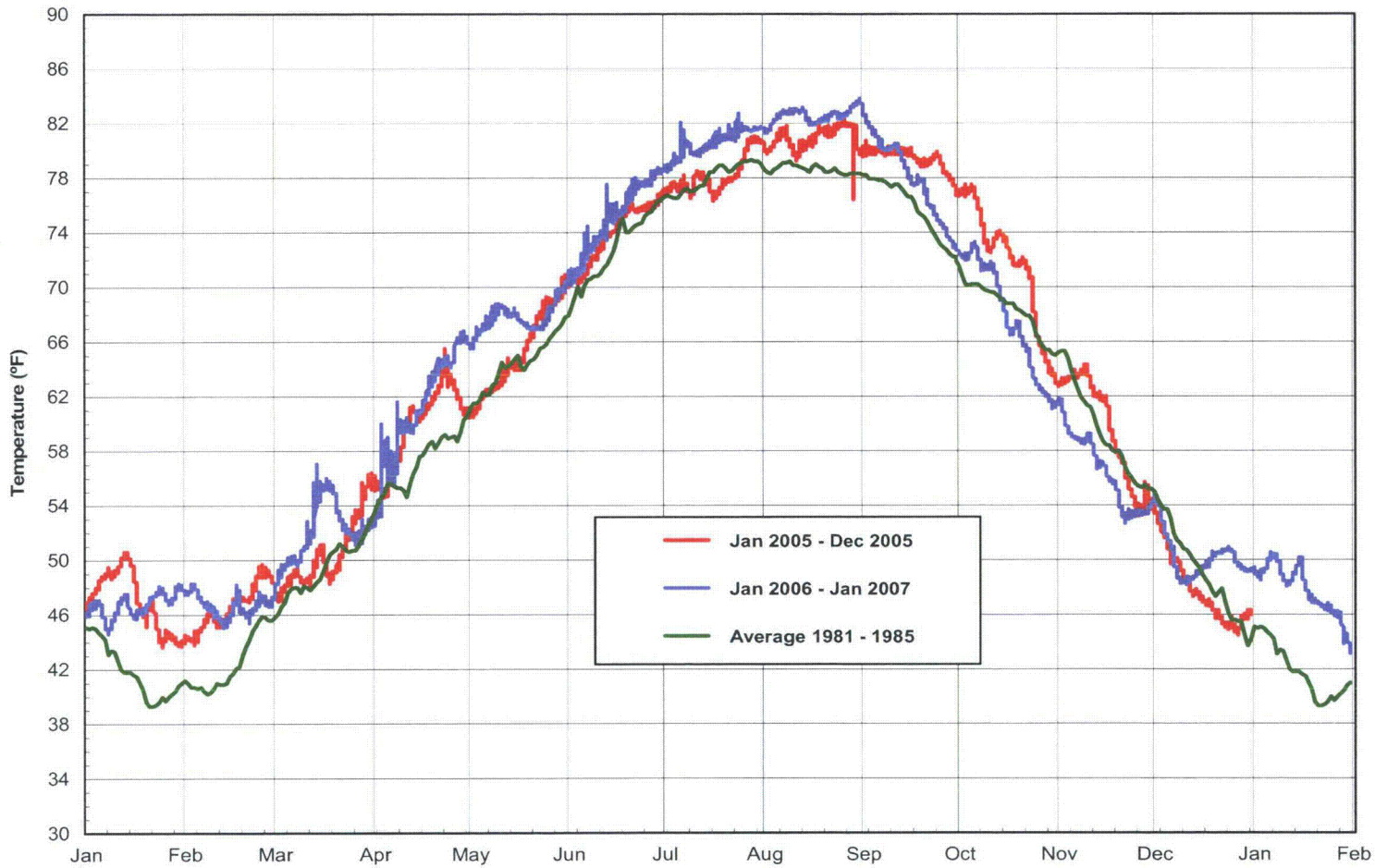

Figure 5. Ambient daily (24-hr avg) water temperature at Sequoyah Nuclear Plant intake during historical (1981-1985) and recent (2005-2007) impingement monitoring.

Entrainment Monitoring
At
Sequoyah Nuclear Plant 2004

by
Dennis S. Baxter
and
Johnny P. Buchanan

October 2006
Final

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Acronyms

AMSL	Above Mean Sea Level
BIP	Balanced Indigenous Population
CCW	Condenser Cooling Water
CFS	Cubic Feet per Second
NPDES	National Pollutant Discharge Elimination System
RFAI	Reservoir Fish Assemblage Index
SFI	Sport Fishing Index
SQN	Sequoyah Nuclear Plant
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
VS	Vital Signs

EXECUTIVE SUMMARY

Sequoyah Nuclear Plant's (SQN) current National Pollutant Discharge Elimination System permit number TN0026450 states, "For Section 316(b), the permittee shall summarize previous data and indicate whether significant changes have occurred in plant operation, reservoir operations or instream biology that would necessitate significant changes to the variance." Condenser Cooling Water (CCW) withdrawn from Chickamauga Reservoir potentially affects the fish community by entrainment (small fish and eggs drawn through the intake screens) and impingement (fish trapped against screens by the intake water velocity). Densities of fish in the reservoir near the intake and daily volume of water transported past the SQN were compared to daily CCW demand and densities of fish at the intake skimmer wall to estimate percent entrainment.

During operational monitoring from 1980 through 1985, the entrainment of total fish larvae was estimated to be 8.6 percent of those passing the plant. In order to compare the current larval fish assemblage and level of hydraulic entrainment with data collected during operational monitoring, ichthyoplankton sampling was conducted during May through July 2004. Clupeids (primarily gizzard and threadfin shad) were the dominant taxon collected in entrainment sampling and estimated entrainment was 15.4 percent. Freshwater drum larval entrainment was estimated to be 45.4 percent, the highest for any of the significant taxa. Overall larval entrainment was estimated to be 15.6 percent during 2004.

Entrainment estimates for total larvae in 2004 were higher than those from historical samples colleted during 1981 through 1985. Historical fluctuations in rates of entrainment and recent Reservoir Fish Assemblage Index evaluations indicate the Chickamauga Reservoir near SQN supports a balanced and diverse indigenous fish community with no significant impacts observed from current plant operation.

Introduction

Section 316(a) of the Clean Water Act allows point-source dischargers of heated water to obtain a variance from state water quality standards if the point-source can demonstrate maintenance of balanced indigenous populations (BIP) of aquatic life. Compliance requires permittee to characterize the aquatic community in the vicinity of the intake structure prior to operation; monitoring during normal operation to assess impacts; and periodically review current operational demands, reservoir operation, and condition of the aquatic community to ensure no significant changes have occurred. Two potential impacts associated with cooling water intake structures are impingement and entrainment. Impingement occurs when aquatic organisms are trapped against the intake structure (traveling screens) by the withdrawal of cooling water and entrainment occurs when organisms are drawn through the intake structure into the plant cooling system.

Sequoyah Nuclear Plant's (SQN) current National Pollutant Discharge Elimination System (NPDES) permit number TN0026450 states, "For Section 316(b), the permittee shall summarize previous data and indicate whether significant changes have occurred in plant operation, reservoir operations or instream biology that would necessitate significant changes to the variance." In 1991, the Tennessee Valley Authority (TVA) implemented changes in TVA reservoir operations to maintain minimum flows below dams at critical times and locations. These changes were the result of the Tennessee River and Reservoir System Operation and Planning Review (TVA 1991). Other changes included increasing dissolved oxygen below 16 dams by aerating releases, and to delay unrestricted summer drawdown until August 1 on ten tributary reservoirs. Further changes in reservoir operation policy were implemented in 2005 as a result of TVA's Reservoir Operations Study and Environmental Impact Statement (TVA 2004).

During operational monitoring at SQN from 1980 through 1985, the average hydraulic entrainment of fish larvae was estimated to be 8.6 percent of those passing the plant. In order to compare current level of larval fish and hydraulic entrainment with data collected during operational monitoring, ichthyoplankton sampling was conducted during April through July 2004. The purpose of this document is to summarize and provide Tennessee Department of Environment and Conservation the results and comparisons between current and historical entrainment monitoring data.

RESERVOIR AND PLANT OPERATION DURING 2004

Chickamauga Reservoir Operation

Surface elevation of Chickamauga Reservoir and river flow past SQN is dependent on the rate water is released through Watts Bar and Chickamauga Dams. TVA's integrated approach to Chickamauga Reservoir operation includes winter drawdown for flood control, minimum summer pools, and hydroelectric power generation. In 2004, average daily surface elevation of Chickamauga forebay ranged from 206.0 m above mean sea level (AMSL) to 209.5 m AMSL (Figure 1). Daily river flow past SQN ranged from 159 m^3/s to 2634 m^3/s in 2004 (Figure 2).

On May 18, 2004, the daily average release from Chickamauga Hydro was zero cubic feet per second (cfs) while the release from Watts Bar Hydro was 7100 cfs. This unusual situation resulted in essentially zero or negative flow past SQN.

Sequoyah Operation

SQN Units 1 and 2 were both in operation during the 2004 entrainment sampling (Figure 3). The combined generation rate for Units 1 and 2 averaged 2081 megawatts in 2004. The average daily withdrawal rate (hydraulic entrainment) of CCW from Chickamauga Reservoir during 2003 and 2004 was 86 m^3/s (Figure 4). However, CCW demand during entrainment sampling (April 27 through July 12, 2004) reflected normal operation, averaging 91 m^3/s.

Methods

Sample Collection

Larval sampling began on April 20 and continued through July 12, 2004. Ichthyoplankton samples provided temporal abundance of larval fish and eggs at five stations along a transect perpendicular to river flow just upstream of the plant intake channel at Tennessee River Mile (TRM) 485 (Figure 5). Seven samples were collected weekly during both day and night. Samples consisted of one full-stratum sample from both left and right overbanks, three samples from the mid-channel area with one taken from surface to mid-depth, one from mid-depth to bottom and one towed near bottom for the duration of the sample. In addition, two replicate, 20-minute full-stratum samples were collected along the intake skimmer wall.

Samples were collected with a beam net (0.5 m square, 1.8 m long, with 505 micron "nitex" mesh netting) towed upstream at a speed of 1.0 m/s for ten minutes. The volume of water filtered through the net was measured with a large-vaned General Oceanics flowmeter®. Approximately 150 m^3 of water were filtered per ten minute sample. Intake samples were collected by lowering the net to the bottom and gradually raising the net during the 20 minutes to the depth of the skimmer wall (approximately 16-17 meters). Approximately 40-50 m^3 of water were filtered per intake sample. Water temperature was recorded using a mercury thermometer calibrated to the tenth degree Celsius.

Laboratory and Data Analysis

Laboratory Analysis

Larval fish and eggs were removed from the samples, identified to the lowest possible taxon, counted and measured to the nearest millimeter total length following procedures outlined in NROPS-FO-BR-24.1 (TVA 1983). Taxonomic decisions were based on TVA's "Preliminary Guide to the Identification of Larval Fishes in the Tennessee River," (Hogue et al., 1976) and other pertinent literature.

The term "unidentifiable larvae" applies to specimens too damaged or mutilated to identify, while "unspecifiable" before a taxon implies a level of taxonomic resolution (e.g., "unspecifiable catostomids" designates larvae within the family Catostomidae that currently cannot be identified to a lower taxon). The category "unidentifiable eggs" applies to specimens that cannot

be identified due to damage or lack of taxonomic knowledge. Taxonomic refinement is a function of specimen size and developmental stage. Throughout this report, the designation "unspecifiable clupeids" refers to clupeids less than 20 mm in total length and could include *Dorosoma cepedianum* (gizzard shad), *D. petenense* (threadfin shad), and/or *Alosa chrysochloris* (skipjack herring). Any clupeid specimens identified to species level represent postlarvae 20 mm or longer in total length.

Developmental stage of moronids also determines level of taxonomic resolution. *Morone saxatilis* (striped bass) hatch at a larger size than either *M. chrysops* (white bass) or *M. mississippiensis* (yellow bass). Although it is currently impossible to distinguish between larvae of the latter two species, *M. saxatilis* can be eliminated as a possibility based on developmental characteristics of specimens 6 mm or less in total length (hence, the taxonomic designation *Morone*, not *saxatilis*). Specimens identified as *Morone spp.* are greater than 6 mm total length.

Data Analysis

Temporal occurrence and relative abundance of eggs and larvae by taxon are presented and discussed for the entire monitoring period. Densities of fish eggs and larvae are expressed as numbers per 1000 m^3 of water sampled.

Estimated entrainment of fish eggs and larvae at SQN was calculated by the following method: densities of eggs and larvae transported past the plant were estimated for each sample period by averaging densities (all stations) of eggs and larvae from TRM 485 and multiplying by the corresponding 24-hour flow past the plant. Percentage of transported ichthyofauna entrained by the plant was estimated from the formula:

$$E = 100 \frac{D_i Q_i}{D_r Q_r}$$

where D_i = mean density (N/1000 m^3) of eggs or larvae in intake samples;

Dr = mean density (N/1000 m3) of eggs or larvae in river

(TRM 485 transect);

Q_i = plant intake water demand (m^3/d);

Q_r = river flow (m^3/d).

Results and Discussion

During twelve sample periods in 2004, the average volume of water filtered each period was 232.7 m^3 for intake samples and 876.6 m^3 for reservoir samples (Table 1). A list of families of fish eggs and larvae collected during 2004 including the lowest level of taxonomic resolution is presented in Table 2.

Fish Eggs

Freshwater drum eggs comprised 98.8 percent of the total fish eggs and were collected during all twelve sample periods (Table 3), demonstrating the extended spawning season for this species. Densities peaked on May 25 at 24,367/1000 m^3 in reservoir samples and on June 2 at 1,594/1000 m^3 in samples collected near the intake (Table 4) (Figure 6). Average seasonal densities for drum eggs were 549 and 652/1000 m^3 in the intake and reservoir samples respectively (Table 5).

Larval Fish

Relative abundance for all taxa of larval fish collected during the twelve weekly sample periods of 2004 (Table 3) was dominated by clupeids (87.9%), *Morone* (5.5%), freshwater drum (3.2%) and centrarchids (3.1%). Total number of larvae collected for the four dominant taxa was 51,350 and total collected for all taxa was 52,881. A comparison of densities of total fish larvae by sample period between intake and reservoir samples is presented in Figure 7.

Peak densities of clupeid larvae (primarily gizzard and threadfin shad) occurred on April 27 in reservoir samples (20,570/1000 m^3) and on May 3 in intake samples (15,464/1000 m^3) (Table 4). Following the high densities in late April and early May, clupeid densities decreased dramatically through the remainder of the sampling period with a slight increase observed during early June (Figure 8). Average seasonal density for clupeids was 2,249/1000 m^3 for intake and 3,465/1000m^3 for reservoir samples (Table 5).

Larval *Morone* were collected from the first sample period (April 20) through June 9, 2004. Densities of *Morone* (white and yellow bass) larvae also peaked on April 27 (Figure 9) at 1,558 and 277/1000m^3 in the reservoir and intake samples respectively. Average seasonal densities of larval *Morone* were 52/1000 m^3 in intake samples and 247/1000 m^3 in reservoir samples (Table 5).

Centrarchid (*Lepomis and Pomoxis*) larvae were first collected on April 27 and were present in samples throughout the remainder of the sampling season (Figure 10). Peak densities of 897/1000 m^3 occurred in the reservoir samples on June 2 and 1,027/1000 m^3 occurred on June 15 in the intake samples (Table 4). Centrarchid larvae exhibited similar average seasonal densities in both intake (131/1000 m^3) and reservoir samples (128/1000 m^3).

Freshwater drum larvae were first collected on April 27 and were present in samples throughout the remainder of the sampling season. Densities peaked on May 18 at 717/1000 m^3 in the intake samples and on June 9 at 379/1000 m^3 in reservoir samples (Table 4). Average seasonal densities were 200/1000m^3 in intake and 104/1000 m^3 in reservoir samples (Table 5).

Average seasonal densities for all taxa collected are presented in Table 5.

Hydraulic Entrainment Estimates

Hydraulic entrainment by SQN during the twelve sampling periods in 2004 averaged 24.2 percent with a range of 7.4 to 111.1 percent (Table 6). The peak hydraulic entrainment occurred on May 18 and the lowest was recorded on June 30. The entrainment estimate of 111.1 percent on May 18 was a result of zero release at Chickamauga Dam and 7,100 cfs average release from Watts Bar Dam.

Fish Egg and Larvae Entrainment Estimates

Estimated total transport of fish eggs (98.8% drum eggs) past SQN during 12 sample periods in 2004 was 5.4 billion. The seasonal entrainment estimate for drum (Sciaenid) eggs was 11.2 percent (Table 7).

Estimated total transport of fish larvae past SQN during 12 sample periods in 2004 was 9.8 billion. Clupeid larvae comprised 87.9 percent of this total and were entrained at a rate of 15.4 percent of the total passing the plant. The overall estimated rate of entrainment for total fish larvae was 15.6 percent, obviously driven by clupeids as the most dominant taxon. Average seasonal densities of clupeids in intake vs. reservoir samples were 2,249 and 3,465/1000 m^3 respectively (Table 5).

Estimated entrainment of freshwater drum larvae was 45.4 percent. The two highest densities of drum larvae were both observed in intake samples on May 18 and on June 02. The peak density of 717/1000 m^3 at the intake on May 18 occurred coincidentally when the hydraulic entrainment estimate also peaked at 111.1 percent. Overall, densities of freshwater drum larvae were higher in intake samples than channel samples during 8 out of 12 sample periods (Figure 11).

The entrainment estimate for Centrarchids (primarily sunfish and crappie larvae) was 24.2 percent of those passing the plant. Average seasonal density was similar at both intake (131/1000 m^3) and reservoir (128/1000 m^3) samples (Table 5).

Morone larvae were the only other significant taxon with estimated entrainment over one percent (Table 5). An estimated five percent of *Morone* larvae passing SQN during 2004 were entrained.

Cyprinid (minnows) larvae were collected in very low numbers evidenced by seasonal densities of 7 and 2/1000 m^3 in intake and reservoir samples respectively. Higher densities in intake samples resulted in an estimate of 72.6 percent entrainment for this taxon (Table 6).

DISCUSSION WITH HISTORICAL COMPARISONS

Sample methods used to collect fish eggs and larvae during 2004 were only slightly different than those used in 1985 (TVA 1986 and TVA 1987). Seasonal mean hydraulic entrainment was 12.2 percent in 1985 compared to 24.2 percent in 2004. Higher hydraulic entrainment was likely the result of lower reservoir flow rate caused by lower than average runoff from rainfall. This also influenced the total entrainment rate of 15.6 percent for larval fish which was the highest ever recorded.

Estimated entrainment of freshwater drum eggs was 11.2 percent in 2004 compared to 16.6 percent in 1985. Drum larval entrainment was estimated at 30.2 percent in 1985 compared to 45.4 percent in 2004. Considering that hydraulic entrainment doubled from 1985 to 2004, this increased rate of entrainment estimated for drum larvae could be expected. Table 8 compares historical fish egg and larval entrainment estimates between 1981 through 1985 with the recent estimates during 2004. Historical data led to the conclusion that significant spawning by freshwater drum occurs in the vicinity of, or slightly downstream of SQN, producing eggs and larvae that are not subjected to plant entrainment. Even though seasonal larval drum entrainment was abnormally high (45.4%) during 2004, it was primarily attributed to the May 18 sample period when the peak density occurred simultaneously with peak hydraulic entrainment (111 %).

Chickamauga Reservoir Fish Community

Industries responsible for point-source discharges of heated water can obtain a variance from state water quality standards if the industry can demonstrate compliance with thermal criteria by documenting the maintenance of BIP of aquatic life in the vicinity of its discharge. SQN's current NPDES permit number TN0026450 states, "For Section 316(a), the permittee shall summarize previous data and indicate whether significant changes have occurred in plant operation, reservoir operations or in stream biology that would necessitate significant changes to the permitted variance." The permittee shall use the Reservoir Fish Assemblage Index (RFAI) to assess Chickamauga Reservoir fish community health. Any apparent declines in the fish community health will be further investigated to discover whether the decline is a valid conclusion and if the decline is real and to identify possible sources for the fish community decline. As part of the identification of potential sources for the decline, the instream effects of the discharges made under this permit will be investigated (TDEC 2000). In response to this requirement, TVA's Vital Signs (VS) monitoring program (Dycus and Meinert 1993) will be used to evaluate areas of Chickamauga Reservoir upstream and downstream of SQN discharge. Reservoirs are typically divided into three zones for VS Monitoring – inflow, transition and forebay. The inflow zone is generally in the upper reaches of the reservoir and is riverine in nature; the transition zone or mid-reservoir is the area where water velocity decreases due to increased cross-sectional area, and the forebay is the lacustrine area near the dam. The Chickamauga Reservoir inflow zone sample site is located at TRM 529.0; the transition zone sampling site is located at TRM 490.5 and the forebay zone sampling site is located at TRM 472.3. The VS transition zone, which is located approximately 7.2 river miles upstream of the SQN discharge (TRM 483.3), will be used to provide upstream data for the 316(a) thermal variance studies performed in sample years between 1993 and 2005. An additional transition station was later added downstream of the SQN discharge to more closely monitor Chickamauga Reservoir aquatic communities in close proximity to the SQN thermal effluent. This station is located at TRM 482.0 and will be used for downstream comparisons of aquatic communities for the 1999 through 2005 sample seasons. The forebay zone, will serve as the downstream station for 1993 through 1995 and 1997 sample seasons.

Sport Fishing Index

In the past, the Sport Fishing Index (SFI) was used in support of a thermal variance request at SQN (TVA 1996). The SFI was developed to quantify sport fishing quality for individual sport fish species. The SFI provides biologists with a reference point to measure the quality of a sport fishery. Comparison of the population sampling parameters and creel results for a particular sport fish species with expectations of these parameters from a high quality fishery (reference conditions) allows for the determination of fishing quality. Indices have been developed for black bass (largemouth, smallmouth and spotted bass), sauger, striped bass, bluegill, and channel catfish. Each SFI relies on measurements of quantity and quality aspects of angler success and fish population characteristics.

In recent years, SFI information has been used to describe the quality of the resident fishery in conjunction with compliance monitoring, thermal variance requests, and other regulatory issues at TVA nuclear plants in Tennessee. Similar NPDES compliance monitoring programs using the methodologies described above are also being performed at Browns Ferry Nuclear, Colbert and Widows Creek Fossil Plants in Alabama.

The TVA Spring Sport Fish Survey is conducted to evaluate the sport fish population of TVA Reservoirs. The results of the survey are used by state agencies to protect, improve and assess the quality of sport fisheries. Predominant habitat types in the reservoir are surveyed to determine sport fish abundance. In addition to accommodating TVA and state databases, this surveying method aligns with TVA Watershed Team and TVA's Reservoir Operations Study objectives. Sample sites are selected using the shoreline habitat characteristics employed by the Watershed Teams. The survey predominantly targets three species of black bass (largemouth, smallmouth, and spotted bass) and black and white crappie. These species are the predominant sport fish sought after by fisherman.

In the autumn of 2004, Chickamauga Reservoir's sport fish population received similar RFAI scores (Table 9) compared to the eight year average (TVA 2006). Largemouth bass, smallmouth bass, spotted bass, crappie, bluegill, and channel catfish received higher scores than their seven year averages (Figure 12). Channel catfish, largemouth bass, and bluegill received their highest SFI scores to date. Crappie and black bass received lower scores in 2004 compared to scores in 2003. This quality assessment is not necessarily indicative of a trend and historical data indicate that SFI scores typically vary among years. However if future scores would continue to decline, further investigation would be warranted.

CONCLUSIONS

Both historical data and the 2004 sampling results demonstrate the significant variability in the occurrence and spatial-temporal distribution of larval fish in Chickamauga Reservoir near SQN. This variability translates into significant fluctuation in the entrainment rates associated with plant operation. Factors contributing to these fluctuations include:

- Proximity of intake to spawning and nursery areas
- Seasonality and period of occurrence
- Vertical distribution/movement
- Cross-sectional or horizontal distribution
- Diel distribution
- Life-stage/swimming ability
- Growth rate
- Physical parameters and operation of Chickamauga Reservoir in the vicinity of SQN

In calculating entrainment estimates, one or two species usually comprise a high percentage of the total composition, as is the case with clupeids and freshwater drum in the vicinity of SQN. Freshwater drum spawn in open water while shad spawn near shore and each female produces thousands of eggs, creating areas in the reservoir with high densities of fish eggs and early larvae. As these high density pulses of eggs and larvae drift downstream, their occurrence within a sampling area (either near the plant intake or in the open reservoir) may significantly affect individual entrainment estimates.

The 2004 316(b) data and recent fish community assessments in Chickamauga Reservoir near SQN show no significant impacts from current operation of SQN on the fish community near the plant. Furthermore, current 316(b) data support conclusions presented in the 1986 historical assessments. Results demonstrate annual variations in the relative abundance and spatial-temporal distribution of fish and fluctuations in reservoir flow are common in the vicinity of SQN. Life history aspects and dynamics of drifting larvae and fluctuation in reservoir flow past SQN are significant factors influencing variations observed in the annual entrainment estimates. These variations in fish density and reservoir flow in the Chickamauga transition zone have apparently had little affect on the fish community. Based on the 2004 316(b) evaluation and the annual RFAI and SFI scores for Chickamauga Reservoir, a viable balanced indigenous fish community is present in Chickamauga Reservoir in the vicinity of SQN.

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Table 1. Total Volume of Water Filtered by Sample Period at Sequoyah Nuclear Plant during 2004 to Estimate Entrainment of Fish Eggs and Larvae.

Sample Date	2004 Intake m^3	2004 Reservoir m^3	2004 Total m^3
Apr 27	216.7	965.5	1182.2
May 4	271.6	1067.7	1339.3
May 10	299.4	833.8	1133.2
May 18	346.1	799.8	1145.9
May 25	276.4	822.1	1098.5
Jun 2	209.6	901.9	1111.5
Jun 9	97.7	939.0	1036.7
Jun 15	189.9	738.5	928.4
Jun 23	254.5	884.1	1138.6
Jun 30	228.0	688.1	916.1
Jul 7	260.4	977.6	1238.0
Jul 12	142.0	901.3	1043.3
Total	**2792.3**	**10519.4**	**13311.7**
Average	**232.7**	**876.6**	**1109.3**

Table 2. List of Fish Eggs and Larvae by Family Collected at Sequoyah Nuclear Plant in 2004 Entrainment Samples and Lowest Level of Taxonomic Resolution for each Family.

Scientific Name	Common Name	Lowest Level of Taxonomic Identification
Clupeidae	**Shad**	**Family** - all larvae < 20 mm TL. **Genus or species** -larger individuals to *Alosa* spp.- alewife, skipjack, *Dorosoma* spp. - gizzard and threadfin shad.
Cyprinidae	**Minnows and Carps**	**Family** – most minnows, shiners, and chubs **Genus or species** -common carp, golden shiner, and larger individuals to emerald shiner, mimic shiner, *Pimephales* spp.
Catostomidae	**Suckers**	**Subfamily** - ictiobines (buffalo and carpsuckers) **Genus** - Larger individual to buffalo.
Ictaluridae	**Catfishes**	**Species** - Blue, Channel
Moronidae	**Temperate basses**	**Genus** -most larval life phases **Species** - yolk-sac larvae ≥ 5 mm TL (striped bass), larger individuals to white, yellow, and striped bass.
Centrarchidae	**Sunfishes**	**Genus** - crappie, lepomids (sunfishes), and black bass. **Species** - larger individuals to largemouth bass.
Sciaenidae	**Drums**	**Species**. freshwater drum
Unspecified Larvae and Eggs		Identification to family was not possible. Limiting factors were size, stage of development, and season when egg was collected.

Table 3. Percent Composition of Fish Eggs and Larvae by Family in Entrainment Samples at Sequoyah Nuclear Plant during 2004.

	Intake Samples %	Reservoir Samples %	All Samples %
Eggs			
Unspecified	0.0	1.9	1.2
Sciaenidae	100.0	98.1	98.8
Larvae			
Clupeidae	85.2	87.8	87.9
Cyprinidae	0.3	0.1	0.2
Catostomidae	**T**	**T**	**T**
Ictaluridae	**T**	**T**	**T**
Moronidae	2.0	6.3	5.5
Centrarchidae	5.0	3.3	3.1
Sciaenidae	7.6	2.6	3.2

T – Taxon was collected in samples but composition was less than 0.1%.

Table 4. Peak Densities and Sample Dates by Family for Fish Eggs and Larvae from Intake and Reservoir Entrainment Samples Collected at Sequoyah Nuclear Plant during 2004.

	Peak Density Number/1000 m^3			
	Intake/ Skimmer Wall	Sample Date D=Day N=Night	Reservoir	Sample Date D=Day N=Night
EGGS				
Family				
Sciaenidae	1,594	June 2	4,433	May 25
LARVAE				
Family				
Clupeidae	15,464	May 3	20,570	April 27
Cyprinidae	28	April 27	6	April 27
Catostomidae	0	-	7	June 15
Ictaluridae	0	-	2	June 9
Moronidae	277	April 27	1,558	April 27
Centrarchidae	1,027	June 15	897	June 2
Sciaenidae	717	May 18	379	June 9

Table 5. Average Seasonal Density of Fish Eggs and Larvae in Entrainment Samples at Sequoyah Nuclear Plant during 2004.

	Intake Samples 1000 m^3	Reservoir Samples 1000 m^3	All Samples 1000 m^3
Eggs			
Unspecified	0	12	6
Sciaenidae	549	652	601
Totals:	549	664	607
Larvae			
Clupeidae	2249	3465	2857
Cyprinidae	7	2	5
Catostomidae	0	**T**	**T**
Ictaluridae	0	**T**	**T**
Moronidae	52	247	149
Centrarchidae	131	128	129
Sciaenidae	200	104	3.2
Totals:	**2639**	**3946**	**3292**

T – Taxon was collected in samples but density averaged less than 1 individual per 1000 m^3.

Table 6. Estimated Daily Hydraulic Entrainment by Sample Period at Sequoyah Nuclear Plant during 2004.

Sample Date	Volume		
	Intake m^3 day	Reservoir m^3 day	Entrained
	Q_i	Q_r	%
Apr 27	5.90E+06	2.50E+07	23.6%
May 4	6.00E+06	5.50E+07	10.9%
May 10	6.00E+06	5.40E+07	22.2%
May 18	6.00E+06	5.40E+06	111.1%
May 25	6.1.0E+06	2.10E+07	29.0%
Jun 02	6.00E+06	1.80E+07	33.3%
Jun 09	6.00E+06	6.70E+07	9.0%
Jun 15	6.00E+06	4.60E+07	13.0%
Jun 23	6.10E+06	5.90E+07	10.3%
Jun 30	6.10E+06	8.20E+07	7.4%
Jul 07	6.10E+06	5.70E+07	10.7%
Jul 12	6.10E+06	6.20E+07	9.8%
Average	**6.03E+06**	**4.37E+07**	**24.2%**

Table 7. Seasonal Entrainment Estimates for Numerically Significant Fish Taxa Collected at Sequoyah Nuclear Plant during 2004.

Taxa	Intake Number Entrained Per Day $Q_i X D_i$	Reservoir Total Number Per Day $Q_r X D_r$	Entrainment Estimate %
Eggs			
Sciaenidae	6.10E+09	5.40E+10	11.2
Totals:	**6.10E+09**	**5.40E+10**	**11.2**
Larvae			
Clupeidae	1.30E+10	8.60E+10	15.4
Cyprinidae	4.30E+07	5.90E+07	72.6
Catostomidae	0.00E+00	1.40E+07	0.0
Ictaluridae	0.00E+00	6.50E+06	0.0
Moronidae	3.10E+08	6.20E+09	5.0
Centrarchidae	7.70E+08	3.20E+09	24.2
Sciaenidae	1.20E+09	2.60E+09	45.4
Totals:	**1.53E+10**	**9.81E+10**	**15.6**

Table 8. Historical and Current Entrainment Percentages for Fish Eggs and Larvae at Sequoyah Nuclear Plant during 1981-1985 and 2004.

	1981	1982	1983	1984	1985	2004
Freshwater Drum Eggs	6.7	41.4	22.6	9.7	16.6	11.2
Larvae						
Clupeidae	2.1	1.5	2.7	1.8	1.1	15.4
Cyprinidae	4.3	4.2	5.9	2.3	3.1	72.6
Catostomidae	0.0	0.0	6.1	2.6	0.0	0.0
Ictaluridae	8.4	7.7	9.1	45.9	27.8	0.0
Moronidae	1.7	2.7	4.8	2.2	2.46	5.0
Centrarchidae	1.0	1.8	1.1	0.6	0.7	24.2
Percidae	3.6	1.6	10.7	1.6	3.5	0.0
Sciaenidae	5.5	25.6	57.8	22.7	30.2	45.4
Total Larvae	**2.3**	**2.2**	**4.7**	**2.3**	**2.6**	**15.6**

Table 9. Recent (1993-2005) RFAI Scores Collected as Part of the Vital Signs Monitoring Program Upstream and Downstream of Sequoyah Nuclear Plant.

Station	Reservoir	Location	1993	1994	1995	1997	1999	1993-1999 Average	2000*	2001	2002*	2003	2004	2005	1993-2005 Average
Upstream	Chickamauga	TRM 490.5	49	40	46	39	45	44 (Good)	46	45	51	42	49	48	45 (Good)
Sequoyah Transition	Chickamauga	TRM 482.0					41	41 (Good)	48	46	43	45	41	39	43 (Good)
Forebay	Chickamauga	TRM 472.3	44	44	47	39	45	44 (Good)	45	48	46	43	43	46	45 (Good)

*The 2000, and 2002, sample years were not part of the VS monitoring program, however the same methodology was applied.

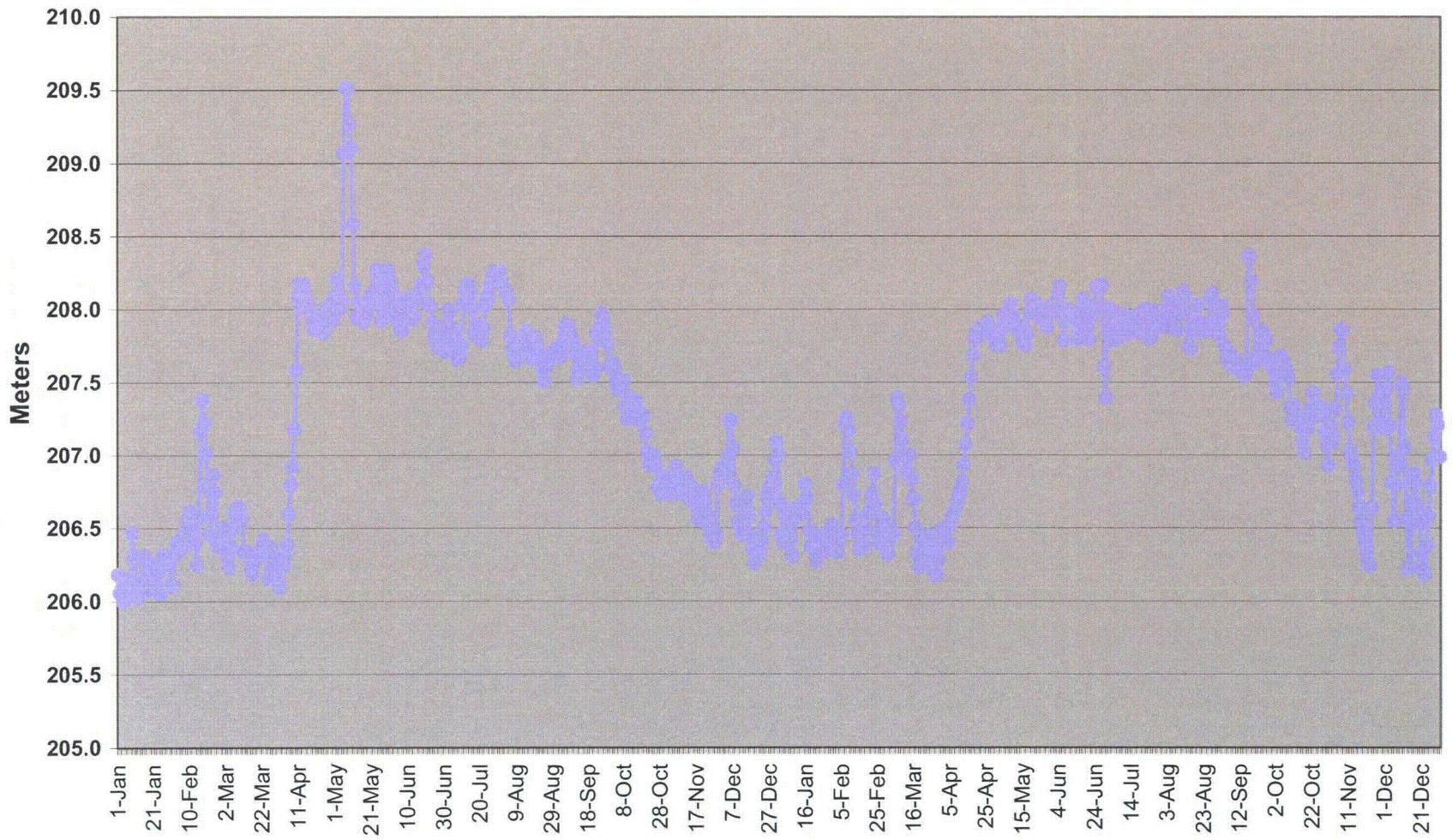

Figure 1. Average daily surface elevation (meters above mean sea level) of Chickamauga Reservoir during 2004.

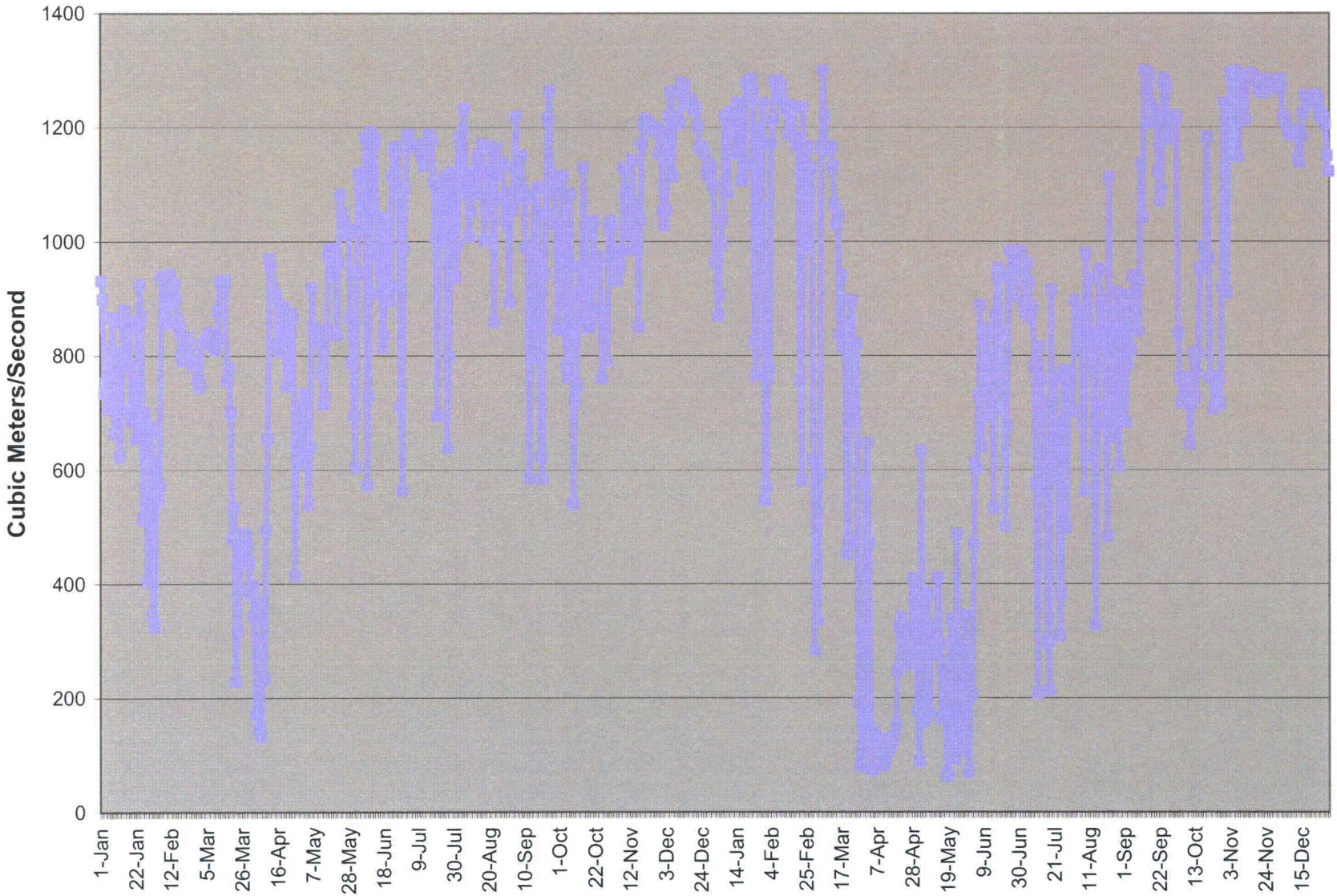

Figure 2. Average daily rate of flow in Chickamauga Reservoir during 2003 and 2004.

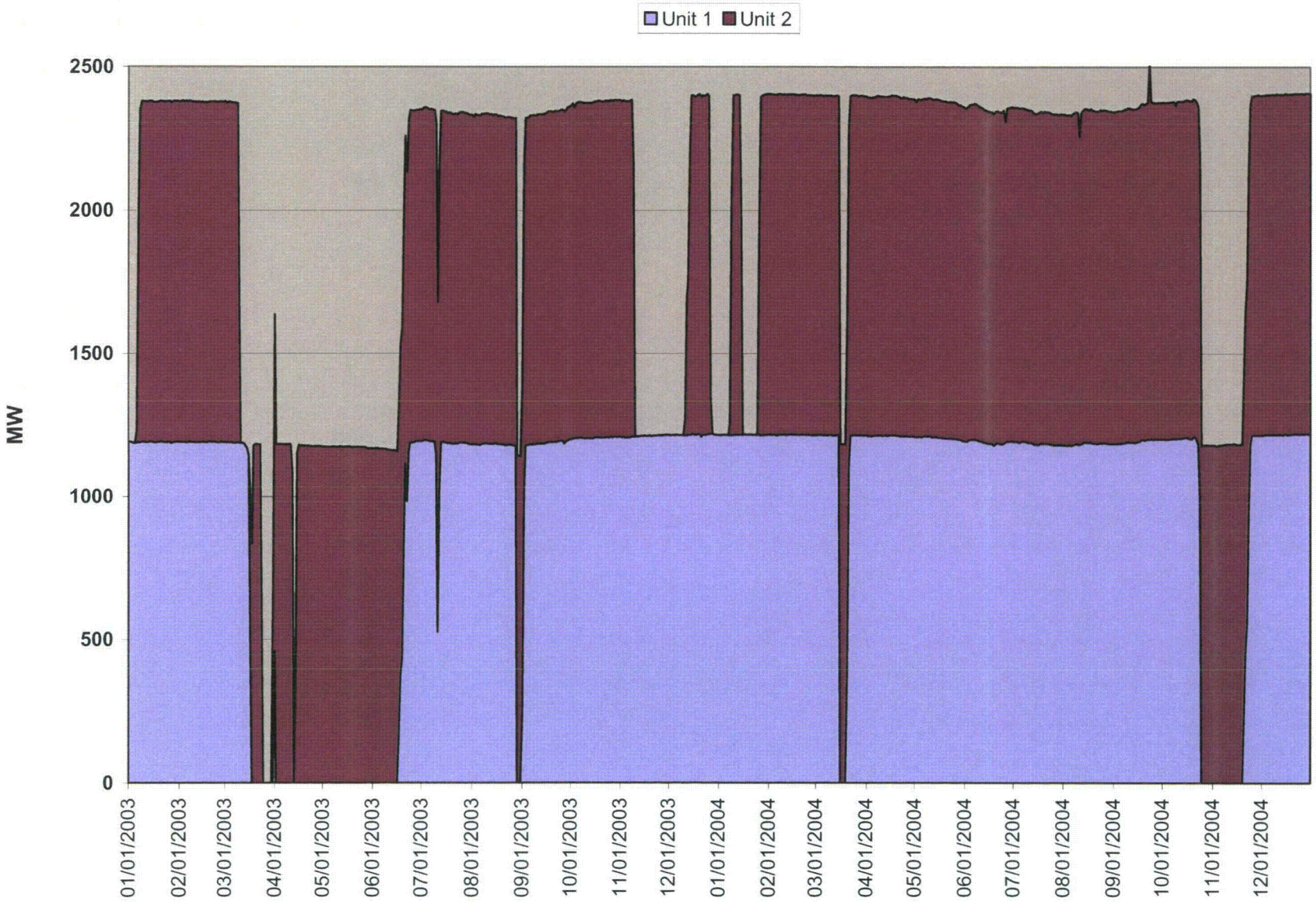

Figure 3. Average daily rate of generation at Sequoyah Nuclear Plant during 2003 and 2004.

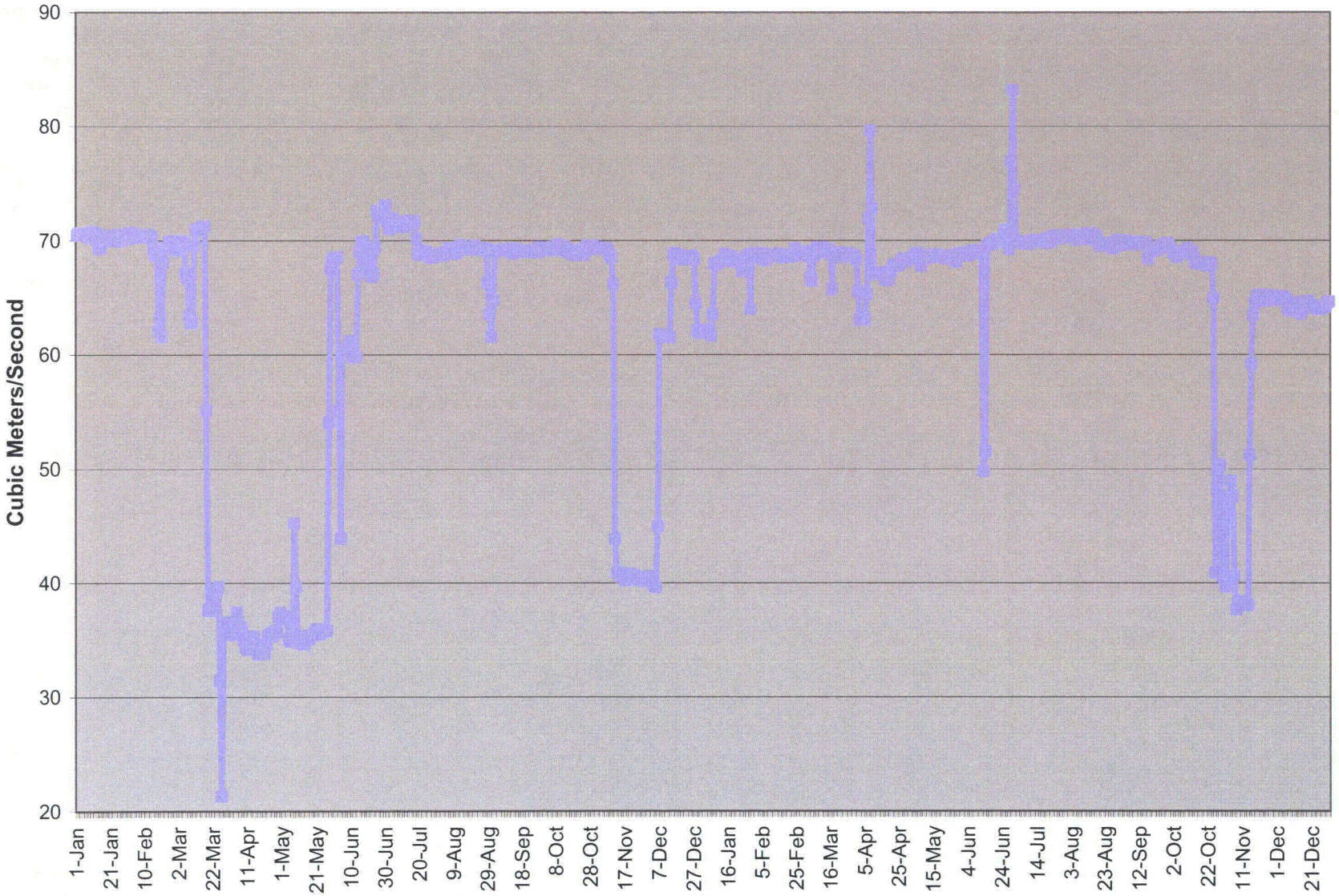

Figure 4. Average daily rate of hydraulic entrainment at Sequoyah Nuclear Plant during 2003 and 2004.

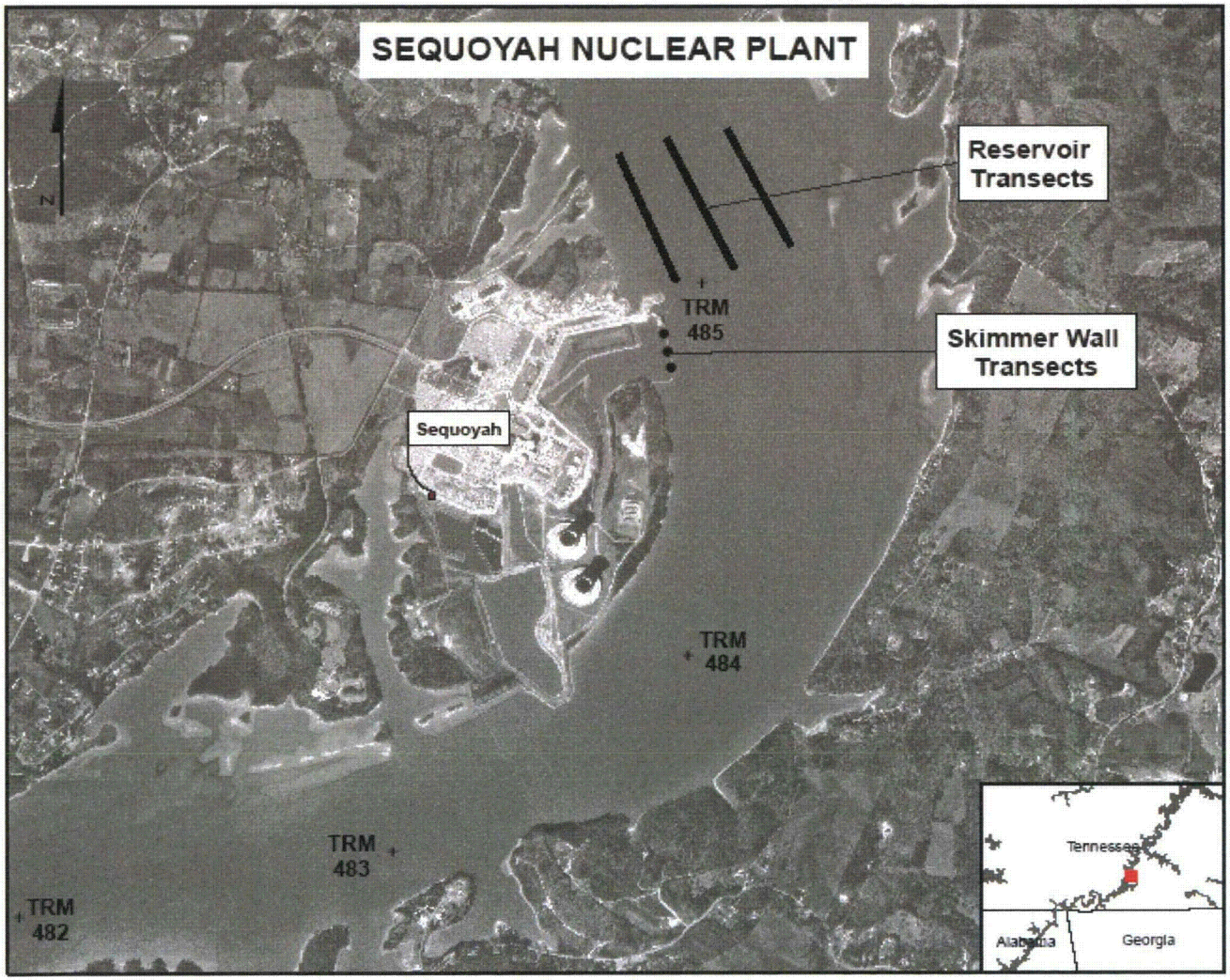

Figure 5. Map of entrainment sample transects in the vicinity of Sequoyah Nuclear Plant during 2004.

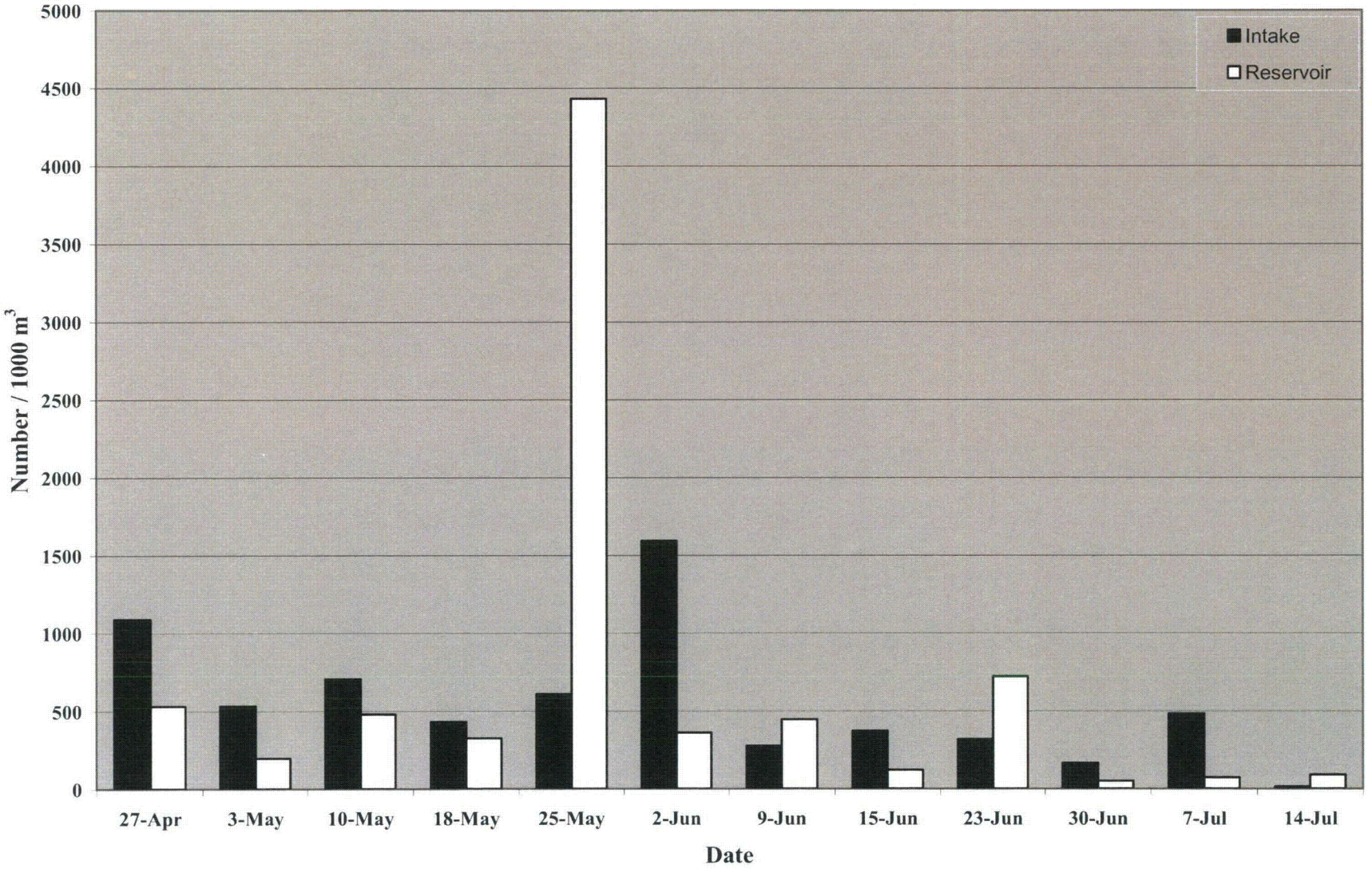

Figure 6. Densities of sciaenid eggs collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

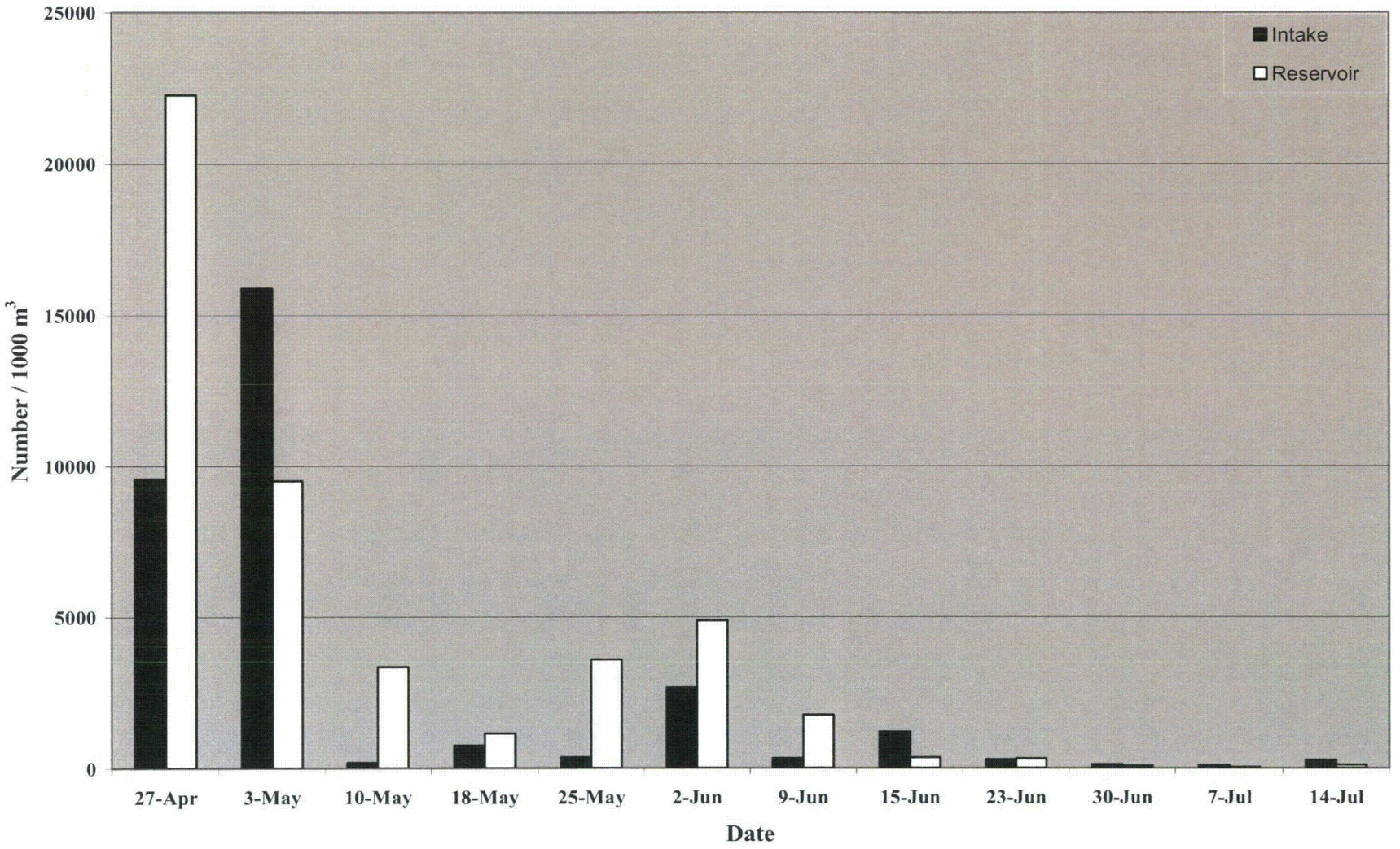

Figure 7. Densities of total larval fish collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

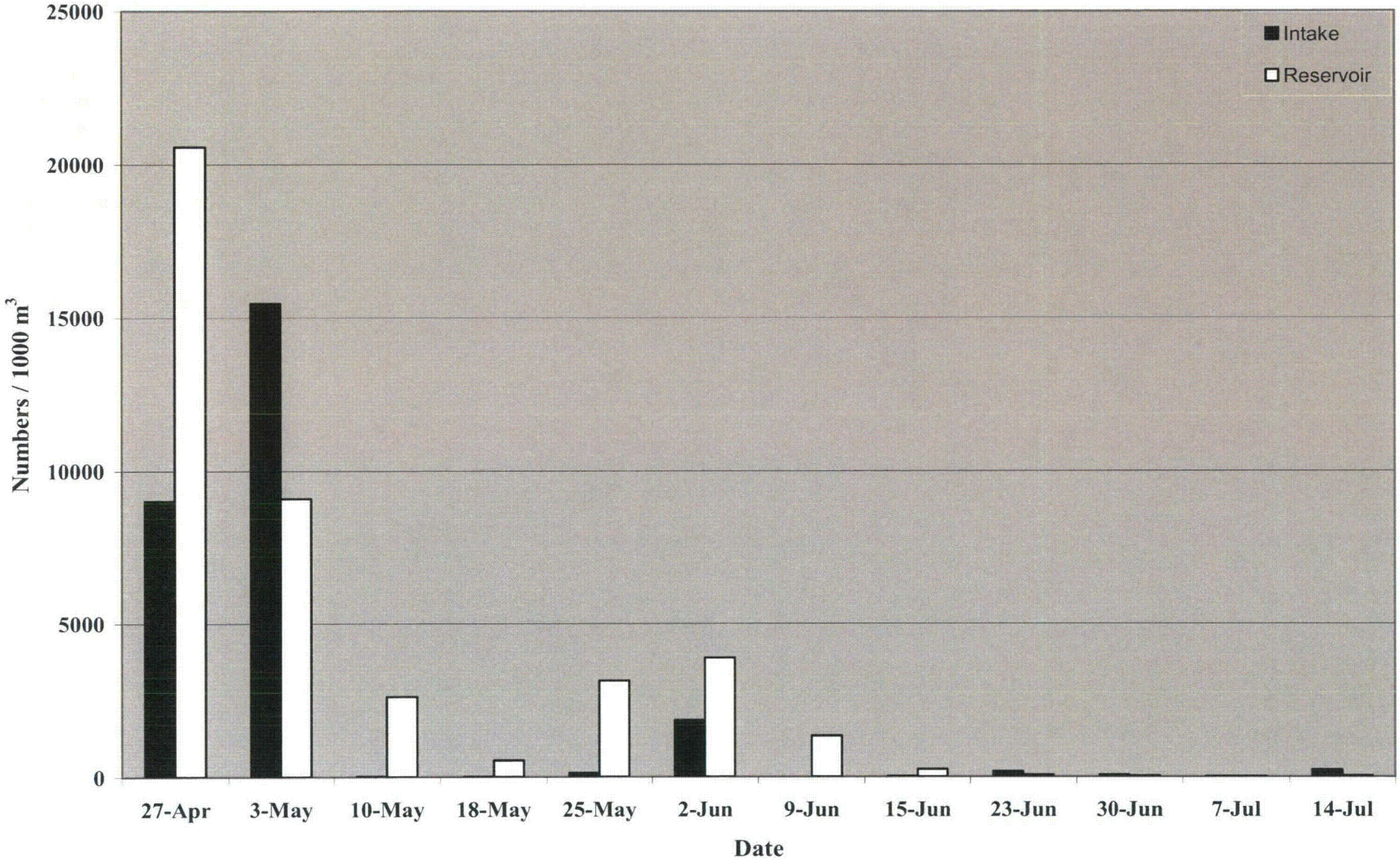

Figure 8. Densities of clupeid larvae collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

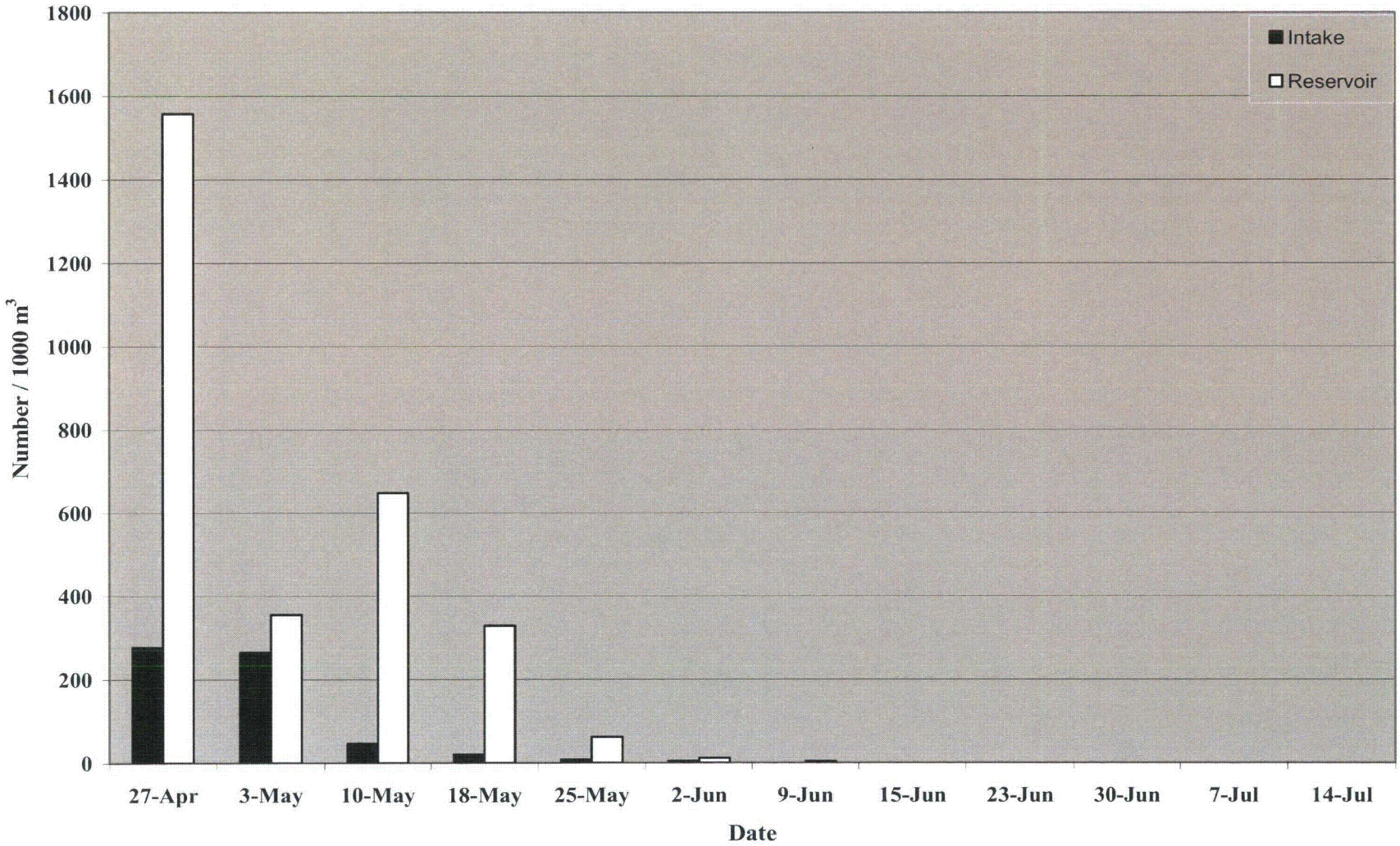

Figure 9. Densities of moronid larvae collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

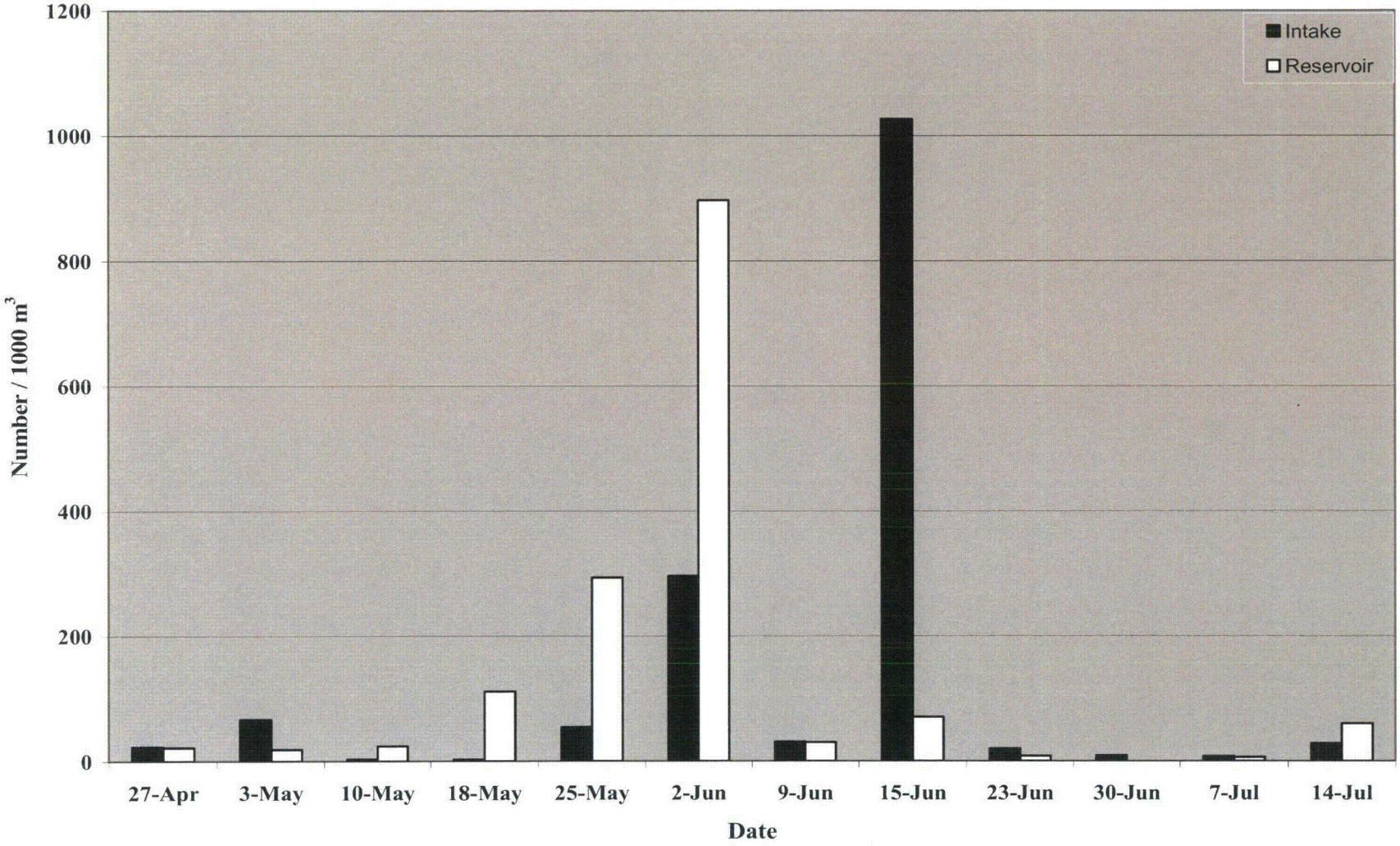

Figure 10. Densities of centrarchid larvae collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

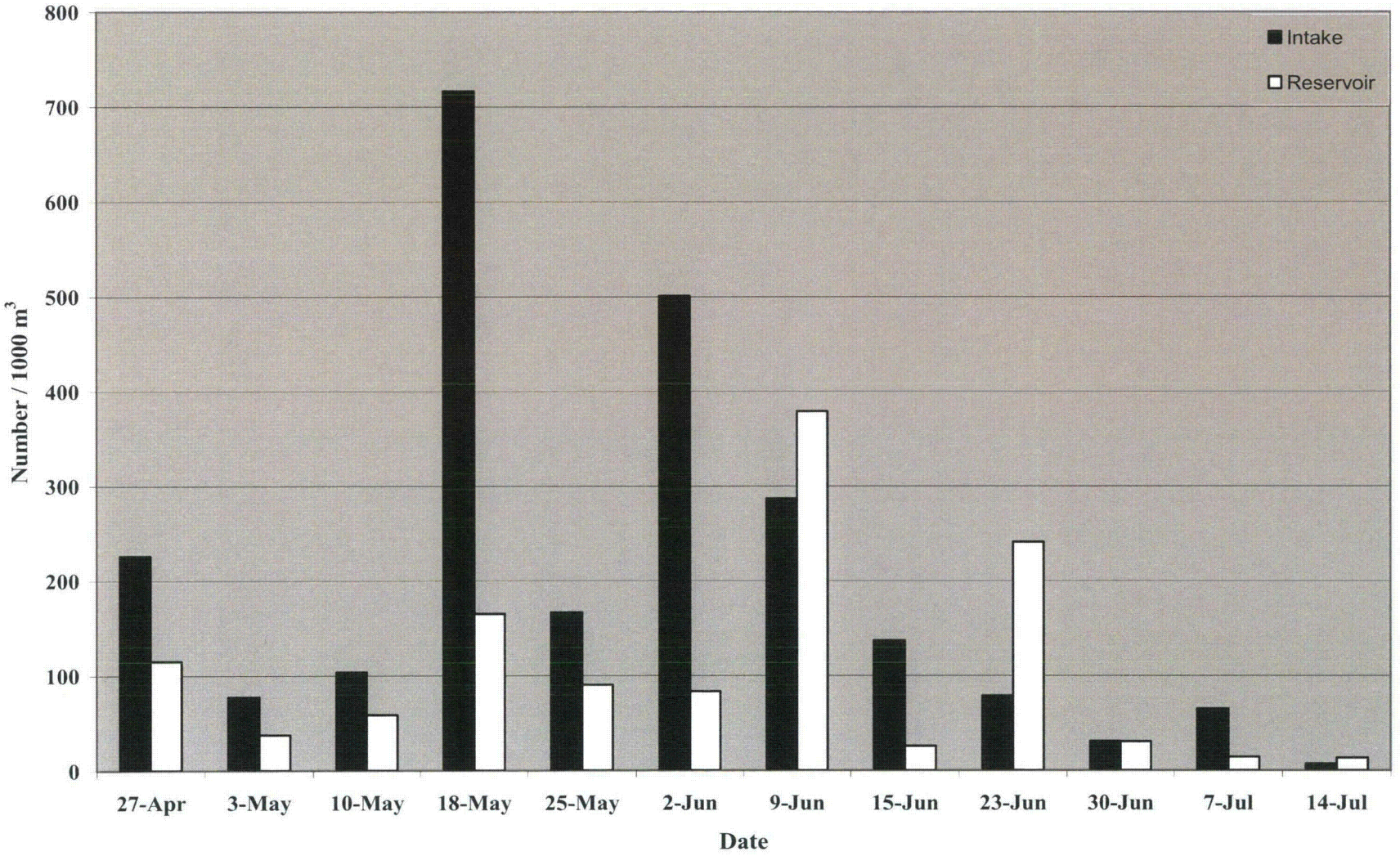

Figure 11. Densities of sciaenid larvae collected in intake and reservoir entrainment samples at Sequoyah Nuclear Plant during 2004.

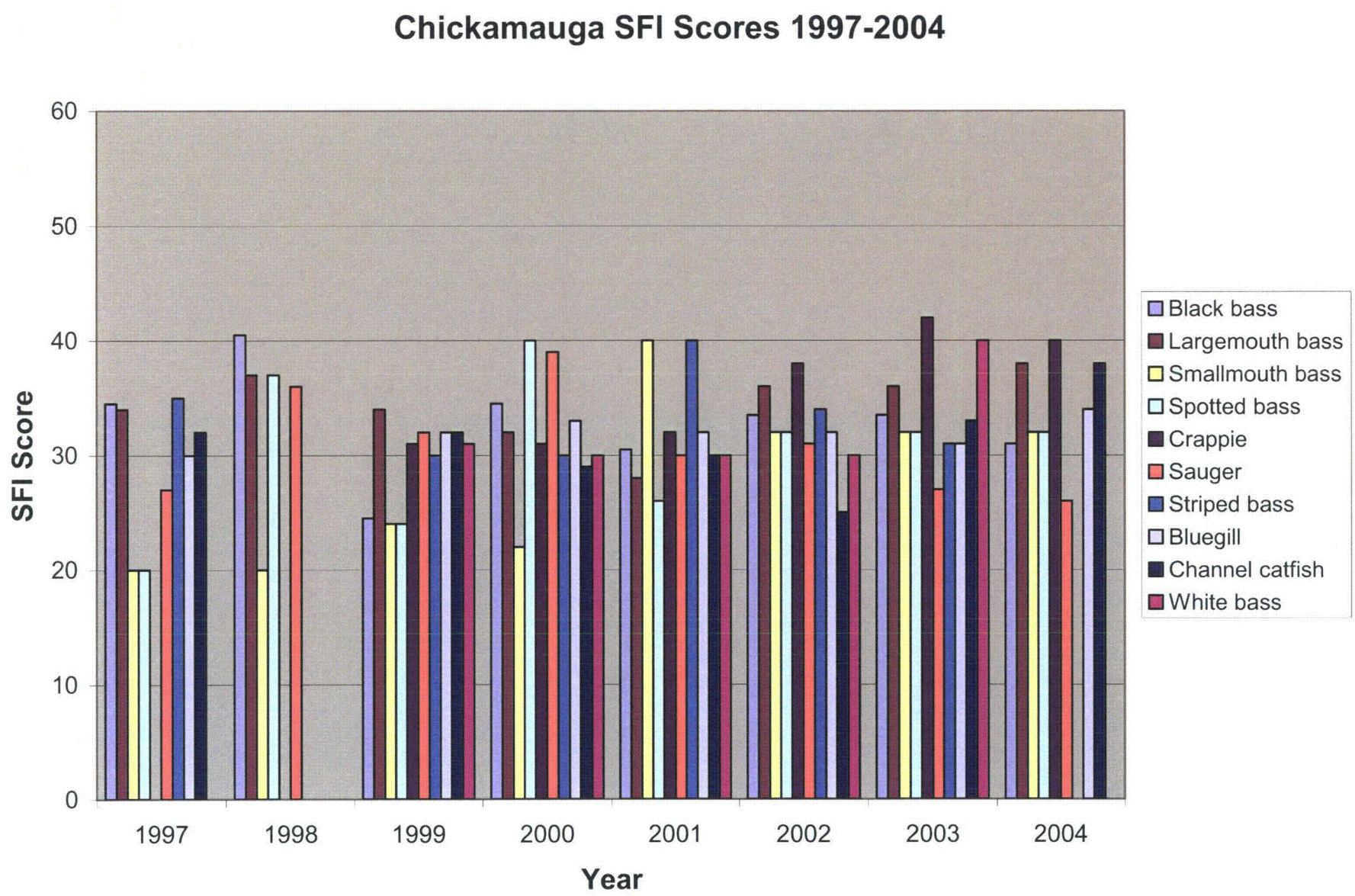

Figure 12. Sport Fishing Index results for Chickamauga Reservoir between 1997 and 2004.

TENNESSEE VALLEY AUTHORITY

RESOURCE STEWARDSHIP

SEQUOYAH NUCLEAR PLANT
316(B) MONITORING PROGRAM

EFFECTS OF IMPINGEMENT ON THE AQUATIC POPULATIONS IN CHICKAMAUGA RESERVOIR

Prepared by

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June 2002

Executive Summary

In accordance with the National Pollutant Discharge Elimination System (NPDES) Number TN0026450 the Tennessee Valley Authority's Sequoyah Nuclear Plant (SQN) conducted monitoring to evaluate the effects of the operation of SQN's condenser-cooling water intake on the aquatic community of Chickamauga Reservoir. Impingement samples were collected in the winter of 2001-2002 from the SQN traveling screens. Seasonal peaks of fish impingement were selected from historical data sets to (1) assess the impact of current operation on the aquatic populations, (2) compare current operation with previous operational data, and (3) to ensure compliance. The 2001-2002 data were similar to the 1981-1985 historical data; threadfin shad was the dominant species and other species were impinged in low numbers. Based on the 2001-2002 data, current operation of SQN is having no significant effect on the aquatic populations in Chickamauga Reservoir.

Introduction

Sequoyah Nuclear Plant (SQN) withdraws condenser-cooling water (CCW) from the Tennessee River and is subject to compliance with the Tennessee Water Quality Act and the Clean Water Act (CWA). Section 316(b) of the CWA requires facilities to demonstrate that the CCW is having no significant impact on the aquatic community. A component of 316(b) is impingement, impact from fish and other aquatic organisms being trapped against the intake screens. TVA conducted impingement studies at SQN from 1981 through July 1985 to assess the effects of operation on the aquatic community. No significant impact was observed in these studies. The Emergency Raw Cooling Water (ERCW) contributes only 0.7 percent (0.5 m^3) of the pumping capacity and, historically, impinge low numbers of fish. Therefore, potential impacts from operation of the ERCW are minimal and no additional evaluations are included in this report. This report presents impingement data collected from the CCW intake screens in the winter of 2001-2002 with comparisons to historical data.

Plant Description and Operation During Study Period

SQN is located on the west shore of Chickamauga Reservoir at Tennessee River Mile (TRM) 484.5 (Figure 1). The two units (water pressurized reactors) have a total nameplate rating of 2,441 megawatts (MW). Natural draft cooling towers enables SQN to operate in an open, closed, or helper mode. In open mode operation with both units at maximum power, total water demand is 72.45 m^3/s (2,558 cfs). CCW is drawn from Chickamauga Reservoir into the intake channel through an opening approximately 165 m in length and 3 m height located near the bottom of the skimmer wall. The skimmer wall is situated near the river channel enabling SQN to withdraw cooler water from the lower stratum. From the intake channel, water passes through six, 3-m wide traveling screens to the intake pumps. Mesh openings on screens are 0.95 cm^3.

Both units were near full load December 2001 through February 2002 (Figure 2). Average daily generation for the two combined was 2373 MV; Unit 1 averaged 1186 MV and Unit 2 1187 MV. Six intake pumps were usually in operation producing an average daily intake flow of 2536 cfs. Velocity at traveling screens averaged 1.2 fps with a maximum of 1.3 and a minimum of 1.2 fps.

Materials and Methods

The 2001-2002 impingement study was conducted in winter, historically, when peak numbers of fish are impinged at SQN. Ten impingement samples were collected from the CCW screens between December 19, 2001 and February 25, 2002. Each of the six intake screens were washed and rotated to remove all fish and debris. After approximately 24 hours, screens were individually washed and rotated. Fish were collected in the catch basket at the end of the sluice pipe. Due to problems, one sample, collected on January 17, 2002, was for a 48-hour period. Fish were identified, separated into 25 mm length classes, enumerated, and weighed. Estimates of monthly impingement rates were calculated and compared with historical data.

Results and Discussion

Fifteen fish species representing eight families and one exotic mussel (zebra mussel) were collected in the SQN impingement samples (Table 1). The prolific non-native zebra mussel is a nuisance species introduced into the Tennessee River system in the last ten years. Zebra mussels are not an impingement concern and must be monitored to ensure accumulation in the intake structure does not impede flow. One species, alewife, was observed for the first time in SQN impingement samples. Alewife is a cool water forage species introduced into Watauga Reservoir in 1976 and continues to extend its range downstream.

A total of 13,570 fish weighing 50,532 grams was collected in the ten samples (Table 2). Threadfin shad was the dominant species comprising 97 percent of the total number collected and 74 percent of the total weight (Table 3). All other species contributed less than one percent of the total number; both bluegill and freshwater drum contributed 0.8 percent. By weight, freshwater drum ranked second comprising 15 percent of total.

Threadfin shad are typically the dominant species impinged at TVA power plants and significant annual and seasonal fluctuations in population estimates for the species is common. The average monthly impingement rate for threadfin shad was 36,427 in the winter of 2001-2002; monthly estimates were 45,720 in December, 53,400 in January, and 6944 in February. This is higher than the historical monthly average (Figure 3) but similar to the 46,000 estimated for December 1981. Historical data was averaged over a 52-week period in 1981 through 1984 and January through July in 1985, whereas, the 2001-2002 data was collected during winter. Threadfin shad have a high fecundity rate, move in large schools, and are intolerant to cold temperatures, often resulting in high mortality rates in winter. These traits are probably major contributing factors to the annual and seasonal fluctuation in numbers of fish impinged at SQN. Annual fluctuation in population estimates for threadfin shad in Chickamauga Reservoir was also observed in historical rotenone data (Figure 4). Gizzard shad, bluegill, and freshwater drum were impinged at rates near the median or below historical estimates (Figures 5, 6, and 7). Impingement estimates for channel catfish was higher for 2001-2002 (Figures 8) but numbers were low compared to reservoir population. Species not impinged in 2001-2002 that ranked in the top five one or more years between 1981 and 1985 were skipjack herring, yellow bass, yellow perch, and spotted bass.

Summary and Conclusions

The 2001-2002 data presented the worse case scenario, samples collected in the winter when peak numbers are typically impinged at SQN. Impingement estimates for all species, except threadfin shad, were low numbers and consistent with the 1981-1985 historical data. Numbers estimated for threadfin shad were similar to historical peaks and the significant drop in the numbers impinged in February 2002 is consistent with seasonal fluctuations previously reported. The 2001-2002 data shows no change in SQN operation since the 1981-1985 operational studies that would potentially impact the fish populations in Chickamauga Reservoir.

Table 1. List of species impinged on the intake screen at Sequoyah Nuclear Plant in ten samples collected between December 18, 2001 and February 25, 2002.

	Family	Common Name	Scientific Name
Fish			
	Clupeidae		
		Alewife	*Alosa pseudoherengus*
		Gizzard shad	*Dorosoma cepedianum*
		Threadfin shad	*Dorosoma petenense*
	Cyprinidae		
		Bluntnose minnow	*Pimephales notatus*
	Ictaluridae		
		Channel catfish	*Ictalurus punctatus*
		Flathead catfish	*Pylodictis olivaris*
	Poeciliidae		
		Mosquitofish	*Gambusia affinis*
	Percichthyidae		
		Striped bass	*Morone saxatilis*
	Centrarchidae		
		Redbreast sunfish	*Lepomis auritus*
		Bluegill	*Lepomis macrochirus*
		Redear sunfish	*Lepomis microlophus*
		Largemouth bass	*Micropterus salmoides*
		White crappie	*Pomoxis annularis*
	Percidae		
		Logperch	*Percina caprodes*
	Sciaenidae		
		Freshwater drum	*Aplodinotus grunniens*
Mussels			
		Zebra mussels	*Dreissena polymorpha*

Table 2. Total number and weight (grams) of each species impinged on the intake screen at Sequoyah Nuclear Plant in ten samples collected between December 18, 2001 and February 25,2002.

Sample Date	19-Dec	2-Jan	9-Jan	17-Jan	23-Jan	30-Jan	6-Feb	20-Feb	22-Feb	25-Feb	Species
Hours Sampled	25.5	25.5	23.2	48.5	25.5	25.0	24.0	24.0	24.0	24.0	Total
Common Name	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Alewife					1	7	10	5	5	3	**31**
Gizzard shad		2		2	1	23	20		2	9	**59**
Threadfin shad	1567	644	3945	3326	2046	640	880	57	33	22	**13160**
Bluntnose minnow		1				2					**3**
Channel catfish		4	6	4	2	12	2	4	1	3	**38**
Flathead catfish				2	1						**3**
Mosquitofish	10		2	4			1		1		**18**
Striped bass						5	14	2	4	8	**33**
Redbreast sunfish					1						**1**
Bluegill	11	4	1	1	39	25	20	2	2	4	**109**
Redear sunfish							3				**3**
Largemouth bass			1								**1**
White crappie	1	1									**2**
Logperch					2	2					**4**
Freshwater drum	3	1	8	32	45	7	4	3		2	**105**
Fish Totals:	**1592**	**657**	**3963**	**3371**	**2138**	**723**	**954**	**73**	**48**	**51**	**13570**
Zebra mussels	4	16									**20**
Common Name	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**	**Weight**
Alewife					37	97	102	85	55	36	**412**
Gizzard shad		140		138	194	90	64		8	36	**670**
Threadfin shad	4189	1611	11440	9407	6692	1280	2552	141	81	48	**37441**
Bluntnose minnow		8				5					**13**
Channel catfish		11	13	10	5	28	5	90	495	15	**672**
Flathead catfish				2360	5						**2365**
Mosquitofish	2		2	1					1		**6**
Striped bass						26	82	57	26	43	**234**
Redbreast sunfish					370						**370**
Bluegill	31	12	3	22	123	48	49	5	5	27	**325**
Redear sunfish							9				**9**
Largemouth bass			135								**135**
White crappie	3	418									**421**
Logperch					20	19					**39**
Freshwater drum	226	233	1021	2036	2819	389	91	567		38	**7420**
Fish Totals:	**4451**	**2433**	**12614**	**13974**	**10265**	**1982**	**2954**	**945**	**671**	**243**	**50532**
Zebra mussels											

Table 3. Percent composition of fish impinged by Sequoyah Nuclear Plant between December 18, 2001 and February 25,2002.

Category	Common Name	Number Percent	Weight Percent
Forage			
	Alewife	0.23	0.82
	Gizzard shad	0.43	1.33
	Threadfin shad	96.98	74.09
	Bluntnose minnow	0.02	0.03
	Mosquitofish	0.13	0.01
	Logperch	0.03	0.08
	Forage Totals	**97.82**	**76.36**
Commercial			
	Channel catfish	0.28	1.33
	Flathead catfish	0.02	4.68
	Freshwater drum	0.77	14.68
	Commercial Totals	**1.07**	**20.69**
Game			
	Striped bass	0.24	0.46
	Redbreast sunfish	0.01	0.73
	Bluegill	0.80	0.64
	Redear sunfish	0.02	0.02
	Largemouth bass	0.01	0.27
	White crappie	0.01	0.83
	Game Totals	**1.09**	**2.95**

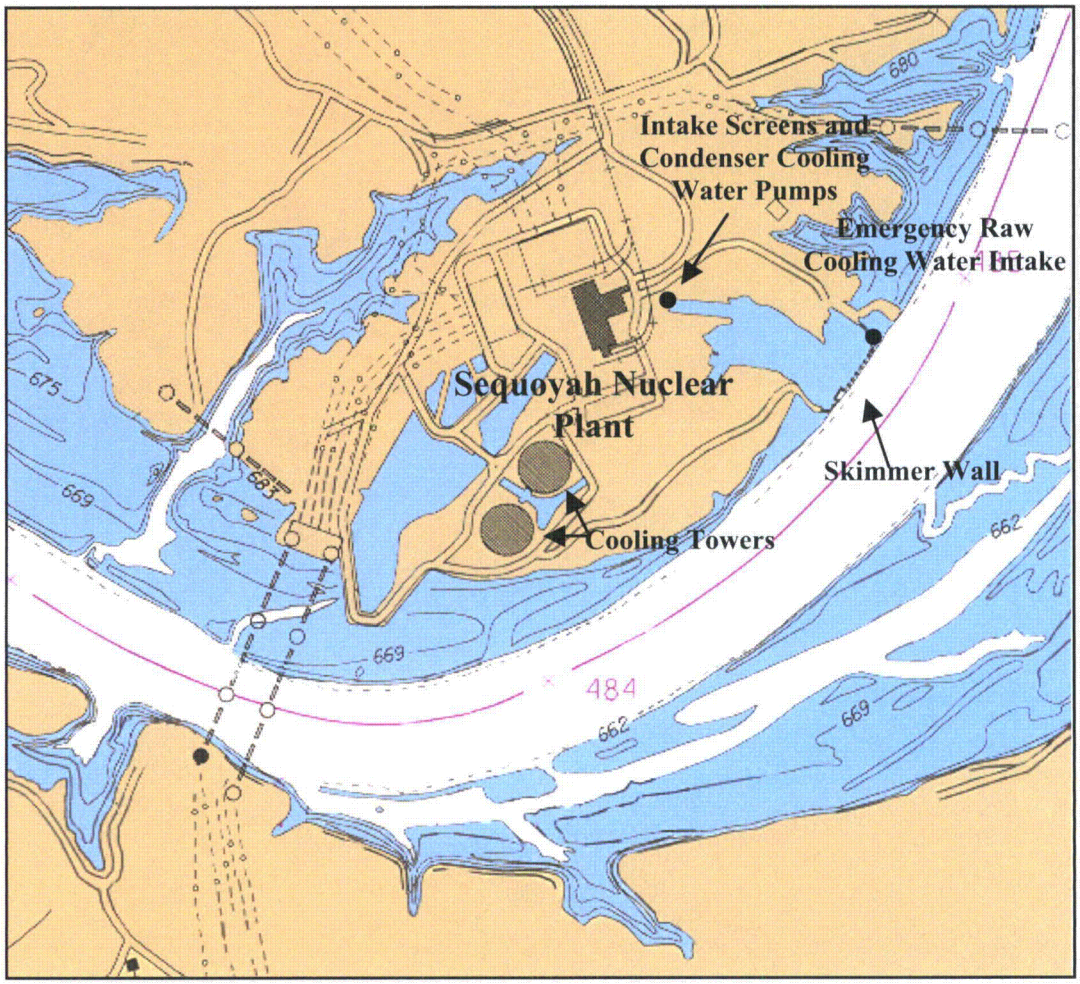

Figure 1. Sequoyah Nuclear Plant cooling water intake structure.

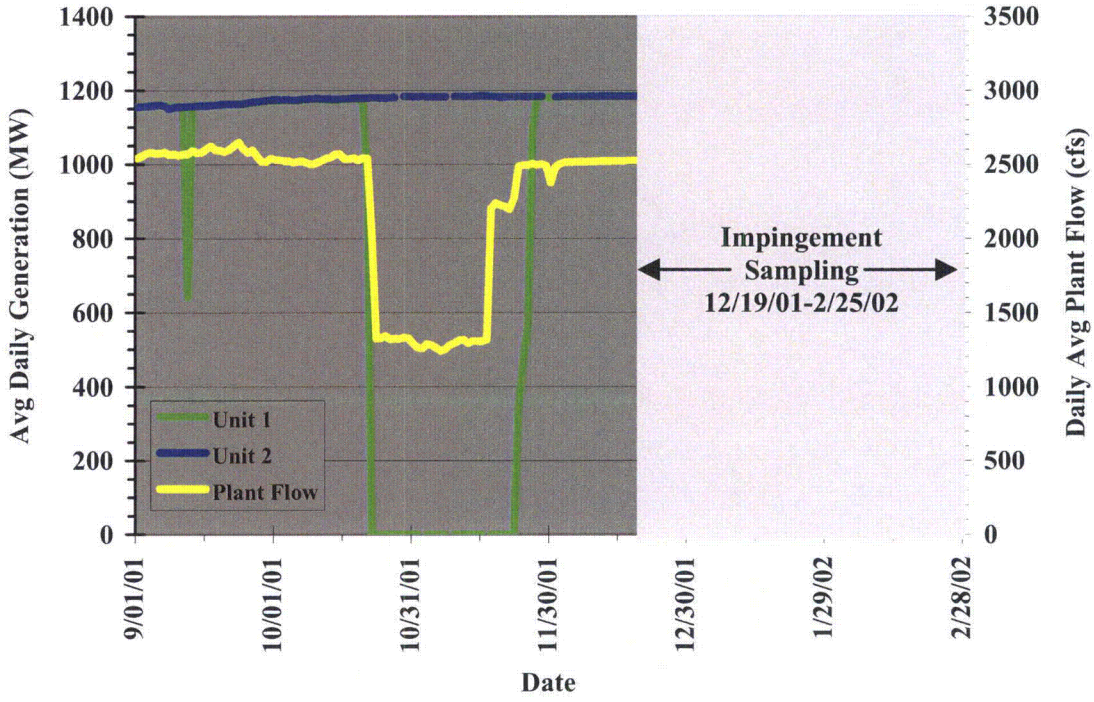

Figure 2. Average Daily Generation (MW) and Intake Flow (cfs) at Sequoyah Nuclear Plant, September 2001 through February 2002. Light gray identifies impingement sampling period.

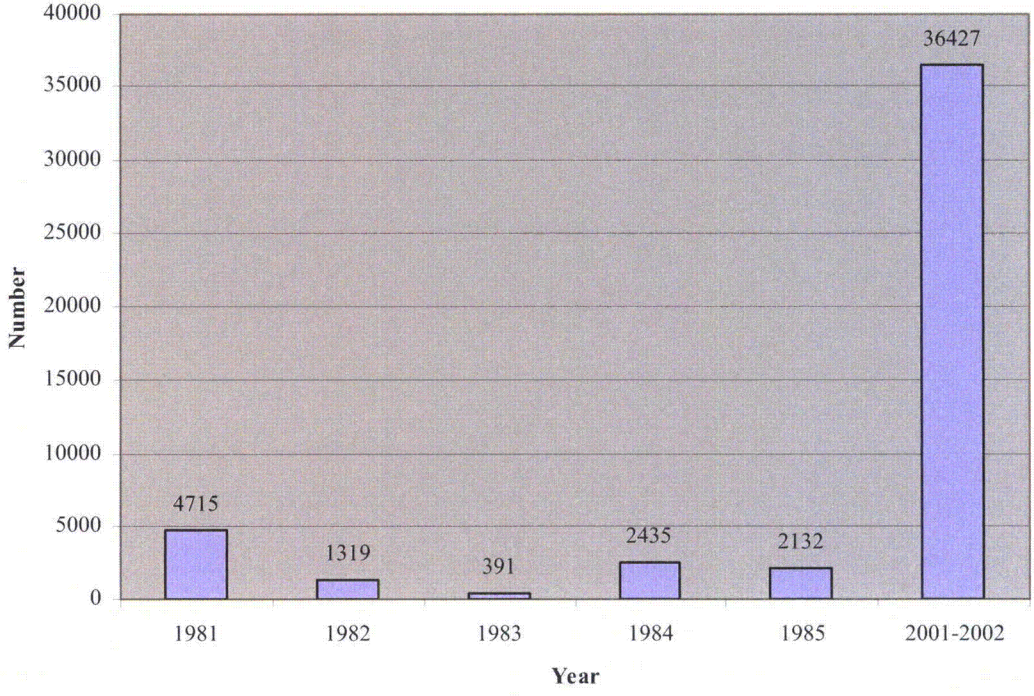

Figure 3. Estimated monthly impingement rate for threadfin shad in winter, 2001-2002, with historical comparisons.

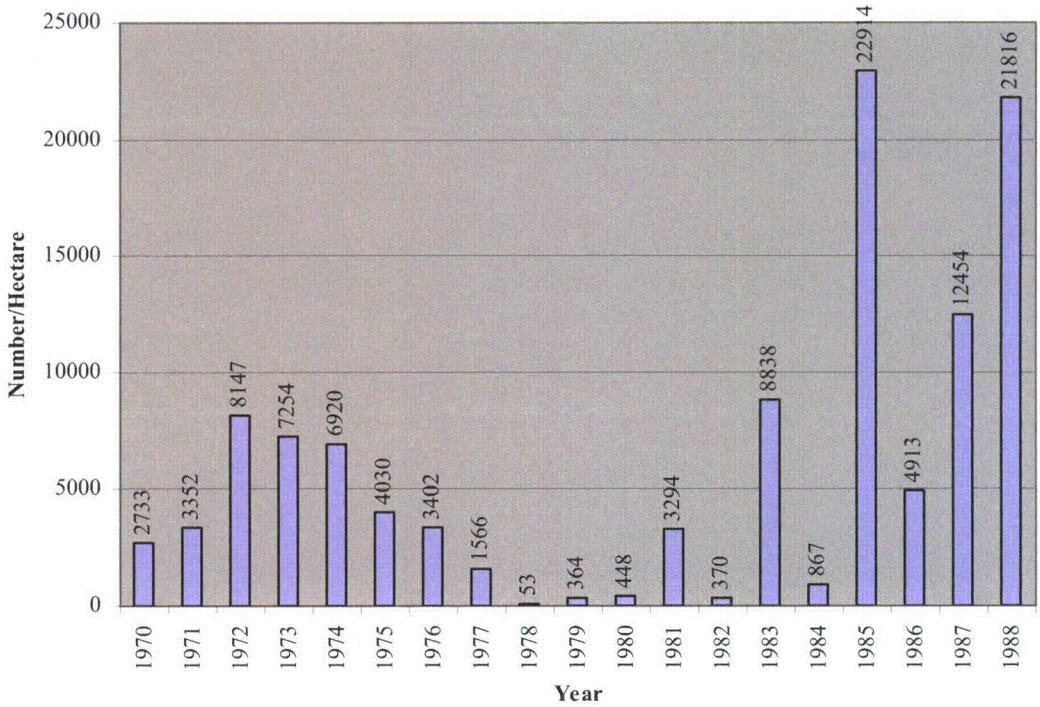

Figure 4. Numbers of threadfin shad in cove rotenone samples, Chickamauga Reservoir, 1970-1988.

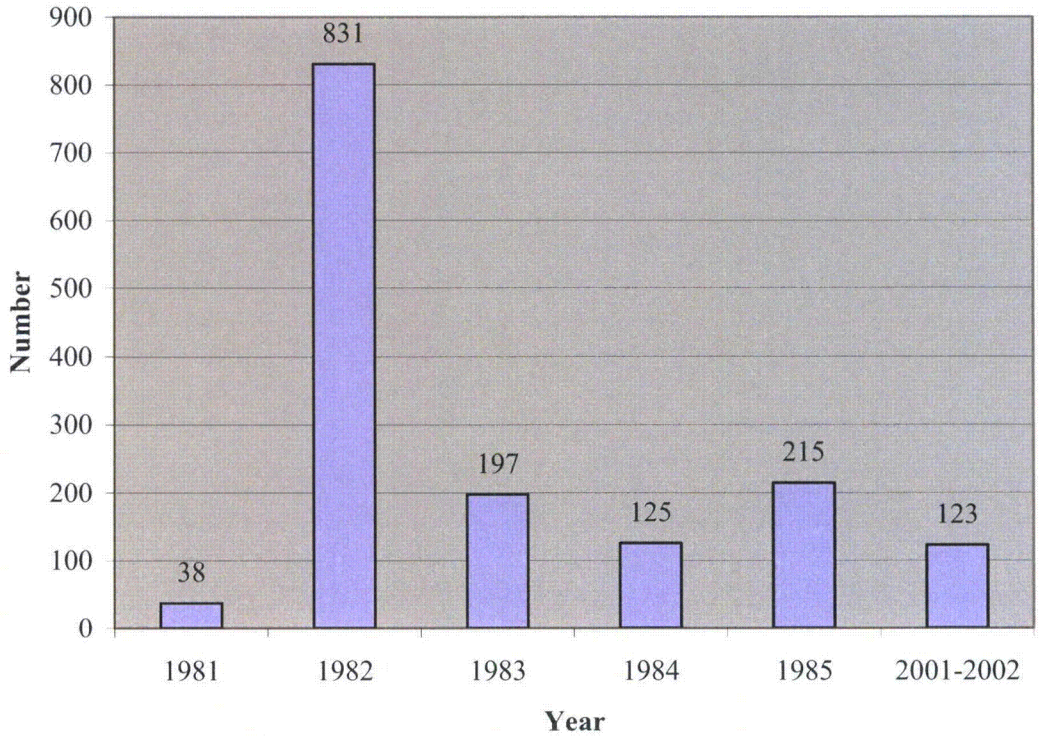

Figure 5. Estimated monthly impingement rate for gizzard shad in winter, 2001-2002, with historical comparisons.

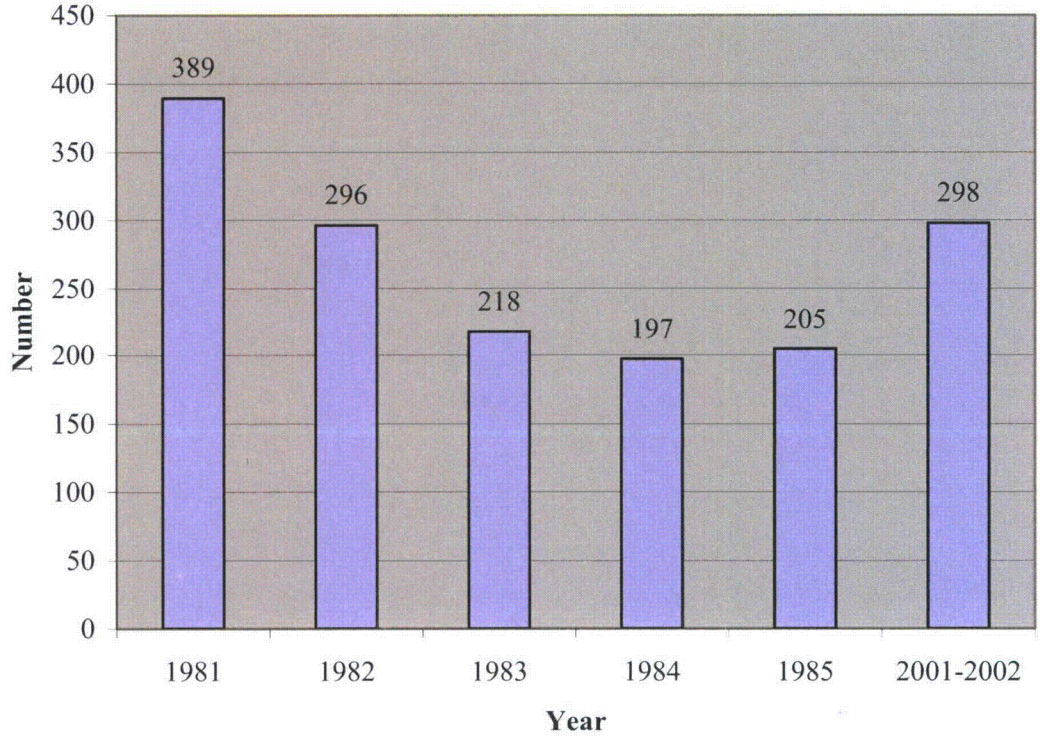

Figure 6. Estimated monthly impingement rate for bluegill in winter, 2001-2002, with historical comparisons.

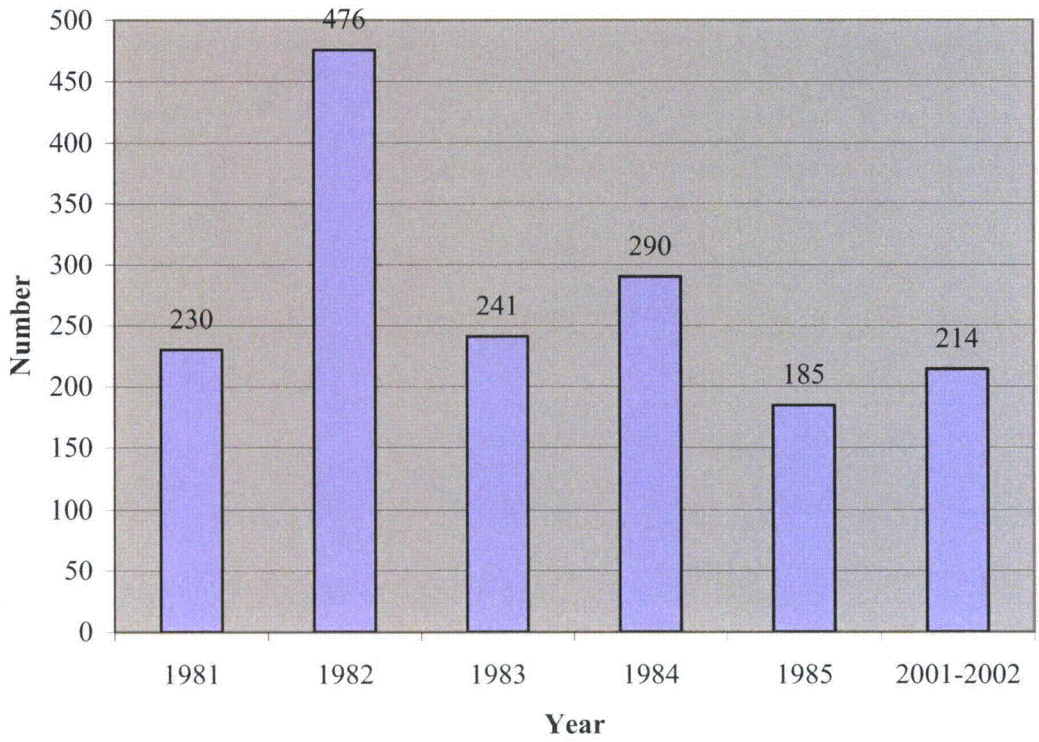

Figure 7. Estimated monthly impingement rate for freshwater drum in winter, 2001-2002, with historical comparisons.

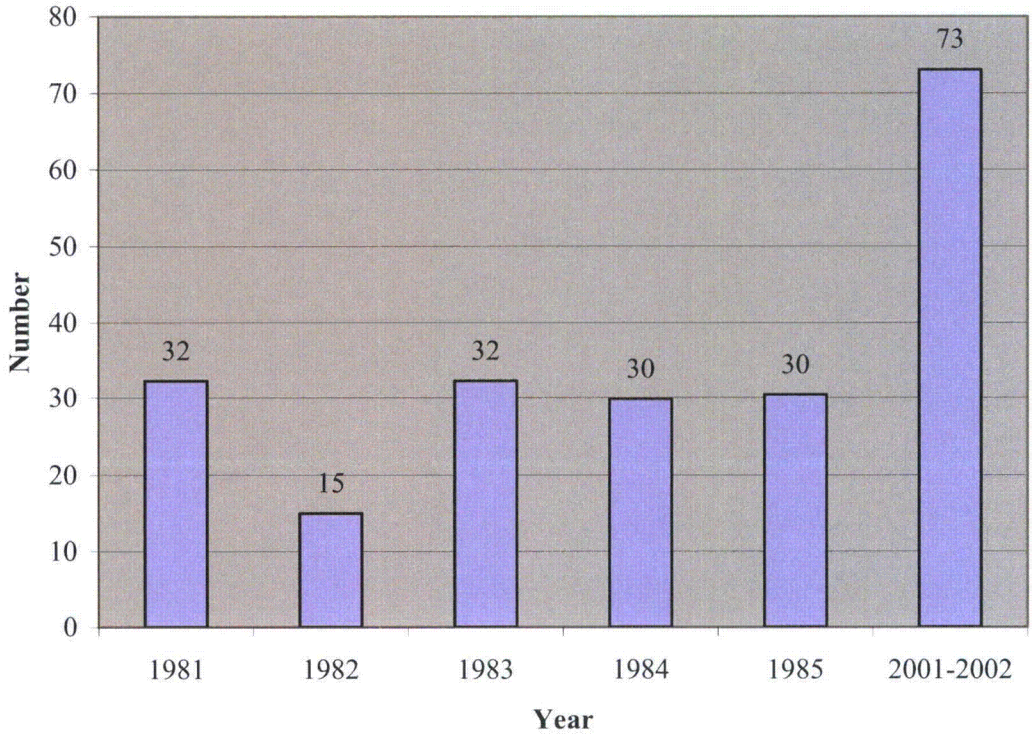

Figure 8. Estimated monthly impingement rate for channel catfish in winter, 2001-2002, with historical comparisons.

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